BEA_P**R Database**

BErkeley Alpha and proton Radioactivity



Explanation of Tables

The explanations below apply to all tables and figures.

All energy units are given in MeV unless otherwise stated.

Energies of emitted particles are reported in the center of mass frame unless otherwise stated.

A blank space in a table indicates the values is unknown.

- indicates that the value is not energetically possible.

A value of "obs" indicates the decay has been observed, but a numeric value is not known.

The 8 digit combination of numbers and letters at the start of each reference refers to the Nuclear Science References (NSR) database keynumber for that reference [2011Pr03].

Unless otherwise stated, all Q and S values are taken from [2021Wa16] or deduced from values therein. If values for S_p and $Q_{\varepsilon\alpha}$ calculated using p and α energies are within error bars of the value from [2021Wa16], the latter is used, otherwise the values from particle energy is used and noted.

Unless otherwise stated, all J^{π} values are taken from ENSDF.

The values for E_{level} (emitter) are deduced from the energy of the emitted particle, the S_p of the emitter and the final level in the daughter.

Energy values in the daughter are rounded to the nearest 0.1 keV, and coincident γ -rays to 1 keV if known to better precision.

The data set with the higher statistics has been preferentially used in the individual nuclide tables unless otherwise stated.

Uncertainities in all cases are defined as $9.0(10) \equiv 9.0 \pm 1.0$.

Hindrance Factors (HF) and nuclear radius parameters (R_0) are calculated using the AlphaHF program written by Jun Chen (part of the ENSDF Analysis and Utility Programs available at https://nds.iaea.org/public/ensdf)

In the figures for each T_z , $T_{1/2}$ and J^{π} values are taken from ENSDF.

$J^{A} \qquad \text{Spin and parity of the parent nucleus} \\ T_{1/2} \qquad \text{The half-life of the parent nucleus} \\ Q_{\varepsilon} \qquad \text{Total electron capture energy } Q_{\varepsilon} = M(A,Z) - M(A, Z-1) \\ Q_{\varepsilon p} \qquad \text{Total energy available for } \beta^+ - p; Q_{\varepsilon p} = M(A,Z) - M(A-1, Z-2) - {}^{1}\text{H} \\ Q_{\varepsilon 2p} \qquad \text{Total energy available for } \beta^+ - 2p; Q_{\varepsilon 2p} = M(A,Z) - M(A-2, Z-3) - 2{}^{1}\text{H} \\ Q_{\varepsilon 3p} \qquad \text{Total energy available for } \beta^+ - 3p; Q_{\varepsilon 3p} = M(A,Z) - M(A-3, Z-4) - 3{}^{1}\text{H} \\ Q_{\varepsilon \alpha} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } Q_{\alpha} = M(A,Z) - M(A-4, Z-3) - {}^{4}\text{He} \\ \text{S} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } S = M(A,Z) - M(A-1, Z, 1) - {}^{1}\text{H} \\ \text{S} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } S = M(A,Z) - M(A-1, Z, 1) - {}^{1}\text{H} \\ \text{S} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } S = M(A,Z) - M(A-1, Z, 1) - {}^{1}\text{H} \\ \text{S} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } S = M(A,Z) - M(A-1, Z, 1) - {}^{1}\text{H} \\ \text{S} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } S = M(A,Z) - M(A-1, Z, 1) - {}^{1}\text{H} \\ \text{S} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } S = M(A,Z) - M(A-1, Z, 1) - {}^{1}\text{H} \\ \text{S} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } S = M(A,Z) - M(A-1, Z, 1) - {}^{1}\text{H} \\ \text{S} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } S = M(A,Z) - M(A-1, Z, 1) - {}^{1}\text{H} \\ \text{S} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } S = M(A,Z) - M(A-1, Z, 1) - {}^{1}\text{H} \\ \text{S} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } S = M(A,Z) - M(A-1, Z, 1) - {}^{1}\text{H} \\ \text{S} \qquad \text{Total energy available for } \beta^+ - \alpha \text{ emission; } \beta^+ - \alpha emissi$
$\begin{array}{llllllllllllllllllllllllllllllllllll$
$\begin{array}{lll} Q_{\varepsilon} & \text{Total electron capture energy } Q_{\varepsilon} = M(A,Z) - M(A, Z-1) \\ Q_{\varepsilon_p} & \text{Total energy available for } \beta^+ \text{-p; } Q_{\varepsilon_p} = M(A,Z) - M(A-1, Z-2) - {}^{1}\text{H} \\ Q_{\varepsilon_{2p}} & \text{Total energy available for } \beta^+ - 2\text{p; } Q_{\varepsilon_{2p}} = M(A,Z) - M(A-2, Z-3) - 2{}^{1}\text{H} \\ Q_{\varepsilon_{3p}} & \text{Total energy available for } \beta^+ - 3\text{p; } Q_{\varepsilon_{3p}} = M(A,Z) - M(A-3, Z-4) - 3{}^{1}\text{H} \\ Q_{\varepsilon_{\alpha}} & \text{Total energy available for } \beta^+ - \alpha \text{ emission; } Q_{\alpha} = M(A,Z) - M(A-4, Z-3) - {}^{4}\text{He} \\ \end{array}$
$\begin{array}{ll} Q_{\varepsilon p} & \text{Total energy available for } \beta^+ \text{-p; } Q_{\varepsilon p} = M(A,Z) - M(A-1,Z-2) - {}^1\text{H} \\ Q_{\varepsilon 2p} & \text{Total energy available for } \beta^+ \text{-2p; } Q_{\varepsilon 2p} = M(A,Z) - M(A-2,Z-3) - 2{}^1\text{H} \\ Q_{\varepsilon 3p} & \text{Total energy available for } \beta^+ \text{-3p; } Q_{\varepsilon 3p} = M(A,Z) - M(A-3,Z-4) - 3{}^1\text{H} \\ Q_{\varepsilon \alpha} & \text{Total energy available for } \beta^+ -\alpha \text{ emission; } Q_{\alpha} = M(A,Z) - M(A-4,Z-3) - {}^4\text{He} \\ \text{S} & \text{Total energy available for } \beta^+ -\alpha \text{ emission; } S = M(A,Z) + M(A-1,Z-1) - {}^1\text{H} \\ \end{array}$
$\begin{array}{ll} Q_{\varepsilon 2p} & \text{Total energy available for } \beta^+ - 2p; \ Q_{\varepsilon 2p} = M(A,Z) - M(A-2, Z-3) - 2^1 H \\ Q_{\varepsilon 3p} & \text{Total energy available for } \beta^+ - 3p; \ Q_{\varepsilon 3p} = M(A,Z) - M(A-3, Z-4) - 3^1 H \\ Q_{\varepsilon \alpha} & \text{Total energy available for } \beta^+ - \alpha \text{ emission; } Q_{\alpha} = M(A,Z) - M(A-4, Z-3) - {}^4 \text{He} \\ \text{S} & \text{Total energy available for direct one proton emission; } S = M(A,Z) + M(A-1,Z,1) - {}^1 H \end{array}$
$\begin{array}{ll} Q_{\varepsilon_{3p}} & \text{Total energy available for } \beta^+-3p; \ Q_{\varepsilon_{3p}}=M(A,Z) - M(A-3, Z-4) - 3^1 \text{H} \\ Q_{\varepsilon\alpha} & \text{Total energy available for } \beta^+-\alpha \text{ emission; } Q_{\alpha}=M(A,Z) - M(A-4, Z-3) - {}^4 \text{He} \\ \text{S} & \text{Total energy available for direct on proton emission; } S = M(A,Z) + M(A-1,Z-1) - {}^1 \text{H} \\ \end{array}$
$Q_{\varepsilon\alpha}$ Total energy available for $\beta^+ - \alpha$ emission; $Q_{\alpha} = M(A,Z) - M(A-4,Z-3) - {}^4\text{He}$
S Total energy available for direct one proton emission: $S = M(\Lambda T) + M(\Lambda T T)^{-1} H$
S_p for a energy available for uncer one proton emission, $S_p = -iv(A, Z) + iv(A-1, Z-1) - \Pi$
S_{2p} Total energy available for direct two proton emission; $S_p = -M(A,Z) + M(A-2, Z-2) - 2^1 H$
Value from systematics [2021Wa16]
$BR_{\beta p}$ Measured branching ratio for β^+ -p emission
$BR_{\beta_{2p}}$ Measured branching ratio for β^+ -delayed two proton emission
$BR_{\beta_{3p}}$ Measured branching ratio for β^+ -delayed three proton emission
BR_{α} Measured branching ratio for direct α emission
$BR_{\beta\alpha}$ Measured branching ratio for β^+ -delayed α emission
$BR_{\beta F}$ Measured branching ratio for β^+ delayed fission
BR _{<i>p</i>} Measured branching ratio for direct one proton emission, not including β -delayed multiple proton emission
BR _{2p} Measured branching ratio for direct two proton emission
BR _{SF} Measured branching ratio for spontaneous fission
$E_n(c.m.)$ Energy (MeV) of the emitted proton in the center of mass frame
$E_p(lab)$ Energy (MeV) of the emitted proton in the laboratory frame
E_{2p} Sum energy (MeV) of the 2 emitted protons in β^+ -2p decay in the center of mass frame
E_{3p} Sum energy (MeV) of the 3 emitted protons in β^+ -3p decay in the center of mass frame
$E_{\alpha}(c.m.)$ Energy of the emitted α particle in the center of mass frame
E_{α} (lab) Energy (MeV) of the emitted α in the laboratory frame
$I_p(rel)$ % Relative intensity of the direct or β^+ -delayed p transition with the largest transition set to 100%
$I_p(abs)\%$ Absolute intensity of the direct or β^+ -delayed p transition per 100 decays.
I_{2p} Intensity of the β^+ -2p transition
I_{3p} Intensity of the β^+ -3p transition
$I_{\alpha}(rel)$ % Relative intensity of the direct or β^+ -delayed α transition with the largest transition set to 100%
$I_{\alpha}(abs)\%$ Absolute intensity of the direct or β^+ -delayed α transition per 100 decays
$E_{emitter}$ (nuclide) Energy (MeV) of the state fed by β^+ -decay that emits a proton, the level energy is calculated from the particle
energy and the particle separation energy taken from [2021 Wa16]. For levels de-excited by more than one proton transition $F_{\rm energy}$ (amittar) is the weighted every $r_{\rm exc}$
E_{level} (condition) is the weighted average.
$L_{daughter}$ (nucled) Energy (new) of the state for by the energy patter emission coincident variables. (n α)
concluent γ -rays - Energies (we v) of gamma-rays concluent with the enfluence heavy enarged particles (p, α)
R ₀ nuclear radius parameter
HF Hindrance Factor



β β β ß

Fig. 1: Known experimental values for heavy particle emission of the T_z = -4 nuclei.

Last updated 3/17/23

Table 1

Observed and predicted β -delayed particle emission from the even-Z, $T_z = -4$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	J^{π}	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon 3p}$	$Q_{\varepsilon \alpha}$	Experimental
⁴⁸ Ni	0^+	$2.1^{+1.4}_{-0.6}~{ m ms}$	16.45(66)#	18.02(66)#	30(20)%	16.02(43)#	15.82(42)#	8.30(52)#	[2014Po05, 2011Po09]

Table 2

Particle separation and emission from the even-Z, $T_z = -4$ nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	S _p	BR_{1p}	S _{2p}	BR _{2p}	Qα	Experimental
⁴⁸ Ni	-0.27(74)#		-2.39(30)#	70(20)%	-4.83(5)*	[2014Po05, 2011Po09 , 2005Do20]

* Prediction from Ref. [2013Ti01].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z T_z = -7/2 nuclei.

Last updated 3/17/23

Observed and predicted β -delayed particle emission from the even-Z, $T_z = -7/2$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	J^{π}	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$BR_{\beta 2p}$	$Q_{\varepsilon 3p}$	$BR_{\beta 3p}$	$Q_{\varepsilon \alpha}$	Experimental
²⁹ Ar			23.95(48)#	26.61(47)#		24.05(44)#		23.24(44)#		15.36(59)#	
³³ Ca			23.49(40)#	25.94(40)#		23.49(40)#		23.22(40)#		24.59(44)#	
³⁷ Ti			21.39(50)#	24.33(40)#		21.77 (40)#		21.68(40)#		15.21(45)#	
⁴¹ Cr			20.10(45)#	22.11(41)#		20.01(40)#		20.60(40)#		14.21(50)#	
⁴⁵ Fe	$(3/2^+)$	3.76(22) ms	19.39(41)#	20.54(29)#	18.9(35)%*	17.75(28)#	7.8(23)%*	17.65(28)#	3.3(16)%*	11.68(34)#	[2012As02, 2012Au08,
											2016ChZV, 2011Bl01,
											2009Gr07, 2009Mi29,
											2008Mi03, 2007Mi36,
											2005Do20, 2007Gi10,
											2005Bl31, 2005Gi15,
											2002Pf02, 2002Gi09,
											2001Gi01, 1996Bl21]
⁴⁹ Ni	7/2-	7.5(10) ms	18.31(78)#	19.25(61)#	83(13)%	16.52(60)#		16.14(60)#		1.09(67)#	[2007Do17, 1996Bl21]

* deduced from values in [2007Mi36]

Table 2

Particle emission from the even-Z, $T_z = -7/2$ nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	\mathbf{S}_p	BR_{1p}	S_{2p}	BR_{2p}	Qα	Experimental
29 .	2 41/25)#		5 00(19)#		0.02((2)#	
Ar 33 C	-2.41(55)#		-5.90(18)#		-8.03(03)#	
³⁵ Ca	-1./5(5/)#		-5.13(45)#		-9.36(59)#	
57/ T 1	-1.73(50)#		-5.40(45)#		-8.29(57)#	
⁴¹ Cr	-0.65(50)#		-3.33(45)#		-7.19(57)#	
⁴⁵ Fe	0.34(41)#		-1.21(5)*	70(4)%**	-8.43(49)#	[2012As02, 2012Au08, 2007Mi36, 2011Bl01,
						2009Gr07, 2009Mi29, 2008Mi03, 2007Gi10,
						2005Do20, 2005B131, 2005Gi15, 2002Pf02,
						2002Gi09]
⁴⁹ Ni	0.49(78)#		-1.08(78)#		-8.30(66)#	
* from ** [200 *** Pro Table 3	[2012Au08], [202 07Mi36]. ediction from Ref.	1Wa16] lists - [2013Ti01].	1.80(20)#.			
direct 2 pro	ton emission from	45 Fe*, T _{1/2} =	$3.76(22) \text{ ms}, BR_p$	=100%.		
				10		
$E_{2p}(\text{c.m.})$		$I_{2p}(abs)$	I	E _{daughter} (⁴³ Cr)		
1.21(5)		100%	C	0.0		

* All values from [2012Au08].

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$$\begin{tabular}{|c|c|c|c|c|c|} \hline $47C0$ & $Qep = 17.75 \mbox{ MeV}$ \\ $Sp = -2.12 \mbox{ MeV}$ \\ $S2p = -1.02 \mbox{ MeV}$ \\ \hline \end{tabular}$$









Fig. 1: Known experimental values for heavy particle emission of the odd T_z = -7/2 nuclei.

Last updated 3/17/23

Table 1
Observed and predicted β -delayed particle emission from the odd-Z, $T_z = -7/2$ nuclei

Nuclide	J^{π}	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon 3p}$	$Q_{\varepsilon \alpha}$	Experimental
31 K		<10 ps	22.94(36)#	22 30(30)#		22 78(30)#	19 54(30)#	14 35(50)#	[2010Ko18]
35 Sc		<10 ps	22.94(30)# 21.91(45)#	21.03(45)#		22.78(30)# 21.91(40)#	18 57(40)#	13.35(30)#	[2017][010]
³⁹ V			21.91(45)# 20.07(45)#	19 53(45)#		21.91(40)# 21.13(40)#	18.17(40)#	13.35(45)# 14.96(45)#	
⁴³ Mn			19 34(45)#	17.33(43)# 17.70(45)#		18 49(40)#	16.03(40)#	17.90(45)# 12.45(45)#	
⁴⁷ Co			17.75(78)#	15.75(61)#		15.55(60)#	12.56(60)#	10.17(63)#	
Table 2 Particle err	nission fr	om the odd-Z	$T_z = -7/2$ nuclei						
						_			
Nuclide		\mathbf{S}_p	BR ₁	D	S _{2p}	Qα		Experimental	
³¹ K		-2.15(15)*	100	6	-5.66(35)#				
³⁵ Sc		-4.92(50)#			-4.980(45)#	-9.59	9(50)#		
³⁹ V		-3.91(50)#			-4.21(50)#	-6.9	6(57)#		
⁴³ Mn		-3.02(50)#			-2.48(45)#	-7.6	3(57)#		
⁴⁷ Co		-2.12(67)#			-1.02(67)#	-9.13	8(72)#		
* Fror	n [2019]	Ko18], [2021W	/a16] lists -4.90(3	5)#.					
Table 3									
direct prote	on emiss	ion from ³¹ K*	, $T_{1/2} = <10 \text{ ps},$	$BR_p = 100\%.$					
$E_{n}(c.m.)$		$I_n($	abs)	Edaua	$htar(^{30}Ar)$				

2.15(15) 100%

* All values from [2019Ko18].

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Fig. 1: Known experimental values for heavy particle emission of the even $Z T_z = -3$ nuclei.

Last updated 3/17/23

Observed and predicted β -delayed particle emission from the even Z, $T_z = -3$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	J^{π}	$T_{1/2}$	Q_{ε}	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$BR_{\beta 2p}$	$Q_{\varepsilon 3p}$	$Q_{\varepsilon \alpha}$	Experimental
²² Si	0^+	28.6(14) ms*	15.44(64)#	15.45(50)#	61.8(52)%*	12.21(50)#	0.7(3)%**	10.02(50)#	6.18(51)#	[2020Le16, 2017Xu01, 2022Ci04,
										1997Cz02, 1996B1111
²⁶ S	0^{+}	< 79 ns	16.71(63)#	16.56(60)#		13.15(60)#		11.29(60)#	7.06(72)#	[2011Fo08]
30 Ar	0^+	< 10 ps	17.40(18)#	17.88(18)		14.64(18)		12.59(18)#	8 67(27)#	[2019Ko18 2016Xu08 2015Mu13]
³⁴ Co	0^+	< 10 ps	17.40(10)#	17.00(10) 16.00(20)#		14.04(10)		12.37(10)#	7.70(20)#	[2017][010, 2010][000, 2013][0113]
	0.	< 55 lls	10.11(50)#	10.99(30)#		15.04(50)#		12.07(50)#	7.79(50)#	
³⁸ Ti	0^+	< 120 ns	15.62(36)#	17.22(30)#		14.21(30)#		12.55(30)#	10.17(36)#	[1996Bl21]
⁴² Cr	0^+	13.3(10) ms***	14.68(36)#	15.47(30)#	94.4(50)%	13.01(30)#		12.48(30)#	8.89(36)#	[2007Do17, 2001Gi01]
⁴⁶ Fe	0^+	13.0(20) ms***	13.63(31)#	13.44(30)#	66(4)% [@]	10.44(30)#	0.4(6)%@	8.66(30)#	6.41(36)#	[2014Po05, 2007Do17, 1992Bo37]
⁵⁰ Ni	0^+	18.5(12) ms***	14.13(52)#	14.00(50)#	$86.7(6)\%^a$	11.26(50)#	14(5)%	9.24(50)#		[2007Do17, 2003Ma34]
⁵⁴ 7n	0^{+}	$1.59^{+0.60}$ ms	1554(45)#	16.64(22)#	b	14.07(22)#	- (()))	12.62(22)#	9 47(26)#	[2011As08 2005Bl15]
50	0	1.57 _{-0.35} ms	15.54(45)	10.04(22)#		14.07(22)		12.02(22)).+/(20)II	[2011/1300, 2003/0115]
³ °Ge	0^+	<100 ns	15.96(58)#	17.68(54)#		16.47(50)#		15.89(50)#	11.24(64)#	[2016Bl05]

* [2020Le16]

** [2017Xu01].

*** [2007Do17]

@ [2014Po05]

^a Energies of individual proton peaks not reported in [2007Do17, 2003Ma34].

^b Events were measured in [2011As08, 2005B115] consistent with β -delayed proton emission.

Table 2

Particle emission from even Z, $T_z = -3$ nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	S_p	BR_{1p}	S_{2p}	BR_{2p}	Qα	Experimental
22 5:	0.74(79)#		1 59/50)#			
260	0.74(78)#		-1.38(30)#		0.20/70\//	
8	-0.20(72)#		-2.36(60)#		-8.39(78)#	
³⁰ Ar	-0.76(13)#		$-2.45^{+0.05}_{-0.10}*$	100%	-8.03(63)#	[2019Ko18, 2016Xu08, 2015Mu13]
³⁴ Ca	-0.06(36)#		-2.51(30)#		-9.61(35)#	
³⁸ Ti	-0.30(42)#		-3.24(30)#		-5.95(42)#	
⁴² Cr	0.54(36)#		-1.48(31)#		-6.74(42)#	
⁴⁶ Fe	1.10(42)#		-0.05(30)#		-8.28(42)#	
⁵⁰ Ni	0.97(71)#		0.03(51)#		-7.09(58)#	
⁵⁴ Zn	-0.15(55)#		-2.28(20)	$90^{+5}_{-10}\%$	-4.67(55)#	[2011As08]
⁵⁸ Ge	-0.54(64)#		-3.23(64)	-10	-4.30(55)#	[2011As08]

* [2019Ko18]

Table 3

 β -p emission from ²²Si*, T_{1/2}= 28.6(14) ms, BR_{βp} = 61.8(52)%

$E_p(c.m.)$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ (²² Al)**	<i>E</i> _{daughter} (²¹ Mg)***	coincident γ-rays***	
0.71(5) 1.95(5) 2.15(5)	12(3) 100(15) 31(6)	5.3(10) 43.0(46) 13.5(21)	0.902(403) 2.142(403) 2.142(403)	0.202(4) 0.202(4) 0	0.202 0.202	

*All values taken from [2020Le16] except where noted. [1997Cz02, 1996B111] reported protons with energies of 1.63(5) and 2.10(5) meV which were nor observed in [2020Le16].

** Calculated from proton energies and S_p (²²Al) = -10(400) keV [2021Wa16]. For levels de-excited by more than one proton transition, E_{level} (emitter) is the weighted average.

*** Values from measured γ energy in [2020Le16].

Table 4

β -2p emission from ²² S	$i^*, T_{1/2} = 28.6(14) \text{ ms}, H$	$BR_{\beta 2p} = 0.7(3)\%.$		
$E_{2p}(c.m.)$	$I_p(abs)$	$E_{emitter}$ (²² Al)	$E_{daughter}(^{20}\mathrm{Na})$	coincident γ-rays
5.600(70)	0.007(3)	8.83(41)	0	

*All values taken from [2017Xu01] except where noted.

** Calculated from two proton energy and S_{2p} (²²Al) = 3230(400)# keV [2021Hu06].

Table 5 β -p emission from ⁴²Cr*, T_{1/2}= 13.3(10) ms**, BR_{β,p} = 94.4(50)%.

$E_p(\text{c.m.})$	$I_p(rel)$	$I_p(abs)$	$E_{emitter}$ (⁴² V)	$E_{daughter}(^{41}\mathrm{Ti})$	coincident γ -rays	
1 537(35)	31(25)	14(11)				
1.951(20)	100(34)	45(15)				
2.551(30)	31(25)	14(11)				
3.186(20)	26(14)	11.8(64)				
3.806(20)	21(14)	9.5(61)				

* Energies and relative intensities are taken from [2001Gi01]. Absolute intensities are calculated from the relative intensities modified by the total branching ratio from [2007Do17].

** [2007Do17].

Table 6

β.	-p emission	from 46Fe*,	$T_{1/2} =$	13.0(20) ms,	$BR_{\beta p} =$	78.7(38)%
----	-------------	-------------	-------------	--------------	------------------	-----------

$E_p(\text{c.m.})$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ (⁴⁶ Mn)**	$E_{daughter}(^{45}\mathrm{Cr})$	coincident γ -rays	
≈0.75***	12(7)	1 2(7)				
≈1.05***	16(8)	1.6(8)				
1.457(28)	100(30)	10(3)				
1.692(23)	40(40)	4(4)				
3.272(23)	61(25)	6.1(25)				
4.239(33)	79(32)	7.9(32)	4.92(9)+x	0.494+x	0.494	

*All values taken from [2007Do17] except where noted.

** Calculated from proton energies and \hat{S}_p (⁴⁶Mn) = 190(90)# keV [2021Hu06].

*** Possible transitions from [2014Po05].

Table 7

$E_{2p}(c.m.)$	$I_p(abs)$	E _{emitter} (⁵⁰ Co)**	$E_{daughter}(^{48}\mathrm{Mn})$	coincident γ-rays
1.972(13)	14(5)	4.82(13)	0	

*All values taken from [2007Do17] except where noted.

** Calculated from two proton energy and S_{2p} (⁵⁰Co) = 2870(130)# keV [2021Hu06].

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Last updated 3/17/23

Observed and predicted β -delayed particle emission from the odd Z, $T_z = -3$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	J^{π}	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon 3p}$	$Q_{\varepsilon \alpha}$	Experimental
24 D			22 28/50)#	10.09/50\#		10.94/50)#	14.24(50)#		
2 · P			23.28(50)#	19.98(50)#		19.84(50)#	14.34(50)#		
²⁸ Cl			24.20(53)#	21.64(50)#		20.83(50)#	15.32(50)#	15.10(50)#	
³² K			24.19(40)#	21.74(40)#		21.47(40)#	16.18(40)#	15.50(43)#	
³⁶ Sc			22.60(20)#	20.03(30)#		19.95(30)#	15.29(30)#	15.93(30)#	
^{40}V			21.46(31)#	19.35(30)#		19.95(30)#	15.40(30)#	16.50(30)#	
⁴⁴ Mn		< 105 ns	20.88(30)#	18.09(30)#		17.99(30)#	14.24(30)#	14.03(31)#	[1992Bo07]
⁴⁸ Co			19.74(51)#	18.02(66)#		16.62(50)#	11.75(50)#	12.73(50)#	
⁵² Cu			20.68(61)#	18.17(60)#		18.02(60)#	13.87(60)#	13.71(61)#	
⁵⁶ Ga			21.55(64)#	20.51(52)#		20.86(50)#	16.95(50)#	16.30(51)#	
⁶⁰ As			21.89(50)#	20.83(43)#		22.08(40)#	19.80(40)#	17.33(57)#	

Table 2

Particle emission from odd Z, $T_z = -3$ nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	\mathbf{S}_p	BR_{1p}	S_{2p}	BR_{2p}	Qα	Experimental
24 D	2 78(71)#		1 24(64)#			
²⁸ Cl	$-1.60(8)^*$	100%	-2.72(54)#		-8.18(71))#	[2018Mu18]
³² K	-3.38(45)#		-2.74(40)#		-8.71(64)#	[]
³⁶ Sc	-3.67(36)#		-2.79(36)#		-8.26(50)#	
^{40}V	-2.68(36)#		-2.14(36)#		-6.11(42)#	
⁴⁴ Mn	-2.14(36)#	100%**	-0.50(36)#		-7.43(42)#	[1992Bo07]
⁴⁸ Co	-01.57(71)#		0.43(51)#		-8.16(58)#	
⁵² Cu	-2.48(78)#		-1.23(61)#		-6.03(78)#	
⁵⁶ Ga	-3.14(64)#		-2.82(64)#		-4.39(78)#	
⁶⁰ As	-3.44(57)#		-3.32(50)#		-4.23(64)#	

* from [2018Mu18], -3.49(30)# in [2021Wa16].

** Inferred from Half-life.

Table 3

direct proton emission from ${}^{28}\text{Cl}^*$, $BR_p = 100\%$.

Eparent	$E_p(\text{c.m.})$	$E_p(lab)$	$I_p(abs)$	$E_{daughter}(^{27}\mathrm{S})$	
0.0	1.60(8)	1.54(8)	100%	0.0	
1.60	3.20(6)	3.09(6)	100%	0.0	

* All values from [2018Mu18].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z T_z = -5/2 nuclei.

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Observed and predicted β -p, β -2p, and β -3p emission from the even-Z $T_z = -5/2$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	J^{π}	$T_{1/2}$	Q_{ε}	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$BR_{\beta 2p}$	$Q_{\varepsilon_{3p}}$	$BR_{\beta 3p}$	$Q_{\varepsilon \alpha}$	Experimental
		1/2			PI		PI		p · i		
¹¹ O	(3/2-)	1.30 MeV	23.37(6)	24.75(6)		20.75(6)		17.637(65)		11.24(64)#	[2019We03]
¹⁵ Ne		0.59 MeV	23.65(7)	24.92(7)		20.30(7)		18.35(7)		13.43(67)#	[2014Wa09]
¹⁹ Mg		4.0(15) ps	18.910(60)	19.23(60)		15.31(60)		14.71(60)		12.85(60)	[2007Mu15]
²³ Si*	$(5/2)^+$	42.3(4) ms	17.20(50)#	17.06(50)#	81.8(11)%**	11.56(50)#	7.73(35)%**	9.13(50)#	$0.029^{+0.038}_{-0.019}\%^{**}$	8.60(50)#	[2022Ci04, 2018Wa05,
									0.017		1997Cz02, 1997Bl04]
²⁷ S	$(5/2)^+$	16.3(2) ms***	18.15(40)#	17.34(40)#	62.2(29)% [@]	11.83(40)#	2.4(5)%***	9.56(40)#	<0.1%	8.32(40)#	[2021Sh23, 2020Su05,
											2019Su14, 2017Ja05,
											2001Ca60, 1991Bo32]
³¹ Ar	$5/2^{+}$	15.1(3) ms ^{@@}	18.36(20)#	18.10(20)#	68.3(3)%	13.71(20)#	9.0(2)%	10.96(20)#	0.07(2)%	9.57(20)#	@@@
³⁵ Ca	$(1/2^+)$	25.7(2) ms	16.36(20)#	16.28(20) #	95.7(15)%	11.62(20)#	4.2(3)%	9.34(20)#		9.80(20)#	[2016Ci05, 2015Li20,
											1999Tr04, 1985Ay01]
³⁹ Ti	$(3/2^+)$	28.5(9) ms	16.67(20)#	17.27(20)#	93.7(28)% ^a	12.72(20)#	a	10.87(20)#		11.25(20)#	[2007Do17, 1992Mo15,
10											2001Gi01, 1990De43]
⁴³ Cr	$(3/2^+)$	21.2(7) ms	15.95(21)#	15.85(20)#	79.3(30)%	12.09(20)#	11.6(10)%	11.01(20)#	$0.13^{+0.18}_{-0.08}\%$	9.78(20)#	[2012Au08, 2007Do17,
											2011Po01, 2001Gi01,
											1992Bo37]
⁴ /Fe	$(7/2^{-})$	21.9(2) ms	15.44(50)#	15.05(50)#	88.4(9)%	10.18(50)#		8.55(50)#		8.37(50)#	[2007Do17 , 1992Bo37]
⁵¹ Ni	7/2-	23.8(2) ms	15.69(50)#	15.54(50)#	87.2(9)% ^b	11.39(50)#	$0.50(2)\%^{c}$	9.30(50)#		8.50(80)#	[2012Au08, 2007Do17]
⁵⁵ Zn	5/2-	19.8(13) ms	17.37(43)#	17.72(40)#	91.0(51)%	13.81(40)#		12.20(40)#		10.65(40)#	[2007Do17]
⁵⁹ Ge		13.3(17) ms	17.39(43)#	18.64(40)#	100%	16.36(40)#		15.67(40)#		12.85(53)#	[2017GoZT, 2016Go26,
											2015Ci06]
⁶³ Se		13.2(39) ms	16.65(54)#	18.00(52)#	100%	15.70(50)#		15.46(50)#		14.49(53)#	[2017GoZT, 2016Go26]
⁶⁷ Kr		7.4(30) ms	16.98(52)#	18.82(47)#	$63(14)\%^d$	16.81(43)#		16.90(42)#		15.52(47)#	[2017GoZT, 2016Go26]

* In addition a branching ratio for β -p α is reported as 0.014^{+0.033}_{-0.012}% [2022Ci04].

** [2022Ci04]

*** [2021Sh23]

[@] From [2021Sh23] plus two high energy peaks from [2001Ca60].

@@ [2015Li20]

@ @ @ [2015Li20, 2000Fy01, 1998Ax02, 1992Ba01, 2019Ko29, 2018Mu18, 2016Ci05, 2016Ma17, 2014Ko17, 2014Ko34, 2013Ko13, 2002Fy01, 2002Bo29, 1999Fy01, 1999Th09, 1998Ax01, 1998Mu06, 1991Bo32, 1990Bo24, 1989Re02]].

^{*a*} Mixture of β -p and β -2p [2007Do17], β -xp is expected to be 100% as ³⁹Sc is unbound to proton emission S_p= -597(24) keV [2021Wa21].

^b [2007Do17].

c [2012Au08].

 ${}^{d}\beta$ -daughter 67 Br is unbound to proton emission.

Table 2

Particle emission from the even-Z $T_z = -5/2$ nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

	~				
Nuclide	S_p	S_{2p}	BR_{2p}	Qα	Experimental
110	1 (5(40)	1.05(())	1000		[2010XV 02]
0	-1.65(40)	-4.25(6)	100%		[2019 we03]
¹⁵ Ne	-0.96(8)	-2.52(7)	100%	-9.95(9)	[2014Wa09]
¹⁹ Mg	0.49(11)	-0.760(50)	100%	-10.80(90)	[2018Xu04, 2016Xu08, 2015Mu13,
e					2012Mu05, 2009Mu17, 2007Mu15]
²³ Si	1.54(64)#	1.53(50)#		-10.31(50)#	
²⁷ S	0.77(45)#	0.91(40)#		-8.88(64)#	
³¹ Ar	0.64(20)#	0.006(34)*		-8.59(45)#	
³⁵ Ca	0.88(28)#	0.00(20)#		-8.56(28)#	
³⁹ Ti	0.54(28)#	-1.06(20)#		-5.12(28)#	
⁴³ Cr	1.64(28)#	0.85(20)#		-6.90(28)#	
⁴⁷ Fe	2.00(51)#	2.19(50)#		-7.58(54)#	
⁵¹ Ni	1.35(52)#	1.48(50)#		-6.95(71)#	
⁵⁵ Zn	0.32(57)#	-0.78(40)#		-5.04(64)#	
⁵⁹ Ge	0.12(50)#	-1.60(45)#	$<\!\!0.2\%$	-4.53(57)#	[2017GoZT]
⁶³ Se	-0.28(58)#	-2.36(58)#	$<\!0.5\%$	-2.91(64)#	[2017GoZT]
⁶⁷ Kr	-0.73(58)#	-2.89(30)#	37(14)%	-1.13(66)#	2017GoZT, 2016Go26]

* from [2018Mu18], [2021Wa16] lists 0.64(20)#

Table 3	
β -p Emission from ²³ Si*, T _{1/2} = 42.3(4) ms, $BR_{\beta p} = 81.8(11) \%^{c}$	

$E_p(\text{c.m.})$	$I_p(\text{rel})\%$	$I_p(abs)\%$	$E_{emitter}$ (²³ Al)**	$E_{daughter}(^{22}Mg)^{***}$	coincident γ-rays***
	. 0.22	.0.00			
$0.300(90)^c$	$0.45^{+0.22}_{-0.15}$	$0.12^{+0.06}_{-0.04}$			
0.654(31)	9.1(4)	2.4(1)	0.795(31)	0	
1.333(28)	21.8(14)	5.78(37)	1.474(28)	0	
1.657(37)	17(2)	4.6(6)	1.798(37)	0	
2.356(29)	100(5)	26.5(14)	3.744(29)	1.247	1.247
2.764(35)	36.4(4)	9.64(10)	4.152(35)	1.247	1.247
3.024(36)	31.9(14)	8.5(4)	3.165(36)	0	
3.592(44)	27.2(8)	7.2(2)	3.733(44)	0	
	23.4(4)	$6.2(1)^{a}$	3.952(51)	0	
4.235(39)	18.8(4)	4.99(10)	4.376(39)	0	
4.781(41)	10.1(7)	2.7(2)	4.922(41)	0	
5.545(82) ^a			5.686(82)	0	
$8.680(70)^{b}$	1.5(4)	$0.4(1)^{b}$	8.821(70)	0	
$9.670(70)^{b}$	0.4(2)	$0.11(4)^{b}$	9.811(70)	0	
$10.410(70)^{b}$	0.3(1)	$0.07(3)^{b}$	10.551(70)	0	
$10.930(80)^{b}$	0.3(1)	$0.09(3)^{b}$	11.071(80)	0	
$11.620(100)^b$	0.1(1)	$0.03(2)^{b}$	11.761(100)	0	

* Weighted average of [2018Wa05] and [1997Bl04, 1997Cz02], except where noted. ** Calculated from proton energies [1997Bl04] and Sp (23 Al) = 140.9(4) keV [2021Hu06]. For levels de-excited by more than one proton transition, E_{level} (emitter) is the weighted average. *** Values from adopted levels in ENSDF [2015Ba27].

^{*a*} [2018Wa05]. ^{*b*} [1997Bl04].

^c [2022Ci04].

Table 4

 β -2p emission from ²³Si*, $BR_{\beta 2p} = 7.73(35)\%^{@}$.

$E_{2p}(c.m.)$	$I_{2p}(\text{rel})\%$	$I_{2p}(abs)\%$	E _{emitter} (²³ Al)**	$E_{daughter}(^{21}Na)^{***}$	coincident γ-rays***
5.858(55)	100	1.85(20)	11.78(7)	0.3319(10)	0.332
6.052(55)	86(20)	1.60(20)	11.78(7)	0	

* Weighted average of [2018Wa05] and [1997Bl04, 1997Cz02]. ** Determined from ²³Si β -p emission.

*** Values from adopted levels in ENSDF [2015Fi05].

@ [2022Ci04].

Table 5	
β -p emission from ²⁷ S*, T _{1/2} = 16.3(2) ms ^b , BR _{\beta p} = 62.2(29)%	

$E_p(c.m.)$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter} (^{27} P)^a$	Edaughter (26Si)@	coincident γ -rays [@]
0.318(8)	100(9)	23.1(21)	1.125(12)	0	—
0.762(8)	38.5(61)	8.9(1)	1.569(12)	0	_
0.913(9)	6.5(18)	1.5(3)	4.507(13)	2.7871(1)	0.9889, 1.7922, 2.7870
1.054(9)	7.8(18)	1.8(3)	1.861(13)	0	—
1.282(9)	4.8(12)	1.1(2)	4.876(13)	2.7871(1)	0.9889, 1.7922, 2.7870
1.676(9)	2.6(18)	0.6(3)	5.270(13)	2.7871(1)	0.9889, 1.7922, 2.7870
1.86(12)	1.3(18)	0.3(3)	4.464(15)	1.7973	1.7973
1.951(11)	3.5(18)	0.8(3)	5.545(14)	2.7871(1)	0.9889, 1.7922, 2.7870
2.128(10)	4.3(18)	1(3)	5.722(13)	2.7871(1)	0.9889, 1.7922, 2.7870
2.264(9)	24.7(49)	5.7(8)	5.858(13)	2.7871(1)	0.9889, 1.7922, 2.7870
2.417(11)	6.9(24)	1.6(4)	5.021(14)	1.7973	1.7973
2.576(11)	5.6(24)	1.3(4)	6.170(14)	2.7871(1)	0.9889, 1.7922, 2.7870
2.717(10)	2.6(12)	0.6(2)	3.524(13)	0	_
2.808(10)	8.7(31)	2(5)	6.402(13)	2.7871(1)	0.9889, 1.7922, 2.7870
2.953(12)	4.8(24)	1.1(4)	6.547(15)	2.7871(1)	0.9889, 1.7922, 2.7870
3.03(12)	4.3(18)	1(3)	6.624(15)	2.7871(1)	0.9889, 1.7922, 2.7870
3.121(11)	4.8(24)	1.1(4)	6.715(14)	2.7871(1)	0.9889, 1.7922, 2.7870
3.238(11)	6.1(24)	1.4(4)	5.842(14)	1.7973	1.7973
3.475(12)	3.5(18)	0.8(3)	7.069(15)	2.7871(1)	0.9889, 1.7922, 2.7870
3.720(11)	1.7(12)	0.4(2)	6.324(14)	1.7973	1.7973
3.786(11)	1.7(12)	0.4(2)	7.380(14)	2.7871(1)	0.9889, 1.7922, 2.7870
3.95(11)	1.7(6)	0.4(1)	6.554(14)	1.7973	1.7973
4.05(11)	5.2(18)	1.2(3)	6.654(14)	1.7973	1.7973
4.26(15)	1.7(12)	0.4(2)	6.864(17)	1.7973	1.7973
4.399(15)	2.2(12)	0.5(2)	7.993(17)	2.7871(1)	0.9889, 1.7922, 2.7870
4.693(15)	1.7(12)	0.4(2)	8.287(17)	2.7871(1)	0.9889, 1.7922, 2.7870
4.84(12)	2.2(12)	0.5(2)	7.444(15)	1.7973	1.7973
7.80(40)***	5.4(19)	1.4(5)%***			
10.56(40)***	3.4(15)	0.9(4)%***	13.164(400)	1.7973	1.7973
10100(10)	2(15)	0.2(.)/0	121121(100)	1	11,7,10

* From [2019Su14] unless otherwise stated. ** [2017Ja05]

*** [2017Ja05] **** [2001Ca60] (above energy threshold for [2019Su14]. ^(a) Values from adopted levels in ENSDF [2016Ba18]. ^a Calculated from proton energies and S_p (²⁷P) = 7807(9) keV [2021Hu06].

^b [2021Sh23].

Table 6

 β -2p emission from ²⁷S*, $BR_{\beta 2p} = 2.4(5)\%$

$E_{2p}(c.m.)$	$I_{2p}(\text{rel})$	$I_{2p}(abs)$	$E_{emitter}$ (²⁷ P)**	$E_{daughter}(^{25}\mathrm{Al})^{@}$	coincident γ-rays [@]
6.372(15)	100	0.7(3)%	12.693(17)	0	

* All values taken from [2021Sh23], a 5.3 MeV transition from [2017Ja05] was not observed. ** Calculated from two proton energy and S_{2p} (²⁷P) = 6321(9) keV [2021Hu06].

Table 7	
β -p emission from ³¹ Ar*, T _{1/2} = 15.1(3) ms ^e , BR _{βp} = 68.3(3)%**.	

$E_p(c.m.)$	$I_p(\text{rel})$	$I_p(abs)$	E _{emitter} (³¹ Cl)	$E_{daughter}(^{30}\mathrm{S})^d$	coincident γ -rays ^d	
$0.461(15)^{b}$	$0.49(16)^{b}$	0.14(5)	0.725(15)	0		
$0.779(15)^{b}$	$3.0(3)^{b}$	0.14(3) 0.87(9)	3.254(15)	2 2106(5)	2 211	
$0.844(15)^{ab}$	4.2(4)	1.2(1)	5.254(15)	2.2100(5)	2.211	
$1.006(15)^{b}$	$1 A(2)^{b}$	0.41(6)	1 270(15)	0		
1.000(13) 1.160(5) ^{<i>ab</i>}	1.4(2) 2.7(16) ^b	0.41(0) 0.78(46)	6 651(6)	52174(7)	2nd proton omitted	
1.109(3)	2.7(10)	0.78(40)	6.651(6)	5.126(2)	2106 2 025	
1.231(4) $1.243(13)^{a}$	1.7(3) 0.70(11)	0.49(14) 0.20(3)	6.825(13)	5.130(2) 5.2174(7)	2.2100, 2.925 2nd proton emitted	
1.3+3(13) 1.463(2)	34.0(3)	0.20(3)	1.7527(4)	0	2nd proton ennited	
1.403(2) 1.554(2)	54.0(3)	1.80(6)	1.7527(4)	2 2106(5)	2 211	
1.554(2) 1.608(2)	2.2(2)	0.84(4)	4.029(4) 5.364(4)	2.2100(5)	1 102 2 211 3 402	
$\frac{1.098(2)}{1.880(3)^{a}}$	2.00(14)	0.87(11)	7 361(4)	5.4020(3)	2nd proton emitted	
1.000(3) 1.032(3)	0.8(2)	0.23(6)	5 500(4)	3.4026(5)	1 102 2 211 3 402	
$1.932(3)^{a}$	0.0(2)	0.13(4)	7.469(4)	5.4020(3) 5.2174(7)	2nd proton emitted	
2 075(3)	10.0(2)	2.91(6)	5 742(4)	3.2174(7) 3.4026(5)	1 192 2 211 3 402	
2.073(3)	100.0	29 1(2)	2 417(4)	0		
2.135(2)	4 0(3)	1 16(9)	2 592(4)	0		
2.326(2) 2 405(4)	51(4)	1.10(9) 1.48(11)	2.669(5)	0		
2.403(4) 2.977(3)	0.99(13)	0.29(4)	6.644(4)	3 4026(5)	1 192 2 211 3 402	
3.121(3)	1.08(14)	0.22(4) 0.31(4)	5 595(4)	2 2106(5)	2 211	
3.258(4)	0.44(10)	0.13(3)	5,733(5)	2.2106(5)	2.211	
3 357(4)	1 17(15)	0.34(4)	3 621(5)	0		
3.546(3)	0.89(11)	0.26(3)	7 477(4)	3 6675(10)	1 4566, 2 211	
3.680(11)	3.6(8)	1.0(2)	7.346(11)	3.4026(5)	1.192, 2.211, 3.402	
3.755(3)	6.1(8)	1.8(2)	4.019(4)	0		
$3.933(4)^a$	0.53(13)	0.15(4)	9.414(5)	5.2174(7)	2nd proton emitted	
4.032(3)	2.22(14)	0.65(4)	6.507(4)	2.2106(5)	2.211	
4.164(3)	7.0(2)	2.03(6)	6.639(4)	2.2106(5)	2.211	
$4.340(4)^{a}$	1.09(18)	0.32(5)	12.295(5)	7.693(4)	2nd proton emitted	
$4.432(4)^{a}$	0.31(8)	0.09(2)	12.295(5)	7.598(4)	2nd proton emitted	
$4.535(5)^a$	0.59(11)	0.17(3)	12.295(5)	7.485(4)	2nd proton emitted	
$4.778(9)^{b}$	0.7(2) ^b	0.20(6)	5.042(9)	0		
4.888(5)	1.68(18)	0.49(5)	7.361(6)	2.2106(5)	2.211	
5.454(5)	17.6(3)	5.06(9)	5.716(6)	0		
$5.820(9)^{a}$	0.31(5)	0.09(1)	12.286(9)	5.389(2)	2nd proton emitted	
$6.150(7)^a$	0.19(6)	0.05(2)	12.256(8)	5.843(5)	2nd proton emitted	
6.251(9)	0.51(12)	0.15(3)	6.515(9)	0		
6.350(7)	0.51(12)	0.15(3)	6.614(8)	0		
$6.599(7)^a$	0.26(5)	0.08(1)	12.252(8)	5.389(2)	2nd proton emitted	
6.758(8) ^a	0.84(11)	0.24(3)	12.239(9)	5.2174(7)	2nd proton emitted	
7.182(9)	0.70(9)	0.20(2)	7.446(9)	0		
7.310(16)	0.49(7)	0.14(2)	7.574(9)	0		
8.362(12)	0.25(4)	0.07(1)	12.295(6)	3.6675(10)	1.457, 2.211	
8.625(15)	0.51(6)	0.15(2)	12.295(6)	3.4026(5)	1.192, 2.211, 3.402	
9.155(19)	0.22(19)	0.064(55)	9.419(19)	0		
9.809(20)	0.30(4)	0.087(12)	12.284(20)	2.2106(5)	2.211	
12.042(28)	0.23(11)	0.067(32)	12.310(25)	0		
12.253(29)	0.034(3)	0.010(1)	12.517(29)	0		

*All values are taken from [2000Fy01] except where indicated. (Values from [2016Ma17] are listed as preliminary and are not included in this table). ** From [2015Li20].

** From [2015L120]. ^a Single proton from a β -2p decay. ^b [1998Ax02] ^c Calculated from proton energies and S_p (³¹Cl) = 264(3) keV [2021Hu06]. ^d Values from adopted levels in ENSDF [2010Ba29].

^e [2015Li20].

$E_{2p}(c.m.)$	$I_{2p}(\text{rel})$	$I_{2p}(abs)$	<i>E_{emitter}</i> (³¹ Cl)***	$E_{daughter}(^{29}\mathrm{P})^{@}$	coincident γ -rays [@]	
5.680(20)	48(23)	0.61(11)	12.295(5)	1.9539(2)	1.954, 0.570, 1.384	
6.230(20)	56(23)	0.71(12)	12.295(5)	1.3836(1)	1.384	
7.635(25)	100	1.26(20)	12.295(5)	0		

 β -2p emission from ³¹Ar*, $BR_{\beta 2p} = 9.0(2)\%$ **

*All values are taken from [1998Ax02] except where indicated.

** From [2015Li20].

*** Determined from ³¹Ar β -p emission.

[@] Values from adopted levels in ENSDF [2012Ba18].

Table 9

 β -3p emission from ³¹Ar, $BR_{\beta 3p} = 0.07(2)\%^{**}$.

$E_{3p}(c.m.)*$	$I_{3p}(\text{rel})$	$I_{3p}(abs)^{**}$	$E_{emitter}$ (³¹ Cl)***	$E_{daughter}(^{29}\mathrm{Si})$	coincident γ -rays	
5.03(29)	100	0.07(2)	12.295(5)	0		
* [1992Ba01] ** [2016Ci02 *** Determin	, 2015Li20]. ed from ³¹ Δr β n em	viscion				

*** Determined from ³¹Ar β -p emission.

Table 10

<u>β</u>-p emission from ³⁵Ca*, $T_{1/2}$ = 25.7(2) ms, $BR_{\beta p} = 95.7(15)\%^{**}$.

$E_p(\text{c.m.})$	$E_p(lab)$	$I_p(rel)$	$I_p(abs)$	E _{emitter} (³⁵ K)***	$E_{daughter}(^{34}\mathrm{Ar})^{@}$	coincident γ-rays [@]
1,469(5)	1 427(5)	100	48.5(13)	1 511(5)	0	
1.965-2725	1.909-2.647 ^a	11(2)	5.4(9)	4.084-4.822	2.0911(3)	2.091
1.965-2725	1.909-2.647 ^a	2.1(8)	1.0(4)	5.280-6.018	3.2877(5)	1,197, 2,091, 3,286
1.965-2725	1.909-2.647 ^a	4.1(14)	2.0(7)	5.866-6.604	3873(3)	0.585, 1.197, 1.782, 2.091
2.807(13)	2.727(13)	12.4(10)	6.0(5)	4.902(13)	2.0911(3)	2.091
3.034-3.603	2.947-3.500 ^a	4.5(6)	2.2(3)	5.122-5.675	2.0911(3)	2.091
3.698(25)	3.592(25)	6.2(6)	3.0(3)	3.676(25)	0	
3.934(36)	3.822(36)	7.8(6)	3.8(3)	3.906(36)	0	
4.160(71)	4.041(71)	6.0(6)	2.9(3)	6.216(71)	2.0911(3)	2.091
4.704(48)	4.570(48)	6.0(6)	2.9(3)	4.654(48)	0	
4.894(38)	4.754(38)	8.7(8)	4.2(4)	4.838(38)	0	
5.166(71)	5.018(71)	8.0(6)	3.9(3)	5.102(71)	0	
5.450(48)	5.294(48)	1.5(4)	0.72(18)	5.378(48)	0	
5.627(48)	5.466(48)	1.26(31)	0.61(15)	5.550(48)	0	
5.781(37)	5.616(37)	2.95(35)	1.43(17)	5.700(37)	0	
6.006(60)	5.834(60)	2.9(4)	1.40(19)	5.918(60)	0	
6.159-6.845	5.983-6.649 ^a	2.25(35)	1.09(17)	6.067-6.733	0	
6.983(22)	6.783(22)	7.8(4)	3.8(2)	8.958(22)	2.0911(3)	2.091
7.341-8.119	7.131-7.887 ^a	2.3(4)	1.1(2)	4.084-7.971	0	
9.061(89)	8.802(89)	0.85(12)	0.41(6)	8.886(89)	0	

* All values are taken from [1999Tr04], except where noted.

** From [2016Ci05, 2015Li20].

*** Calculated from proton energies and S_p (³⁵K) = 83.6(5) keV [2021Wa16].

[@] Values from adopted levels in ENSDF [2012Si06].

^a unresolved multiplet

Table 11

 β -2p emission from ³⁵Ca*, $BR_{\beta 2p} = 4.2(3)\%^{**}$.

$E_{2p}(c.m.)$	$E_{2p}(lab)$	$I_p(\text{rel})$	$I_p(abs)$	<i>E_{emitter}</i> (³⁵ K)****	$E_{daughter}(^{33}\text{Cl})$	coincident γ -rays
	4.305(26)	100	4.2(3)	9.053(27)	0	

* All values are taken from [1999Tr04], except where noted.

** From [2016Ci05].

*** Calculated from two-proton energy and S_{2p} (³⁵K) = 4747.5(6) keV [2021Hu06].

β -p emission from ³⁹ Ti*, T _{1/2} = 28.5(9) ms, $BR_{\beta p} = 93.7(28)\%^{**}$.							
$E_p(\text{c.m.})$	$I_p(\text{rel})^{***}$	$I_p(abs)^{***}$	$E_{emitter}$ (³⁹ Sc)	$E_{daughter}(^{38}\mathrm{Ca})$	coincident γ-rays [@]		
3.27(2) $5.17(3)^a$	70(20) 100(30)	7(2) 10(3)					

* All values taken from [2007Do17], except where noted.

** Mixture of β -p and β -2p [2007Do17], β -xp is expected to be 100% as ³⁹Sc is unbound to proton emission S_p= -597(24) keV [2021Hu06].

*** Note that there is considerable disagreement between the published works in this nucleus, and many β -p transitions are unknown.

^{*a*} Possible two proton peak from the β -2p decay of 39Ti to the ground state of ³⁷K [2001Gi01, 1992Mo15].

Та	ble	13
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 $\beta$ -2p emission from ³⁹Ti*

$E_{2p}(c.m.)$	$I_{2p}(\text{rel})$	$I_{2p}(abs)$	$E_{emitter}$ ( ³⁹ Sc)	$E_{daughter}(^{37}\mathrm{K})^{**}$	coincident γ-rays **
≈2.50 ≈4.75	≈100 ≈55			2.1702(1) 0	2.170

* All values taken from [1992Mo15], except where noted.

** Value from adopted levels in ENSDF [2012Ca15].

#### Table 14

 $\beta$ -p emission from ⁴³Cr*,T_{1/2} = 21.2(7) ms,  $BR_{\beta p}$  = 79.3(30)%**.

$E_p(\text{c.m.})$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( ⁴³ V)***	$E_{daughter}(^{42}\mathrm{Ti})$	coincident γ-rays	
1.014(17)	8(1)	0.6(1)				
1.614(34)	30(15)	2.1(11)				
1.812(15)	100	7.1(12)				
2.179(17)	66(10)	4.7(7)				
2.753(19)	17(6)	1.2(4)				
3.138(17)	48(10)	3.4(7)				
3.382(25)	14(6)	1.0(4)				
3.744(27)	42(20)	3.0(14)				
4.671(26)	63(11)	4.5(8)				

* All proton energies, intensity and half-life values taken from [2007Do17].

** From [2012Au08]. [2007Do17] gives a value of 92.5(28)% for the sum of  $\beta$ -p and  $\beta$ -2p.

*** Calculated from proton energies and  $S_p$  (⁴³V) = 100(40) keV [2021Hu06].

<b>Table 15</b> $\beta$ -2p emission from $\beta$ -2p for $\beta$ -2p emission from $\beta$ -2p	pm ${}^{43}Cr^*, BR_{\beta 2p} = 1$	12.09(40)%**.		
$E_{2n}(c.m.)$	I ₂ n	$E_{emitter}$ ( ⁴³ V)***	$E_{daughter}$ ⁽⁴¹ Sc)	coincident '

$E_{2p}(c.m.)$	$I_{2p}$	$E_{emitter}$ ( ⁴³ V)***	$E_{daughter}(^{41}\mathrm{Sc})$	coincident $\gamma$ -rays
4.348(16)		8.198(43)	0	

* All values taken from [2007Do17] except where noted.

** [2012Au08].

*** Calculated from two-proton energy and  $S_{2p}$  (⁴³V) = 3850(40) keV [2021Hu06].

$E_p(\text{c.m.})$	<i>I_p</i> (rel)	$I_p(abs)$	E _{emitter} ( ⁴⁷ Mn)**	$E_{daughter}(^{46}\mathrm{Cr})$	coincident $\gamma$ -rays	
1 548(19)	36(13)	19(7)				
1.718(20)	75(23)	4.0(12)				
1.864(15)	100	5.3(7)	5.44(3)	1.9871(3)	0.892, 1.095	
2.462(29)	36(13)	1.9(7)				
3.973(20)	83(23)	4.4(12)	7.55(4)	3.1965(6)	0.892, 1.095	
5.00(22)	38(8)	2.0(4)	$7.38(4)^a$	1.9871(3)	0.892, 1.095	
6.104(24)	70(13)	3.7(7)	$7.38(4)^a$	0.8922(1)	0.829	

 $\beta$ -p emission from ⁴⁷Fe*, T_{1/2} = 21.5(7) ms,  $BR_{\beta p}$  = 88.4(9)%.

* All values taken from [2007Do17], except where noted.

** Calculated from proton energy and  $S_p$  (⁴⁷Mn) = 380(30) keV [2021Hu06].

^aIAS state [2007Do17].

#### Table 17

 $\beta$ -p Emission from ⁵¹Ni*, T_{1/2} = 23.8(2) ms,  $BR_{\beta p} = 87.2(9)\%^*$ .

$E_p(c.m.)$	$I_p(rel)$	$I_p(abs)$	$E_{emitter}$ ( ⁵¹ Co)**	$E_{daughter}(^{50}\text{Fe})^{***}$	coincident γ-rays***	
1.084(41)	14(9)	1.3(8)				
1.356(23)	17(6)	1.5(5)				
1.859(20)	35(10)	3.0(9)				
2.234(18)	21(6)	1.8(5)				
2.515(28)	55(25)	4.8(22)				
2.915(17)	46(10)	4.0(9)				
3.121(31)	24(12)	2.1(10)				
3.421(23)	6(5)	0.5(4)				
3.709(29)	17(6)	1.5(5)				
3.929(24)	13(7)	1.1(6)				
4.415(27)	6(3)	0.5(3)				
4.662(16)	100	8.7(8)	6.664(52)	1.8515(5)	0.765, 1.087	
5.664(30)	10(5)	0.9(4)				

* All values taken from [2007Do17], except where noted.

** Calculated from proton energy and  $S_p$  (⁵¹Co) = 150(50) keV [2021Hu06].

*** Values from adopted levels in ENSDF [2011El01].

#### Table 18

 $\beta$ -p Emission from ⁵⁵Zn*, T_{1/2} = 19.8(13) ms,  $BR_{\beta 2p}$  = 91.0(51)%.

$E_p(\text{c.m.})$	$I_p$	E _{emitter} ( ⁵⁵ Cu)	$E_{daughter}(^{54}\mathrm{Ni})$	coincident γ-rays
4.689(38)	obs	≈7.30*	2.5-2.6**	

* All values taken from [2007Do17], except where noted.

** The emitted proton is assumed to be from IAS in  55 Cu at  $\approx$ 7.300 MeV to the second excited state in  54 Ni which is expected to be  $\approx$ 2.5-2.6 MeV.

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = -5/2 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the odd-Z  $T_z = -5/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\epsilon 2p}$	$BR_{\beta 2p}$	$Q_{\varepsilon 3p}$	$Q_{\varepsilon \alpha}$	Experimental
12-										
¹⁵ F			18.92(50)#	17.40(50)#		16.80(50)#		8.11(50)#	10.7(50)#	[2021Ch19]
¹⁷ Na			18.22(6)	16.76(6)		17.29(6)#		9.99(6)#	9.18(6)	[2017Br07]
²¹ Al		< 35ns	16.19(60)#	12.95(60)#		10.76(60)#		4.35(60)#	8.17(60)#	[1997Au04]
²⁵ P		< 35 ns	16.36(40)#	12.95(40)#		11.09(40)#		3.50(40)#	6.86(40)#	[1997Au04]
²⁹ Cl		< 20  ns	17.12(19)#	13.88(19)#		11.83(19)#		4.36(19)#	7.77(19)#	[2015Mu13]
³³ K			16.93(20)#	13.59(20)#		12.00(20)#		5.87(20)#	8.21(20)#	
³⁷ Sc			16.92(30)#	13.91(30)#		12.25(30)#		6.35(30)#	10.74(30)#	
$^{41}V$			16.01(20)#	13.55(20)#		13.02(20)#		7.24(20)#	11.02(20)#	
⁴⁵ Mn			14.54(30)#	11.54(30)#		9.76(30)#		5.27(30)#	8.29(30)#	
⁴⁹ Co			14.97(50)#	12.23(50)#		10.21(50)#		5.43(50)#	7.31(50)#	
⁵³ Cu		< 130 ns	16.49(50)#	13.92(50)#		12.47(50)#		7.62(50)#	9.19(50)#	[2005Bi15]
⁵⁷ Ga			17.14(45)#	15.93(40)#		15.35(40)#		10.73(40)#	11.80(40)#	
⁶¹ As			16.59(42)#	15.10(36)#		15.44(30)#		12.60(30)#	12.93(36)#	
⁶⁵ Br			16.53(58)#	15.75(54)#		15.85(50)#		13.63(50)#	14.88(58)#	

Table 2

Particle emission from the odd-Z  $T_z = -5/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$BR_p$	$S_{2p}$	Qα	Experimental	
$^{13}F$	-2.73(50)#	100%	-3.09(50)#		[2021Ch19]	
¹⁷ Na	-3.44(6)	100%	-3.57(6)	-9.740(10)	[2017Br07]	
²¹ Al	-2.32(60)#	100%	0.42(60)#	-10.06(60)#	[ <b>1997Au04</b> ]	
²⁵ P	-2.16(40)#	100%	1.14(40#	-9.32(72)#	[1997Au04]	
²⁹ Cl	-2.66(10)#	100%	-0.10(19)#	-8.59(44)#	[2015Mu13]	
³³ K	-2.45(20)#		0(200)#	-8.91(28)#		
³⁷ Sc	-2.94(30)#		-0.38(30)#	-6.19(36)#		
$^{41}V$	-2.02(21)#		0.10(20)#	-5.90(36)#		
⁴⁵ Mn	-1.15(30)#		1.64(30)#	-7.72(36)#		
⁴⁹ Co	-0.94(51)#		1.79(50)#	-7.23(58)#		
⁵³ Cu	-2.13(51)#		0.38(50)#	-5.79(71)#		
⁵⁷ Ga	-2.69(57)#		-1.65(43)#	-4.70(64)#		
⁶¹ As	-3.04(42)#		-1.98(35)#	-4.22(50)#		
⁶⁵ Br	-3.08(71)#		-2.43(54)#	-1.72(58)#		

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Table	1
Table	т

Observed and predicted  $\beta$ -delayed particle emission from the even Z,  $T_z = -2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\varepsilon}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$BR_{\beta 2p}$	$Q_{\varepsilon 3p}$	$Q_{\varepsilon \alpha}$	Experimental
120	$0^{+}$	< 72 keV	14.675(12)	14 075(12)	·	5 384(12)		-1.202(12)	6 666(12)	[2012]a11]
¹⁶ Ne	$0^{+}$	< 80  keV	13312(21)	13 842(20)		6 546(20)		-1.005(20)	4224(20)	[2008Mu13]
²⁰ Mg	$0^+$	90.4(6) ms	10.627(2)	8 437(2)	30.0(12)%	2.027(2)		-3.580(2)	4.378(5)	[ <b>1995Pi03</b> 2019Gl02
8		,(.)		01101(_)		/				2016Lu13, 2012Wa15]
²⁴ Si	$0^{+}$	141.4(15) ms	10,794(19)	8 930(19)	33.3(16)%	1.349(19)		-5.390(19)	1.469(19)	[ <b>2011]c06</b> , 2020Lo05
~ -										2016Su22, 2015Su15,
										2001Ba07, 1998Cz01,
										1997Cz02]
²⁸ S	$0^+$	125(10) ms	11.22(16)	9.17(16)	20.7(20)%	1.702(160)	)	-4.604(160)	1.69(16)	[1989Po10]
³² Ar	$0^{+}$	98(2) ms	11.134(2)	9.553(2)	35.58(22)%	3.423(2)		-2.172(2)	2.523(2)	[2021Bl02, 2008Bh08,
			( )		× /					<b>1985Bj01</b> , 2002Fy01,
										2020Ar04, 1999Ad10,
										1999Th09, 1993Sc16,
										1985Bj01, 1977Ha29]
³⁶ Ca	$0^+$	100.8(20) ms	10.970(40)	9.310(40)	53.5(15)%*	3.412(40)		-1.731(40)	4.46(4)	[ <b>2015Su01</b> , 2007Do17,
										2001Lo11, 1997Tr05,
										1995Tr02]
⁴⁰ Ti	$0^+$	52.4(3) ms	11.530(70)	11.000(70)	$99.0^{+10}_{-16}\%$	5.233(70)		0.091(70)	6.002(70)	[2007Do17, 2001Gi01,
					10					1990De43, 1998Bh12,
										1998Li46, 1998Le45,
										1997Tr11, 1997Li25]
⁴⁴ Cr	$0^+$	42.8(6) ms	10.390(50)	8.600(50)	14.0(9)%	4.123(50)		-0.149(50)	4.678(50)	[2007Do17, 2020Fu05,
										2014Po05]
⁴⁸ Fe	$0^+$	$51(3) \text{ ms}^{b}$	11.290(90)	9.270(90)#	14.4(7)%	4.488(90)		-0.867(90)	3.373(90)	[2016Or03, 2014Po05,
										2016Ru04]
										[2007Do17, 1996Fa09]
⁵² Ni	$0^+$	42.8(3) ms	11.780(80)	10.340(80)	31.1(5)%	5.489(80)		0.905(80)	4.312(80)	[ <b>2016Or03</b> , 2007Do17,
										1994Fa06]
⁵⁶ Zn	$0^+$	32.9(8) ms	13.24(40)#	12.66(40)#	88.5(26)%	8.04(40)	6.55(40)#	3.69(40)		[ <b>2016Or03</b> , 2015Or02,
										2014Or04, 2014Or03,
										2007Do17]
⁶⁰ Ge	$0^+$	25.0(3) ms	12.06(36)#	12.40(30)#	67(3)%	9.56(30)#	<14%	6.69(30)#	8.68(30)#	[2021Or01, 2016Ci01]
⁶⁴ Se	$0^+$	>180 ns	12.67(54)#	12.77(50)#		10.55(50)#		7.62(50)#	10.31(54)#	[2005St34]
⁶⁸ Kr	$0^+$	21.6(33) ms	13.17(56)#	13.67(51)#	$89^{+11}_{-10}\%$	11.82(50)#		8.98(50)#	11.48(54)#	[2017GoZT, 2016Bl05]

* Weighted average of 53.9(72)% [2015Su01], 54.3(18)% [2097Do17], 54.3(18)% [2001Lo11] and 56.8(13)% [1999Tr05].

#### Table 2

Particle emission from the even Z,  $T_z = -2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	$BR_{2p}$	Qα	Experimental	
$^{12}O$	-0.359(13)	-1.737(12)	100%	-5.476(22)	[2012Ja11]	
¹⁶ Ne	-0.131(25)	-1.401(20)		-10.451(24)		
²⁰ Mg	2.741(11)	2.418(2)		-8.934(21)		
²⁴ Si	3.292(19)	3.433(19)		-9.157(20)		
²⁸ S	2.56(16)	3.36(16)		-9.10(16)		
³² Ar	2.455(4)	2.719(2)		-8.70(16)		
³⁶ Ca	2.57(4)	2.65(4)		-6.68(4)		
⁴⁰ Ti	2.110(70)	1.510(70)		-4.970(80)		
⁴⁴ Cr	2.790(70)	2.900(50)		-6.850(90)		
⁴⁸ Fe	2.73(10)	3.110(90)		-7.010(110)		
⁵² Ni	2.51(10)	2.660(80)		-6.98(12)		
⁵⁶ Zn	1.04(43)#	0.69(40)#		-5.26(41)#		
⁶⁰ Ge	1.06(35)#	-0.19(30)#		-4.57(50)#		
⁶⁴ Se	0.65(54)#	-0.70(52)#		-1.75(58)#		
⁶⁸ Kr	0.64(40)#	-1.46(54)#		-1.19(71)#		

Table 3	
$\beta$ -p emission from ²⁰ Mg ^{<i>a</i>} , BR _{$\beta p$} = 30.3(14)%*.	

$E_p(\text{c.m.})$	$I_p(\text{rel})\%$	$I_p(abs)\%$	E _{emitter} ( ²⁰ Na)	$E_{daughter}(^{19}\mathrm{Ne})^b$	coincident $\gamma$ -rays ^b
0.805(2) ^c	100(3)	$10.6(3)^{c}$	2 995(2)	0	
$1.067(18)^d$	6 6(9)	0.70(9)	4 793(18)	1 5360(4)	1 298 0 238
$1.007(10)^{f}$	0.0(5)	0.70(9)	7 /33(250)	4.0329(24)	4 033 1 298 0 238
$1.210(230)^d$	0.14(3)	3.8(10)	3.855(10)	0.2383(1)	0.238
1.423(10) 1.622(4)	180(28)	1.0(10)	4.087(4)	0.2383(1) 0.2751(1)	0.238
$\frac{1.022(4)}{1.666(10)^c}$	48(3)	$\frac{1.9(3)}{5.1(3)^c}$	3.855(10)	0	0.275
1.853(40)	+3(3)	0.03(2)	5.533(10)	1 5360(4)	1 208 0 238
1.005(5)	1.3(2)	0.03(2) 0.13(4)	5.603(5)	1.5500(4)	1.238, 0.238
$1.903(3)^{\circ}$	1.2(4)	0.13(4)	4.007(3)	0	1.252, 0.275
1.907(3) 2.120(70)	4.3(4) 1.03(7)	0.43(4)	5.817(10)	1 5076(3)	1 232 0 275
$\frac{2.120(70)}{2.335(14)^{e}}$	5.2(7)	0.11(1) 0.6(1) ^e	4.800(14)	0.2751(1)	0.275
2.333(14) 2.344(19)	3.2(7)	0.0(1) 0.21(8)	4.000(14)	0.2791(1) 0.2382(1)	0.275
2.344(10) 2.560(14)	2.9(8) 2.1(0)	0.31(0) 0.22(0)	4.772(10) 6.286(14)	0.2363(1) 1 5260(4)	1 208 0 228
2.300(14) 2.567(4)	3.1(9) 21.7(10)	0.33(9)	4.758(4)	0	1.298, 0.238
2.307(4)	21.7(19) 3.8(10)	2.3(2) 0.4(2)	4.730(4)	1 5076(3)	1 232 0 275
$\frac{2.020(14)}{2.700(220)f}$	2.0(1)	0.4(2)	6.505(250)	1.5070(5)	1.252, 0.275
2.700(250)	2.0(1)	$0.212(7)^{3}$	(509(12))	1.0130(3)	1.010, 1.577, 1.541, 0.275, 0.258
2.782(13)	4.4(7)	0.4/(7)	0.508(15)	1.5360(4)	1.298, 0.238
2.850(10)	0.95(28)	0.10(3)	0.528(10)	1.5076(3)	1.232, 0.275
3.033(12)	4.4(8)	0.40(8)	5.498(12)	0.2751(1)	0.275
3.096(17)	5.1(8)	0.54(8)	5.552(17)	0.2383(1)	0.238
3.389(19)	3.5(6)	0.37(6)	5.817(19)	0.2383(1)	0.238
3.389(18)	0.76(19)	0.08(2)	5.854(18)	0.2751(1)	0.275
3.813(14) ^c	2.7(8)	0.28(8) ^c	6.281(14)	0.2751(1)	0.275
3.820(12)	4.2(5)	0.44(5)	6.242(12)	0.2383(1)	0.238
4.033(12)	2.9(7)	0.31(7)	6.496(4)	0.2751(1)	0.275
4.051(2)	8.3(9)	$0.9(1)^{e}$	6.242(4)	0	
4.053(12)	2.8(19)	0.3(2)	6.481(12)	0.2383(1)	0.238
$4.305(4)^{c}$	9.7(6)	$1.02(7)^{c}$	6.496(4)	0	
4.347(20)	2.6(8)	0.27(8)	6.775(20)	0.2383(1)	0.238
4.544(15)	3.0(1)	0.319(10)	6.734(15)	0	
4.993(16)	0.75(28)	0.08(3)	7.183(16)	0	

^a Values taken from [2016Lu13], except where noted.
^b Values from adopted levels in ENSDF [1995Ti07].
^c Weighted average of [2016Lu13], [1995Pi03] and [2017Su05].
^d Weighted average of [1995Pi03] and [2017Su05].
^e Weighted average of [2016Lu13] and [2017Su05].
^f [2019Gl02].

Table 4		
$\beta$ -p emission from ²⁴ Si,	$T_{1/2} = 141.4(15) \text{ ms}^*, BR_{B_1}$	$m = 33.3(16)\%^{**}$ .

$E_{\rm p}(\rm c~m.)^a$	L _r (rel)%	$I_{\rm p}({\rm abs})\%^b$	$E_{\text{amittar}}$ ( ²⁴ Al)	$E_{daughtar}(^{23}Mg)^c$	coincident 7-rays ^c
2p(eiiii)	<i>1p</i> (101)/0	1p(400)/0	Demuter ( 111)		
1.125(15)	50(4)	5.7(4)	2.989(15)	0	
1.497(13)	100(7)	11.3(8)	3.361(13)	0	
1.723(13)	38(4)	4.3(4)	5.944(13)	2.3570(7)	0.451, 1.906, 2.358
2.021(10)	9.2(9)	1.0(1)	6.242(10)	2.3570(7)	0.451, 1.906, 2.358
2.515(9)	5.8(7)	0.65(8)	4.379(9)	0	
2.826(7)	12(2)	1.4(2)	4.691(7)	0	
3.104(8)	8.7(9)	0.98(10)	4.968(8)	0	
$3.510(10)^d$	6(1)	$0.68(10)^d$	5.374(10)	0	
3.938(26) ^b	9.4(18)	1.1(2)	5.802(26)	0	
4.082(7)	59(5)	6.6(6)	5.947(7)	0	
4.370(9)	15(2)	1.7(2)	6.234(9)	0	
$4.615(11)^d$	2.3(4)	$0.26(4)^d$	6.479(11)	0	
$4.863(11)^d$	0.6(2)	$0.07(2)^d$	6.727(11)	0	

* Weighted average of 143.4(22)ms [2015Su15] and 140.5(15)ms [2011Ic06].

** [2011Ic06]

^a Weighted average of [2015Su22, 2015Su15], [2009Ic05, 2011Ic06], [1998Ba53] and [1998Cz01], except where noted.

^b Weighted average of [2015Su12] and [2009Ic05], except where noted.

^c Values from adopted levels in ENSDF [2021Ba01].
 ^d Only reported in [1998Ba53]. No I_p or energy error bars on the energy are assigned in the paper.

^e Only reported in [2009Ic05].

#### Table 5

 $\beta$ -p emission from ²⁸S*, T_{1/2} = 125(10) ms,  $BR_{\beta p} = 20.7(20)\%$ .

$E_p(\text{c.m.})$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( ²⁵ Al)**	$E_{daughter}(^{24}Mg)^{@}$	coincident γ-rays [@]	
1.0(0/25)	20(2)	1 4(4)				
1.260(25)	20(3)	1.4(4)				
1.510(25)	30(5)	2.1(6)				
1.695(30)	24(3)	1.7(4)				
1.892(30)	19(3)	1.3(3)				
2.195(30)	15(3)	1.0(3)				
2.630(25)	22(3)	1.6(4)				
2.872(30)***	25(3)	1.75(4)	5.779(30)	0.9574(2)	0.957	
3.095(20)***	100	7.0(15)	5.817(20)	0.7809(2)	0.781	
3.570(30)	13(2)	0.9(2)				
3.835(20)***	28(3)	2.0(4)	5.750(20)	0		

* All values taken from [1989Po10], except where noted. ** Calculated from proton energies and  $S_p$  (²⁸P) = 2052.2(12) keV [2021Wa16].

*** [1989Po10] list these three transitions as depopulating a 5.900(21) MeV IAS.

[@] Values from adopted levels in ENSDF [2011Ba29].

Table 6	
$\beta$ -p emission from ³² Ar, T _{1/2} = 98(2) ms*, $BR_{\beta p}$ = 35.58(22)%**	

$E_p(\text{c.m.})^a$	$I_p(\text{rel})\%$	$I_p(abs)\%^g$	$E_{emitter}$ ( ³² Cl)	$E_{daughter}(^{31}S)^b$	coincident $\gamma$ -rays ^b	
				· · ·		
0.6273(46)	1.876(39)	0.385(8)	2.2084(46)	0		
$0.9416(50)^c$	$0.070(40)^c$	0.014(8)	3.7716(50)	1.24887(9)	1.2489(1)	
1.2501(42)	1.557(112)	0.319(23)	4.0801(42)	1.24887(9)	1.2489(1)	
$1.731(12)^d$	$0.143(65)^d$	0.029(13)	4.561(12)	1.24887(9)	1.2489(1)	
2.1906(37) ^e	17.66(30) ^e	3.62(7)	3.7717(37)	0		
2.2152(36) ^f	$1.286(41)^{f}$	0.264(9)	5.0452(36)	1.24887(9)	1.2489(1)	
2.4729(32) ^f	$0.58(11)^{f}$	0.119(22)	5.3029(32)	1.24887(9)	1.2489(1)	
2.5016(37) ^e	35.28(47) ^e	7.24(11)	4.0827(37)	0		
2.5935(30)	3.26(25)	0.668(51)	5.4235(30)	1.24887(9)	1.2489(1)	
$2.7006(86)^d$	$0.247(63)^d$	0.051(13)	5.5306(86)	1.24887(9)	1.2489(1)	
2.8656(54)	0.429(80)	0.088(16)	5.6956(54)	1.24887(9)	1.2489(1)	
3.2178(43) ^e	$0.136(12)^{e}$	0.028(2)	4.7989(43)	0		
$3.218(11)^d$	$0.090(22)^d$	0.018(5)	6.0483(11)	1.24887(9)	1.2489(1)	
3.4621(22)	100	20.51(17)	5.0432(22)	0		
3.6996(44)	0.270(34)	0.055(7)	6.5296(44)	1.24887(9)	1.2489(1)	
$3.722.3(82)^d$	$0.394(58)^d$	0.081(12)	5.3034(82)	0		
3.7675(37)	0.325(23)	0.067(5)	6.5975(37)	1.24887(9)	1.2489(1)	
3.8481(44) ^e	0.413(46) ^e	0.085(9)	5.4292(44)	0		
3.9052(39) ^f	$0.300(98)^{f}$	0.062(20)	6.7352(39)	1.24887(9)	1.2489(1)	
4.1208(46)	0.926(50)	0.190(10)	5.7019(46)	0		
4.4825(41)	0.138(33)	0.028(7)	7.3125(41)	1.24887(9)	1.2489(1)	
4.4838(30)	0.496(18)	0.102(4)	6.0649(30)	0		
4.6728(30)	0.457(21)	0.094(4)	6.2539(30)	0		
4.7754(32)	0.165(30)	0.034(6)	7.6054(32)	1.24887(9)	12489(1)	
5.0246(43)	0.259(24)	0.053(5)	7.8546(43)	1.24887(9)	1.2489(1)	
5.1391(89)	0.063(17)	0.013(4)	6.7202(89)	0		
5.7403(40)	0.547(25)	0.112(5)	7.3214(40)	0		
5.8683(85)	0.022(8)	0.005(2)	7.4494(85)	0		
6.0116(60)	0.423(32)	0.087(7)	7.592(60)	0		
6.2677(88)	0.109(8)	0.022(2)	7.8488(88)	0		
6.572(13)	0.057(7)	0.012(1)	8.153(13)	0		

* [1985Bj01]

** [2008Bh08]

^{*a*} Values are a weighted average of [2021Bl02], [2008Bh08], and [1985Bj01] except as indicated.

^b Values from adopted levels in ENSDF [2013Ou01].

c [2008Bh08]

^d [2021Bl02]

^e Weighted average of [2021Bl02] and [1985Bj01]

f Weighted average of [2021Bl02] and [2008Bh08]

^{*g*} Absolute values were determined by setting the sum of the relative intensities equal to the measured  $\beta$ -p branching ratio. Note that if there are a significant amount of unobserved transitions in the measured  $\beta$ -p branching ratio, these values will be lower.

#### Table 7

 $\beta$ -p emission from ³⁶Ca*, T_{1/2} = 100.8(20) ms**, *BR*_{$\beta p$} = 54.3(18)%

$E_p(\text{c.m.})^a$	$I_p(\text{rel})\%$	$I_p(abs)\%$	$E_{emitter} ({}^{36}\mathrm{K})^b$	$E_{daughter}(^{35}\mathrm{Ar})^c$	coincident $\gamma$ -rays ^c
1.444(8)	<10.8	<4.1	4.290(23)	1.184	1.184
1.704(23)	25(3)	9.3(8)	3.358(23)	0	
2.628(8)	100(3)	37(1)	4.290(23)	0	
2.798(23)	9.7(14)	3.5(5)	4.457(23)	0	
3.011(37)	2.8(8)	1.0(3)	4.644(46)	0	
3.591(23)	1.7(6)	0.6(2)	$5.250(23)^d$	0	
4.102(69)	2.5(6)	0.9(2)	$5.761(69)^d$	0	
4.274(46)	4.7(8)	1.7(3)	5.919(46)	0	
5.136(69)	0.8(3)	0.3(1)	6.791(69)	0	

* All values from [2001Lo11], except where noted.

** Weighted average of 100.0(24) [2015Su01], 100.1(23) [2007Do11], and 102(2) [1997Tr05].

^{*a*} Calculated using  $E_{emitter}$  energies from [2001Lo11] and  $S_p(^{36}K) = 1.658.9(8)$  [2021Wa16].

^b Values taken from a weighted average of [2001Lo11] and [1997Tr05] except where noted.

^c Values from adopted levels in ENSDF [2011Ch48].

^d [2011Lo11]
Table 8	
$\beta$ -p emission from ⁴⁰ Ti*, T _{1/2} = 52	2.4(3) ms**, $BR_{\beta p} = 95.8(13)\%^{**}$

$E_p(\text{c.m.})$	$I_p(\text{rel})\%$	$I_p(abs)\%$	$E_{emitter}$ ( ⁴⁰ Sc) ^a	$E_{daughter}(^{39}Ca)^c$	coincident $\gamma$ -rays ^c	
0.248(80) ^b	4.4(14)	$1.3(4)^{b}$	3.246(80)	2.4685(9)	2.469	
$0.410(60)^{b}$	2.4(10)	$0.7(3)^{b}$	3.408(60)	2.4685(9)	2.469	
0.766(36)	1.6(6)	0.5(2)	3.764(36)	2.4685(9)	2.469	
$0.975(86)^{b}$	2.7(11)	$0.8(3)^{b}$	4.531(86)	3.026(3)	3.026	
1.139(20)	1.8(6)	0.53(18)	4.138(20)	2.4685(9)	2.469	
1.359(7)	12(2)	3.6(6)	4.357(8)	2.4685(9)	2.469	
1.649(17)	1.3(6)	0.38(19)	4.647(17)	2.4685(9)	2.469	
1.745(6)	80(2)	23.8(6)	2.274(7)	0		
1.896(14)	4.8(13)	1.4(4)	4.895(14)	2.4685(9)	2.469	
2.007(21)	2.9(14)	0.86(34)	5.005(21)	2.4685(9)	2.469	
2.079(28)	1.5(6)	0.44(17)	5.077(28)	2.4685(9)	2.469	
2.215(6)	100(2)	29.8(7)	2.754(7)	0		
2.401(10)	6.5(13)	1.95(41)	2.931(10)	0		
2.607(16)	3.1(7)	0.9(2)	3.137(16)	0		
$2.676(60)^b$	3.5(14)	$1.1(4)^{b}$	3.205(60)	0		
2.798(16)	2.0(6)	0.58(17)	3.328(16)	0		
3.033(47)	0.4(4)	0.1(1)	3511(40)	0		
3.117(8)	5.8(7)	1.7(2)	3.647(9)	0		
3.251(8)	7.0(10)	2.1(3)	3.781(9)	0		
$3.325(41)^d$	0.4(4)	0.1(1)	3.855(41)	0		
3.531(21)	1.4(5)	0.43(14)	4.061(21)	0		
3.576(25)	1.1(5)	0.33(16)	4.106(25)	0		
3.732(8)	6.9(7)	2.1(2)	4.262(9)	0		
3.830(7)	73(3)	22(1)	4.359(8)	0		
3.987(11)	6.2(9)	1.9(3)	4.516(11)	0		
4.120(10)	5.3(11)	1.6(3)	4.650(10)	0		
4.291(18)	2.4(7)	0.7(2)	4.821(18)	0		
4.483(23)	1.8(9)	0.53(26)	5.013(23)	0		
4.547(31)	1.4(9)	0.42(27)	5.076(31)	0		
$4.689(28)^d$	0.4(4)	0.1(1)	5.219(28)	0		
$4.823(60)^{b}$	1.8(7)	$0.55(21)^b$	5.352(60)	0		
$5.035(40)^{b}$	0.7(3)	$0.20(7)^{b}$	5.564(40)	0		
5.163(22)	0.8(3)	0.24(9)	5.693(22)	0		
5.473(19)	0.7(2)	0.21(7)	6.002(19)	0		
$5.588(60)^{b}$	0.6(4)	$0.17(10)^{b}$	6.117(60)	0		
$5.887(60)^b$	0.34(20)	$0.10(6)^{b}$	6.417(60)	0		

* Values are from [1998Bh12] except where indicated. Values from [1998Bh12] were preferentially used because of the better energy resolution than [1998Li46].

** [2007Do17]

^{*a*} Calculated from proton energies and  $S_p$  (⁴⁰Sc) = 529.6(29) keV [2021Wa16].

^b [1998Li46]

^c Values from adopted levels in ENSDF [2006Si02].

^{*d*} Transition is questionable, as  $I_p$  is consistent with zero.

#### Table 9

 $\beta$ -p emission from ⁴⁴Cr^{*a*}, T_{1/2} = 42.8(6) ms,  $BR_{\beta p} = 14.0(9)\%$ 

$E_p$	$I_p(\text{rel})\%$	$I_p(abs)\%$	$E_{emitter} (^{44}\mathrm{V})^e$	$E_{daughter}(^{43}\mathrm{Ti})$	
$0.759(26)^b$	31(12)	$0.6(2)^{b}$			
0.908(11)	100(15)	$2.0(3)^{c}$	$2.689(14)^d$	0	
1.384(12)	63(19)	$1.3(3)^{c}$			
1.741(15)	28(18)	$0.6(3)^{c}$			

^a Values from [2007Do17] except where indicated. Many of the delayed protons have not been measured resulting in a total intensity for individual protons to be lower than the total  $\beta^+$ -p intensity. Other experimental  $\beta^+$ -p reference: [1992Bo37]. ^b [2014Po05]

^c Weighted average of [2007Do17] and [2014Po05]

^d Assigned as the IAS [2007Do17]

^{*e*} Calculated from proton energy and  $S_p$  (⁴⁴V) = 1781(9) keV [2021Wa16].

Table 10					
$\beta$ -p emission	from ⁴⁸ Fe*. 7	$\Gamma_{1/2} = 51(3)$	ms**.BRen	$= 14.4(7)\%^{**}$	

$E_p(c.m.)$	$I_p(rel)\%$	$I_p(abs)\%$	<i>E_{emitter}</i> ( ⁴⁸ Mn)***	$E_{daughter}(^{47}\mathrm{Cr})$	coincident $\gamma$ -rays
1.018(10)	100	4.8(3)	3.041(12)	0	
1.186(10)	21(6)	1.0(3)	3.209(12)	0	
1.477(10)	38(6)	1.8(3)	3.500(12)	0	
1.601(10)	19(6)	0.9(3)	3.624(12)@	0@	
1.695(10)	27(4)	1.3(2)	3.718(12)	0	
2.281(10)	25(6)	1.2(3)	4.304(12)@	0@	
2.381(10)	19(8)	0.9(4)	4.404(12)	0	
2.499(10)	27(10)	1.3(5)	4.522(12)	0	
2.737(10)	17(3)	0.8(1)	4.760(12)	0	

* All values taken from [2016Or03], except as noted. ** From [2016Or03]. Others: 15.9(6)% [2007Do17], > 2.5% [1996Fa09]. *** Calculated from proton energy and  $S_p$  (⁴⁸Mn) = 2023(6) keV [2021Wa16]. [@] Possibly decaying to 98 keV state in ⁴⁷Cr, with resulting  $E_{level}$  (emitter) 98 keV higher [2016Or03].

#### Table 11

β-p emission from ⁵²Ni*,  $BR_{\beta p} = 31.1(5)\%$ .

$E_p(c.m.)$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( ⁵² Co)**	$E_{daughter}(^{51}\mathrm{Fe})$	coincident $\gamma$ -rays	
1.048(10)	53.3(7)	7.30(9)	2.492(11)	0		
1.352(10)	100	13.7(2)	2.796(11)	0		
1.575(10)	8.5(3)	1.17(4)	3.019(11)	0		
1.681(10)	11.0(3)	1.50(4)	3.125(11)	0		
1.836(10)	3.1(2)	0.42(3)	3.280(11)	0		
1.949(10)	9.3(2)	1.28(3)	3.393(11)	0		
2.061(10)	8.3(2)	1.14(3)	3.505(11)	0		
2.802(10)	7.4(2)	1.01(3)	4.246(11)	0		
2.888(10)	1.3(2)	0.18(2)	4.332(11)	0		
3.451(10)	0.80(7)	0.11(1)	4.895(11)	0		

* All values taken from [2016Or03], except as noted. ** Calculated from proton energy and  $S_p$  (⁵²Co) = 1444(5) keV [2021Wa16].

## Table 12

 $\beta$ -p emission from ⁵⁶Zn*,  $BR_{\beta p} = 88.5(26)\%$ .

$E_p(c.m.)$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( ⁵⁶ Cu)**	$E_{daughter}(^{55}Ni)$	coincident γ-rays	
0.921(10)	12(2)	2.0(4)	1 414(12)	0		
1.131(10)	13(2)	23.8(11)	1.714(12)	0		
1.977(10)	19(4)	4.6(8)	2.560(12)	0		
2.101(10)	72(5)	17.1(9)	2.684(12)	0		
2.863(10)	89(6)	21.2(10)	3.446(12)	0		
2.948(10)	79(6)	18.8(10)	3.531(12)	0		

* All values taken from [2016Or03], except where noted. ** Calculated from proton energy and  $S_p$  (⁵⁶Cu) = 583(6) keV [2021Wa16].

$E_{\rm p}({\rm c.m.})$	$I_{\rm p}({\rm rel})$	$I_{\rm p}({\rm abs})$	Equittar ( ⁶⁰ Ga)**	$E_{daughtar}(^{59}$ Zn)	coincident <i>Y</i> -rays	
p(++++)	-p()	-p()		-uuugmer ()		
0.820(13)	8.5(12)	2.8(4)	0.910(20)	0		
1.076(23)	12.1(15)	4.0(5)	1.166(27)	0		
1.359(19)	15.5(12)	5.1(4)	1.449(24)	0		
1.684 (17)	12.7(9)	4.2(3)	1.774(23)	0		
2.067(15)	30.9(15)	10.2(5)	2.620(21)	0.4633(1)	0.4633(1)	
2.522 (15)	100(3)	33(1)	2.612(21)	0		
2.981(23)	9.7(9)	3.2(3)	3.071(27)	0		
3.490(22)	5.8(6)	1.9(2)	3.580(27)	0		

Table 13  $\beta$ -p emission from ⁶⁰Ge*,  $BR_{\beta p} = 67(3)\%^*$ .

* All values taken from [2021Or01], except where noted.

** Calculated from proton energy and  $S_p$  (⁶⁰Ga) = 90(15) keV [20210r01].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = -2 nuclei.

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#### Table 1

Observed and predicted  $\beta$ -delayed particle emission from the odd Z,  $T_z = -2$  nuclei. Unless otherwise stated, all Q-values values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$BR_{\beta 2p}$	$Q_{\varepsilon 3p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta\alpha}$	Experimental
¹⁰ N	$(1^{-})$	$2.5^{+2.0}$ MeV	23.10(40)	19.09(40)		19.28(40)		2.03(40)	18.00(40)		[2017Ho10]
$^{14}F$	2-	0.91(10) MeV	23.96(4)	19.33(4)		17.382(40)		1.425(40)	13.836(40)		[2010Go16]
¹⁸ Na	$(1)^{-}$	<0.2 MeV	19.72(9)	15.80(9)		15199(90)		3.072(90)	14.607(90)		[2012Mu05]
²² Al	4+	91.1(5) ms	18.60(40)#	13.10(40)#	54.5(25)%	10.66(40)#	1.10(11)%	-2.18(40)#	10.46(40)#	0.038(17)%	[ <b>2006Ac04</b> , 1997B103, 1982Ca16]
²⁶ P	3+	43.6(3) ms	18.285(61)*	12.775(61)**	33.5(20)%	10.505(61)**	3.20(42)%	-1.37(20)#	9.225(61)**		[2022Li66, 2020Li06, 2017Ja05, 2015Sc16, [2004Th09, 1983Ho23, 1983Ca06]
³⁰ Cl	$(3^{+})$	<30 ns	18.734(24)	14.338(24)		11.590(24)		0.005(24)	8.95(20)		-
³⁴ K		<25 ns	17.16(20)#	12.49(20)#		10.22(20)#		1.35(20)#	10.41(20)#		
³⁸ Sc			17.81(20)#	13.26(20)#		11.40(20)#		2.90(20)#	11.70(20)#		
$^{42}V$		<55 ns	17.49(20)#	13.73(20)#		12.65(20)#		4.32(20)#	12.01(20)#		
⁴⁶ Mn	4+	36.2(4) ms	17.050(90)	12.180(90)	57.0(8)%	10.551(90)		1.901(90)	12.01(20)		[ <b>2007Do17</b> , 2001Gi01, 1992Bo37]
⁵⁰ Co	$(6^{+})$	38.8(2) ms	16.89(13)	12.74(13)	70.5(7)%	10.65(13)#		2.55(13)#	9.46(13)		[2007Do17, 1996Fa09]
⁵⁴ Cu	(3 ⁺ )	< 75 ns	18.04(40)#	14.13(40)#		12.51(40)#		5.14(40)#	10.81(40)#		
⁵⁸ Ga			18.76(30)#	16.48(30)#		15.79(30)#		8.62(30)#	13.31(30)#		
⁶² As			17.72(33)#	15.43(30)#		15.18(30)#		10.07(30)#	15.46(30)#		
⁶⁶ Br			18.09(45)#	16.08(41)#		16.17(40)#		11.11(40)#	16.15(42)#		

* Taken from [2022Li66], 18.11(20)# in [2021Wa16]. ** Deduced from  $Q_{\varepsilon}$  [2022Li66] of ²⁶P, and daughter values from [2021Wa16].

#### Table 2

Particle emission from the odd Z,  $T_z = -2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	Sp	$BR_{1p}$	$S_{2p}$	Qα	Experimental	
$^{10}N$	-2.60(40)	100%	-1.30(40)	-10.95(20)#	[2017Ho10]	
$^{14}F$	-1.560(40)	100%	-0.050(40)	-9.26(400	[2010Go16, 2012Go11]	
¹⁸ Na	-1.250(90)	100%	0.220(90)	-9.35(10)	[2012Mu05, 2018Xu04]	
²² Al	-0.01(40)#		3.23(40)#	-9.26(41)#	[2006Ac04]	
²⁶ P	0.14(20)#		3.56(20)#	-9.65(45)#		
³⁰ Cl	-0.480(20)		2.756(24)	-8.72(20)#		
³⁴ K	-0.88(20)#		2.46(20)#	-8.32(20)#		
³⁸ Sc	-1.60(20)#		1.41(20)#	-5.45(28)#		
⁴² V	-0.79(20)#		1.67(20)#	-5.80(28)#		
⁴⁶ Mn	0.19(90)		3.19(90)	-7.22(21)#		
⁵⁰ Co	0.13(13)		2.87(13)	-7.60(15)		
⁵⁴ Cu	-1.10(40)#		1.47(40)#	-6.08(42)#		
⁵⁸ Ga	-1.72(36)#		-0.51(30)#	-4.73(50)#		
⁶² As	-2.08(42)#		-0.59(36)#	-3.31(42)#		
⁶⁶ Br	-2.16(30)#		-1.39(45)#	-1.57(50)#		

		F 4				
$E_p(c.m.)$	$I_p(\text{rel})$	$I_p(abs)$	E _{emitter} ( ²² Mg)**	E _{daughter} ( ²¹ Na)***	coincident γ-rays***	
	1	1			· ·	
0.475(8)	25.6(42)	4.73(63)	6.311(8)	0.3319(1)	0.332	
0.721(8)	40(7)	7.4(10)	6.225(8)	0		
0.975(8)	1.4(3)	0.25(5)	6.479(8)	0		
1.033(8)	16(2)	3.00(34)	6.869(8)	0.3319(1)	0.332	
1.223(8)	4.05(66)	0.75(10)	6.727(8)	0		
1.299(8)	100	18.51(17)	7.135(8)	0.3319(1)	0.332	
1.551(10)	4.38(96)	0.81(16)	7.055(10)	0		
1.753(8)	2.4(5)	0.45(8)	7.257(8)	0		
2.072(8)	2.59(45)	0.48(7)	7.576(8)	0		
2.503(10)	3.46(77)	0.64(13)	8.007(10)	0		
2.583(8)	26.4(28)	4.89(24)	8.419(8)	0.3319(1)	0.332	
2.838(8)	11.4(12)	2.11(9)	8.342(8)	0		
3.088(8)	10.2(10)	1.89(7)	8.592(8)	0		
3.484(8)	11.8(14)	2.18(15)	8.988(8)	0		
4.017(8)	5.6(19)	1.04(33)	9.521(8)	0		
4.224(9)	4.5(7)	0.84(11)	9.728(9)	0		
4.464(8)	13.6(15)	2.52(14)	9.968(8)	0		
4.912(10)	1.5(17)	0.27(32)	10.416(10)	0		
5.177(13)	1.6(6)	0.29(11)	10.681(13)	0		
5.667(8)	1.9(6)	0.35(11)	14.012(3)@	2.8291(7)	1.113, 1.384, 2.497, 0.332	
5.808(49)	3.0(2)	0.18(55)	11.312(49)	0		
5.909(56)	1.1(34)	0.21(62)	11.413(56)	0		
6.774(8)	2.2(7)	0.41(12)	14.012(3)@	1.7161(3)	1.384, 0.332	
7.517(11)	1.8(4)	0.33(7)	13.021(11)	0		

# Table 3 $\beta$ -p emission from ²²Al*, T_{1/2} = 91.1(5) ms, $BR_{\beta p} = 54.5(25)\%$

* All values taken from [2006Ac04], except where noted. ** Calculated from proton energies and  $S_p$  (²²Al) = 5504.10(16) keV [2021Wa16].

*** Values from adopted levels in ENSDF [2015Fi05].

@ Assigned as IAS.

## Table 4

 $\beta$ -2p emission from ²²Al*,  $BR_{\beta 2p} = 1.10(11)\%$ 

$E_{2p}(c.m.)$	$I_{2p}(\text{rel})$	$I_{2p}(abs)$	$E_{emitter}$ ( ²² Mg)	$E_{daughter}(^{20}\text{Ne})^{***}$	coincident γ-rays [@]
4.464(8)	100	0.69(8)	13.997(8)**	1.6337	1.634
6.085(8)	59(12)	0.41(7)	14.012(3)**	0	

* All values taken from [2006Ac04], except where noted.

** Assigned as IAS.

*** Values from adopted levels in ENSDF [1998Ti06].

## Table 5

 $\beta$ - $\alpha$  emission from ²²Al*,  $BR_{\beta\alpha} = 0.038(17)\%$ 

$E_{\alpha}(c.m.)$	$I_{\alpha}(abs)$	$E_{emitter}$ ( ²² Mg)**	<i>E</i> _{daughter} ( ¹⁸ Ne)***	coincident γ-rays***
4.017(8)	0.038(17)	12.160(8)	1.8873(2)	1.887

* All values taken from [2006Ac04].

*** Calculated from  $\alpha$  energies and  $S_{\alpha}$  (²²Mg) = 8142.5(4) keV [2021Wa16]. **** Values from adopted levels in ENSDF [1995Ti07].

Fable 6	
3-p emission from ²⁶ P*, $T_{1/2}$ =43.6(3) ms, $BR_{\beta p}$ = 33.5(20)%**.	

$E_p(c.m.)^{@@}$	$I_p(\text{rel})$	$I_p(abs)^{@@}$	$E_{emitter}$ ( ²⁶ Si)***	$E_{daughter}(^{25}\text{Al})^{@}$	coincident γ-rays [@]	
0.412(2)	100(7)	17.96(90)	5.926(2)	0		
0.778(3)	4.3(5)	0.78(7)	6.292(3)	0		
0.866(2)	9.5(10)	1.71(15)	6.380(2)	0		
1.248(2)	8.4(8)	1.51(12)	6.762(2)	0		
1.499(2)	5.5(5)	0.99(7)	7.958(2)	0.9449(5)	0.493, 0.945	
1.638(3)	3.6(4)	0.65(6)	7.604(3)	0.4517(5)	0.452	
1.798(4)	1.1(3)	0.20(5)	8.251(3)	0.9449(5)	0.452, 0.493	
1.983(2)	13.3(11)	2.39(16)	7.497(2)	0		
2.139(4)	3.0(8)	0.54(14)	9.429(3)	1.7895(5)	0.452, 0.493, 1.338	
2.288(3)	8.2(9)	1.47(12)	9.429(3)	1.6125(5)	1.612	
2.541(6)	0.5(2)	0.09(3)				
2.593(13)	1.5(3)	0.27(6)	8.559(13)	0.4517(5)	0.452	
2.638(18)	0.6(2)	0.11(4)	8.152(18)	0		
2.732(4)	2.6(4)	0.47(6)	8.251(4)	0		
2.855(17)	< 0.8(2)	< 0.14(4)				
2.908(11)	0.3(3)	0.06(5)	9.367(11)	0.949(5)	0.452, 0.493	
2.968(5)	1.8(3)	0.32(5)	9.419(4)	0.949(5)	0.452, 0.493	
3.097(6)	1.7(4)	0.31(6)	10.401(6)	1.7895(5)	0.452, 0.493, 0.845, 1.790	
3.258(4)	1.9(2)	0.23(4)	9.717(4)	0.949(5)	0.452, 0.493	
3.766(9)	2.0(4)	0.36(7)	9.732(9)	0.4517(5)	0.452	
3.817(6)	0.7(3)	0.13(5)	10.291(3)	0.949(5)	0.452, 0.945	
3.879(3)	4.4(6)	0.79(12)			1.369	
3.920(5)	6.7(9)	1.21(14)	9.419(4)	0		
4.097(5)	<2.1(3)	< 0.37(4)				
4.719(6)	1.3(2)	0.24(4)	10.685(6)	0.4517(5)	0.452	
4.793(3)	3.0(4)	0.54(6)	10.291(3)	0		
4.858(4)	2.5(3)	0.44(5)	10.824(4)	0.4517(5)	0.452	
5.751(3)@@@	4.5(8)	0.81(14)@@@	13.055(2) ^{@@@a}	1.7895(5)	0.452, 0.493, 0.845, 1.790	
5.921(4)@@@	2.4(5)	0.43(9)@@@	13.055(2) ^{@@@a}	1.6125(5)	1.625	
6.401(10)@@@	0.40(32)	0.072(57)@@@	11.912(4)@@@	0.0		
6.587(6) ^{@@@}	0.67(12)	0.12(2)@@@	13.055(2) ^{@@@a}	0.9449(5)	0.493, 0.945	
7.075(16)@@@	1.0(2)	0.18(3)@@@	13.055(2) ^{@@@a}	0.4517(5)	0.452	
7.54394)@@@	1.6(2)	$0.29(4)^{@@@}$	13.055(2) ^{@@@a}	0.0		
7.854(6)@@@	0.39(11)	0.07(2)@@@	13.380(13)@@@	0.0		

* All values taken from [2004Th09], except where noted.

** From [2017Ja05].

*** Calculated from proton energies and  $S_p$  (²⁶Si) = 5514.00(11) keV [2021Wa16]. For levels de-excited by more than one proton transition,  $E_{level}$  (emitter) is the weighted average. ^(a) Values from adopted levels in ENSDF: B. Singh Janurary 2018, http://www.nndc.bnl.gov/ensdf/ ^(a) ^(a)

 $E_p(keV) / I_p (abs) \%$ 0.418(8) / 11.1(12) 0.787(8) / 0.74(17) 0.870(8) / 1.44(30) 1.256(8) / 1.45(21) 1.507(9) / 0.80(18) @@@ [2022Li66]. a IAS.

# Table 7

 $\beta$ -2p emission from ²⁶P*,  $BR_{\beta 2p} = 3.2(4)\%$ .

$E_{2p}(c.m.)$	$I_{2p}(\text{rel})$	$I_{2p}(abs)$	$E_{emitter}$ ( ²⁶ Si)	$E_{daughter}(^{24}Mg)$	coincident $\gamma$ -rays	
2 758(7)	15 1(6)	0.18(11)	11.012(4)	1 360	1 360	
3.902(3)	53(21)	0.63(22)	13.055(2)**	1.369	1.369	
4.125(5)	24(10)	0.29(10)	11.912(4)	0.0		
4.250(10)	61(21)	0.72(21)	13.380(13)	1.369	1.369	
5.277(4)	100(20)	1.19(24)	13.055(2)**	0.0		
5.630(20)	16(7)	0.19(7)	13.380(13)	0.0		

* All values taken from [2022Li66].

** IAS

$E_p(c.m.)$	$I_p(rel)$	$I_p(abs)$	E _{emitter} ( ⁴⁶ Cr)**	$E_{daughter}(^{45}V)^{***}$	coincident γ-rays***	
1.224(12)	28(6)	1.8(3)				
2.358(13)	26(7)	1.7(4)				
3.003(13)	100	6.5(9)	9.144(11)	1.2722(4)	1.272, 0.886, 0.329, 0.055	
3.494(25)	54(12)	3.5(6)	9.144(11)	0.7972(5)	0.411, 0.329, 0.055, 0.741	
4 254(15)	85(15)	5 5(9)	9 144(11)	0		

**Table 8**  $\beta$ -p emission from ⁴⁶Mn*, T_{1/2}=36.2(4) ms,  $BR_{\beta p} = 57.0(8)\%$ .

* All values taken from [2007Do17], except where noted.

** IAS. Listed energy is the weighted average calculated from proton energies and  $S_p$  (⁴⁶Cr) = 4874(11) keV [2021Wa16].

*** Values from adopted levels in ENSDF [2008Bu01].

Table	9
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-p emission	from ⁵⁰ Co*,	$T_1$	/2=38.8(2) ms,	$BR_{\beta p}$	= 70.	5(7	!)%
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$E_p(\text{c.m.})$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( ⁵⁰ Fe)	$E_{daughter}(^{49}Mn)^{***}$	coincident γ-rays***	
1.874(16)	2.4(5)	1.0(2)	8.473(12)**	2.4813(4)	0.940, 0.482, 1.279, 0.798, 0.261	
2.044(14)	7.3(15)	3.0(6)			•••• •••, ••••••, •••••••, ••••••	
2.296(27)	2.2(7)	0.9(3)				
2.770(12)	100	41.1(24)	8.473(12)**	1.54131(25)	0.482, 1.279, 0.798, 0.261	

* All values from [2007Do17], except where noted. Many of the delayed protons have not been measured resulting in a total intensity for individual protons to be lower than the total  $\beta^+$ -p intensity.

** IAS. Listed energy is the weighted average calculated from proton energies and  $S_p$  (⁵⁰Fe) = 4146(9) keV [2021Wa16].

*** Values from adopted levels in ENSDF [2008Bu17].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = -3/2 nuclei.

Last updated 7/27/23

#### Table 1

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = -3/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\varepsilon}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon 3p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta\alpha}$	Experimental
⁹ C	(3/2-)	126.5(9) ms	16.495(23)	16.680(2)	61.1(17)%*	-0.574(2)	-10.548(2)	14.806(50)	37.6(56)%**	[ <b>2001Be51, 2001Bu05, 1972Es05</b> , 2004Ti06, 2000Ge09, 1988Mi03, 1972Es05, 1971EsZR, 1971EsZW, 1965Ha09]
¹³ O	(3/2 ⁻ )	8.58(5) ms	17.770(10)	15.826(10)	11.3(20)%	-0.131(10)	-11.360(10)	8.274(10)	0.078(6)%***	[2023Bi03, 2005Kn02, 1990As01, 1971EsZR, 1970Es03, 1966Ce02, 1965L 00, 1966D (21)
¹⁷ Ne	1/2-	109.3(6) ms	14.5488(4)	13.9485(4)	94.4(29)%	1.8211(4)	-8.3865(4)	8.7300(5)	3.51(16)% [@]	[2002Mo19, 1965Ba65] [2002Mo19, 1988Bo39, 2002Ch61, 1971EsZR, 1971Ha05, 1967Es02, 1966Es04, 1965Ha20, 1964Da13, 1964F103, 1964Mc16, 1963Ba63, 1963Ka36]
²¹ Mg	5/2+	118.6(5) ms	13.0887(8)	10.657(1)	20.9(13)%	-2.187(1)	-10.180(1)	6.527(1)	0.115(19)% ^{@@}	[ <b>2015Lu12</b> , 2015Lu13, 1992Go10, 1985Zh05, 1974ScZL, 1973Go06, 1973GoZL, 1973Se08, 1973SeYM, 1965Ha20, 1965Mc01, 1964Fl03, 1963Ba63, 1963Ka36]
²⁵ Si	5/2+	220(4) ms	12.743(10)	10.472(10)	35.0(20)%	-1.221(10)	-10.015(10)	3.587(10)		[2021Su03, 2004Th09, 1993Ro06, 1992Ha28, 1985Zh05, 1975ScZC, 1974SeZL, 1974SeZM, 1973GoZL, 1973SeYM, 1966Ha22, 1966Re07, 1966Re15, 1965Ha20, 1965Mc01 1963Ba63, 1963Mc08]
²⁹ S	(5/2+)	187(6) ms	13.858(13)	11.109(13)	47(5)%	-0.475(13)	-8.747(13)	3.397(13)		[ <b>1985Zh05, 1979Vi01</b> , 1978ViZT, 1978ViZT, 1973Go06, 1973GoZL
³³ Ar	1/2+	173.0(20) ms	11.6190(6)	9.3423(4)	38.8(14)%	0.4782(4)	-6.8183(4)	5.1435(6)		1964Ha45, 1967Fi10] [ <b>2010Ad03</b> , 2014Ko17, 2002Fy01, 2000Ga61, 1999Th09, 1996Ho24, 1993Sc16, 1987Bo21, 1971EsZR, 1971Ha05, 1966Po12, 1965Ha08, 1964Po201
³⁷ Ca	3/2+	181.1(10) ms	11.6641(6)	9.8065(6)	82.1(8)%	1.299(1)	-5071(1)	5.442(1)		[ <b>1997Tr05</b> , <b>1991Ga23</b> , 2015Su01, 1997Ka10, 1995Tr03, 1974Se11, 1966Be12, 1064Ue42, 1064Be081
⁴¹ Ti	3/2+	81.9(5) ms	12.945(28)	11.860(28)	92.4(6)% ^{@@@}	3.531(28)	-2.850(28)	6.677(28)		[2015Sh16, 2007Do17,1998Bh12, 1998Li46, 1974Se11, 1997Tr11, 2014Ka01, 1997Ho12, 1998Jo20, 1985Zh05, 1973Go06, 1966Po12, 1964Pe08]
45Cr	$(7/2^{-})$	60 9(4) ms	12 370(40)	10 74(4)	34 4(8)%	2 100(40)	-2 830(40)	6 707(40)		[2007Do17 1987Ki14 1974Ia10]
⁴⁹ Fe	( <i>1</i> /2 ⁻ ) 7/2 ⁻	64.7(3) ms	12.869(24)	10.782(25)	56.7(4)%	2.678(24)	-2.490(24)	4.710(24)		[ <b>2007Do17</b> , 1961R114, 1974stato] [ <b>2007Do17</b> , 2002Pf03, 1996Fa09, 1970Ce02]
⁵³ Ni	7/2-	55.2(7) ms	13.029(25)	11.412(13)	22.7(10)% ^a	4.0354(25)#	-1.237(25)	5.564(25)		[ <b>2016Su10, 2007Do17</b> , 2013Su07, 1993Xu04, 1978ViZT]
⁵⁷ Zn	(7/2-)	43.6(2) ms	14.76(20)#	14.07(20)#	90(10)%	6.90(20)#	1.84(20)#	7.68(20)#		[2022Sa20, 2020Ci04, 2007Bl09, 2002Jo09 2002Lo13, 1979Vi01]
⁶¹ Ge	(3/2 ⁻ )	40.7(4) ms	13.35(30)#	13.10(30)#	78(3)%	7.99(30)#	4.57(30)#	11.09(30)#		[ <b>2017GoZT, 2007Bl09</b> , 2002Lo13, 1987Ho01, 1978ViZT]
⁶⁵ Se	(3/2 ⁻ )	34.2(2) ms	13.92(31)#	14.01(30)#	$94^{+6}_{-4}\%$	8.95(30)#	6.28(30)#	11.69(30)#		[ <b>2017GoZT, 2011Ro47</b> , 1993Ba12, 1978ViZT]
⁶⁹ Kr	(5/2-)	28(1) ms	14.12(30)#	14.76(30)#	100% ^b	9.87(30)#	7.60(30)#	12.38(30)#		[2011Ro47, 2014De41, 2017GoZT]
⁷³ Sr	(3/2 ⁻ )	23.1(14) ms	14.06(40)#	14.70(40)#	100% ^c	9.97(40)#	8.11(40)#	11.89(40)#		[ <b>2019Si33, 2020Ho17</b> , 2020Ho06, 1993Ba61]
$_{77}Zr$			14.84(45)#	15.36(40)#		11.04(40)#	8.87(40)#	11.99(40)#		
⁸¹ Mo		>450 ns	14.90(64)#	16.01(58)#		11.76(51)#	9.85(50)#	12.55(54)#		[2017Su26]
⁸⁵ Ru		>450 ns	15.22(64)#	16.25(58)#		12.40(53)#	11.12(50)#	13.31(64)#		[2017Su26]

* Branching ratio is taken from [2001Bu05], normalized to the 54.1(15)% proton transition from the ground state of ⁹B from Ref. [2001Be51]. The  $\beta$ -delayed p emission from ⁹C ends in ⁸Be which then decays into 2  $\alpha$  particles. Therefore this decay can be called  $\beta$ -p2 $\alpha$  emission. ** The  $\beta$ -delayed  $\alpha$  emission from ⁹C ends in ⁵Li which is proton unbound. Therefore this decay can be called  $\beta$ - $\alpha$  emission.

*** [2023Bi03] report a value of 0.078(6)% for  $\beta$ -delayed 3 $\alpha$ p decay. This value is a combination of both  ${}^{13}O \xrightarrow{\beta}{}^{13}N \xrightarrow{p}{}^{12}C \xrightarrow{\alpha}{}^{8}Be \xrightarrow{2\alpha}{}^{2\alpha}$  and  ${}^{13}O \xrightarrow{\beta}{}^{13}N \xrightarrow{\alpha}{}^{9}B \xrightarrow{p}{}^{2\alpha}$ ⁸Be $\xrightarrow{2\alpha}$ .

^{*a*} In addition a  $BR_{\beta p\alpha} = 0.0014(4)\%$  is reported [2002Mo19].

[@] [@] In addition a  $BR_{\beta p\alpha} = 0.016(3)\%$  is reported [2015Lu12].

[@] [@] [@] Weighted average of 91.6(6)% [2007Do17], 95.3(23)% [1998Bh12], and 100.3(22)% [1997Tr11].

^a Weighted average of 23.4(10)% [2007Do17] and 22.0(10)% [2016Su10].

^b Expected to be 100% as the daughter ⁶⁹Br is unbound by 640(40) keV [2017Wa10]. ^c Expected to be 100% as the daughter ⁷³Rb is unbound by 570(20) keV [2017Wa10].

## Table 2

Particle emission from the even-Z,  $T_z = -3/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	Experimental
90	1.000((0.4)	1 42((0)	10 (5(000) //	
¹² C	1.2996(24)	1.430(2)	-10.65(200)#	
150	1.512(10)	2.112(10)	-8.220(10)	
¹⁷ Ne	1.464(5)	0.933(1)	-9.040(10)	
²¹ Mg	3.2356(13)	5.4261(8)	-8.0215(8)	
²⁵ Si	3.413(10)	5.277(10)	-9.501(19)	
²⁹ S	3.236(13)	5.288(13)	-9.347(16)	
³³ Ar	3.3386(7)	4.9197(5)	-8.715(13)	
³⁷ Ca	3.0079(7)	4.667(1)	-6.177(1)	
⁴¹ Ti	2.463(28)	2.993(28)	-4.986(28)	
⁴⁵ Cr	3.000(40)	4.780(40)	-6.240(50)	
⁴⁹ Fe	2.743(25)	4.766(25)	-7.660(40)	
⁵³ Ni	2.576(26)	4.020(25)	-7.310(30)	
⁵⁷ Zn	1.21(20)#	1.79(20)#	-5.34(20)#	
⁶¹ Ge	1.49(36)#	1.15(30)#	-3.67(36)#	
⁶⁵ Se	0.78(36)#	0.68(30)#	-1.66(42)#	
⁶⁹ Kr	0.64(40)#	0.14(31)#	-1.55(42)#	
⁷³ Sr	0.91(64)#	0.20(42)#	-2.24(50)#	
⁷⁷ Zr	0.64(50)#	-0.44(46)#	-2.08(57)#	
⁸¹ Mo	0.33(64)#	-0.73(58)#	-2.29(64)#	
⁸⁵ Ru	0.22(64)#	-1.13(64)#	-1.60(71)#	

#### Table 3

 $\beta$ -p Emission from ⁹C, T_{1/2}=126.5(9) ms^{@@},  $BR_{\beta p} = 61.1(17)\%^{**}$ 

$E_p^*$	$I_p(\text{rel})$	$I_p(abs)^{**}$	E _{emitter} ( ⁹ B)***	Edaughter( ⁸ Be)***	coincident γ-rays
0 1858(9)	100	58(11)	0	0	100% a
2.529(30)	0.23(3)	0.136(14)	2.34(3)	0	100% α
3.113(20)	0.18(1)	0.112(6)	2.93(20)	0	100% α
3.25(30)	8.6(9)	5.0(5)	3.10(30)	0	100% α
5.4(14)	1.2(6)	0.72(36)	$5.3^{+1.4}_{-0.5}$	0	100% α
9.32(40)	2.1(7)	1.2(4)	$12.16^{+0.03}_{-0.4}$	3.03	100% α
12.35(40)	0.084(19)	0.049(6)	$12.16_{-0.4}^{+0.03}$	0	100% α
13.526(20)	$1.7(9) \ge 10^{-5}$	$9.3(5) \times 10^{-6}$	13.34(20)	0	100% α
14.22(10)	0.069(7)	0.07(2)	14.03(10)	0	100% α
@	0.38(20)	0.22(12)			100% α

*  $E_p$  values calculated from  $E_{level}$  (emitter) [2001Bu05] and  $S_p = -0.1858(9)$  MeV [2021HWa16]. ** Branching ratio is taken from [2001Bu05], normalized to the 54.1(15)% proton transition from the ground state of ⁹B from Ref. [2001Be51].

*** From (table 3 and figure 7) in [2001Bu05].

[@] Background states [2001Be51].

@@ [1972Es05]

## Table 4 $\beta$ - $\alpha$ emission from ⁹C, $BR_{\beta\alpha} = 37.6(56)\%^{**}$

$E_{\alpha}^{*}$	$I_{\alpha}$ (rel)	$I_{\alpha} (abs)^{***}$	$E_{emitter}$ ( ⁹ B)***	<i>E</i> _{daughter} ( ⁵ Li)	coincident γ-rays	
0 653(58)	100(19)	29 3(56)	234(3)	0	100% proton	
1.237(53)	0.61(33)	0.18(9)	2.93(20)	0	100% proton	
1.37(30)	0.11(3)	0.031(4)	3.1(3)	0	100% proton	
$3.6^{+1.4}_{-0.5}$	1.7(9)	0.49(25)	$5.3^{+1.4}_{-0.5}$	0	100% proton	
10.47(40)	12.0(10)	3.5(3)	12.16(40)	0	100% proton	
12.34(11)	0.61(33)	0.18(9)	14.03(10)	0	100% proton	
10.58 [@]	0.18(12)	$0.06(4)^{@}$	12.16(40)	1.49@	100% proton	
#	0.105(5)	0.035(2)			100% proton	

*  $E_{\alpha}$  values deduced from  $E_{emitter}$  (⁹B) [2001Bu05] and  $Q_{\alpha}$  = -1.690(50) MeV [2021Wa16]. ** Branching ratio is taken from [2001Bu05], normalized to the 54.1(15)% proton transition from the ground state of ⁹B from Ref. [2001Be51]. *** From (table 3 and figure 7) in [2001Bu05] unless otherwise stated.

[#] Background states [2001Be51].

@ From [2001Be51].

#### Table 5

 $\beta$ -p emission from ¹³O*, T_{1/2}= 8.58(5) ms[@], BR_{$\beta p$} = 10.9(20)%.

$E_p$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( ¹³ N)	$E_{daughter}(^{12}C)^{**}$	coincident γ-rays**	
1.006(6)	2 4(3)	0.23(5)	7 376(9)***	4 4389(3)	4 4 3 8	
1.5597(10)	100	9.5	3.502(2)***	0		
2.591(6)	4.5(3)	0.43(8)	8.918(11)***	4.4389(3)	4.438	
3.175(6)	1.06(11)	0.10(2)	9.476(8)***	4.4389(3)	4.438	
5.445(6)	0.09(4)	0.009(4)	7.376(9)***	0		
7.030(6)	5.3(4)	0.50(10)	8.918(11)***	0		
7.396(53)	0.011(2)	0.0010(3)	15.300(200)	7.6542(2)	3.215, 4.438	
7.614(6)	1.40(13)	0.13(3)	9.476(8)***	0		
8.714(53)	0.030(5)	0.003(1)	15.0646(4)***	4.4389(3)	4.438	
9.78(6)	0.15(4)	0.040(14)	11.700(30)***	0		
11.32(9)	0.11(9)	0.010(9)	13.26(10)	0		
13.152(53)	0.049(7)	0.005(1)	15.0646(4)***	0		
13.5(4)	0.04(3)	0.004(3)	15.300(200)	0		

* All values taken from [2005Kn02], except where noted.

** Values from adopted levels in ENSDF [2017Ke05].

*** Values from adopted levels in ENSDF [1991Aj01].

@ [1990As01]

Fable 6	
3-p Emission from ¹⁷ Ne*, $T_{1/2} = 109.3(5) \text{ ms}^{@}$ , $BR_{\beta p} = 94.4(29)\%$	

$E_p$	$I_p(rel)$	$I_p(abs)$	$E_{emitter}$ ( ¹⁷ F)***	$E_{daughter}(^{16}\mathrm{O})^{@@}$	coincident $\gamma$ -rays [@]
0.358	< 0.10	< 0.049	8.075	7.1169(1)	7.115
0.47	0.066(59)	0.033(29)	10.655	9 585(11)	9 582 6 916 2 688
0.48	3.06(24)	1.51(9)	8 197	7 1169(1)	7 115
0.557	< 0.12	<0.058	8 074	6 9171(6)	6916
0.560	< 0.12	<0.000	10.032	8 8719(5)	2 742 6 129 1 755 7 115
0.500	3 61(27)	1 78(13)	8 107	6.0171(6)	6.016
0.080	1.28(6)	0.63(3)	8.137	7 1160(1)	7 115
0.719	$(2.8) \times 10^{-6}$	$< 1.4 \times 10^{-6}$	10 005	0.585(11)	0.522 6.016 2.622
0.720	$< 2.8 \times 10$ 1 28(6)	$< 1.4 \times 10$ 0.62(2)	8 425	9.383(11)	9.382, 0.910, 2.088
1.002	0.020(8)	0.03(3)	0.433	0.9171(0)	0.522 6.016 2.699
1.002	0.029(8)	1.25(5)	0 0 0 2 5	9.383(11)	9.382, 0.910, 2.088
1.108	2.55(10)	1.23(3)	0.023	7.1109(1) 8.8710(5)	7.115
1.19	< 0.020	< 0.02	10.002	6.0719(3)	2.742, 0.129, 1.755, 7.115
1.307	2.4/(11)	1.22(5)	8.824	6.9171(6)	0.910
1.344	0.10(15)	0.080(7)	8.075	6.129(89)	0.129
1.425	0.91(6)	0.45(5)	8.075	0.0494(1)	
1.44	$< 3.1 \times 10^{-4}$	<0.00015	10.912	8.8/19(5)	2.742, 6.129, 1.755, 7.115
1.47	0.97(23)	0.48(12)	8.200	6.129(89)	6.129
1.55	$< 3.3 \times 10^{-5}$	$< 1.6 \times 10^{-5}$	8.200	6.0494(1)	**
1.706	4.83(17)	2.38(8)	8.436	6.1299	6.129
1.721	0.24(4)	0.12(2)	11.193	8.8719(5)	2.742, 6.129, 1.755, 7.115
1.73	0.62(4)	0.31(2)	9.447	7.1169(1)	7.115
1.786	0.70(3)	0.35(2)	8.436	6.0494(1)	**
1.93	1.83(7)	0.90(4)	9.447	6.9171(6)	6.916
2.095	0.16(2)	0.08(1)	8.825	6.1299	6.129
2.175	3.45(20)	1.7(1)	8.825	6.0494(1)	**
2.313	< 0.026	< 0.013	10.027	7.1169(1)	7.115
2.504	0.31(3)	0.15(2)	3.104	0	
2.51	0.22(2)	0.11(1)	10.030	6.9171(6)	6.916
2.72	0.295(20)	0.15(1)	9.450	6.1299	6.129
2.8	0.93(5)	0.46(3)	9.450	6.0494(1)	**
2.94	< 0.011	< 0.006	10.657	7.1169(1)	7.115
3.14	< 0.015	< 0.008	10.657	6.9171(6)	6.916
3.19	0.23(2)	0.112(8)	10.907	7.1169(1)	7.115
3.3	0.034(10)	0.017(5)	10.030	6.1299	6.129
3.38	0.90(5)	0.45(3)	10.030	6.0494(1)	**
3.39	0.12(2)	0.057(9)	10.907	6.9171(6)	6.916
3.476	0.37	0.18	11.193	7.1169(1)	7.115
3.676	0.009(3)	0.004(1)	11.193	6.9171(6)	6.916
3.93	< 0.07	< 0.035	10.660	6.1299	6.129
4.01	1.20(7)	0.59(4)	10.660	6.0494(1)	**
4.04	28.6(6)	14.1(8)	4.640	0	
4.18	< 0.07	< 0.035	10.910	6.1299	6.129
4.26	1.20(7)	0.59(3)	10.910	6.0494(1)	**
4.463	0.50(2)	0.245(10)	11.193	6.1299	6.129
4.543	0.090(7)	0.045(3)	11.193	6.0494(1)	**
4.888	100(5)	49.4(27)	5.488	0	
5.437	15.1(8)	7.5(4)	6.037	0	
7.475	9.7(5)	4.8(3)	8.075	0	
7.6	0.39(3)	0.19(1)	8.200	0	
7.836	1.25(7)	0.62(4)	8.436	0	
8.225	0.81(5)	0.40(2)	8.825	0	
8.85	0.043(4)	0.022(2)	9.450	0	
9.43	0.043(4)	0.021(2)	10.030	0	
10.06	0.004(2)	0.0021(2)	10.660	0	
10.31	0.028(4)	0.014(2)	10.910	0	
10.5924	0.13(1)	0.063(4)	11.193	0	
11.65	0.004(2)	0.0021(8)	12.250	0	

* All values taken from [2002Mo19], error bars for energies are not given. ** E0 transition *** Calculated from alpha energies and S_p (¹⁷F) = 600.27(25) keV [2021Wa16]. [@] [1988Bo39] [@] Walues from adopted levels in ENSDF [1993Ti07].

Table 7				
$\beta$ - $\alpha$ emission from	17Ne*.	BRea	= 3.51	(16)%.

			17	12 @		
Eα	$I_{\alpha}$ (rel)	$I_{\alpha}$ (abs)	$E_{emitter} ({}^{1}{}^{r}\mathrm{F})^{***}$	$E_{daughter}(^{13}N)^{@}$	coincident $\gamma$ -rays	
1.827	0.08(4)**	0.002(1)**	11.193	3.547(4)	3.547	
1.872			11.193	3.502(2)	3.502	
2.256	100(6)	2.7(2)	8.075	0		
2.381	10.3(8)	0.28(2)	8.2	0		
2.617	4.4(3)	0.12(1)	8.436	0		
3.006	8.5(6)	0.23(2)	8.825	0		
3.63	2.7(2)	0.074(5)	9.45	0		
4.21	2.4(2)	0.065(5)	10.03	0		
4.84	0.031(28)	0.00085(76)	10.66	0		
5.09	0.55(7)	0.025(2)	10.91	0		
5.374	0.12(3)	0.003(1)	11.193	0		

* All values taken from [2002Mo19], error bars for energies are not given.

** Sum of  $I_{\alpha}$  for  $E_{\alpha} = 1.827$  and 1.872.

*** Calculated from proton energies and  $S_{\alpha}$  (¹⁷F) = 5818.7(4) keV [2021Wa16].

[@] Values from adopted levels in ENSDF [1991Aj01]

## Table 8

 $\beta$ - $\alpha p$  emission from ¹⁷Ne*,  $Q_{\varepsilon \alpha p} = 6.787(1)$  MeV,  $BR_{\beta \alpha p} = 0.0014(4)\%$ .

Eα	$E_{\alpha-emitter}(^{17}F)$	$E_p$	$E_{p-emitter}(^{13}N)$	$E_{final}(^{12}C)$	coincident $\gamma$ -rays
3.0089	11.193	0.422	2.365	0	

* All values taken from [2002Mo19], uncertainties for energies are not given.

#### Table 9

16	au									
β.	-p	emission	from	²¹ Mg*,	$T_{1/2} =$	118.6(5)	ms, BR	$\beta_{p} = 2$	0.9(1	3)%

$E_p$	$I_p(\text{rel})$	$I_p(abs)$	<i>E_{emitter}</i> ( ²¹ Na)***	$E_{daughter}(^{20}\mathrm{Ne})^{@}$	coincident γ-rays [@]	
0.396(10)	3 91(45)	0.22(3)	4 468(10)	1 6337	1 634	
0.906(10)	2.0(5)	0.11(3)	8.303(10)	4 9665(2)	1 634 3 333	
0.919(21)	0.28(3)	0.016(2)	$8.975(10)^a$	5 6214(17)	1 634 3 987	
0.937(10)	194(5)	1.10(3)	7 609(10)	4 2477(11)	1 634 2 614	
1.102(10)	3.34(6)	0.19(3)	3.544(10)	0		
1.316(10)	20.01(15)	1.13(1)	5.380(10)	1.6337	1 634	
1.427(10)	2.84(11)	0.16(1)	8.135(10)	4 2477(11)	1 634 2 614	
1.564(10)	4.66(9)	0.26(1)	$8.975(10)^a$	4.9665(2)	1.634, 3.333	
1.630(10)	2.95(17)	0.17(1)	8.303(10)	4.2477(11)	1.634, 2.614	
1.861(10)	44.05(24)	2.50(2)	4.294(10)	0		
2.037(10)	100.0(4)	5.66(2)	4.468(10)	0		
2.144(10)	4.58(14)	0.26(1)	6.165(10)	1.6337	1.634	
2.263(11)	3.79(55)	0.22(3)	6.341(11)	1.6337	1.634	
2.302(10)	0.73(20)	0.04(1)	$8.975(10)^a$	4.247(11)	1.634, 2.614	
2.587(10)	20.89(24)	1.18(2)	5.020(10)	0		
3.443(10)	34.6(31)	1.96(18)	5.884(10)	0		
3.585(11)	8.0(15)	0.45(9)	7.609(11)	1.6337	1.634	
4.055(10)	33.58(2.45)	1.90(14)	6.468(10)	0		
4.257(10)	1.99(20)	0.11(1)	8.303(10)	1.6337	1.634	
4.356(10)	1.94(19)	0.11(1)	8.397(10)	1.6337	1.634	
4.769(10)	10.9(8)	0.62(5)	8.827(10)	1.6337	1.634	
4.913(10)	24.29(176)	1.4(1)	8.975(10) ^a	1.6337	1.634	
5.171(12)	5.63(75)	0.32(4)	7.609(12)	0		
5.868(10)	1.56(18)	0.09(1)	8.303(10)	0		
5.983(10)	1.37(13)	0.078(7)	8.397(10)	0		
6.388(11)	2.86(29)	0.16(2)	8.827(11)	0		
6.537(10)	8.85(65)	0.50(4)	8.975(10) ^a	0		
7.20(30)	0.05(2)	0.003(1)	9.725(30)	0		

* All values are taken from [2015Lu12], except where noted.

*** Energy levels from 2015Lu12 based on proton energies and known resonances in ²⁰Ne [1981Fe05, 1969Bl03, 1964Va10, 2004Fi10].

[@] Values from adopted levels in ENSDF [1998Ti06].

^a IAS [2015Lu12].

# **Table 10** $\beta$ - $\alpha$ emission from ²¹Mg*, $BR_{\beta\alpha} = 0.115(19)\%$ .

Eα	$I_{\alpha}$ (rel)	$I_{\alpha}$ (abs)	$E_{emitter}$ ( ²¹ Na)	$E_{daughter}(^{17}\mathrm{F})$	coincident γ-rays
2.201(27)	0.11(1)	0.0062(5)	8.827(27)	0	
2.397(10)	1.79(5)	0.100(3)	8.975(10)	0	
2.700(43)	0.10(1)	0.0056(6)	9.725(30)	0.495	0.495
3.060(81)	0.04(1)	0.0022(6)	9.725(30)	0	

* Values are taken from [2015Lu12].

#### Table 11

 $\beta$ -p $\alpha$  emission from ²¹Mg*,  $Q_{\varepsilon p\alpha} = 5.927(1)$  MeV,  $BR_{\beta p\alpha} = 0.016(3)\%$ .

$E_p$ (c.m.)	$E_{p-emitter}$ ( ²¹ Na)	$E_{\alpha}(c.m.)$	$E_{\alpha-emitter}$ ( ²⁰ Ne)	$E_{final}(^{16}O)$	coincident γ-rays
0.921(21)	8.975(10)	0.882(18)	8.054(18)	0	

* Values are taken from [2015Lu12].

# Table 12

<u> $\beta$ -p emission from ²⁵Si*, T_{1/2} = 220(4) ms[@], BR_{$\beta p$} = 35.0(20)%</u>

$E_p$	$I_p(\text{rel})\%^b$	$I_p(abs)\%$	$E_{emitter}$ ( ²⁵ Al)**	Edaughter( ²⁴ Mg)***	coincident γ-rays**
0.4020(9)	59(17)	6.1(15)	2.6733(6)	0	
0.554(10)	4.8(25)	0.49(25)	4.192(4)	1.369	1.369
0.724(4)	0.3(15)	0.036(15)	7.240(3)	4.238	1.369, 2.870, 4.238
0.9437(11)	17(5)	1.7(5)	4.582(2)	1.369	1.369
1.037(16)	1.6(6)	0.16(6)	7.422(5)	4.123	1.369, 2.754
1.268(5)	4.0(22)	0.41(22)	4.906(4)	1.369	1.369
1.380(5)	3.7(14)	0.38(14)	7.901(2)	4.238	1.369, 2.870, 4.238
1.492(6)	2.5(13)	0.26(13)	7.901(2)	4.123	1.369, 2.754
1.584(3)	2.9(16)	0.30(16)	3.8591(8)	0	
1.684(12)	1.7(10)	0.18(10)	8186(3)	4.238	1.369, 2.870, 4.238
1.794(3)	5.0(20)	0.51(19)	8.186(3)	4.123	1.369, 2.754
1.9243(20)	25(8)	2.6(7)	4.192(4)	0	
2.164(3)	17(5)	1.7(4)	5804(4)	1.369	1.369
2.3100(9)	15(4)	1.5(3)	4.582(2)	0	
2.453(25)	0.40(12)	0.040(11)	6063(7)	1.369	1.369
2.486(25)	1.0(3)	0.10(3)	6.170(2)	1.369	1.369
2.632(10)	0.50(12)	0.048(10)	4.906(4)	0	
3.006(11)	4.1(25)	0.42(25)	6.650(5)	1.369	1.369
3.236(6)	4.1(16)	0.42(16)	6.877(7)	1.389	1.369
3.327(4)	5(3)	0.5(3)	5.597(6)	0	
3.464(3)	35(15)	3.6(15)	7.118(5)	1.369	1.369
3.606(4)	10(5)	1.0(5)	7.240(3)	1.369	1.369
3.896(8)	2.9(10)	0.3(1)	6.170(2)	0	
4.257(3)	100(14)	10.3(14)	7.901(2)	1.369	1.369
4.345(17)	4.4(16)	0.45(15)	7.936(20)	1.369	1.369
4.551(5)	2.9(10)	0.3(1)	8.186(3)	1.369	1.369
4.614(9)	0.30(12)	0.035(11)	6.909(10)	0	
4.614(9)	0.30(12)	0.035(11)	6.909(10)	0	
4.845(4)	11(8)	1.1(8)	7.118(5)	0	
4.980(4)	2.7(23)	0.28(23)	7.240(3)	0	
5.382(11)	2.2(14)	0.23(14)	7.646	0	
5.549(15)	3.1(10)	0.32(9)	7.819(20)	0	
5.6288(15)	21(7)	2.2(6)	7.901(2)	0	
6.798(5)	1.3(10)	0.13(10)	9.073(7)	0	
7.000(25)	0.10(2)	0.0127(17)	9.275(25)@@	0	
7.141(30)	0.10(2)	0.0127(17)	9.415(30)@@	0	

* average of all data from [2021Su03], [1993Ro06], [1992Ha28], [1985Zh05], taken from table 3 of [2021Su03],

** Values from adopted levels in ENSDF [2009Fi05] except where noted.

*** Values from adopted levels in ENSDF [2007Fi14].

[@] Weighted average of 225(6) ms [1965Mc01] and 218(4) ms [1966Re07].

@@ [1985Zh05].

Table 13
B-p emission from ²⁹ S*, $T_{1/2} = 187(6)$ ms, $BR_{\beta p} = 47(5)\%$ .

$E_p(\text{c.m.})$	$I_p(\text{rel})\%$	$I_p(abs)\%^{@@}$	$E_{emitter}$ ( ²⁹ P)	Edaughter( ²⁸ Si)**	coincident $\gamma$ -rays**	
$0.766^{@}$	22(2)	3.4(3)	5.294(6)	1.779	1.779	
1.042(25)	1.0(4)	0.16(6)	8.389(13)	4.619	1.779, 2.838	
1.302(10)	24(3)	3.8(4)	5.826(8)	1.779	1.779	
1.829(15)	2.4(3)	0.38(5)	6.357(15)	1.779	1.779	
1.978(15)	1.9(3)	0.30(4)	6.506(15)	1.779	1.779	
2.206 [@]	75(3)	11.9(4)	4.955(9)	0		
2.545 [@]	3.4(3)	0.53(4)	5.294(6)	0		
2.621(10)	6.8(5)	1.08(7)	7.149(10)	1.779	1.779	
2.986(15)	0.52(10)	0.082(15)	7.514(15)	1.779	1.779	
3.067(15)	1.14(13)	0.18(2)	5.826(8)	0		
3.212(15)	1.14(13)	0.18(2)	5.961(15)	0		
3.326(15)	1.01(13)	0.16(2)	6.075(15)	0		
3.414(15)	2.2(2)	0.34(3)				
3.579(15)	2.4(3)	0.38(5)	6.328(15)	0		
3.715(15)	1.3(3)	0.21(4)	8.243(11)	1.779	1.779	
3.853 [@]	14.8(9)	2.34 12	8.389(13)	1.779	1.779	
3.905(15)	4.5(4)	0.71(6)	6.654(15)	0		
4.008(20)	1.7(4)	0.27(6)	8.535(14)	1.779	1.779	
4.335(20)	6.8(5)	1.08(7)	7.085(20)	0		
4.493(20)	2.1(3)	0.33(4)	7.242(20)	0		
4.640(25)	1.6(3)	0.25(4)	7.389(25)	0		
4.852(20)	1.7(3)	0.27(4)	9.394(17)	1.779	1.779	
5.008(20)	1.5(3)	0.23(4)	7.757(20)	0		
5.359(15)	4.4(5)	0.69(7)	8.108(15)	0		
5.493(15)	5.8(5)	0.92(7)	8.243(11)	0		
5.632 [@]	100(3)	15.8(4)	8.389(13)	0		
5.784(20)	5.5(5)	0.87(7)	8.535(14)	0		
6.062(30)	0.89(19)	0.14(3)	8.811(20)	0		
6.676(30)	1.0(2)	0.16(3)	9.394(17)	0		
6.965(50)***	0.10(2)***	0.016(3)	9.714(50)	0		
7.105(30)***	0.21(2)***	0.033(3)	9.854(30)	0		
7.343(30)***	0.12(1)***	0.019(2)	10.092(30)	0		
7.789(30)***	$0.18(1)^{***}$	0.028(2)	10.538(30)	0		

* All values taken from [1979Vi01] except where noted.
** Values from adopted levels in ENSDF [2013Ba53].
*** [1985Zh05].
[@] Proton peaks that were used as energy calibrations.
[@] Deduced by evaluator from beta branching (table 2 in [1979Vi01]) and proton branching ratios from these states (tables 3 and 4 in [1979Vi01]).

Table 14	
$\beta$ -p emission from ³³ Ar*, T _{1/2} = 173(2) ms, $BR_{\beta p} = 38.8(14)\%^{**}$	

$E_p$	$I_p(rel)$	$I_p(abs)$	E _{emitter} ( ³³ Cl)***	$E_{daughter}(^{32}\mathrm{S})^{@}$	coincident γ-rays [@]	
0.786(10)	0.065(6)	0.0202(17)	5.307(4)	2.2306(2)	2.230	
1.358(8)	0.54(4)	0.168(9)	5.866(8)	2.2306(2)	2.230	
1.696(2)	1.33(64)	0.41(20)	3 973(2)	0		
1.090(2) 1.717(6)	0.019(4)	0.0060(11)	7 762(3)	3 7784(10)	1 549 2 230	
1.744(6)	0.017(4) 0.107(11)	0.0000(11) 0.0332(32)	6 254(3)	2 2306(2)	2 230	
1.744(0)	0.026(4)	0.0332(32)	6 326(5)	2.2306(2)	2.230	
1.019(3)	1.52(10)	0.0081(13) 0.471(22)	0.320(3)	2.2300(2)	2.250	
1.657(2)	1.32(10)	0.4/1(22) 0.0042(7)	4.115(2)	0	2,220	
2.087(5)	0.014(2)	0.0043(7)	0.595(5)	2.2306(2)	2.230	
2.166(3)	8.81(56)	2.73(12)	4.442(3)	0	1.540, 2.220	
2.442(6)	0.004(1)	0.0012(3)	8.491(5)	3.7784(10)	1.549, 2.230	
2.444(5)	0.049(4)	0.0153(12)	6.951(5)	2.2306(2)	2.230	
2.559(2)	1.17(8)	0.362(17)	4.835(2)	0		
2.795(7)	0.022(4)	0.0069(12)	7.292(3)	2.2306(2)	2.230	
2.830(3)	0.156(16)	0.0483(44)	5.107(3)	0		
2.898(10)	0.045(5)	0.00141(14)	7.405(10)	2.2306(2)	2.230	
2.976(7)	0.121(13)	0.0376(35)	7.484(7)	2.2306(2)	2.230	
3.033(4)	0.24(2)	0.0748(55)	5.310(4)	0		
3.049(7)	0.116(12)	0.0359(32)	7.557(7)	2.2306(2)	2.230	
3.110(10)	0.0023(7)	0.0007(2)	9.153(4)	3.7784(10)	1.549, 2.230	
3.162(6)	0.0145(65)	0.0045(20)	7.666(3)	2.2306(2)	2.230	
3.272(3)	100	31.0(14)	5.549(3)	0		
3.455(4)	0.296(16)	0.0918(48)	5.731(4)	0		
3.577(6)	0.171(15)	0.0531(40)	8 077(3)	2,2306(2)	2.230	
3 625(6)	0.048(8)	0.0150(25)	8 132(6)	2.2306(2)	2.230	
3 688(5)	0.07((5))	0.0190(29) 0.0085(16)	8 183(3)	2.2306(2)	2.230	
3.078(3)	2 37(15)	0.735 (34)	6 254(3)	0	2.230	
3.978(3) 4.049(5)	2.37(13) 0.026(4)	0.733(34) 0.0082(13)	8 558(4)	2 2306(2)	2 230	
4.049(5)	0.020(4) 0.021(2)	0.0062(13)	8.558(4)	2.2300(2)	2.230	
4.341(3)	0.021(3) 0.0046(13)	0.00043(80) 0.00142(40)	8.646(5)	2.2306(2)	2.230	
4.403(8)	0.0040(13)	0.00142(40) 0.002(7(55))	0.110(4)	2.2300(2)	2.230	
4.014(5)	0.0118(19)	0.00367(55)	9.119(4)	2.2306(2)	2.230	
4.646(6)	0.0151(21)	0.00467(62)	9.153(4)	2.2306(2)	2.230	
4.866(5)	0.0025(3)	0.000/9(10)	7.143(5)	0		
5.012(4)	0.031(3)	0.0097(8)	7.292(3)	0		
5.077(6)	0.0021(5)	0.00066(16)	9.584(6)	2.2306(2)	2.230	
5.196(4)	0.723(51)	0.224(12)	7.473(4)	0		
5.260(4)	0.152(18)	0.047(5)	7.537(4)	0		
5.388(4)	0.0742(84)	0.0234(24)	7.666(3)	0		
5.483(3)	0.0268(41)	0.0083(12)	7.760(3)	0		
5.799(3)	0.400(29)	0.124(7)	8.077(3)	0		
5.902(3)	0.297(21)	0.092(5)	8.183(3)	0		
6.038(9)	0.0092(14)	0.00284(40)	8.315(9)	0		
6.199(10)	0.0032(5)	0.00100(15)	8.491(5)	0		
6.291(10)	0.0445(52)	0.0138(15)	8.558(4)	0		
6.542(8)	0.0017(3)	0.00053(9)	8.819(8)	0		
6.589(10)	0.0009(3)	0.00027(8)	8.865(10)	0		
6.683(10)	0.0332(39)	0.0103(10)	8.969(5)	0		
6.835(10)	0.0055(8)	0.00170(23)	9.119(4)	0		
6.865(9)	0.0016(3)	0.00049(10)	9.142(9)	0		
6 925(9)	0.00012(3)	0.0032(4)	9 202(9)	0		
7 01-7 12	0.00012(3)	0.00023(9)	9.202(9)	0		
7 12-7 22	0.00073(10)	0.00023(3)		0		
7 22-7 32	0.00023(10)	0.00037(3)		0		
7 43 7 52	0.00103(14)	0.00032(4)		0		
7 52 7 62	0.00039(10)	0.00012(3)		0		
1.33-1.03	0.00032(10)	0.00010(3)		0		
1.03-1.13	0.00026(10)	0.00008(3)		0		
1.15-8.25	0.00019(10)	0.00006(3)		0		
8.25-9.28	0.00013(10)	0.00004(3)		0		

* All values taken from [2010Ad03], except where noted. ** From [2010Ad03]. Other: 38.7(10)% [1987Bo21]. *** Energy calculated from proton energies and  $S_p$  (³³Cl) = 2276.8(4) keV [2021Wa16]. For levels de-excited by more than one proton transition,  $E_{level}$ (emitter) is the weighted average. [@] Values from adopted levels in ENSDF [20110u01].

Table 15		
$\beta$ -p emission from ³⁷ Ca,	$T_{1/2} = 181.1(10) \text{ ms*},$	$BR_{\beta p} = 82.1(8)\%^{**}$

$E_{p}^{***}$	$I_p(rel)^{@@}$	$I_p(abs)^@$	<i>E_{emitter}</i> ( ³⁷ K)**	$E_{daughter}(^{36}\mathrm{Ar})^{@@@}$	coincident γ-rays ^{@@@@}	
0.418(5)	a@	a@	6.6040(47)	4.3291(7)	2.359, 1.970	
0.585(2)	b [@]	b [@]	4.4128(13)	1.9704(1)	2.359, 1.970	
0.893(2)	11(1)	5.2(5)	2.7501(8)	0		
1.223(2)	c [@]	c@	5.0506(13)	1.9704(1)	1.970	
1.293(2)	d [@]	d [@]	5.1202(16)	1.9704(1)	1.970	
1.382(2)	$\approx 0.4$	$\approx 0.2$	3.2394(18)	0		
1.438(4)	e [@]	e [@]	7.4733(33)	4.1783(1)	2.208, 1.970	
1.496(2)	$f^{@}$	$f^{@}$	5.3230(18)	1.9704(1)	1.970	
1.596(3)	0.124(28)	0.058(13)	5.423.7(30)	1.9704(1)	1.970	
1.765(3)	6.9(4)	3.2(2)	3.6222(25)	0		
1.796(3)	g [@]	g [@]	5.6234(24)	1.9704(1)	1.970	
1.983(3)	7.5(4)	3.5(2)	3.8402(31)	0		
2.187(3)	h [@]	h [@]	6.0142(28)	1.9704(1)	1.970	
2.264(3)	i [@]	i [@]	6.0915(28)	1.9704(1)	1.970	
2.334(9)	0.13(4)	0.06(2)	4.191(9)	0		
2.566(2)	2.4(1)-b [@]	1.10(5)-b [@]	4.4128(13)	0		
2.604(4)	j [@]	j [@]	6.4313(33)	1.9704(1)	1.970	
2.638(4)	3.0(2)	1.4(1)	4.4955(39)	0		
3.159(5)	2.1(21)	1.0(10)	5.0161(43)	0		
3.194(2)	100-c [@]	46.7-c [@]	5.0506(13)	0		
3.263(2)	18.2(9)-d [@]	8.5(4)-d [@]	5.1202(16)	0		
3.411(5)	k [@]	k [@]	7.2380(47)	1.970	1.970	
3.466(2)	1.20(9)-f [@]	0.56(4)-f [@]	5.3230(18)	0		
3.500(7)	0.11(2)	0.052(7)	5.3570(66)	0		
3.541(4)	1@	1 [@]	7.2380(47)	1.9704(1)	1.970	
3.589(5)	0.28(2)	0.13(1)	5.4459(47)	0		
3.608(5)	0.47(4)	0.22(2)	5.4648(46)	0		
3.646(4)	e' [@]	e' @	7.4733(33)	1.9704(1)	1.970	
3.712(5)	0.084(15)	0.039(7)	5.5693(45)	0		
3.766(3)	0.32(4)-g@	0.15(2)-g [@]	5.6234(24)	0		
3.804(5)	0.21(2)	0.10(1)	7.6315(47)	1.9704(1)	1.970	
3.931(5)	0.12(2)	0.054(8)	5.7882(49)	0		
3.978(4)	m [@]	m [@]	7.8053(37)	1.9704(1)	1.970	
4.007(5)	0.21(2)	0.1(1)	7.8343(46)	1.9704(1)	1.970	
4.075(5)	0.39(4)	0.18(2)	5.9316(46)	0		
4.157(3)	1.24(9)-h [@]	0.58(4)-h [@]	6.0142(28)	0		
4.234(3)	0.80(6)-i [@]	0.37(3)-i [@]	6.0915(28)	0		
4.466(5)	0.30(2)	0.14(1)	6.3228(48)	0		
4.557(5)	0.163(3)	0.076(12)	6.4144(48)	0		
4.574(4)	0.28(4)-j [@]	0.13(2)-j [@]	6.4313(33)	0		
4.747(5)	0.13(6)-a [@]	0.06(3)-a [@]	6.6040(47)	0		
4.826(5)	0.043(9)	0.020(4)	6.6827(47)	0		
4.882(5)	0.017(4)	0.008(2)	6.7389(47)	0		
4.966(5)	0.032(9)	0.015(4)	6.8229(47)	0		
5.116(5)	0.34(4)	0.16(2)	6.9729(47)	0		
5.216(5)	0.24(2)	0.11(1)	7.0727(47)	0		
5.325(4)	0.64(15)	0.30(7)	7.1823(35)	U		
5.381(5)	0.099(15)-k [®]	0.046(7)-k ^w	7.238(5)	U		
5.511(4)	0.45(4)-1	0.21(2)-1	7.3685(33)	0		
5.616(4)	0.75(9)-e-e'"	0.35(4)-e-e [*]	7.4733(33)	0		
5.685(5)	0.045(9)	0.021(4)	7.5423(47)	0		
5.803(5)	0.073(15)	0.034(7)	7.6598(49)	0		
5.948(4)	0.34(4)-m ^w	0.16(2)-m ^w	7.8053(37)	0		
0.170(5)	0.084(15)	0.039(7)	8.02/3(53)	0		

* [1997Tr05]. ** [1991Ga23]. ***  $E_p$  values deduced from ³⁷K level [1991Ga23] and S(p)=1857.0(14) [2021Wa16] for ³⁷K. [@] Sum of unresolved proton intensities from the emitting state. [1991Ga23] recorded multiple decays from the state with B(GT) values, but did not record individual proton branching ratios. [@] @ I_p values from [2012Ni01] based on B(GT) values [1991Ga23]. [@] @ @</sup> Values from adopted levels in ENSDF [2012Ni01].

Table 16	
B-p emission from ⁴¹ Ti*, $T_{1/2} = 81.9(5) \text{ ms}^{@}$ , $BR_{\beta p} = 92.4(6)\%^{@@}$ .	

$E_p$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( ⁴¹ Sc)**	$E_{daughter}(^{40}Ca)^{***}$	coincident γ-rays***
0.771(12)	3.3(25)	0.86(66)	5.762(12)	3.9044	3.904
1.011(2)	19.78(12)	5.15(3)	2.096(2)	0	
1.280(15)	3.92(73)	1.02(19)	6.270(15)	3.9044	
1.581(2)	18.28(19)	4.76(5)	2.666(2)	0	
1.627(10)	2.61(8)	0.68(2)	2.712(10)	0	
1.888(40)	2.99(12)	0.78(3)	6.893(28)	3.9044	3.904
2.026(10)	1.98(69)	0.52(18)	6.464(10)	3.3526(1)	3.353
2.131(25)	2.99(8)	0.78(2)	6.953(25)	3.7367(1)	3.737
2.328(3)	15.67(8)	4.08(2)	3.413(3)	0	
2.472(3)	8.96(8)	2.33(2)	3.559(3)	0	
2.604(13)	2.35(50)	0.61(13)	3.689(13)	0	
2.721(8)	4.10(12)	1.07(3)	3.806(8)	0	
2.873(8)	2.5(6)	0.66(16)	3.958(8)	0	
3.159(4)	62.7(3)	16.33(6)	4.244(4)	0	
3.232(19)	3.0(7)	0.78(18)	4.317(19)	0	
3.422(9)	2.61(8)	0.68(2)	4.507(9)	0	
3.570(9)	2.5(2)	0.65(6)	4.655(9)	0	
3.690(5)	5.9(6)	1.55(16)	4.775(5)	0	
3.750(8)	11.6(4)	3.01(10)	4.868(4)	0	
3.843(4)	28.4(3)	7.39(7)	4.928(5)	0	
3.928(8)	3.0(5)	0.78(14)	5.013(8)	0	
3.987(18)	2.7(5)	0.71(12)	5.072(18)	0	
4.294(4)	13.8(7)	3.59(17)	5.379(4)	0	
4.410(12)	1.49(8)	0.39(2)	5.495(12)	0	
4.495(6)	5.8(6)	1.5(2)	5.580(6)	0	
4.683(7)	2.4(4)	0.62(9)	5.768(7)	0	
4.754(4)	14.93(19)	3.89(5)	5.839(4)	0	
4.800(10)	4.48(12)	1.17(3)	5.885(10)	0	
4.853(3)	100.00(8)	26.05(2)	5.938(3)	0	
4.951(10)	7.84(19)	2.04(5)	6.036(10)	0	
4.999(17)	3.3(4)	0.86(9)	6.084(15)	0	
5.068(11)	3.2(4)	0.83(10)	6.153(11)	0	
5.288(14)	3.0(4)	0.79(10)	6.373(14)	0	
5.349(40)	2.4(5)	0.63(13)	6.434(40)	0	
5.498(60)	1.40(8)	0.36(2)	6.583(60)	0	
5.587(40)	2.2(5)	0.58(13)	6.672(40)	0	
5.743(14)	2.8(15)	0.73(38)	6.828(14)	0	
5.861(14)	1.0(4)	0.27(10)	6.946(14)	0	
6.096(20)	0.75(19)	0.19(5)	7.181(20)	0	
6.274(19)	0.56(19)	0.15(5)	7.359(19)	0	
6.530(38)	0.37(12)	0.10(3)	7.615(38)	0	
6.893(60)	0.28(10)	0.073(25)	7.978(60)	0	

* Values are from a weighted average of [1998Bh12, 1998Li46, 1997Ho12, 1974Se11, 2015Sh16], except where noted. ** Energy calculated from proton energies and  $S_p$  (⁴¹Sc) = 1084.93(7) keV [2021Wa16].

*** Values from adopted levels in ENSDF [2017Ch09].

[@] [2015Sh16]. [@] Weighted average of 91.6(6)% [2007Do17], 95.3(23)% [1998Bh12], and 100.3(22)% [1997Tr11].

#### Table 17

 $\beta$ -p emission from ⁴⁵Cr*, T_{1/2} = 60.9(4) ms,  $BR_{\beta p}$  = 34.4(8)%

$E_p$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( ⁴⁵ V)**	$E_{daughter}(^{44}\mathrm{Ti})^{***}$	coincident γ-rays***
0.945(31)	2 0(15)	0.4(3)			
1.303(25)	2.6(10)	0.5(2)			
1.468(27)	2.0(15)	0.4(2)			
1.609(28)	2.0(15)	0.4(2)			
2.087(9)	100	19.6(15)	4.796(9)	1.0831(1)	1.083

* All values taken from [2007Do17] except where noted. ** Energy calculated from proton energies and  $S_p$  (⁴⁵V) = 1626.8(11) keV [2021Wa16].

*** Values from adopted levels in ENSDF [2011Ch39].

Table 18
$\beta$ -p emission from ⁴⁹ Fe*, T _{1/2} = 64.7(3) ms, BR _{$\beta p$} = 56.7(4)%

$E_p$	$I_p(rel)$	<i>I_p</i> (abs)	$E_{emitter}$ ( ⁴⁹ Mn)	$E_{daughter}(^{48}\mathrm{Cr})^{**}$	coincident γ-rays**
1.120(39)	3.8(14)	1.3(5)	3.921	0.7522(1)	0.752
1.321(24)	0.6(3)	0.2(1)			
1.544(17)	4.3(7)	1.5(3)	4.380	0.7522(1)	0.752
1.975(13)	100	34.5(2)	4.809	0.7522(1)	0.752

* Values are taken from [2007Do17], energy and intensity values are from a weighted average of [2007Do17, 1996Fa09, 1970Ce02]: ** Values from adopted levels in ENSDF [2006Bu08].

 $\beta$ -p emission from ⁵³Ni*, T_{1/2} = 55.2(7) ms,  $BR_{\beta p} = 22.7(10)\%^{@@}$ 

$E_p$	$I_p(rel)$	$I_p(abs)$	<i>E_{emitter}</i> ( ⁵³ Co)***	$E_{daughter}(^{52}\mathrm{Fe})^{@}$	coincident γ-rays [@]
1.077(28)	15(4)	0.8(2)			
1.251(27)	15(4)	0.8(2)			
1.639(22)	33(4)	1.8(2)		0.0.05(4)	0.040
1.921(7)**	100	5.5(4)	4.395(7)	0.8495(1)	0.849
2.111(24)	44(6)	2.4(3)			
2.399(26)	59(9)	3.2(5)			

* Values are from [2007Do17], except where noted.

** [2016Su10].

*** Energy calculated from proton energies and  $S_p$  (⁵³Co) = 1616.3(17) keV [2021Wa16].

[@] Values from adopted levels in ENSDF [2015Ya15].

[@][@] Weighted average of 23.4(10)% [2007Do17] and 22.0(10)% [2016Su10].

# Table 20

 $\beta$ -p emission from ⁵⁷Zn*, T_{1/2} = 38(2) ms,  $BR_{\beta p} = 90(10)\%$ **.

$E_p$	$I_p(\text{rel})$	$I_p(abs)$	E _{emitter} ( ⁵⁷ Cu)***	$E_{daughter}(^{56}\mathrm{Ni})^{@}$	coincident γ-rays [@]	
1.168(15)	16(4)	3.5(12)	4.559(15)	2.7006(7)	2.701	
1.685(17)	4(2)	0.9(5)	2.375(17)	0		
1.836(15)	36(6)	8(2)	2.526(15)	0		
1.902(12)	100(10)	22(5)	5.293(12)	2.7006(7)	2.701	
2.531(16)	66(8)	14.5(36)	3.221(16)	0		
3.092(21)	25(5)	5.5(16)	3.782(21)	0		
3.514(24)	11(3)	2.4(8)	4.204(24)	0		
3.684(25)	6(2)	1.3(5)	4.374(25)	0		
3.871(26)	3(2)	0.7(5)	4.561(26)	0		
4.474(30)	7(3)	1.5(7)	5.164(30)	0		
4.595(29)	81(9)	18(4)	5.300(29)	0		

* Values are taken from [2002Jo09] except where noted.

** From [2007B109]. Other: >65% [1979Vi01].

*** Energy calculated from proton energies and  $S_p$  (⁵⁷Cu) = 690.3(4) keV [2021Wa16].

[@] Values from adopted levels in ENSDF [2011Hu08].

# Table 21

 $\beta$ -p emission from ⁶¹Ge*, T_{1/2} = 40.7(4) ms, BR_{$\beta p$} = 78(3)%**.

$E_p$	$I_p(abs)$	E _{emitter} ( ⁶¹ Ga)***	$E_{daughter}(^{60}\mathrm{Zn})$	coincident $\gamma$ -rays	
3.169(11)	62(4)	3.419(50)	0		

* All values taken from [2017GoZT], except where noted.

** Weighted ave of [2017GoZT] and [2007B109].

*** Energy calculated from proton energy and  $S_p$  (⁶¹Ga) = 250(40) keV [2021Wa21].

#### Table 22

$E_p$	$I_p(\text{rel})$	$I_p(abs)$	<i>E_{emitter}</i> ( ⁶⁵ As)***	$E_{daughter}(^{64}\text{Ge})^{@}$	coincident $\gamma$ -rays [@]
2.642(15)	40(5)	18(2)	3.448(57)	0.9017(3)	0.902
3.532(16) 3.77(3)**	100(5)	44(2)	3.448(57)	0	

<u> $\beta$ -p emission from ⁶⁵Se*, T_{1/2} = 34.2(2) ms,  $BR_{\beta p} = 94^{+6}_{-4}\%$ .</u>

* All values taken from [2017GoZT], except where noted.

** from [2011Ro47] only

*** Energy calculated from proton energies and  $S_p$  (⁶⁵As) = -90(80) keV [2021Wa16]. Value shown is the weighted average of the two transitions. ^(a) Values from adopted levels in ENSDF [2011Hu08].

#### Table 23

 $\beta$ -p emission from ⁶⁹Kr, T_{1/2} = 28(1) ms*, BR_{$\beta p$} = 100%.

$E_p$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( ⁶⁹ Br)	$E_{daughter}(^{68}\mathrm{Se})^{@}$	coincident γ-rays [@]	
0.641(42)*	3.6(9)	1.9(5)*	0*	0		
$\begin{array}{c} 0.751^{**+.132} \\ 2.939(22)^{*} \end{array}$	1.0(2) 100	0.5(1)** 52.5(65)*	0+x** 3.153(45)***	0 0.8538(2)	0.854	

^{* [2014}De41].

*** Energy calculated from proton energies and  $S_p$  (⁶⁹Br) = -640(40) keV [2021Wa16].

#### Table 24

 $\beta$ -p emission from ⁷³Sr*, T_{1/2} = 23.1(14) ms,  $BR_{\beta p} = 100\%$ **.

$E_p$	$I_p(rel)\%$	$I_p(absb)\%$	$E_{emitter}$ ( ⁷³ Rb)***	$E_{daughter}(^{72}\mathrm{Kr})$	coincident $\gamma$ -rays	
0.64(4)	5(3) [@]	2(1) [@]	0.0	0.0		
1.15(4)	10(5)@	4(2)@				
3.14(2)	61(6)	24(9)	3.21(5)	0.709	0.709	
3.85(2)	100	39(7)	3.21(5)	0		

* All values taken from [2019Si33], except where noted.

** Expected to be 100% as the daughter  73 Rb is unbound by 570(20) keV [2017Wa10].

*** Energy calculated from proton energies and  $S_p$  (⁷³Rb) = -640(40) keV [2021Wa16].

[@] Estimated from Fig 1 of [2020Ho17].

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^{** [2011}Ro47]

[@] Values from adopted levels in ENSDF [2012Mc02].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = -3/2 nuclei.

Last updated 5/25/25

Table	1
Table	1

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = -3/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon 3p}$	$Q_{\varepsilon \alpha}$	Experimental
				-		-	-		
$^{7}B$	$(3/2^{-})$	801(20) keV	11.908(25)	6.301(25)		1.868(32)	-19.51(21)	10.321(25)	[2011Ch32]
$^{11}N$	$1/2^{+}$	830(30) keV	13.716(5)	5.026(5)		-1.561(5)	-18.447(5)	6.172(5)	[ <b>2006Ca05</b> , 2000Ma62,
									1996Ax01]
¹⁵ F	$1/2^{+}$	660(20) keV	13.711(14)	6.414(14)		-1.136(14)	-18.669(14)	3.493(14)	[2010Mu12, 2006AcZY]
¹⁹ Na	$(5/2^+)$	<40 keV	11.177(11)	4.767(11)		-0.840(11)	-14.622(11)	7.648(11)	[2010Mu12, 2006AcZY]
²³ Al	$5/2^{+}$	446(6) ms*	12.2217(3)	4.6405(4)	1.22(5)%	-2.0981(3)	-15.1014(3)	2.5711(4)	[2011Sa15, 2011Ki26,
									2006Ia03, 2015Su15,
									2014Ka01, 2000Pe28,
									1995Ti08, 1972Go03,
									1971GoZH]
$^{27}P$	$(5/2)^+$	260(80) ms	11.725(9)	4.262(9)	$\approx 0.07\%$	-2.044(9)	-14.108(9)	2.390(9)	[1996Og01,1985Ay02,
									1983Ay02]
³¹ Cl	$3/2^{+}$	190(1) ms	12.008(3)	5.877(3)	2.4(2)%	0.282(3)	-11.705(3)	2.925(3)	[2022Bu14, 2011SaZM,
									2018Be12, 2016Sa60,
									2014Ka01, 2006Ka11,
									1996Og01, 1985Ay02,
									1983Ay02, 1982Ay01]
³⁵ K	$3/2^{+}$	175(2) ms	11.8744(9)	5.9782(5)	0.37(15)%	0.8349(5)	-8735(1)	5.445(1)	[2018Sa54, 1998Sc19, 1980Ew02]
³⁹ Sc	(7/2-)	<300ns	13.110(24)	7.339(24)#		2.197(24)	-6.521(40)	6.449(24)	[1994Bl10]
⁴³ V		79.3(24) ms	11.400(40)	6.920(40)	<2.5%***	2.640(40)	-6.251(40)	6.938(40)	[2007Do17]
⁴⁷ Mn	$(5/2^{-})$	88.0(13) ms	12.000(30)	7.220(30)	>1.7%	1.862(30)	-6.621(30)	4.321(31)	[1996Fa09]
⁵¹ Co		68.8(19) ms	12.850(50)	8.000(50)	<3.8%***	3.414(50)	-4.729(50)	4.798(50)	[2007Do17]
⁵⁵ Cu	3/2-	55.4(18) ms	13.70(16)	9.09(16)	?@	4.73(16)	-2.80(16)	6.12(16)	[2017GoZT, 2013Tr09,
									2007Do17]
⁵⁹ Ga		<43 ns	13.46(17)#	10.62(17)#		7.75(17)#	0.41(17)#	9.15(17)#	[2005St29]
⁶³ As	$(3/2^{-})$	< 43 ns	13.420(20)#	11.20(20)#		8.27(20)#	2.98(20)#	11.29(20)#	[2005St29]
⁶⁷ Br			14.05(31)#	12.21(30)#		9.37(30)#	4.44(30)#	11.97(30)#	
⁷¹ Rb			14.04(42)#	11.85(40)#		9.57(40)#	4.74(40)#	11.87(41)#	
⁷⁵ Y			14.80(37)#	12.81(30)#		10.15(30)#	5.38(30)#	12.09(33)#	
⁷⁹ Nb			15.12(58)#	13.23(58)#		11.58(50)#	6.96(50)#	12.55(55)#	
⁸³ Tc			15.02(64)#	13.20(58)#		11.62(51)#	7.96(50)#	13.03(58)#	

* [2006Ia03].

** [2011SaZM].

*** Not observed.

[@] Reported as 15.0(43)% in [2007Do17], but [2013Tr09] and [2017GoZT] report no observation of delayed protons despite having much higher statistics.

# Table 2

Particle emission from the odd-Z,  $T_z = -3/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$BR_{1p}$	$S_{2p}$	Qα	experimental	
$^{7}B$	-2.013(26)	100%	-1.420(60)	-3.42(200)#	[2011Ch32]	
¹¹ N	-1.378(5)	100%	2.629(5)	-5.736(26)	[2006Ca05,1996Ax01, 2000Ma62]	
¹⁵ F	-1.27(14)	100%	3.357(14)	-10.224(15)	[2010Mu12, 2006AcZY]	
¹⁹ Na	-0.323(11)	100%	3.600(11)	-6.062(18)	[2010Mu12, 2006AcZY]	
²³ Al	0.1409(4)		5.6450(3)	-8.606(11))		
$^{27}P$	0.807(9)		6.321(9)	-9.832(9)		
³¹ Cl	0.264(3)		4.660(3)	-8.800(10)		
³⁵ K	0.0836(5)		4.7475(6)	-6.563(3)		
³⁹ Sc	-0.597(24)		3.950(24)	-5.425(24)		
⁴³ V	0.100(40)		3.850(40)	-6.170(50)		
⁴⁷ Mn	0.380(30)		5.260(30)	-7.070(50)		
⁵¹ Co	0.150(50)		4.300(50)	-7.200(60)		
⁵⁵ Cu	-0.35(16)		3.55(16)	-6.72(16)		
⁵⁹ Ga	-1.25(18)#		1.03(17)#	-4.55(23)#		
⁶³ As	-1.35(24)#		0.94(20)#	-2.17(26)#		
⁶⁷ Br	-1.84(36)#		0.17(31)#	-1.45(36)#		-
⁷¹ Rb	-1.52(45)#		0.61(40)#	-2.19(50)#		
⁷⁵ Y	-1.72(32)#		0.39(30)#	-1.96(50)#		
⁷⁹ Nb	-1.91(64)#		-0.21(54)#	-2.26(58)#		
⁸³ Tc	-1.76(64)#		-0.46(64)#	-2.09(71)#		
				. /		

Table 3	
$\beta$ -p emission from ²³ Al*, T _{1/2} = 446(6) ms ^{@@} , BR _{Bp} = 1.2	2(5)%**.

$E_p$	$I_p(\text{rel})$	$I_p(abs)$	<i>E_{emitter}</i> ( ²³ Mg)***	$E_{daughter}(^{22}\mathrm{Na})$	coincident $\gamma$ -rays
0.206(11)	32(6)	0.14(3)	7.787(11)	0	
0.267(9)	42(8)	0.18(4)	7.848(9)	0	
0.337(14)	8(2)	0.03(1)	7.918(14)	0	
0.443(14)	4(2)	0.02(1)	8.025(14)	0	
0.579(8)	65(2)	0.28(1)	8.160(8)	0	
0.866(8)	100	0.41(1)	8.447(8)	0	
1.204(8)	0.04(1)	0.02(1)	8.785(8)	0	
1.338(9)	6(1)	0.02(1)	8.919(9)	0	
1.419(10)	4(1)	0.02(1)	9.000(10)	0	
1.520(5)*	0.7(2)	0.0032(6)	9.101(5)	0	
1.561(9)		0.03(1)	9.142(9)	0	
1.729(25)	4(1)	0.02(1)	9.310(25)	0	
1.843(9)	11(1)	0.05(1)	9.424(9)	0	
$1.887(5)^{@}$		$0.0084(6)^{@}$	9.468(5)	0	
2.023(5) [@]		$0.0025(3)^{@}$	9.604(5) [@]	0	
2.100(7) [@]		$0.0008(2)^{@}$	9.682(7) [@]	0	

* Values are taken from [2011Sa15], except where noted.

*** From [2011Sa15]. Others: 0.46(23)% [2000Pe28],  $\approx 1.1\%$  [1995Ti08]. *** Energy calculated from proton energies and S_p (²³Mg) = 7581.25(14) keV [2021Wa16].

@ [2011Ki26].
@ @ [2006Ia03].

#### Table 4

 $\beta$ -p emission from ²⁷P*, T_{1/2} = 260(80) ms[@], BR_{$\beta p$} =  $\approx 0.07\%$ .

$E_p$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( ²⁷ Si) **	$E_{daughter}$ ( ²⁶ Al)***	coincident γ-rays
0.484(3)	9(2)	$\approx 0.0063(14)$	8 176(3)	0 2283	$100\% \beta^+$
0.636(2)	97(3)	≈0.034(1)	8.327(2)	0.2283	$100\% \beta^+$
0.759(2)	100	≈0.035	8.451(2)	0.2283	$100\% \beta^+$
1.376(4)	7(2)	≈0.0025(7)	9.068(30)	0.2283	$100\% \beta^+$

* All values taken from [1996Og01] except where noted.

** Energy calculated from proton energies and  $S_p$  (²⁷Si) = 7463.34(13) keV [2021Wa16].

*** Values from adopted levels in ENSDF [2016Ba18].

@ [1985Ay02]

## Table 5

 $\beta$ -p emission from ³¹Cl*, T_{1/2} = 190(1) ms,  $BR_{\beta p} = 2.4(2)\%$ .

F	L (m-1)07	$\mathbf{I}$ $(-1, -)\vec{D}$		E (30D)		
$E_p$	$I_p(rel)\%$	$I_p(abs)\%$	$E_{emitter}$ (PCI)	$E_{daughter}(^{\circ\circ}P)$	coincident $\gamma$ -rays	
0.260 ***	$0.063^{+9}_{-0.7}$	$8.3^{+1.2}_{-0.9} \times 10^{-4}$	6.3902(7)	0		
0.806(2)	20.4(2)	0.367(6)	6.936(2)	0		
0.906(2)	12.4(2)	0.161(6)	7.037(2)	0		
1.026(2)	100(4)	1.31(2)	7.157(2)	0		
1.225(3)	2.7(1)	0.035(2)	7.355(3)	0		
1.390(17)	1.3(12)	0.017(16)	7.521(17)	0		
1.571(3)	21.0(4)	0.273(6)	7.702(3)	0		
1.647(17)	1.4(2)	0.019(25)	7.778(17)	0		
1.763(3)	6.4(2)	0.084(3)	7.894(3)	0		
1.891(3)	10.9(2)	0.143(3)	8.022(3)	0		
1.991(17)	1.4(1)	0.019(1)	8.122(17)	0		
2.139(17)	1.3(1)	0.017(1)	8.270(17)	0		
2.298(3)	2.3(1)	0.030(1)	8.429(3)	0		
2.362(17)	0.9(7)	0.011(1)	8.493(17)	0		
2.572(17)	0.91(6)	0.012(1)	8.703(17)	0		
2.729(17)	0.19(4)	0.002(1)	8.860(17)	0		
2.901(17)	0.3(1)	0.004(1)	9.031(17)	0		

* All values taken from [2011SaZM], except where noted. ** energy calculated from proton energies and  $S_p$  (³¹S) = 6130.65(24) keV [2021Wa16].

*** From [2022Bu14].

$E_p(\text{com})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(abs)$	<i>E_{emitter}</i> ( ³⁵ Ar)***	E _{daughter} ( ³⁴ Cl) [@]	coincident $\gamma$ -rays [@]
1.000/000	1 001 (00)		0.000/02			
1.320(20)	1.281(20)	16(3)%	0.020(9)%			
1.467(20)	1.425(20)	100(8)%	0.12(5)%	7.503(20)	0.1464	0.146
1.601(20)	1.555(20)	41(5)%	0.051(2)%	7.503(20)	0	
1.755(20)	1.705(20)	42(6)%	0.052(2)%			
1.930(20)	1.875(20)	24(4)%	0.030(1)%			
2.038(20)	1.980(20)	17(3)%	0.021(9)%	8.393(20)		
2.349(20)	2.282(20)	23(4)%	0.029(1)%	8.393(20)	0.1464	0.146
2.496(20)	2.425(20)	19(4)%	0.024(1)%	8.393(20)	0	
2.651(20)	2.575(20)	10(3)%	0.012(6)%			
2.890(20)	2.807(20)	5.7(18)%	$7.1(4) \times 10^{-3}\%$			

 $\beta$ -p emission from ³⁵K*, T_{1/2} = 175(2) ms**,  $BR_{\beta p} = 0.37(15)\%$ .

*All values taken from [1980Ew02] except where noted.

** [2018Sa54].

Table 6

*** Listed energy calculated from proton energies and  $S_p$  (³⁵Ar) = 5896.2(7) keV [2021Wa16]. For levels de-excited by more than one proton transition,  $E_{level}$  (emitter) is the weighted average.

[@] Values from adopted levels in ENSDF [2012Ni10].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = -1 nuclei.

Last updated 6/27/22

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = -1$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	Experimental
$^{30}S$		$0^+$	1.178(5) s	6.1416(2)	0.5471(4)		-11.7866(2)	[1980Wi13]
³⁴ Ar		$0^{+}$	846.46(35) ms	6.06179(6)	0.9186(1)		-8.6514(1)	[2020Ia01]
³⁸ Ca		$0^+$	443.63(35) ms	6.74226(6)	1.6002(3)		-7.1145(2)	[2015Bl02]
⁴² Ti		$0^+$	211.7(19) ms	7.01648(22)	2.7446(2)		-6.1469(3)	[2015Mo01]
⁴⁶ Cr		$0^+$	224.3(13) ms	7.604(11)	2.250(11)		-6.234(11)	[2015Mo01]
⁵⁰ Fe		$0^+$	152.1(6) ms	8.151(8)	3.567(9)		-4.576(5)	[2017Ku12, 2017RuZX]
⁵⁴ Ni		$0^+$	114.2(3) ms	8.732(5)	4.380(5)		-3.145(5)	[2012MoZW]
^{54m} Ni	6.4574(9)	$10^{+}$	155(3) ns	15.189(5)	10.837(5)		3.312(5)	[2021Gi18, 2008Ru09]
⁵⁸ Zn		$0^+$	86(2) ms*	9.370(50)	6.500(50)	0.7(1)%**	-0.838(50)	[2020Ci04, 2017Ku12, 2012OrZY,
								2009Fu15, 2005Ka46, 2002Lo13,
								1998Jo18]
⁶² Ge		$0^+$	82.9(14) ms	10.25(14)#	6.92(14)#		1.63(14)#	[2014Gr10]
⁶⁶ Se		$0^+$	42(12) ms	10.37(20)#	7.53(20)#		2.60(20)#	[2002B117]
⁷⁰ Kr		$0^{+}$	40(6) ms	10.33(20)#	8.05(20)#	<1.3%	3.22(20)#	[2014Ro14]
⁷⁴ Sr		$0^+$	27(8) ms	11.09(10)#	8.44(10)#		3.65(10)#	[2014He29]
⁷⁸ Zr		$0^+$	>170 ns	11.32(50)#	9.67(40)#		5.05(40)#	[2001Ki13]
⁸² Mo		$0^+$	>400 ns	11.44(50)#	9.80(41)#		6.20(40)#	[2017Su26]
⁸⁶ Ru		$0^+$	>400 ns	11.80(50)#	10.45(40)#		6.85(40)#	[2017Su26]
⁹⁰ Pd		$0^{+}$	>760 ns	11.92(45)#	11.26(50)#		7.38(40)#	[2016Ce02]
⁹⁴ Cd		$0^+$	>760 ns	11.96(64)#	11.57(58)#		7.98(50)#	[2016Ce02]
⁹⁸ Sn		$0^{+}$		11.55 ^c	10.66 [@]		$7.40^{b}$	

* [2017Ku12] ** [2020Ci04] [@] Predictions taken from [1995Mo29].

#### Table 2

Particle emission from the even-Z,  $T_z = -1$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$BR_p$	$S_{2p}$	Qα	$Q_{\varepsilon \alpha}$	$BR_{\beta \alpha}$	Experimental
30 g	1 205 1 (1)		7.1.4.40(21)	0.04017(00)	1 27 12(2)		
50S	4.3954(4)		7.14440(21)	-9.34317(23)	-4.2/42(2)		
⁵⁴ Ar	4.6639(4)		6.94070(8)	-6.74395(22)	-0.6024(1)		
³⁸ Ca	4.54727(22)		6.4049(2)	-6.10513(21)	-0.0434(2)		
⁴² Ti	3.75096(27)		4.83589(27)	-5.4708(3)	1.2714(4)		
⁴⁶ Cr	4.874(11)		6.501(11)	-6.792(11)	0.224(11)		
⁵⁰ Fe	4.146(9)		6.233(11)	-7.430(14)	0.175(8)		
⁵⁴ Ni	3.908(5)		5.524(5)	-7.227(10)	0.924(5)		
^{54m} Ni**	-2.549(5)	49.5(21)%	-0.933(5)	-0.779(10)	7.381(5)		[2021Gi18, 2008Ru09]
⁵⁸ Zn	2.280(50)		2.970(50)	-5.450(50)	3.285(50)		
⁶² Ge	2.29(15)#		2.54(14)#	-2.27(15)#	7.10(14)#		
⁶⁶ Se	2.01(22)#		1.92(20)#	-1.95(24)#	7.90(20)#		
⁷⁰ Kr	2.13(21)#		1.49(20)#	-1.87(28)#	8.50(20)#		
⁷⁴ Sr	2.11(11)#		1.47(10)#	-2.15(22)#	8.17(10)#		
⁷⁸ Zr	1.70(45)#		1.18(40)#	-2.45(41)#	8.64(40)#		
⁸² Mo	1.30(57)#		0.19(50)#	-1.95(57)#	9.38(50)#		
⁸⁶ Ru	1.21(57)#		0.18(50)#	-1.83(57)#	9.62(50)#		
⁹⁰ Pd	1.35(54)#		-0.50(500)#	-2.36(57)#	9.44(50)#		
⁹⁴ Cd	1.33(64)#		0.24(61)#	-3.16(64)#	8.77(54)#		
⁹⁸ Sn	1.65*		1.31*	-4.57*	7.02*		

* Predictions taken from [1995Mo29].

** Excitation energy = 6.4574(9) MeV [2008Ru09].

#### **Table 3** Direct proton emission from ^{54m}Ni*, Ex. = 6.4574(9) MeV, $T_{1/2} = 155(3)$ ns, BR_p = 49.5(21) %.

$E_p(\text{lab})$	$E_p(c.m.)$	$I_p(rel)$	$I_p(abs)$	$E_{daughter}(^{53}\mathrm{Co})$	coincident γ-rays
1.1979(44)	1.2205(45)	100(5) %	28.4(13) %	1.3270(9)	1.327
2.5002(43)	2.5477(44)***	74(7) %	21.1(16) %	0.0	

* All values taken from [2021Gi18].

** [2008Ru09].

*** [2021Gi18] uses the masses of ⁵³Co and ^{53m}Co From [2010Ka26] to get this value.

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = -1 nuclei.

Last updated 3/17/23

Tabla	1
Table	T

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = -1$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{arepsilon 2p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta \alpha}$	Experimental
4 <b>1</b> ;		2-		22.00(21)	2 (19(21)					
⁸ B		$\frac{2}{2^{+}}$	768(3) ms	17.980(1)	0.7255(10)		-9.248(1)	6.106(1)	100%	[ <b>1988Ai01</b> , 1971Wi05,
5		-	/00(0) 110	1,1,500(1)	011200(10)		) <u>12</u> (0(1)	01100(1)	10070	1964Ma35]
$^{12}N$		$1^{+}$	11.000(16) ms	17.3881(10)	1.3814(10)		-9.847(1)	9.971(1)	4.12(22)%	[2020Bi15, 2020Bi11,
										2009Hy01,2009Hy02,
										2010Hy01]
¹⁰ F		0-	40 (20) keV	15.412(5)	3.285(5)		-6.923(5)	8.250(5)	20.05/20.07	[ <b>1993Ti07</b> , 2014Wu03]
²⁰ Na		2+	447.9(40) ms	13.8924(11)	1.0490(11)		-6.9447(11)	9.1625(11)	20.05(22)%	[2021Wa06, 2013La22,
										1989Cl02, 19721008, 1072Ma08, 1071Ca18
										197201008, 1971G018, 1989Ra171
²⁴ Al		$4^+$	2.053(4) s	13.8848(2)	2,19207(23)	0.0012(3)%	-6.6021(2)	4.5681(2)	0.035(6)%	[ <b>1994Ba54</b> , 2011Ma88]
										1979Ho08
$^{24m}Al$	0.4258(1)	$1^+$	130.9(13) ms	14.3106(2)	2.6179(3)		-6.1763(2)	4.9939(2)	0.028(6)%	[1994Ba54, 1979Ho08,
										2011Ma88, 1979Ho08]
²⁸ P		3+	270.3(5) ms	14.3449(11)	2.7600(11)	0.0013(4)%	-5.5114(11)	4.3607(11)	0.00086(25)%	[1996Og01, 1968Ar03,
22										1979Ho27]
⁵² Cl		$1^{+}$	298(1) ms	12.6808(6)	3.8169(6)	0.026(5)%	-3.4797(6)	5.7331(6)	0.054(8)%	[ <b>1979Ho27</b> , 2008Bh08,
										2018Ab06, 2012Me03,
36 <b>v</b>		$2^+$	342(2) ms	12 8144(3)	4 3074(3)	0.048(0)%	2 0635(3)	6 1733(3)	0.0034(7)%	1965DJU1J [1006H02 1080E=01
К		2	342(2) IIIS	12.0144(3)	4.3074(3)	0.040())//	-2.0055(5)	0.1755(5)	0.0034(7)70	1997II03 1980Ew011
⁴⁰ Sc		4-	182.7(8) ms	14.3230(28)	5,9949(28)	0.44(7)%	-0.3866(28)	7.2831(28)	0.017(5)%	[ <b>1982Ho09</b> , 1968Ar03,
										1969Ve04, 1974Se11]
$^{44}V$		$(2)^+$	111(7) ms	13.4741(7)	5.091(7)		0.161(7)	8.613(7)	obs	[1977Ha04, 1971Ce02]
⁴⁸ Mn		$4^{+}$	158.1(22) ms	13.525(10)	5.421(7)	0.280(37)%	0.253(7)	5.827(7)		[1991Sz03, 1987Se07]
⁵² Co		(6 ⁺ )	111(4) ms	13.988(5)	6.610(5)		1.339(5)	6.052(9)		[2017Ku12]
⁵⁶ Cu		$(4^{+})$	80(2) ms	15.278(6)	8.111(6)#	0.40(12)%	3.047(6)	7.277(6)		[2001Bo54, 2017Ku12]
⁶⁰ Ga		$(2^+)$	69.4(2) ms	14.58(20)#	9.48(20)#	1.6(7)%	6.06(20)#	11.89(20)#		[ <b>2021Or01</b> , 2017Ku12,
64			(0.0/1.4)	14.79(20)#	0.72(20)#		7.0((20))	12 22(20) //		2001Ma96]
68 D.#			69.0(14)  ms	14./8(20)#	9.73(20)#		7.06(20)#	12.22(20)#		[2020G102] [2010W:09 1005D104
DI			55(5) lis	13.40(20)#	10.31(20)#		8.24(20)#	15.10(20)#		[ <b>2019 W108</b> , 1993 <b>D</b> 100, 1997 <b>A</b> 1041
⁷² Rb		$(5^+)$	103(22) ns	15 61(50)#	10.88(50)#		9.02(50)#	13 43(50)#		[2019Si33, 2017Su31]
⁷⁶ Y		(5)	$24^{+12}$ ms	16.00(30)#	11.68(30)#		9.50(30)#	13.27(30)#		[2019Si33]
⁸⁰ Nb			6	16.34(50)#	12.09(41)#		10.18(40)#	13.41(40)#		[
⁸⁴ Tc				16.47(50)#	12.62(43)#		11.34(40)#	14.37(50)#		
⁸⁸ Rh				17.48(50)#	13.54(40)#		12.67(40)#	14.89(50)#		
⁹² Ag			**	17.25(53)#	13.75(50)#		12.78(40)#	14.39(50)#		[2016Ce02]
⁹⁶ In			**	17.48(65)#	14.53(64)#		13.43(50)#	14.27(61)#		[2016Ce02]

* Calculated from the sum of the  $\beta$  feeding to states [2020Bi15] above the alpha separation energy ** Observed at RIKEN with BigRIPS and ZDS that have a time of flight 760 ns [2016Ce02].

Particle emission from the odd-Z,  $T_z = -1$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	S _n	$BR_{1n}$	$S_{2n}$	Ο _α	Experimental
	P	• <i>P</i>	- <i>p</i>	<b>C</b> ⁴⁴	1 I
⁴ Li	-3.10(21)	100%	-6.80(200)#		[1996Ed02, 1990Br14, 1973Fr04]
${}^{8}B$	0.1364(10)		5.7433(10)	-4.83(21)	
¹² N	0.6003(10)		9.2905(10)	-8.0084(14)	
¹⁶ F	-0.531(5)	100%	6.766(5)	-9.088(5)	[ <b>2014Wu03</b> , 1993Ti07]
²⁰ Na	2.1905(11)		8.6006(12)	-6.250(5)	
²⁴ Al	1.86411(23)		9.44536(26)	-9.3242(11)	
$^{24m}Al^{@}$	2.2899(3)		9.8712(3)	-9.7500(11)	
$^{28}P$	2.0523(12)		9.5157(11)	-9.52240(12)	
³² Cl	1.5811(5)		7.7118(6)	-8.6118(13)	
³⁶ K	1.6589(8)		7.5550(3)	-6.5074(6)	
40 Sc	0.5296(29)		6.3005(28)	-5.5311(28)	
$^{44}V$	1.781(9)		6.265(7)	-5.710(8)	
⁴⁸ Mn	2.023(6)		6.799(7)	-7.913(10)	
⁵² Co	1.444(5)		6.295(5)	-7.472(9)	
⁵⁶ Cu	0.583(6)		5.198(6)	-6.711(8)	
⁶⁰ Ga	-0.34(20)#		2.50(20)#	-3.39(20)#	
⁶⁴ As	-0.10(20)#		2.12(20)#	-2.37(29)#	
⁶⁸ Br	-0.50(25)#	100%**	1.34(26)#	-1.68(33)#	[2019Wi08, 1995Bl06, 1997Au04]
⁷² Rb	-0.71(52)#	100%**	1.48(50)#	-1.96(56)#	[2019Si33, 2017Su31]
⁷⁶ Y	-1.08(37)#		0.91(30)#	-2.35(58)#	
⁸⁰ Nb	-1.06(50)#		70.83(50)#	-2.60(50)#	
⁸⁴ Tc	-1.35(57)#		0.47(50)#	-1.71(57)#	
⁸⁸ Rh	-1.58(57)#		-0.13(50)#	-1.59(57)#	
⁹² Ag	-1.35(58)#	100%**	0.47(45)#	-3.10(57)#	[2016Ce02]
⁹⁶ In	-1.68(76)#	100%**	0.27(64)#	-2.99(64)#	[2016Ce02]

[@] Excitation energy = 0.4258(1) MeV.

** Inferred by half-life

# Table 3

 $\beta$ - $\alpha$  emission from ²⁰Na*, T_{1/2} = 447.9(40) ms[@], BR_{$\beta\alpha$} =20.05(22) %.

$E_{\alpha}$ (c.m.)	$I_{\alpha}(\text{rel})\%$	$I_{\alpha}(abs)\%$	$E_{emitter}$ ( ²⁰ Ne)	$E_{daughter}(^{16}\text{O})^{***}$	coincident $\gamma$ -rays
0.8915(17)	0.039(6)	0.0063(9)	5.6214(17)	0	
1.5073(35)	0.0099(44)	0.0016(7)	12.367(35)	6.12989(4)	6.130
1.0579(26)	0.0099(31)	0.0016(5)	5.7877(26)	0	
1.9902(5)	0.0149(44)	0.0024(7)	6.720(5)	0	
2.6937(18)	100(4)	16.1(6)	7.4235(18)	0	
3.1020(23)	4.3(3)	0.69(3)	7.8318(23)	0	
3.324(7)**	0.074(6)	0.015(1)**	8.054(7)**	0	
4.0402(50)	0.21(5)	0.034(8)	8.770(50)	0	
4.7587(22)	1.91(13)	0.307(18)	9.4885(22)	0	
5.5469(2)	17.4(10)	2.80(12)	10.2767(20)	0	
5.8522(3)	0.53(3)	0.085(4)	10.582(3)	0	
6.1117(22)	1.21(7)	0.195(8)	11.300(10)	0	
6.383(7)**	0.055(7)	0.011(2)**	11.116(9)**	0	
6.561(4)**	0.165(11)	0.033(2)**	11.291(4)**	0	
6.5702(10)	0.217(15)	0.035(2)	11.870(50)	0	
7.1402(50)	0.014(1)	0.0023(1)	12.367(35)	0	

* All values taken from [2021Wa06], except where noted.

** [1989Cl02].

*** Values from adopted levels in ENSDF [1998Ti06].

[@] Weighted average of 442(5) ms [1971Go18], 446(8) ms [1972Mo08], 448(4) ms [1972To08], and 452(4) ms [1989Cl02].

$E_p$	$I_p(rel)$	$I_p(abs)(\times 10^{-4})$	E _{emitter} ( ²⁸ Si)**	$E_{daughter}(^{27}\text{Al})$	coincident $\gamma$ -rays	
0.486(1)	6(1)	0.4(14)	12.071(1)	0		
0.480(1) 0.704(1)	100	6.8(21)	12.289(1)	0		
0.859(1)	6(1)	0.41(14)	12.444(1)	0		
0.988(1)	56(4)	3.8(12)	12.573(1)	0		
1.129(1)	4(1)	0.27(11)	12.714(1)	0		
1.314(1)	18(2)	1.2(4)	12.899(1)	0		
1.506(4)	2(1)	0.14(8)	13.091(4)	0		

 $\beta$ -p emission from ²⁸P*, T_{1/2} = 270.3(5) ms***,  $BR_{\beta p} = 0.0013(4)\%$ .

*All values taken from [1996Og01], except where noted. ** Calculated from proton energies and  $S_{\alpha}$  (²⁸Si) = 11584.90(5) keV [2021Wa16].

*** [1968Ar03]

## Table 5

 $\beta$ - $\alpha$  emission from ²⁸P*,  $BR_{\beta\alpha} = 0.00086(25)\%$ .

Eα	$I_{\alpha}(rel)$	$I_{\alpha}(abs)(\times 10^{-5})$	E _{emitter} ( ²⁸ Si)**	$E_{daughter}(^{24}Mg)$	coincident $\gamma$ -rays	
1.528(1)	25(3)	8(2)	11.512(1)	0		
1.671(1)	79(6)	24(7)	11.65(1)7	0		
1.945(1)	<3	<0.9	11.929(1)	0		
2.085(1)	15(4)	4(2)	12.069(1)	0		
2.303(1)	14(5)	5(2)	12.287(1)	0		
2.457(1)	100	31(9)	12.441(1)	0		
2.563(1)	23(6)	7(3)	12.547(1)	0		
2.738(1)	6(2)	1.8(8)	12.722(1)	0		
2.912(1)	13(3)	4.0(15)	12.896(1)	0		
3.107(1)	3(1)	0.9(4)	13.091(1)	0		

*All values taken from [1996Og01], except where noted. ** Calculated from  $\alpha$  energies and  $S_{\alpha}$  (²⁸Si) = 9984.14(1) keV [2021Wa16].

# Table 6

 $\beta$ -p emission from ³²Cl*, T_{1/2} = 298(1) ms,  $BR_{\beta p} = 0.026(5)\%$ .

$E_p$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( ³² S)	$E_{daughter}(^{31}\mathrm{P})$	coincident γ-rays	
0 787(5)	47(10)	0.0052(8)	9 651(5)	0		
1.023(5)	100	0.0113(17)	9.887(5)	0		
1.085(5)	17(4)	0.0019(4)	9.949(5)	0		
1.367(5)	47(10)	0.0052(8)	10.231(5)	0		
1.426(5)	7(2)	0.00078(2)	10.290(5)	0		
1.916(5)	14(3)	0.0016(3)	10.780(5)	0		

*All values taken from [1979Ho27], except where noted. ** Calculated from proton energies and  $S_p$  (³²S) = 8863.96 keV [2021Wa16].

# Table 7 $\beta$ - $\alpha$ emission from ³²Cl*, T_{1/2} =*BR*_{$\beta \alpha$} = 0.054(8)%.

Eα	$I_{\alpha}(rel)$	$I_{\alpha}(abs)$	$E_{emitter}$ ( ³² S)	$E_{daughter}(^{28}\mathrm{Si})$	coincident γ-rays	
1.744(5)	3.7(8)	0.0011(2)	8.692(5)	0		
1.912(5)	49(9)	0.0146(20)	8.860(5)	0		
2.283(5)	0.7(3)	0.0002(1)	9.231(5)	0		
2.515(5)	100	0.0300(42)	9.463(5)	0		
2.762(5)	13(3)	0.0040(7)	9.710(5)	0		
3.035(5)	2.3(5)	0.00069(20)	9.983(5)	0		
3.345(5)	5.7(13)	0.0017(3)	10.293(5)	0		
3.511(5)	0.8(3)	0.00024(10)	10.459(5)	0		
3.583(5)	2.8(8)	0.00084(20)	10.531(5)	0		
3.845(5)	1.7(4)	0.00051(10)	10.792(5)	0		
4.115(5)	0.2(1)	0.00006(3)	11.063(5)	0		

*All values taken from [1979Ho27], except where noted. ** Calculated from  $\alpha$  energies and  $S_{\alpha}$  (³²S) = 6947.66 keV [2021Wa16].

# Table 8

<u> $\beta$ </u>-p emission from ³⁶K*, T_{1/2} = 342(2) ms**,  $BR_{\beta p} = 0.048(14)\%$ **.

$E_p$	$I_p(rel)$	$I_p(abs) (X \ 10^{-4})$	$E_{emitter}$ ( ³⁶ Ar)**	$E_{daughter}(^{35}\text{Cl})$	coincident γ-rays
0.5161(11)	0.33(9)	0.011(3)	9.023(1)	0	
0.6405(14)	0.45(12)	0.015(4)	9.1475(14)	0	
0.7133(8)	23.(6)	0.76(20)	9.2203(8)	0	
0.876(1)	6.7(18)	0.22(6)	9.383(1)	0	
0.9973(12)	100(27)	3.3(9)	9.5043(12)	0	
1.2019(14)	0.18(6)	0.006(2)	9.7089(14)	0	
1.2327(11)	0.73(18)	0.024(6)	9.7397(11)	0	
1.308(2)	0.45(12)	0.015(4)	9.815(2)	0	
1.3723(7)	13(3)	0.43(11)	9.8793(7)	0	
1.4496(22)	0.30(9)	0.010(3)	9.9566(22)	0	
1.928(10)	0.33(15)	0.011(5)	10.435(10)	0	
2.049(10)	1.45(58)	0.048(19)	10.556(10)	0	
2.107(10)	1.42(55)	0.047(18)	10.614(10)	0	
2.528(10)	0.88(36)	0.029(12)	11.035(10)	0	
2.715(10)	0.61(27)	0.020(9)	11.222(10)	0	

*All values taken from [1996Il02], except where noted.

** [1980Es01]

*** Calculated from proton energies and  $S_p$  (³⁶Ar) = 8506.98(4) keV [2021Wa16].

# Table 9

 $\beta$ - $\alpha$  emission from ³⁶K*,  $BR_{\beta \alpha} = 0.031(6)\%$ **.

Eα	$I_{\alpha}(rel)$	$I_{\alpha}(abs) (X \ 10^{-6})$	<i>E_{emitter}</i> ( ³⁶ Ar)***	$E_{daughter}(^{32}\mathrm{S})$	coincident γ-rays
1 712(2)	2 2(7)	0.5(1)	0.252(2)	0	
1.712(3)	3.3(7)	0.5(1)	8.333(3)	0	
1.757(3)	1.6(5)	0.24(8)	8.398(3)	0	
2.208(3)	4.0(13)	0.6(2)	8.849(3)	0	
2.268(3)	100(27)	15(4)	8.909(3)	0	
2.508(3)	10(3)	1.5(4)	9.149(3)	0	
2.721(3)	0.73(20)	0.11(3)	9.362(3)	0	
2.827(3)	0.53(20)	0.08(3)	9.468(3)	0	
3.068(3)	67(20)	10(3)	9.709(3)	0	
3.355(3)	0.53(13)	0.08(2)	9.996(3)	0	
3.566(3)	0.73(27)	0.11(4)	10.207(3)	0	
3.688(3)	2.7(7)	0.4(1)	10.329(3)	0	
3.808(3)	1.7(5)	0.26(7)	10.449(3)	0	
3.923(3)	7.3(20)	1.1(3)	10.564(3)	0	
3.958(3)	4.0(13)	0.6(2)	10.599(3)	0	
4.065(4)	0.27(13)	0.04(2)	10.706(4)	0	
4.217(3)	1.1(3)	0.17(5)	10.858(3)	0	
4.330(4)	0.23(10)	0.034(15)	10.971(4)	0	
4.417(3)	1.9(5)	0.28(8)	11.058(3)	0	
4.597(4)	0.40(13)	0.059(20)	11.238(4)	0	

*All values taken from [1996Il02], except where noted.

** [1980Es01] *** Calculated from  $\alpha$  energies and S_{$\alpha$} (³⁶Ar) = 6640.92(3) keV [2017Wa10].

# Table 10

 $\beta$ -p Emission from ⁴⁰Sc*, T_{1/2} =182.7(8) ms**,  $BR_{\beta p} = 0.44(7)\%$ .

$E_p$	$I_p(rel)$	$I_p(abs) (X \ 10^{-4})$	$E_{emitter}$ ( ⁴⁰ Ca)	$E_{daughter}(^{39}\mathrm{K})^{***}$	coincident $\gamma$ -rays
1.032(3)	65(14)	7 2(11)	9 360(3)	0	
1.087(8)	40(9)	4 40(75)	9 415(8)	õ	
1.098(6)	50(12)	5.50(95)	9 427(6)	0	
1.123(3)	100.00	11.0(17)	9.451(3)	0	
1.273(3)	29(6)	3.2(5)	9.601(3)	0	
$\frac{1.278(8)}{1.482(4)}$	8(2)	0.88(15)	9.810(4)	0	
1.501(8)	2.4(7)	0.26(7)	9.829(8)	0	
1.592(3)	4.5(11)	0.50(9)	9.920(3)	0	
1.650(5)	0.8(5)	0.092(5)	9.978(5)	0	
1.721(4)	3.8(10)	0.42(9)	10.049(4)	0	
1.797(4)	1.2(4)	0.13(4)	10.125(4)	0	
1.882(4)	12.6(28)	1.39(22)	10.210(4)	0	
2.003(4)	0.42(19)	0.046(2)	10.331(4)	0	
2.037(8)	0.27(19)	0.03(2)	10.365(8)	0	
2.118(4)	2.(6)	0.28(5)	10.446(4)	0	
2.143(4)	8.5(18)	0.94(14)	10.471(4)	0	
2.175(4)	11.4(25)	1.25(19)	10.504(4)	0	
2.253(5)	1.5(4)	0.17(4)	10.582(5)	0	
2.268(10)	0.32(19)	0.035(20)	10.596(10)	0	
2.364(5)	0.7(3)	0.076(30)	10.692(5)	0	
2.426(8)	0.8(3)	0.092(30)	10.754(8)	0	
2.447(5)	11.6(26)	1.28(20)	10.775(5)	0	
2.485(9)	0.74(30)	0.081(3)	10.813(9)	0	
2.520(5)	3.5(6)	0.38(2)	10.8548(5)	0	
2.581(5)	0.32(19)	0.035(20)	10.909(5)	0	
2.628(8)	1.82(46)	0.20(4)	10.956(8)	0	
2.644(7)	1.82(46)	0.20(4)	10.972(7)	0	
2.709(7)	0.63(21)	0.069(20)	11.037(7)	0	
2.786(6)	1.00(31)	0.11(3)	11.114(6)	0	
2.813(6)	2.09(49)	0.23(4)	11.142(6)	0	
2.888(5)	6.2(14)	0.68(11)	11.216(5)	0	
2.987(5)	0.46(20)	0.051(20)	11.315(5)	0	
3.089(7)	0.25(19)	0.028(20)	11.417(7)	0	
3.123(9)	0.75(22)	0.083(20)	11.451(9)	0	
3.287(10)	0.22(10)	0.024(10)	11.615(10)	0	
3.393(10)	0.66(29)	0.073(30)	11.721(10)	0	
3.463(10)	0.24(19)	0.026(20)	11.791(10)	0	
3.676(10)	0.09(9)	0.01(1)	12.004(10)	0	
3.706(10)	0.22(10)	0.024(10)	12.034(10)	0	
3.743(10)	0.11(9)	0.012(10)	12.071(10)	0	

*All values taken from [1982Ho09], except where noted.

** [1968Ar03] *** Calculated from proton energies and  $S_p$  (⁴⁰Ca) = 8328.18(2) keV [2021Wa16].

Eα	$I_{\alpha}(rel)$	$I_{\alpha}(abs)$	$E_{emitter}$ ( ⁴⁰ Ca)**	$E_{daughter}(^{36}\mathrm{Ar})$	coincident $\gamma$ -rays	
2.321(6)	14.9(5)	8.8(2)	9.361(6)	0		
2.911(8)	2.7(2)	1.6(1)	9.951(8)	0		
3.089(8)	3.2(2)	1.9(1)	10.129(8)	0		
3.113(8)	5.4(2)	3.2(1)	10.153(8)	0		
3.152(8)	3.6(2)	2.1(1)	10.192(8)	0		
3.424(7)	13.2(4)	7.8(2)	10.464(7)	0		
3.480(7)	14.1(4)	8.3(2)	10.520(7)	0		
3.559(7)	11.7(4)	6.9(2)	10.599(7)	0		
3.684(5)	100.0	59(12)	10.724(5)	0		
3.779(7)	7.1(4)	4.2(2)	10.819(7)	0		
3.947(12)	1.9(2)	1.1(1)	10.986(12)	0		
4.048(12)	1.7(2)	1.0(1)	11.088(12)	0		
4.164(5)	64.4(19)	38(8)	11.204(5)	0		
4.266(7)	4.1(2)	2.4(1)	11.305(7)	0		
4.431(7)	6.1(2)	3.6(1)	11.471(7)	0		
4.509(6)	11.2(4)	6.6(2)	11.549(6)	0		
4.622(7)	3.9(2)	2.3(1)	11.662(7)	0		
4.687(7)	1.5(2)	0.9(1)	11.726(7)	0		
4.800(6)	4.7(2)	2.8(1)	11.840(6)	0		
4.958(7)	8.5(4)	5.0(2)	11.998(7)	0		
5.021(9)	2.7(2)	1.6(1)	12.061(9)	0		

**Table 11**  $\beta$ - $\alpha$  emission from ⁴⁰Sc*,  $BR_{\beta-\alpha} = 0.017(5)\%$ .

* All values taken from [1982Ho09], except where noted.

** Calculated from  $\alpha$  energies and  $S_{\alpha}$  (⁴⁰Ca) = 7039.78(3) keV [2021Wa16].

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = -1/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{$\pi$} values for ³⁹Ca, ⁴³Ti, ⁴⁷Cr, ⁵¹CFe, and ⁵⁵Ni are taken from ENSDF.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
³⁹ Ca	$3/2^{+}$	859.4(16) ms	6.5245(6)	0.1431(6)		-10.099(1)	-0.694(1)	[1977Az01]
⁴³ Ti	$7/2^{-}$	509(5) ms	6.8673(6)	1.943(6)		-8.3345(7)	2.066(7)	[1987Ho14]
⁴⁷ Cr	$3/2^{-}$	508(10) ms	7.444(5)	2.276(5)		-8.069(5)	-0.800(65)	[1985Bu07]
⁵¹ Fe	5/2-	288(6) ms	8.0540(14)	2.77832(14)		-6.805(2)	-0.607(1)	[2017Ku12]
⁵⁵ Ni	7/2-	203(2) ms	8.9640(6)	3.6297(6)		-5.2237(8)	0.482(1)	[2017Ku12]
⁵⁹ Zn	3/2-	174(2) ms*	9.1428(6)	5.7242(7)	0.023(8)%	-2.4480(9)	4.389(1)	[1981Ho19, 2017Ku12, 1984Ar12]
⁶³ Ge	3/2-	153.6(11) ms*	9.630(40)	6.960(40)		0.486(40)	7.014(40)	[2017GoZT, 2017Ku12,
								2014Ro14, 2002B117]
⁶⁷ Se	(5/2-)	133(4) ms	10.010(70)	7.740(70)	0.5(1)%	1.500(70)	7.542(70)	[1995Bl23, 2002Lo13, 2002Bl17,
		. ,				. ,		2014Ro14]
⁷¹ Kr	$(5/2^{-})$	100(3) ms	10.18(13)	8.31(13)	2.1(7)%	2.20(13)	7.83(13)	[1997Oi01, 1995Bl23]
⁷⁵ Sr	$(3/2^{-})$	88(3) ms	10.60(22)	8.42(22)	5.2(9)%	2.45(22)	7.46(22)	[ 1995Bl23, 2003Hu01]
⁷⁹ Zr		56(30) ms	11.03(31)#	9.12(30)#		3.48(30)#	8.02(30)#	[1999Bl08]
⁸³ Mo		$6^{+30}_{-3}$ ms	11.27(43)#	9.99(40)#		4.80(40)#	9.04(41)#	[2001Ki13]
⁸⁷ Ru		>1.5 us	11.96(40)#	11.09(40)#		5.97(40)#	9.46(43)#	[1995Le14, 1995Ry03]
⁹¹ Pd		32(3) ms	12.40(30)#	11.43(42)#	$3.0^{+1.1}_{0.0}$ %	6.65(42)#	9.10(42)#	[2018Pa20, 1995Le14, 1995Ry03]
⁹⁵ Cd		32(3) ms	12.85(400)#	11.76(57)#	$4.5^{+1.2}_{-1.0}$ %	7.37(57)#	9.09(64)#	[ <b>2018Pa20</b> , 2017Da07, 2016Ce02]
⁹⁹ Sn		24(4) ms	13.40(50)#	12.37(58)#	$3.9^{+3.4}_{-1.7}$ %	8.35(58)#	9.51(71)#	[2018Pa20]

* [2017Ku12]

# Table 2

Particle emission from the even Z,  $T_z = -1/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	
20				
³⁹ Ca	5.7709(6)	10.9130(6)	-6.6603(9)	
⁴³ Ti	4.484(6)	8.756(6)	-4.458(6)	
⁴⁷ Cr	4.776(5)	10.131(5)	-7.672(8)	
⁵¹ Fe	4.8513(14)	9.44348(26)	-8.051(5)	
⁵⁵ Ni	4.6149(7)	8.9664(18)	-7.5717(16)	
⁵⁹ Zn	2.8368(7)	5.7097(8)	-4.3046(10)	
⁶³ Ge	2.220(40)	5.150(40)	-2.130(40)	
⁶⁷ Se	1.840(70)	4.680(70)	-2.08(80)	
⁷¹ Kr	2.19(13)	4.47(13)	-2.17(15)	
⁷⁵ Sr	1.99(22)	4.64(22)	-2.72(25)	
⁷⁹ Zr	1.89(42)#	3.55(30)#	-2.58(37)#	
⁸³ Mo	1.82(50)#	3.39(41)#	-2.00(50)#	
⁸⁷ Ru	1.45(50)#	2.80(40)#	-1.82(57)#	
⁹¹ Pd	1.83(47)#	2.38(42)#	-2.87(58)#	
⁹⁵ Cd	1.94(69)#	2.65(68)#	-3.31(71)#	
⁹⁹ Sn	1.36(66)#	1.82(72)#	-3.35(81)#	

**Table 3**  $\beta$ -p Emission from ⁵⁹Zn*, T_{1/2} = 174(2) ms**,  $BR_{\beta,p} = 0.023(8)\%$ .

$E_p$	$I_p(\text{rel})\%$	$I_p(abs) (X \ 10^{-5})\%$	$E_{level}$ (emitter)***	$E_{level}$ (daughter)	coincident $\gamma$ -rays	
						-
0.929(10)	16(8)	7(3)	4.348(10)	0		
1.081(5)	31(14)	14(5)	4.500(5)	0		
1.286(10)	9(7)	4(3)	4.705(10)	0		
1.354(10)	9(7)	4(3)	4.773(5)	0		
1.400(5)	51(21)	23(7)	4.819(5)	0		
1.809(5)	100	45(13)	5.228(5)	0		
1.848(5)	58(24)	26(8)	5.267(5)	0		
1.889(5)	38(17)	17(6)	5.308(5)	0		
2.060(5)	36(15)	16(5)	5.479(5)	0		
2.125(5)	62(27)	28(9)	5.544(5)	0		
2.220(10)	24(11)	11(4)	5.639(10)	0		
2.235(10)	22(11)	10(4)	5.654(10)	0		
2.289(10)	18(8)	8(3)	5.708(10)	0		
2.452(15)	36(17)	16(6)	5.871(15)	0		
2.497(15)	11(5)	5(2)	5.916(15)	0		

* All values taken from [1981Ho19], except where noted.

** [2017Ku12]

*** Calculated from proton energies and  $S_p$  (⁵⁹Cu) = 3418.6(4) keV [2021Wa16].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = -1/2 nuclei.

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = -1/2$ nuclei.	Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein. $J^{\pi}$ values for $57$ Cu, and $61$ Ga are taken from ENSDF.	

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	$O_{\mathcal{F}}$	$O_{\mathcal{E},n}$	$BR_{\beta p}$	$O_{\mathcal{F}^{2n}}$	$O_{\mathcal{E}\mathcal{A}}$	Experimental
			1/2		$z_{p}$	PP	$z_{e_{2p}}$	204	1
⁵³ Co		$(7/2^{-})$	245(3) ms	8.2881(4)	0.7630(24)		-5.7867(17)	0.248(3)	[2017Ku12]
^{53m} Co	3.1752(23)	$(19/2^{-})$	245(102) ms	11.403(8)	2.321(8)		-2.613(8)	3.422(8)	[2023SaXX, 2015Sh16, 1972Ce01,
									1976Vi02, 1971Ce01, 1970Ce04]
⁵⁷ Cu		3/2-	195(4) ms	8.7749(4)	1.4425(5)		-4.4056(6)	1.214(2)	[2017Ku12]
⁶¹ Ga		3/2-	163(5) ms	9.210(40)	3.920(40)	<0.25%**	-0.551(40)	6.529(40)	[2017Ku12, 2002We07]
⁶⁵ As			130.3(6) ms	9.540(80)	4.610(80)		0.695(80)	6.984(82)	[2017GoZT, 2002Lo13]
⁶⁹ Br		3/2-	<24ns	10.180(40)	5.350(40)	7.793(40)	1.836(40)	7.793(40)	[2014De41]
⁷³ Rb		$(3/2^{-})$	< 81 ns	10.540(40)	5.760(40)		2.559(40)	8.00(40)	[2020Ho17, 2020Ho061]
⁷⁷ Y		$(5/2^+)$	$57^{+22}_{-12}$ ms	11.37(20)#	6.75(20)#	7.69(20)#	3.31(20)#	7.69(20)#	[2002Fa13]
⁸¹ Nb			< 40 ns	11.16(41)#	7.50(40)#		4.54(40)#	9.02(40)#	[2017Su26]
⁸⁵ Tc			< 43 ns	11.66(40)#	8.06(40)#		5.48(40)#	9.25(41)#	[2017Su26]
⁸⁹ Rh			< 120 ns	12.72(36)#	8.73(36)#		6.66(36)#	9.435(36)#	[2016Ce02]
⁹³ Ag		$(9/2^+)$	228(16) ns	12.58(55)#	9.31(40)#		7.26(40)#	9.54(40)#	[2016Ce02]
⁹⁷ In		$(9/2^+)$	36(6) ms	13.34(58)#	9.83(41)#	$1.7^{+1.7}_{-0.8}$ %	8.00(40)#	9.17(55)#	[2018Pa20, 2016Ce02, 2011StZV]
^{97m} In	0.61(18)	$(1/2^{-})$	$120(110) \ \mu s$	13.95(61)#	10.44(45)#	0.0	8.61(44)#	9.78(58)#	[2018Pa20]

* Deduced from  $Sp(^{53}Co)$  and p energy.

** Not observed.

#### Table 2

Particle emission from the odd-Z,  $T_z = -1/2$  nuclei, Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Mualida	S	DD	c	0	Execution	
Nuclide	$\mathfrak{S}_p$	DK _{1p}	$\mathfrak{s}_{2p}$	Qα	Experimental	
⁵³ Co	1.6163(17)		8.9941(17)	-7.464(3)		
^{53m} Co	-1.580(30)	1.3(1)%	5.798(30)	-4.267(30)	[2023SaXX, 2015Sh16, 1972Ce01,	
					1976Vi02, 1971Ce01, 1970Ce04]	
⁵⁷ Cu	0.6903(4)		7.8570(5)	-7.0746(18)		
⁶¹ Ga	0.250(40)		5.350(40)	-2.250(40)		
⁶⁵ As	-0.090(80)		4.970(80)	-2.230(90)		
⁶⁹ Br	-0.640(40)	100%	4.250(40)	-1.750(90)	[2014De41, 2011Ro18, 2011Ro47]	
⁷³ Rb	-0.640(40)	100%	4.090(40)	-2.180(60)	[2020Ho06, 2020Ho17, 2017Su31]	
⁷⁷ Y	-0.52(20)#		3.80(20)#	-2.85(21)#		
⁸¹ Nb	-1.11(50)#	100 %*	3.14(41)#	-2.35(45)#	[2017Su26, 2016Ce02, 2001Ki13]	
⁸⁵ Tc	-1.03(50)#	100 %*	2.82(43)#	-1.91(57)#	[ <b>2017Su26</b> , 2016Ce02	
⁸⁹ Rh	-1.40(20)#	100 %*	2.54(36)#	-2.23(54)#	[2016Ce02]	
⁹³ Ag	-1.09(53)#	100 %*	2.41(50)#	-3.17(54)#	[2016Ce02]	
⁹⁷ In	-0.89(57)#		2.06(57)#	-3.42(57)#		
^{97m} In	-1.50(60)#	100 %	1.45(60)#	2.81(60)#	[2018Pa20]	

* Inferred by half-life

# Table 3

Direct proton emission from  53m Co*, Ex = 3.1752(23) MeV, T_{1/2} =250(10) ms, BR_p 1.3(1) %.

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(rel)$	$I_p(abs)$	$E_{daughter}(^{52}\mathrm{Fe})$	coinc γ-rays
0.7095(16)	0.6961(16)	1.90(29)%	0.025(4)%	0.849	0.849
1.5589(16)	1.5295(16)	100%	1.3(1) %	0.0	

* All values taken from [2023SaXX].

#### Table 4 Direct proton emission from ⁶⁹Br*, $T_{1/2} = \langle 24 \text{ ns}, BR_p \approx 1.5 \%$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(abs)$	$E_{emitter}$ ( ⁶⁹ Br)	$E_{daughter}(^{68}\mathrm{Se})$
0.641(42)	0.632(42)	100 %	0	0

* All values taken from [2014De41].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = 0 nuclei.

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Table 1
Observed and predicted $\beta$ -delayed particle emission from the even- <i>Z</i> , $T_z = 0$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein

Nuclide	$J^{\pi}$	Ex	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
⁶⁴ Ge		$0^+$	63.7(25) s	4.517(4)	0.609(4)		-6.107(4)	1.604(4)	[1974Ro16]
⁶⁸ Se		$0^+$	35.5(7) s	4.7051(19)	1.195(4)		-5.044(1)	2.218(2)	[1994Ba50]
⁷² Kr		$0^+$	17.1(2) s	5.121(8)	1.917(8)	$< 1 \times 10^{-6}\%$	-4.185(8)	2.529(8)	[2003Pi03, 2015Br17]
⁷⁶ Sr		$0^+$	7.89(7) s	6.230(30)	2.790(40)	$3.4(8) \times 10^{-5}\%$	-3.540(31)	2.387(30)	[2004De24, 2013Pe13]
⁸⁰ Zr		$0^+$	4.6(6) s	6.39(30)#	3.43(30)#		-2.40(30)#	3.29(30)#	[2003Au02]
⁸⁴ Mo		$0^+$	2.2(2) s	7.02(30)#	4.45(30)#		-0.68(30)#	4.55(30)#	[2009St04]
⁸⁸ Ru		$0^+$	1.9(5) s	7.33(30)#	5.26(30)#	<3.6%	0.22(30)#	4.43(30)#	[2019Pa16, 2001Ki13]
⁹² Pd		$0^+$	1.06(3) s	8.22(35)	6.17(35)	1.6(2)%	1.37(35)	4.47(35)	[2019Pa16]
⁹⁶ Cd		$0^+$	1.02(6) s	8.94(40)#	7.11(41)#	1.7(4)%	2.76(41)#	5.00(41)#	[2019Pa16, 2017Da07, 2012Lo08]
^{96m} Cd	5.81(156)	$16^{+}$	0.53(3) s	14.7(16)#	12.9(16)#	19.5(29)%	8.6(16)#	10.8(16)	[2019Pa16, 2017Da07]
¹⁰⁰ Sn		$0^{+}$	1.18(8) s	7.03(24)	5.245(7)	<17%	1.34(24)	4.94(26)	[2019Lu08, 1997Su06, 2012Hi07,
									2012Lo08, 2008Ba53]
¹⁰⁴ Te		$0^+$	<18 ns	9.67(33)#	10.18(33)#		6.49(32)	12.12(32)	[2018Au04, 2019Xi06]
¹⁰⁸ Xe		$0^+$	$58^{+106}_{-23} \ \mu s$		10.74(39)#		9.27(38)	14.25(39)#	[2018Au04, 2019Xi06, 2008Ko04]

Particle emission from the even-Z,  $T_z = 0$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
⁶⁴ Ge	5.057(4)	7.725(4)	-2.566(4)		
⁶⁸ Se	4.8912(7)	7.1604(25)	-2.299(4)		
⁷² Kr	4.727(10)	6.589(8)	-2.176(8)		
⁷⁶ Sr	4.320(30)	6.490(30)	-2.91(71)		
⁸⁰ Zr	4.25(31)#	6.16(30)#	-2.94(30)#		
⁸⁴ Mo	3.85(34)#	5.13(30)#	-1.84(42)#		
⁸⁸ Ru	3.94(30)#	4.91(30)#	-2.59(42)#		
⁹² Pd	3.50(46)#	4.47(35)	-2.86(46)#		
⁹⁶ Cd	2.96(57)#	4.05(41)#	-3.22(54)#		
^{96m} Cd	-2.85(16)#	-1.76(16)#	1.88(16)#		
¹⁰⁰ Sn	3.06(38)#	4.09(25)	-4.00(48)#		
¹⁰⁴ Te	0.25(44)#	-0.73(33)	5.10(21)	100%	[2019Xi06, 2018Au04]
¹⁰⁸ Xe	0.49(48)#	-1.01(39)#	4.57(21)	100%	[ <b>2018Au04</b> , 2019Xi06, 2008Ko04]

# Table 3

Table 3			
$\beta$ -p Emission from	$^{96m}Cd^*, T_{1/2} =$	$0.53(3) \text{ s}, BR_{\beta_1}$	y = 19.5(29)%.

$E_p$	$I_p(\text{rel})\%$	$I_p(abs)\%$	E _{emitter} ( ⁹⁶ Ag)	$E_{daughter}(^{95}\mathrm{Pd})$	coincident $\gamma$ -rays
**	22(14)	2.1(14)		4.751	0.130, 0.691, 0.821, 1.375
**	72(42) 100(62)	7.0(42) 9.8(62)		4.071 2.696	0.130, 0.691, 0.821, 1.375 0.130, 0.691, 0.821

* All values taken from [2019Pa16]. ** Unresolved multiplet (Ep  $\approx$  1.5-6 MeV) - see Fig 8 in ref. [2019Pa16].

# Table 4

direct  $\alpha$  emission from ¹⁰⁴Te*, J^{$\pi$} = 0⁺, T_{1/2} =<18 ns, *BR*_{$\alpha$} =100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{100}\mathrm{Sn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.096(20)	4.90(20)	100%	$0^+$	0.0		$1.890\substack{+.058\\035}$	>0.41

* All values from [2018Au04].

		/ 20					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{104}\text{Te})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.569(20)	4.40(20)	100%	0+	0.0		$2.046^{+0.060}_{-0.036}$	0.75(30)

**Table 5** direct  $\alpha$  emission from ¹⁰⁸Xe*, J^{$\pi$} = 0⁺, T_{1/2} = 58⁺¹⁰⁶₋₂₃ µs, BR_{$\alpha$} =100%.

* All values from [2018Au04].

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Fig. 1: Known experimental values for heavy particle emission of the odd- $Z T_z = 0$  nuclei.

last updated 11/23/22

Table 1
Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = 0$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
⁶² Ga		$0^+$	116.121(21) ms	9.1811(4)	2.7081(11)		-2.0918(7)	5.8169(7)	[2008Be21]
⁶⁶ As		$(0^{+})$	95.77(23) ms	9.582(6)	3.343(6)		-0.599(5)	6.718(5)	[2014Ro14]
⁷⁰ Br		$0^+$	78.42(51) ms	10.504(15)	4.400(40)		0.975(25)	7.756(15)	[2017Mo18]
⁷⁴ Rb		$(0^{+})$	64.9(5) ms	10.416(3)	4.441(7)		1.374(4)	7.589(3)	[2013Du14]
⁷⁸ Y		$(0^+)$	47(5) ms	11.00(30)#	5.37(30)#		2.27(30)#	7.74(30)#	[2007Na13]
⁸² Nb		$(0^{+})$	50(4) ms	11.80(30)#	6.61(30)#		3.92(30)#	8.940(30)#	[1999Lo07, 1998Lo17]
⁸⁶ Tc		$(0^{+})$	$59^{+8}_{-7}$ ms	12.54(30)#	7.42(30)#		5.274(300)#	9.619(30)#	[2002Fa13]
⁹⁰ Rh		$(0^{+})$	29(3) ms	13.25(20)#	8.47(30)#		6.48(20)#	10.06(20)#	[2019Pa16]
^{90m} Rh	х	$(7^{+})$	0.56(2) s	13.25(20)# + x	8.47(30)# + x	9.6(10)%	6.48(20)#+x	10.06(20)#+x	[2019Pa16]
⁹⁴ Ag		$(0^{+})$	27(2) ms	13.70(40)#	9.32(40)#	$<\!0.2\%$	7.32(40)	10.01(40)#	[2019Pa16, 2004Mu30, 1994Sc35]
$^{94m1}Ag$	х	$(7^{+})$	0.47(1) s	13.70(40)# + x	9.32(40)# + x	17.0(6)%	7.313 # + x	10.01(40)#+x	[2019Pa16, 2004Mu30, 1994Sc35]
$^{94m2}Ag$	6.49(63)#	$(21/2^+)$	0.39(4) s	20.19(75)#	15.81(75)#	$\approx 27\%$	13.81(75)#	16.50((75)#	[2004Mu30, 005Mu15, 2007Ro16,
									2006Mu03]
98In		$0^{+}$	30(1) ms	13.73(30)#	9.71(31)#	< 0.13%	7.70(30)#	9.77(30)#	[2019Pa16, 2012Lo08]
98mIn	0.82(73)	$(9^+)$	0.89(2) s	14.55(79)#	10.53(79)#	44(2)%	8.52(79)#	9.77(30)#+x	[2019Pa16]
102 Sb				13.84(41)#	10.16(40)#		8.52(40)#	14.12(40)#	
$^{106}I$				14.92(41)#	13.43(40)#		13.75(40)#	19.21(41)#	

Particle emission from the odd-Z,  $T_z = 0$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$BR_{1p}$	$S_{2p}$	$BR_{2p}$	Qα	Experimental
62.0	2.027(1.0)		0.0105(15)		0.5141/5	
⁶² Ga	2.927(16)		8.2197(17)		-2.7441(7)	
⁶⁶ As	2.836(6)		7.770(6)		-2.463(6)	
70 Br	2.280(15)		7.109(15)		-1.825(16)	
⁷⁴ Rb	2.653(7)		7.432(3)		-2.915(15)	
⁷⁸ Y	1.66(30)#		6.27(30)#		-2.68(30)#	
⁸² Nb	1.57(31)#		5.24(30)#		-2.06(42)#	
⁸⁶ Tc	1.35(30)#		4.95(30)#		-2.19(42)#	
⁹⁰ Rh	0.55(20)#		4.54(20)#		-2.49(36)#	
^{90m} Rh	0.55(20)#-x		4.54(20)#-x		-2.49(36)#+x	
⁹⁴ Ag	0.71(55)#		3.98(40)#		-3.19(45)#	
^{94m1} Ag	0.71(55)#-x		3.98(40)#-x		-3.19(45)#+x	
^{94m2} Ag	-5.78(84)#	4.1(6)%	-2.50(75)#	0.5(3)%	3.00(77)#	[2006Mu03, 2005Mu15]
⁹⁸ In	0.46(52)#		3.97(32)#		-3.93(50)#	
98mIn	0.46(52)# -x		3.97(32)# -x		-3.93(50)# +x	
¹⁰² Sb	-1.92(50)#		1.50(40)#		0.38(50)#	
$^{106}I$	-2.22(50)#		-1.42(41)#		5.38(57)#	

# Table 3

 $\beta$ -p emission from ^{90m}Rh*, Ex. = unk, T_{1/2} =0.56(2) s,  $BR_{\beta p} = 9.6(10)\%$ .

$E_p(\text{c.m.})$	$I_p(rel)\%$	$I_p(abs)\%$	$E_{emitter}$ ( ⁹⁰ Ru)	$E_{daughter}(^{89}\mathrm{Tc})$	coincident $\gamma$ -rays	
**	37(21) 100(56)	2.6(15) 7.0(40)		0.796 0	0.796	

* All values taken from [2019Pa16]. ** Unresolved multiplet (Ep  $\approx$  1.5-6 MeV) - see Fig 8 in ref. [2019Pa16].

$ \begin{array}{c c cm} F^{**} & L_p(rcl)\%^{**} & E_{emitter} (^{44} Pd) & E_{dampter} (^{89} Tc) & coincident \gamma-rays \\ \hline 3.3(7) & 0.0 & \\ 1.7 & 0.2401(1) & 0.241 \\ 0.4 & 0.622(1) & 0.622 \\ 6.8 & 0.8529(1) & 0.853 \\ 3.0 & 0.8942(1) & 0.894 \\ 0.3 & 1.4510(7) & 0.557, 0.894, 1.451 \\ 0.3 & 1.4510(7) & 0.557, 0.894, 1.451 \\ 0.3 & 1.4510(7) & 0.557, 0.894, 1.451 \\ 0.3 & 1.4510(7) & 0.557, 0.894, 1.451 \\ 0.3 & 1.4510(7) & 0.557, 0.894, 1.451 \\ 0.3 & 1.4510(7) & 0.557, 0.894, 1.451 \\ 0.3 & 1.21978(5)^{***} & 2.198 \\ 0.7 & 2.1978(5)^{***} & 2.198 \\ 0.3 & 2.5951(2) & 0.333, 0.542, 0.853, 0.866 \\ 0.2 & 2.8905(3) & 0.295, 0.333, 0.542, 0.853 \\ 0.1 & 3.5430(4) & 0.295, 0.333, 0.542, 0.653 \\ 0.1 & 0.887(3) & 0.295, 0.333, 0.542, 0.554 \\ 0.1 & 0.887(3) & 0.295, 0.333, 0.542, 0.554 \\ 0.1 & 0.653, 0.853, 0.866, 0.948 \\ 0.1 & 0.653, 0.853, 0.866, 0.948 \\ 0.4 & 0.653, 0.853, 0.866, 0.948 \\ 0.4 & 0.650, 0.138, 0.295, 0.333, 0.497 \\ 0.542, 0.853, 0.866, 1.361 \\ 0.1 & 0.542, 0.853, 0.866, 1.361 \\ 0.1 & 0.542, 0.853, 0.866 \\ 0.18, 0.295, 0.333, 0.497 \\ 0.542, 0.522, 0.698, 0.853 \\ 0.66 & 5.6938(5) & 0.138, 0.295, 0.333, 0.497 \\ 0.542, 0.522, 0.698, 0.853 \\ 0.698, 0.853, 0.866, 1.362 \\ 0.4 & 0.5797(6) & 0.138, 0.295, 0.333, 0.497 \\ 0.4 & 6.799(7)^{***} & 0.130, 0.138, 0.191, 0.247 \\ \end{array}$					
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$E_p(c.m.)^{**}$	$I_p(rel)\%^{**}$	$E_{emitter}$ ( ⁹⁴ Pd)	$E_{daughter}(^{89}\mathrm{Tc})$	coincident γ-rays
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		22(7)		0.0	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		5.5(7)		0.0	0.241
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		1.7		0.2401(1)	0.241
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		0.4		0.022(1)	0.022
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		0.0		0.8529(1) 0.8942(1)	0.804
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		0.2		1.4510(7)	0.557 0.904 1.451
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		0.3		1.4510(7)	0.557, 0.094, 1.451
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		0.5		1.4037(8)	1,719
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		0.5		1.7180(1)	1./10
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		1.5		1./109(1) 2.1078(5)***	2 108
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		0.7		2.1978(3)	0.222.0.542.0.952.0.966
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		0.5		2.3931(2) 2.8005(3)	0.353, 0.342, 0.833, 0.800
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		0.2		2.8903(3)	0.295, 0.355, 0.342, 0.855
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		0.1		3 5430(4)	0.205 0.333 0.542 0.653
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		0.1		3.3430(4)	0.853 0.866 0.048
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		0.1		4 0887(3)	0.205 0.333 0.542 0.546
0.3 4.7084(11) 0.159, 0.295, 0.297, 0.333   0.1 4.7489(4) 0.158, 0.295, 0.333, 0.497   0.1 4.7489(4) 0.542, 0.522, 0.853, 0.866   0.8 5.4469(5) 0.138, 0.295, 0.333, 0.497   0.8 5.4469(5) 0.138, 0.295, 0.333, 0.497   0.8 5.4469(5) 0.138, 0.295, 0.333, 0.497   0.8 5.6938(5) 0.138, 0.247, 0.295, 0.333   0.6 5.6938(5) 0.138, 0.247, 0.295, 0.333   0.4 6.5797(6) 0.138, 0.191, 0.247, 0.295   0.4 6.7099(7)*** 0.130, 0.138, 0.191, 0.247		0.1		4.0887(3)	0.295, 0.355, 0.342, 0.340
$\begin{array}{cccccccccccccccccccccccccccccccccccc$					1 404
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		0.3		4 7084(11)	0.150 0.205 0.207 0.333
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		0.5		4.7084(11)	0.542 0.853 0.866 1.361
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		0.1		4 7480(4)	0.138 0.205 0.333 0.407
0.542, 0.522, 0.635, 0.800 1.362, 1.494 0.8 5.4469(5) 0.138, 0.295, 0.333, 0.497 0.542, 0.522, 0.698, 0.853 0.866, 1.362, 1.494 0.6 5.6938(5) 0.138, 0.247, 0.295, 0.333 0.497, 0.542, 0.522, 0.698 0.853, 0.866, 1.362, 1.494 0.4 6.5797(6) 0.138, 0.191, 0.247, 0.295 0.333, 0.497, 0.542, 0.522 0.698, 0.853, 0.866, 1.362 1.494 0.4 6.7099(7)*** 0.130, 0.138, 0.191, 0.247		0.1		4.7489(4)	0.542 0.522 0.853 0.866
0.8 5.4469(5) 0.138, 0.295, 0.333, 0.497 0.8 5.4469(5) 0.138, 0.295, 0.333, 0.497 0.542, 0.522, 0.698, 0.853 0.866, 1.362, 1.494 0.6 5.6938(5) 0.138, 0.247, 0.295, 0.333 0.497, 0.542, 0.522, 0.698 0.853, 0.866, 1.362, 1.494 0.4 6.5797(6) 0.138, 0.191, 0.247, 0.295 0.333, 0.497, 0.542, 0.522 0.698, 0.853, 0.866, 1.362 1.494 0.4 6.7099(7)*** 0.130, 0.138, 0.191, 0.247					1 362 1 494
0.6 5.6938(5) 0.136, 0.297, 0.353, 0.477 0.542, 0.522, 0.698, 0.853 0.866, 1.362, 1.494 0.6 5.6938(5) 0.138, 0.247, 0.295, 0.333 0.497, 0.542, 0.522, 0.698 0.853, 0.866, 1.362, 1.494 0.4 6.5797(6) 0.138, 0.191, 0.247, 0.295 0.333, 0.497, 0.542, 0.522 0.698, 0.853, 0.866, 1.362 1.494 0.4 6.7099(7)*** 0.130, 0.138, 0.191, 0.247		0.8		5 4469(5)	0.138, 0.205, 0.333, 0.407
0.542, 0.522, 0.693 0.866, 1.362, 1.494 0.6 5.6938(5) 0.138, 0.247, 0.522, 0.698 0.4 6.5797(6) 0.138, 0.191, 0.247, 0.295 0.333, 0.497, 0.542, 0.522 0.698, 0.853, 0.866, 1.362 1.494 0.4 6.7099(7)*** 0.130, 0.138, 0.191, 0.247		0.0		5.4409(5)	0.542 0.522 0.698 0.853
0.6 5.6938(5) 0.138, 0.247, 0.295, 0.333 0.6 6.5797(6) 0.138, 0.191, 0.247, 0.295 0.4 6.5797(6) 0.138, 0.191, 0.247, 0.295 0.333, 0.497, 0.542, 0.522 0.698, 0.853, 0.866, 1.362 1.494 0.4 6.7099(7)*** 0.130, 0.138, 0.191, 0.247					0.866, 1.362, 1.494
0.4 0.4 0.4 0.4 0.4 0.4 0.4 0.4		0.6		5 6938(5)	0 138 0 247 0 295 0 333
0.4 0.4 0.4 0.4 0.4 0.4 0.4 0.4		0.0		5.0750(5)	0.497 0.542 0.522 0.698
0.4 6.5797(6) 0.138, 0.191, 0.247, 0.295 0.333, 0.497, 0.542, 0.522 0.698, 0.853, 0.866, 1.362 1.494 0.4 6.7099(7)*** 0.130, 0.138, 0.191, 0.247					0.853, 0.866, 1.362, 1.494
0.4 6.7099(7)*** 0.130, 0.131, 0.247		0.4		6 5797(6)	0 138 0 191 0 247 0 295
0.4 6.7099(7)*** 0.130, 0.138, 0.191, 0.247		0.1		0.5777(0)	0 333 0 497 0 542 0 522
0.4   6.7099(7)***   0.130, 0.138, 0.191, 0.247					0.698, 0.853, 0.866, 1.362
0.4 6.7099(7)*** 0.130, 0.138, 0.191, 0.247					1 494
0.100,0100,0100,0100,0100,0100		0.4		6 7099(7)***	0 130 0 138 0 191 0 247
0.295, 0.333, 0.497, 0.542		0.1		0.1000(1)	0.295, 0.333, 0.497, 0.542
0.522, 0.698, 0.853, 0.866					0.522, 0.698, 0.853, 0.866
1.362, 1.494					1.362, 1.494

# Table 4 $\beta$ -p emission from ^{94m1,94m2}Ag*, T_{1/2} (^{94m1}Ag)=0.47(1) s[@], T_{1/2}(^{94m2}Ag)=390(40) ms

* All values taken from [2004Mu30] and are a combination of the (7*) and (21⁺) isomers. The ratio of the the two is estimated to be is estimated to be 89% and 11%, respectively.

** Individual proton energies not measured. Intensities in daughter inferred by gammas and TAS measurements [2004Mu30].

***tentative assignment

[@] [2019Pa16] [@] [@] [2004Mu30]

#### Table 5

direct proton emission from  ${}^{94m^2}$ Ag*, Ex = 6.49(63)#**, T_{1/2} =390(40) ms***, *BRp* =4.1(6)%.

$E_p(c.m.)$	$E_p(lab)$	$I_p$ (rel)%	$I_p(abs)\%$	$E_{daughter}(^{93}\text{Pd})$	coincident $\gamma$ -rays
0.790(30)	0.781(30)	86 (28)	1.9(5)	4.994	0.167, 0.196, 0.208, 0.275, 0.349, 0.361, 0.887, 0.984, 0.991, 1.096, 1.132
1.010(30)	0.999(30)	100(18)	2.2(4)	4.751	0.167, 0.196, 0.208, 0.275, 0.349, 0.361, 0.403, 0.614, 0.887, 0.984, 0.991, 1.096

* All values from [2005Mu13], except where noted.

** Excitation Energy = 6.49(63)# MeV, based on  $Q_p = 5.78(30)$  MeV [2005Mu13] and  $S_p$  (⁹⁴Ag) = 0.71(55) MeV # [2021Wa16].

*** [2004Mu30]

E _{2p} (c.m.)	$E_{2p}(lab)$	I _{2p} (abs)%	E _{daughter} ( ⁹² Rh)	coincident γ-rays
1.90(10)	1.860(10)	0.5(3)	1.549	0.235, 0.278, 0.364, 0.672, 1.036

direct 2-proton emission from  94m2 Ag*, Ex = 6.49(63)#**, T_{1/2} =390(40) ms***, BR_{2p} =0.5(3)%.

* All values from [2005Mu13], except where noted.

** Excitation Energy = 6.49(63)# MeV, based on  $Q_p = 5.78(30)$  MeV [2005Mu13] and  $S_p$  (⁹⁴Ag) = 0.71(55) MeV # [2021Wa16].

*** [2004Mu30]

Table 7		
$\beta$ -p Emission from ^{98m} In*	, Ex = 0.82(73) MeV, $T_{1/2} = 30(1)$ ms,	$BR_{\betap}=44(2)\%.$

$E_p$	$I_p(\text{rel})\%$	$I_p(abs)\%$	$E_{emitter}$ ( ⁹⁸ Cd)	$E_{daughter}(^{97}\mathrm{Ag})$	coincident $\gamma$ -rays
**	61(14)	9.7(22)		2.343	0.290, 0.763, 1.290
**	100(22)	15.8(36)		2.053	0.763, 1.290
**	78(17)	12.3(27)		2.020	0.602, 0.730, 1.290, 1.470
**	36(31)	5.7(49)		1.290	1.290

* All values taken from [2019Pa16].

** Unresolved multiplet (Ep  $\approx$  1.5-6 MeV) - see Fig 8 in ref. [2019Pa16].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$  = +1/2 nuclei.

Last updated 3/20/23

Observed and predicted $\beta$ -delayed particle emission from the even-Z, $T_z = +1/2$ nuclei.	Unless otherwise stated, all Q-values are taken from [2021Wa16] or
deduced from values therein. The J ^{$\pi$} value for ⁶¹ Zn is taken from ENSDF.	

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Q _ε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{arepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
⁶¹ Zn ⁶⁵ Ge		3/2 ⁻ 3/2 ⁻	89.1(2) s 30.8(7) s	5.635(16) 6.1793(23)	0.835(16) 2.2368(23)	0.011(3)%	-8.67(16) -5.476(2)	0.572(16) 3.045(2)	[ <b>1972Du09</b> ] [ <b>1987Vi01</b> , 2000Gi11,
⁶⁹ Se		(1/2 ⁻ )	27.4(2) s	6.680(30)	3.2551(24)	0.052(8)%	-4.134(2)	3.798(2)	[ <b>2000Gi11</b> , 1988De28, 1977Ma24, 1976Ha22, 1976Ha29]
⁷³ Kr		(3/2 ⁻ )	27.3(10) s	7.094(9)	4.027(7)	0.25(3)%	-3.237(8)	4.133(31)	[ <b>2000Gi11</b> , 1999Mi17, 1981Ha44, 1972Ho20, 1976Ha29]
⁷⁷ Sr ⁸¹ Zr		5/2 ⁽⁺⁾ (3/2 ⁻ )	9.0(2) s 5.5(4) s	7.027(8) 8.190(90)	3.921(9) 5.500(90)	0.08(3)% 0.12(2)%	-3.274(9) -1.295(90)	3.418(11) 4.886(90)	[ <b>2000Gi11</b> , 1976Ha29] [ <b>1999Hu05</b> , 2005Xu04, 1997Hu15, 1977Ce05, 1976HaWO]
⁸⁵ Mo		(1/2 ⁻ )	3.2(2) s	8.770(16)	6.623(17)	0.14(2)%	0.118(25)	5.778(17)	[ <b>1999Hu05</b> , 2005Xu04, 1997Hu15, 1976HaWO]
⁸⁹ Ru		(9/2+)	1.31(3) s	9.025(25)	7.028(25)	3.1(2) %	0.927(25)	5.486(24)	[ <b>2019Pa16</b> , <b>2012Lo08</b> , 2005Xu04, 1999Li33]
⁹³ Pd		(9/2+)	1.18(2) s	10.03(37)	8.03(37)	7.4(2)%	2.43(37)	5.990(30)	[ <b>2019Pa16</b> , 2012Lo08, 2005Xu04, 2001Xu05, 2000Sc31]
⁹⁷ Cd		(9/2+)	1.20(7) s	10.17(42)	8.16(42)	7.4(2)%	3.03(42)	5.87(42)	[ <b>2019Pa16</b> , 2012Lo08, 1982Ku15]
^{97m} Cd	2.62(58)	(25/2+)	3.86(6) s	12.79(72)	10.78(72)	25.1(5)%	5.65(72)	8.49(72)	[ <b>2019Pa16</b> , 2012Lo08, 2011Lo09]
¹⁰¹ Sn		(5/2+)	2.22(5) s	8.24(30)	6.60(30)	23.6(8)%	1.82(30)	8.17(30)	[ <b>2019Pa16, 2012Lo08</b> , 2020Pa25, 2007Ka15, 2007Se04, 1995Ia16]
¹⁰⁵ Te		(5/2+)	0.62(7) µs	11.20(30)	11.53(30)		7.24(30)	13.31(30)	[ <b>2006Li41</b> , 2010Da17, 2019Xi06, 2007Li83, 2007LiZP 2006Se08]
¹⁰⁹ Xe		(7/2+)	13(2) ms	11.50(30)	12.32(30)		9.91(30)	15.42(30)	[2006Li41, 2019Xi06, 2010Da17, 2007Li83, 2007LiZP, 2006Li41, 2006Se08]
¹¹³ Ba				12.06(30)#	13.03(30)#		10.67(30)#	15.54(30)#	

* Excitation Energy = 2.62(58) MeV [2019Pa16].

# Table 2

Particle emission from the even-Z,  $T_z = +1/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
(1					
⁶¹ Zn	5.293(16)	9.770(16)	-2.690(16)		
⁶⁵ Ge	4.9344(26)	8.8427(27)	-2.554(16)		
⁶⁹ Se	4.8292(24)	8.339(5)	-2.3814(26)		
⁷³ Kr	4.779(7)	7.983(7)	-2.542(7)		
⁷⁷ Sr	4.613(8)	8.058(11)	-3.677(10)		
⁸¹ Zr	3.670(90)	6.620(90)	-2.150(90)		
⁸⁵ Mo	3.605(16)	6.176(17)	-2.140(90)		
⁸⁹ Ru	3.988(25)	6.063(24)	-3.285(29)		
⁹³ Pd	3.270(37)	5.32(37)	-3.04(37)		
⁹⁷ Cd	3.51(43)	5.35(42)	-4.18(56)		
^{97m} Cd	0.89(72)	2.73(72)	-1.56(81)		
¹⁰¹ Sn	3.42(30)	4.95(30)	-2.00(52)		
¹⁰⁵ Te	0.81(32)	0.30(32)	5.069(3)	100%	[2010Da17, 2019Xi06, 2006Li41, 2006Se08]
¹⁰⁹ Xe	0.69(32)	0.09(32)	4.217(7)	100%	[2010Da17, 2019Xi06, 2006Li41, 2006Se08]
¹¹³ Ba	0.58(32)#	-0.23(32)#	4.04(42)#		

p-p emiss	p emission from $\gamma \mathbf{r}_{4}^{\prime}, 1_{1/2} = 1.16(2)$ s, $b \kappa_{\beta p} = 7.4(2)\%$ .						
$E_p$	$I_p(\text{rel})\%$	$I_p(abs)\%$	E _{emitter} ( ⁹³ Rh)	$E_{daughter}(^{92}\mathrm{Ru})$	coincident $\gamma$ -rays		
**	< 5.5	< 0.3		2.672	0.817, 0.865, 0.990		
**	14(3)	0.74(15)		1.855	0.865, 0.990		
**	100(7)	5.3(4)		0.865	0.865		
**	$\approx 25(7)$	$\approx 1.3(4)$		0.0			

#### **Table 3** $\beta$ -p emission from ⁹³Pd*, $T_{1/2} = 1.18(2)$ s, $BR_{\beta,p} = 7.4(2)\%$ .

* All values taken from [2019Pa16].

** Unresolved multiplet (Ep  $\approx$  1.5-5 MeV) - see Fig 8 in ref. [2019Pa16].

#### Table 4

|--|

$E_p$	$I_p(rel)\%$	$I_p(abs)\%$	$E_{emitter}$ ( ⁹⁷ Ag)	$E_{daughter}(^{96}Pd)$	coincident $\gamma$ -rays	
**	4.7(23)	0.16(7)		3.342	1.415, 1.972	
**	19.6(52)	0.64(17)		2.391	0.192, 0.684, 1.415	
**	100(23)	3.3(8)		2.099	0.684, 1.415	
**	73(27)	2.4(9)		1.415	1.415	
**	30(27)	1.0(9)		0.0		

* All values taken from [2019Pa16].

** Unresolved multiplet (Ep  $\approx$  1.5-6 MeV) - see Fig 8 in ref. [2019Pa16].

#### Table 5

$\beta$ -p emission from 97m Co	$I^*$ , Ex = 2.62(58) MeV, T ₁	$_{/2} = 3.86(6) \text{ s}, BR_{\beta}$	$_{p} = 25.1(5)\%$ .
--------------------------------------	-------------------------------------------	-----------------------------------------	----------------------

$E_p$	$I_p(\text{rel})\%$	$I_p(abs)\%$	E _{emitter} ( ⁹⁷ Ag)	$E_{daughter}(^{96}Pd)$	coincident γ-rays
**	15.4(18)	2.16(25)		5.282	0.106, 0.423, 0.684, 1.253, 1.415, 1.499
**	58.4(13)	8.18(24)		4.574	0.106, 0.423, 0.684, 0.790, 1.253, 1.415
**	100(7)	14(1)		3.784	0.106, 0.423, 0.684, 1.253, 1.415

* All values taken from [2019Pa16].

** Unresolved multiplet (Ep  $\approx 1.5-5$  MeV) - see Fig 8 in ref. [2019Pa16].

# Table 6

direct $\alpha$ emission from ¹⁰³ Te [*] , J ^{<i>n</i>} = 5/2 ⁺ , T _{1/2} = 0.62(7) $\mu$ s ^{**} , BR _{$\alpha$} = 1	:100%.
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	--------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{101}\mathrm{Sn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.898(3)	4.711(3)	100(4)%	89(4)%	5/2 ⁺	0.172(2)	0.172	1.696(74)	$3^{+5}_{-2}$
5.073(20)	4.880(20)	12(4)%	11(4)%	7/2 ⁺	0.0		1.696(74)	$100^{+18}_{-7}$

* All values from [2010Da17], except where noted ** [2006Li47]

[200

# Table 7

direct  $\alpha$  emission from ¹⁰⁹Xe*, J^{$\pi$} = 5/2⁺, T_{1/2} = 13(2) ms**, BR_{$\alpha$} =100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	$E_{daughter}(^{105}\text{Te})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.059(10) 4.218(4)	3.910(10) 4.063(4)	45(8)% 100(10)%	31(7)% 69(7)%	7/2+ 5/2+	0.150(3) 0.0	0.150	1.65(12) 1.65(12)	$\substack{3^{+12}_{-3}\\7^{+30}_{-6}}$

* All values from [2010Da17], except where noted.

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +1/2 nuclei.

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +1/2$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduce	d
from values therein. J [#] values for ⁷¹ Br, ⁷⁵ Rb, ⁷⁹ Y, ⁸³ Nb, are taken from ENSDF.	

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
⁷¹ Br	$(5/2^{-})$	21 4(6) s	6 644(6)	0 543(6)		-3 979(5)	3 747(6)	[1982Ha32]
⁷⁵ Rb	$3/2^{(-)}$	$19.2(10)  s^*$	7.105(8)	0.780(6)		-3.570(7)	3.503(3)	[1983Ke08, 1977Da04]
⁷⁹ Y	$(5/2^+)$	14.9(6)	7.680(80)	1.840(80)		-2.209(80)	4.099(80)	[1992Mu12]
⁸³ Nb	$(5/2^+)$	3.8(2)	8.30(16)	3.16(16)		-0.66(16)	5.45(16)	[2009St04]
⁸⁷ Tc	$(9/2^+)$	2.0(3) s	9.195(5)	4.155(7)	$<\!0.7\%$	0.907(7)	5.797(7)	[2019Pa16, 2001Ki13, 2000StZU]
⁹¹ Rh	(7/2+)	1.60(2) s	9.67(30)#	4.87(30)#	0.18(4)%**	1.87(30)#	5.89(30)#	[2019Pa16, 2012Lo08]
⁹⁵ Ag	$(9/2^+)$	1.80(7) s	10.06(40)#	5.71(40)#	1.76(9)%	2.73(40)#	5.90(40)#	[2019Pa16, 2012Lo08, 1994Sc35]
⁹⁹ In	$(9/2^+)$	3.11(6) s	8.56(30)#	4.40(30)#	0.29(3)%	1.85(30)#	6.16(30)#	[2020Pa25, 2019Pa16, 2012Lo08]
¹⁰³ Sb		< 46 ns	10.42(32)#	6.74(30)#		4.59(30)#	10.84(30)#	[2017Su26, 2013Su23, 1995Ry03]
$^{107}I$			11.23(32)#	9.76(30)#		9.33(30)#	15.24(32)#	
111Cs			11.62(23)#	10.28(21)#		10.24(20)#	15.34(22)#	

* Weighted average of 21.4(10) s [1983Ke08] and 17.0(10) s [1977Da04].

** Decay from combination of ground state and  $(1/2^{-})$  isomer.

#### Table 2

Particle separation and emission from the odd-Z,  $T_z = +1/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$BR_{1p}$	$S_{2p}$	Qα	$Q_{\varepsilon \alpha}$	Experimental
71-						
^{/1} Br	1.861(6)		7.970(30)	-2.340(5)		
⁷⁵ Rb	2.1758(23)		8.151(7)	-3.141(6)		
⁷⁹ Y	1.920(80)		7.550(80)	-3.010(80)		
⁸³ Nb	1.29(16)		6.48(16)	-2.23(18)		
⁸⁷ Tc	0.868(5)		5.988(6)	-2.50(16)		
⁹¹ Rh	0.98(30)#		5.75(30)#	-3.30(30)#		
⁹⁵ Ag	1.09(40)#		5.47(40)#	-3.76(50)#		
⁹⁹ In	1.03(30)#		5.05(30)#	-3.90(50)#		
¹⁰³ Sb	-0.98(32)#	100 %	2.70(30)#	2.28(42)#		[2017Su26, 2013Su23, 1995Ry03
$^{107}I$	-1.50(32)#		-0.010(300)#	4.82(42)#		·
¹¹¹ Cs	-1.73(22)#		-0.20(20)#	4.11(36)#		

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Fig. 1: Known experimental values for heavy particle emission of the even- $Z T_z = +1$  nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +1$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon lpha}$	Experimental
827.	0+	22(5) -	4.450(6)	0 (25(4)		(017(2))	0.99((2))	[1000] 171
~-Zr	U	52(5) s	4.430(0)	0.023(4)		-0.017(5)	0.880(5)	[1962L117]
⁸⁰ Mo	$0^+$	19.1(3) s	5.023(6)	1.775(7)		-4.795(5)	1.528(6)	[2005Ka39]
⁹⁰ Ru	$0^+$	11.7(9) s	5.841(4)	2.842(5)		-3.292(60)	1.825(6)	[2004De40]
⁹⁴ Pd	$0^+$	9.6(2) s	6.805(5)	3.825(5)		-1.754(5)	2.198(4)	[2006Ba55]
⁹⁸ Cd	$0^+$	9.3(1) s	5.430(40)	2.880(50)	< 0.029%	-2.530(51)	2.843(50)	[2019Pa16, 1997Ra22, 1996He25]
¹⁰² Sn	$0^{+}$	3.8(2) s	5.76(10)	3.61(10)		-1.37(10)	5.72(10)	[2002Fa13]
¹⁰⁶ Te	$0^+$	$70^{+20}_{-15} \mu s$	8.25(10)	7.83(10)		3.39(10)	10.05(10)	[2016Ca33, 2005Ja03, 2002Ma19,
		15						1994Pa11, 1981Sc17]
¹¹⁰ Xe	$0^+$	93(3) ms	8.55(12)	8.50(10)		5.95(10)	12.13(10)	[2016Ca33, 2007Sa36, 2002Ma19,
								1993HeZV, 1992HeZU, 1981Sc17]
¹¹⁴ Ba	$0^+$	$380^{+190}_{-110}$ ms	8.78(13)	9.01(10)	20(10)%	6.58(10)	12.14(12)	[2016Ca33, 2002Ma19, 1997Ja12,
		110						2003Mb01, 2001Ro35, 1995Gu10]

### Table 2

Particle emission from the even-Z,  $T_z = +1$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	Experimental	
<u>87</u> _						
⁸² Zr	5.190(6)	7.881(4)	-2.865(8)			
⁸⁶ Mo	5.120(5)	7.267(6)	-2.922(3)			
⁹⁰ Ru	4.778(5)	6.775(5)	-3.198(5)			
⁹⁴ Pd	4.379(5)	6.379(5)	-3.643(6)			
⁹⁸ Cd	4.020(50)	6.030(50)	-3.960(50)			
¹⁰² Sn	3.68(10)	5.32(10)	0.28(11)			
¹⁰⁶ Te	1.49(10)	1.17(10)	4.290(9)	100%	[2016Ca33, 1994Pa11, 2005Ja03,	
					2002Ma19, 1981Sc17]	
¹¹⁰ Xe	1.54(10)	0.72(10)	3.872(9)	64(35)%	[2016Ca33, 2002Ma19, 2007Sa36,	
					1993HeZS, 1992HeZU, 1981Sc17]	
¹¹⁴ Ba	1.43(10)	0.46(10)	3.592(19)	0.9(3)%	[2016Ca33, 2002Ma19, 2003Mb01,	
					2001Ro35, 1997Ja12, 1995Gu10]	

# Table 3

direct $\alpha$ emission from ¹⁰	06 Te*, J ^{$\pi$} = 0 ⁺ , T _{1/2} = 70 $^{+20}_{-15}$ $\mu$ s**, BR _{$\alpha$} =100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{102}\mathrm{Sn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.290(9)	4.128(9)	100%	100%	$0^+$	0.0		1.684(49)	0.94(27)

* All values from [1994Pa11], except where noted.

# ** [2016Ca33].

# Table 4

direct $\alpha$ emissi	t $\alpha$ emission from ¹¹⁰ Xe*, J ^{$\pi$} = 0 ⁺ , T _{1/2} = 93(3) ms**, BR _{$\alpha$} =64(35)%.											
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{106}\text{Te})$	coincident $\gamma$ -rays	R ₀ (fm)	HF				
3.860(20)	3.720(20)	100%	64(35)%	$0^+$	0.0		1.655(47)	$0.9^{1.1}_{-0.3}$				

* All values from [2016Ca33], except where noted

** [2007Sa36].

**Table 5** direct  $\alpha$  emission from ¹¹⁴Ba*, J^{$\pi$} = 0⁺, T_{1/2} = 380⁺¹⁹⁰₊₁₀ ms, BR_{$\alpha$} =0.9(3)%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{110}\mathrm{Xe})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
3.610(20)	3.480(20)	100%	0.9(3)%	$0^+$	0.0		1.700(47)	$1.2^{1.5}_{-0.8}$

* All values from [2016Ca33].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +1 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z = +1$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{$\pi$} values for ⁶⁸As, ⁷²Br, ⁷⁶Rb, ⁸⁰Y, ⁸⁴Tc are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Q _ε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
⁶⁸ As		3+	151.5(9) s	8.0843(26)	0.6957(22)		-4.5733(19)	4.685(2)	[1977Pa13]
⁷² Br		$1^{+}$	78.6(24) s	8.8064(22)	1.543(4)		-3.0778(13)	5.492(2)	[1974Co14]
⁷⁶ Rb		$1^{(-)}$	36.2(2) s	8.535(4)	1.339(4)		-2.8439(9)	4.964(2)	[1993Al03]
⁸⁰ Y		(4-)	30.1(5) s	9.163(7)	2.366(7)		-1.548(6)	5.441(7)	[1998Do04]
⁸⁴ Nb			9.5(10) s	10.228(6)	3.723(19)		0.238(6)	6.692(3)	[2003Do01]
⁸⁸ Tc		(6+)	5.8(4) s*	11.016(6)	4.915(8)	<0.3%*	1.721(6)	7.327(6)	[2019Pa16]
⁹² Rh		(6+)	5.7(1) s	11.302(5)	5.699(5)	1.9(1)%	2.596(5)	7.263(6)	[ <b>2019Pa16</b> , 2012Lo08, 2005Xu04, 2001Xu05]
⁹⁶ Ag		(8+)	4.46(4) s	11.670(90)	6.540(90)	4.4(5) %	3.496(90)	7.366(90)	[ <b>2019Pa16</b> , 2012Lo08, 2003Ba39, 1997Sc30]
^{96m} Ag	х	(2+)	4.395(85) s	11.67+x	6.540+x	14.7(24)%	3.496+x	7.366+x	[ <b>2019Pa16</b> , 2012Lo08, 2003Ba39, 1997Sc30]
¹⁰⁰ In		(6+)	5.62(6) s	10.164(28)	5.245(7)	1.66(3)%	2.565(6)	9.580(5)	[ <b>2019Pa16</b> , 2012Lo08, 2002Pl03, 1995Sz01]
¹⁰⁴ Sb			$440^{+150}_{-110}$ ms	12.33(10)#	8.05(10)#	<7%	5.78(10)#	12.47(10)#	[ <b>1996FaZZ</b> , 2019Au02, 1995Le14, 1995Sc28]
¹⁰⁸ I			26.4(8) ms	13.01(10)#	10.59(10)#		10.01(10)#	16.43(10)#	[ <b>2019Pa16</b> , 1996IkZZ, 1994Pa11, 1991Pa05]
¹¹² Cs		(1 ⁺ )	486(37) µs**	13.61(12)#	11.25(12)#		11.24(12)#	16.94(12)#	[ <b>2012Ca03, 2012Wa10</b> , 1996IkZZ, 1994Pa12]
¹¹⁶ La			50(22) ms	13.48(20)#@	11.51(20)#@		11.61(20)#@	16.75(20)# [@]	[2022Zh76]

* Combined result for ground state and isomer.

** Weighted average of 506(55)  $\mu$ s [2012Wa10] and 470(50)  $\mu$ s [2012Ca03]. ^(a) Mass excess of ¹¹⁶La is calculated to be -40897(200)# keV (-40050(320)# keV in [2021Wa16]) from the emitted proton energy and the mass excess for ¹¹⁵Ba of -48920(200)# keV [2021Wa16]. This value is compared to the mass excess of the daughter from [2021Wa16] to deduce the value shown.

#### Table 2

Particle emission from the odd-Z,  $T_z = +1$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$BR_{1p}$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
69 .	0.510(5)		0 = 40 = (0.1)	a (0.66/aa)		
⁰⁸ As	3.510(5)		9.7487(21)	-2.4866(23)		
72 Br	3.2042(30)		9.3057(17)	-2.5921(21)		
⁷⁶ Rb	3.444(8)		9.769(6)	-3.8423(14)		
80 Y	2.957(10)		8.791(7)	-3.094(6)		
⁸⁴ Nb	2.571(6)		7.708(6)	-2.471(6)		
⁸⁸ Tc	2.074(5)		7.114(7)	-2.901(4)		
⁹² Rh	2.048(5)		6.852(4)	-3.754(6)		
⁹⁶ Ag	1.83(9)		6.18(9)	-2.93(64)		
^{96m} Ag	1.83-x		6.18-x	-2.93+x		
¹⁰⁰ In	1.5360(27)		5.690(30)	-2.090(90)		
¹⁰⁴ Sb	-0.510(20	<1%	3.18(10)#	2.46(10)#		[2019Au02]
$^{108}I$	-0.597(13)	<1%	0.88(10)#	4.099(5)	100%	[2019Au02, 1994Pa11]
¹¹² Cs	-0.816(4)	100%	0.53(13)#	3.940(20)**		[2012Ca03, 2012Wa10,
						1996IkZZ, 1994Pa12]
¹¹⁶ La	-0.734(9)**	60(18)%	0.79(20)#@	3.09(20)#@		[2022Zh76]

* [2019Au02]

** From [2022Zh76], -1.58(38)# in [2021Wa16].

[@] Mass excess of ¹¹⁶La is calculated to be -40897(200)# keV (-40050(320)# keV in [2021Wa16]) from the emitted proton energy and the mass excess for ¹¹⁵Ba of -48920(200)# keV [2021Wa16]. This value is compared to the mass excess of the daughter from [2021Wa16] to deduce the value shown.

direct $\alpha$ emissi	on from ¹⁰⁸ I*, J ^{$\pi$} = , T ₁	$_{/2} = 26.4(8) \text{ ms}, BR_{\alpha} =$	99.50(21)%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{105}\mathrm{Te})$	coincident γ-rays	
4.097(10)	3.945(10)	99.50(21)%		0.0		
* All value	es from [2019Au02].					
Table 4     direct proton er	mission from ¹⁰⁸ I*, J ^{$\pi$} =	$BR_p = 0.50(21)\%.$				
$E_p(\text{c.m.})$	$E_p(lab)$	<i>I_p</i> (absb)	${f J}_f^\pi$	$E_{daughter}(^{111}\mathrm{Xe})$	coincident γ-rays	
0.597(13)	0.591(13)	0.50(21)%	(5/2+)	0.0		
Table 5direct proton er $E_p(c.m.)$	mission from ¹¹² Cs*, J ^{$\pi$} $E_p$ (lab)	= $T_{1/2}$ = 486(37) $\mu$ s** $I_p$ (rel)	*, $BR_p = 100\%$ . $I_p(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{111}{ m Xe})$	coincident γ-rays
0.716(20) 0.817(5)	0.710(20) 0.810(5)	$\approx 10\%$ 100%	≈ 9% ≈91%		0.0	
* All value ** Weighte	es from [2012Wa10], exe ed average of 506(55) $\mu$	cept where noted. s [2012Wa10] and 470	(50) μs [2012Ca03].			
direct proton er	nission from ¹¹⁶ La*, J ^{$\pi$}	$= T_{1/2} = 50(22) \text{ ms}, B$	$R_p = 60(18)\%.$			
$E_p(c.m.)$	$E_p(\text{lab})$	$I_p(abs)$	${ m J}_f^{\pi}$	<i>E</i> _{daughter} ( ¹¹⁵ Ba)	coincident γ-rays	
0.734(9)	0.718(9)	60(18)%	(5/2+)	0.0		

* All values from [2022Zh76].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +3/2 nuclei.

Last updated 3/20/23

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +3/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{$\pi$} values for ⁶⁷Ge, ⁷¹Se, ⁷⁵Kr, ⁷⁹Sr, ⁸³Zr are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon_{2p}}$	$Q_{\varepsilon \alpha}$	Experimental
⁶⁷ Ge		$1/2^{-}$	19.0(3) m	4.205(4)	-1.063(4)		-9.988(4)	0.481(4)	[1969Ba07]
⁷¹ Se		$(5/2^{-})$	4.74(5) m	4.747(5)	0.1266(29)		-8.397(3)	1.308(3)	[1980Te01]
⁷⁵ Kr		5/2+	4.60(7) m	4.783(9)	0.601(8)		-7.949(9)	1.144(9)	[1995BeZS]
⁷⁹ Sr		$3/2^{(-)}$	2.31(6) m	5.323(8)	1.410(7)		-6.823(8)	1.202(8)	[1981Li12]
⁸³ Zr		$(1/2^{-})$	42(2) s	6.294(20)	2.809(9)	obs	-5.033(8)	2.466(6)	[2015Mc011983Ha06]
⁸⁷ Mo		$(7/2^+)$	14.5(3) s	6.990(7)	3.795(5)	15(8)%	-3.621(19)	2.896(19)	[1997Hu07, 1983Ha06, 1981Mi15]
⁹¹ Ru		$(9/2^+)$	7.6(2) s	7.747(3)	4.644(4)	<0.2%*	-2.192(24)	3.209(7)	[2019Pa16, 1983Ha06]
⁹⁵ Pd		$(9/2^+)$	7.4(5) s	8.375(5)	5.329(4)	0.23(5)%	-0.938(3)	3.596(4)	[2019Pa16]
^{95m} Pd	1.8751(1)	$(21/2^+)$	13.2(4) s	10.250(5)	7.204(4)	0.71(7)%	-0.937(3)	5.471(4)	[2019Pa16, 1982Ku15,1982No06,
⁹⁹ Cd		$(5/2^+)$	17(1) s	6.781(6)	4.101(5)	0.21(2)%	-1.909(40)	5.985(4)	[2019Pa16, 1978El09, 1982Ku15]
¹⁰³ Sn		$(5/2^+)$	7.0(2) s	7.54(10)#	5.28(10)#	1.2(1)%	-0.33(10)#	7.20(10)#	[2005Ka34, 2004Mu32, 1981Ti03]
¹⁰⁷ Te		$(5/2^+)$	3.1(1) ms	10.00(10)#	9.41(10)#		4.40(10)#	11.55(10)#	[1994Pa11, 2019Au02, 2020Ca01,
									2004Ha59, 2002Se10, 1981Sc17,
									1991He21, 1979Sc22]
¹¹¹ Xe		$(7/2^+)$	0.81(20) s	10.43(12)#	10.42(12)#		7.15(12)#	13.71(12)#	[2010Da17, 1994Pa11, 2012Ca03
									2020Ca01, 1993HeZS, 1991He21,
									1981Sc17]
¹¹⁵ Ba		$(5/2^+)$	0.45(5) s	10.78(23)#	10.88(20)#	>15%	7.62(20)#	13.61(20)#	[1997.Ja12, 1995Gu01]
¹¹⁹ Ce				11.20(58)#	11.09(54)#		8.09(50)#	13.46(51)#	

* Combination of ground state and  $(1/2^{-})$  isomer.

** Excitation energy = 1.8751(1) MeV.

#### Table 2

Particle emission from the even-Z,  $T_z = +3/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental	
⁶⁷ Ge	6.239(4)	11.340(4)	-2.885(5)			
⁷¹ Se	6.102(3)	10.624(3)	-2.898(5)			
⁷⁵ Kr	6.324(10)	10.674(11)	-3.602(9)			
⁷⁹ Sr	5.833(8)	9.888(8)	-3.581(11)			
⁸³ Zr	5.137(8)	8.961(7)	-2.857(10)			
⁸⁷ Mo	5.040(6)	8.288(7)	-3.398(7)			
⁹¹ Ru	4.8041(24)	7.803(4)	-3.780(4)			
⁹⁵ Pd	4.347(5)	7.327(4)	-4.151(4)			
^{95m} Pd	2.472(5)	5.419(4)	-2.276(4)			
99Cd	4.150(30)	6.703(5)	-2.390(3)			
¹⁰³ Sn	3.69(10)#	5.83(10)#	0.41(10)#			
¹⁰⁷ Te	1.47(10)#	1.90(10)#	4.010(5)#	70(30)%*	[2019Au02, 2002Se10, 1991He21,	
					1981Sc17, 1979Sc22, 2020Ca01,	
					2004Ha59, 1994Pa11 ]	
¹¹¹ Xe	1.34(13)#	1.38(12)#	3.719(10)**	10.4(19)%	[12012Ca03, 2020Ca01, 2010Da17,	
					1994Pa11, 1993HeZS, 1991He21,	
					1981Sc17]	
¹¹⁵ Ba	1.52(22)#	1.30(20)#	3.18(23)#		-	
¹¹⁹ Ce	1.49(58)#	0.94(56)#	2.68(54)#			

* The short half-life suggests  $BR_{\alpha}$  is  $\approx 100\%$ . ** From [2010Da070], 3.710(60)# in [2021Wa16].

Table 3	5
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direct $\alpha$ emission from	n ¹⁰⁷ Te, J $^{\pi}$ =	$(5/2^+), T_{1/2} =$	3.1(1) ms [@] ,	$BR_{\alpha} = 70(30)\%^*$ .
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{110}\mathrm{Xe})$	coincident γ-rays	R ₀ (fm)	HF
3.836(7)**	3.692(7)	0.67(13)%	0.47(9)%	(7/2 ⁺ )	0.1680(1)	0.1680(1)	1.672(31)	$50^{+5}_{-2}$
4.004(6)***	3.854(6)	100%	70(30)%	(5/2 ⁺ )	0.0		1.672(31)	$2.4^{+2.3}_{-1.2}$

[@] [1994Pa11].

** [2002Se10].

*** Weighted average of 3.982(15) [1979Sc22], 4.012(10) [1991He21] and 4.007(10) [2019Au02].

#### Table 4

direct $\alpha$ emission from	111 Xe*, J ^{$\pi$} =	$(7/2^+), T_{1/2}$	$= 0.81(20) s^{**},$	$BR_{\alpha} = 10.4(19)\%^{***}$	
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})^*$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{107}\text{Te})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
3.631(15) 3.719(10)	3.500(15) 3.582(10)	58(32)% 100(32)%	3.8(22)% 6.5(24)%	(7/2 ⁺ ) (5/2 ⁺ )	0.0903(4) 0.0	0.0903(4)	1.663(61) 1.663(61)	$7^{+11}_{-5} \\ 14^{+21}_{-9}$

* All values from [2012Ca03] except where noted.

** [2010Da17]

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$  = +3/2 nuclei.

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +3/2$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein. $J^{\pi}$ values for 69 As, 73 Br, 77 Rb, 81 Y, 85 Nd, 89 Tc, 93 Rh, 97 Ag are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_1$	/2	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
(0)										
⁶⁹ As		$5/2^{-}$	15	.1(3) m	3.990(30)	-3.320(30)		-9.808(20)	0.377(20)	[1979Su02]
⁷³ Br		$1/2^{-}$	3.4	4(2) m	4.582910)	-2.705(8)		-8.317(7)	1.030(7)	[1987He21]
⁷⁷ Rb		$3/2^{-}$	3.7	78(4) m	5.3390(24)	-1.830(9)		-7.212(1)	0.999(7)	[1993Al03]
⁸¹ Y		$(5/2^+)$	69	.0(11) s	5.815(6)	-0.826(6)		-5.849(6)	2.032(5)	[1993Mi11]
⁸⁵ Nb		$(9/2^+)$	20	.9(7) s	6.896(8)	0.326(6)		-4.060(8)	2.823(5)	[1988Ku14]
⁸⁹ Tc		$(9/2^+)$	12	.8(9) s	7.620(5)	1.490(60)		-2.626(6)	3.355(7)	[1991He04]
⁹³ Rh		$(9/2^+)$	11	.9(7) s	8.205(3)	2.625(4)		-1.381(7)	3.578(5)	[2004De40]
⁹⁷ Ag		$(9/2^+)$	25	.3(3) s	6.902(13)	1.495(16)		-2.024(16)	3.888(12)	[1997Sc30]
¹⁰¹ In		$(9/2^+)$	14	.9(12) s	7.292(12)	2.304(13)	<1.7%	-0.940(13)	6.836(13)	[2019Pa16, 1997Sz04]
¹⁰⁵ Sb		$(5/2^+)$	1.2	22(11) s	9.323(22)	4.878(23)	< 0.1%	2.059(22)	9.397(22)	[2007Ma35, 1997Sh13, 2007MaZB, 2005Li47,
		( )						,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	,	2005LiZY, 1995Sc28,1995Sc33, 1994Ti03]
¹⁰⁹ I		$1/2^{+}$	93	.5(3) µs	10.043(8)	7,484(9)		6.261(9)	13.240(8)	[2007Ma35, 2019Au02, 2012Ca03, 1995Ho26,
				· / ·						2007MaZB, 1999Yu02, 1997IkZZ, 1995Ho26,
										1993HeZS, 1993Se04, 1991He21, 1987FaZT,
										1987Gi02, 1984Fa04]
¹¹³ Cs		$(3/2^+)$	17	.1(2) µs	10.439(11)	8.010(13)		7.244(11)	13.525(10)	[2015Wa02, 1995Ho26, 1994Pa12, 2012Ca03,
		( )								2012Wa10, 2002Rv02, 1998GrZT, 1998GrZZ,
										1993HeZS, 1987Gi02, 1987FaZT, 1984Fa041
¹¹⁷ La		C	$3/2^{+}$	20.1(25)	ms 11.19(32	)# 8 48(22)#	¥	7.81(20)#	13.51(20)#	[ <b>20227h76, 2011Li28</b> 2001Ma69, 2001So02
Du		(1	,,_ )	2011(20)		) 01.10(22).		,	10101(20)	2007LiZR1
$^{-117m}$ La	0.1510	(12) (9	$\frac{1}{2^{+}}$	10(5) ms	11.34(32	)# 8.63(22)#	¥	7.96(20)#	13.66(20)#	[2001So02]
121 pr	5.151	() () ()	3/2)	$10^{+6}$ ms	11 14(64	)# 8.73(58)	¥	8 46(54)#	13 46(56)#	[2005Bo19 2007Da7U 1972Bo28]
11		(.	<i>~~</i> )	$10_{-3}$ ms	11.14(04	,	,	0.+0(0+)#	13.40(30)#	[20031017, 2007[2020, 1772[020]

 

 Table 2

 Particle emission from the odd-Z,  $T_z = +3/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from

 values therein.

Nuclide	$S_p$	$BR_{1p}$	$S_{2p}$	Qα	BRα	Experimental
69 .	2 (20/20)		10.010/20	2 000 (20)		
⁰⁵ As	3.420(30)		10.810(30)	-2.880(30)		
⁷³ Br	3.067(7)		10.330(8)	-2.960(30)		
//Rb	3.106(4)		10.301(4)	-3.610(7)		
⁸¹ Y	2.690(6)		9.488(6)	-3.307(6)		
⁸⁵ Nb	2.147(7)		8.652(19)	-4.072(7)		
⁸⁹ Tc	1.997(5)		8.098(8)	-3.540(6)		
⁹³ Rh	2.000(4)		7.603(4)	-4.042(5)		
⁹⁷ Ag	2.010(13)		7.141(13)	-4.317(12)		
¹⁰¹ In	1.639(12)		6.410(13)	-0.066(17)		
¹⁰⁵ Sb	-0.323(22)	< 0.1%	3.961(24)	2.104(25)		[2007Ma35, 1997Sh13, 2007MaZB, 2005Li47,
						2005LiZY, 1995Sc28, 1995Sc33, 1994Ti03]
¹⁰⁹ I	-0.820(4)	99.846(4)%	1.597(8)	3.918(21)	0.014(4)%	[2007Ma35, 1995Ho26, 2019Au02, 2012Ca03,
						2007Ma35, 1999Yu02, 1997IkZZ, 1995Ho26,
						1993HeZS, 1993Se04, 1991He21, 1987FaZT,
						1987Gi02, 1984Fa04]
113Cs	-0.9728(22)	100%	1.389(10)	3.483(8)		[1995Ho26, 2015Wa02, 1994Pa12, 2012Ca03,
						2012Wa10, 2010Ho16,2002Ry02, 1998GrZT,
						1998GrZZ, 1993HeZS, 1993HeZV, 1987Gi02,
						1987FaZT, 1984Fa04]
¹¹⁷ La	-0.820(3)	100%	1.15(23)#	3.07(20)#		[2022Zh76, 2011Li28, 2001So02, 2011Ma69,
						2007LiZR. 2003ScZZ]
117m La	-0.970(3)	100%	1.30(23)#	3.22(20)#		[2001So02]
¹²¹ Pr	-0.890(10)	$\approx 100\%$	1 11(58)#	2 30(54)#		$[2005B_019, 2007D_87U, 1972B_028]$
	5.670(10)	3 100 /0				[

Table 3     direct proton e	emission from ¹⁰⁹ I*,	$J^{\pi} = 1/2^+, T$	$\Gamma_{1/2} = 93.5(2) \ \mu s^{**},$	$BR_p = 99.846(4)\%$	6.			
$E_p(\text{c.m.})$	$E_p(\text{lab})$		$I_p(abs)$	$J_f^{\pi}$	$E_{daughter}(^{108}\mathrm{Te})$	coincide	ent γ-rays	
0.8202(40)	0.8126(4	0)	99.846(4)%	$0^+$	0.0			
* All Val ** [2007]	ues from [1995Ho26 Ma15].	], except wh	ere noted.					
Table 4 direct $\alpha$ emiss	sion from ¹⁰⁹ I, $J^{\pi} = 1$	$/2^+, BR_{\alpha} = 0$	0.014(4)%*.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{105}\mathrm{Sb})$	coincident γ-rays	R ₀ (fm)	HF
3.915(20)	3.774(20)	100%	0.014(4)%	(5/2+)	0.0		1.658(30)	$31^{+22}_{-14}$
* All Valu	ues from [2007Ma15	j].						
Table 5     direct proton e	emission from ¹¹³ Cs ³	*, $J^{\pi} = (3/2^+)^{\pi}$	T), $T_{1/2} = 17.1(2) \ \mu s$	**, $BR_p = 100\%$ .				
$E_p(\text{c.m.})$	$E_p(\text{lab})$		$I_p(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{112}\mathrm{Xe})$	coinciden	coincident γ-rays	
0.969(3)	0.960(3)		100%	$0^+$	0.0			
* All valu ** [2015] Table 6 direct proton e	wa02]. waission from ¹¹⁷ La,	J ^{$\pi$} = (3/2 ⁺ )	, $T_{1/2} = 20.7(25)$ ms	$*, BR_p = \approx 100\%$				
$E_p(\text{c.m.})$	$E_p(\text{lab})$		$I_p(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{116}\mathrm{Ba})$	coincider	nt γ-rays	
0.819(3)	0.812(3)**	k	$\approx 100\%$	$0^+$	0.0			
* Weighte ** Weigh	ed average of 20.1(2: ted average of 0808(	5) ms [2011] 5) MeV [20]	Li28] and 21.6(31) n 22Zh76] and 0.813(3	ns [2022Zh76]. 3) MeV [2011Li2	8].			
Table 7       direct proton e	emission from ^{117m} La	a, Ex = 0.15	1(12) MeV, $J^{\pi} = (9/2)^{\pi}$	$(2^+), T_{1/2} = 10(5)$ r	ms, $BR_p = 100\%$			
$E_p(\text{c.m.})$	$E_p(\text{lab})$		$I_p(abs)$	$\mathbf{J}_f^{\pi}$	E _{daughter} ( ¹¹⁶ Ba)	coincide	nt γ-rays	
0.941(10)	0.933(10)	1	97.4(13)%	$0^+$	0.0			
* All valu	ues from [2001So02]	, transition r	not observed in [201]	1Li28].				
Table 8         direct proton 6	emission from ¹²¹ Pr*	$J^{\pi} = (3/2), T$	$T_{1/2} = 10^{+6}_{-3} \text{ ms}, BR_{1/2}$	$_{p} \approx 100\%.$				
$E_{\rm r}(\rm c.m.)$	E (lab)		I (abs)	$I^{\pi}_{c}$	$E_{daughter}(^{120}\mathrm{TCe})$	coincide	at M roug	
<b>2</b> <i>p</i> ( <b>em</b> )	$L_p(1ab)$		1p(003)	J J	Luuugmer ( 100)		It y-rays	

* All values from [2005Ro19].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +2 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
⁹⁶ Pd	$0^+$	122(2) s	3 504(11)	-0.015(10)		-6 603(6)	0.318(5)	[1982Kn15]
¹⁰⁰ Cd	$0^{+}$	49.1(5) s	3.943(5)	0.699(5)		-5.598(12)	3.068(10)	[1989Rv02]
¹⁰⁴ Sn	$0^+$	21(1) s	4.556(8)	1.736(6)		-3.958(10)	4.086(8)	[1985Ra19]
¹⁰⁸ Te	$0^+$	2.1(1) s	6.664(8)	5.442(8)	2.4(10)%	0.248(13)	7.976(8)	[1979Sc22, 2019Au02, 2019Xi06, 1994Pa11,
								1993HeZS, 1985Ti02, 1965Ma12]
¹¹² Xe	$0^+$	2.7(8) s	7.037(13)	6.272(10)		2.846(10)	9.940(90)	[1979Sc22, 1994Pa11, 1978Ro19]
¹¹⁶ Ba	$0^+$	1.3(2) s	7.66(22)#	6.99(20)#	3(1)%	3.68(20)#	10.06(20)#	[1997Ja12]
¹²⁰ Ce	$0^+$		7.84(58)#	7.57(54)#		4.10(50)#	9.89(51)#	
¹²⁴ Nd	$0^+$		8.32(64)#	8.17(58)#		5.13(58)#	10.32(58)#	
¹²⁸ Sm	$0^+$		9.07(58)#	9.47(58)#		6.59(54)#	11.58(64)#	

#### Table 2

Particle emission from the even-Z,  $T_z = +2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$BR_{1p}$	$S_{2p}$	Qα	BRα	Experimental
06- 4						
⁹⁰ Pd	5.132(6)		8.178(5)	-4.307(5)		
¹⁰⁰ Cd	4.771(6)		7.452(5)	-0.436(5)		
¹⁰⁴ Sn	4.284(11)		6.545(6)	0.143(6)		
¹⁰⁸ Te	2.417(7)		3.006(7)	3.445(4)*	49(4)%	[1994Pa11, 1991He21, 1993HeZS, 1981Sc17]
¹¹² Xe	2.362(10)		2.374(11)	3.330(6)	$0.8^{+1.1}_{-0.5}$ %	[1994Pa11, 1978Ro19, 1992HeZU, 1981Sc17]
¹¹⁶ Ba	1.97(23)#		1.87(20)#	3.22(30)#	015	
¹²⁰ Ce	2.00(58)#		2.11(54)#	2.23(54)#		
¹²⁴ Nd	1.89(64)#		1.53(64)#	2.48(71)#		
¹²⁸ Sm	1.13(64)#		0.35(58)#	3.26(71)#		

* From  $\alpha$  decay to ground state of ¹⁰⁴Sn [1991He21], 3.420(8) in [2021Wa16].

#### Table 3

direct  $\alpha$  emission from ¹⁰⁸Te, J^{$\pi$} = 0⁺, T_{1/2} = 2.1(1) s^{*}, BR_{$\alpha$} =49(4) %^{**}.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{104}\mathrm{Sn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
3.445(4)	3.318(4)***	100%	49(4) %**	$0^+$	0.0		1.6315(80)	1.50(14)
* [19795 ** [1994 *** [199	Sc22]. IPa11]. 01He21].							
Table 4 direct $\alpha$ emis	ssion from ¹¹² Xe*, J ^π	$T = 0^+, T_{1/2} = 2$	2.7(8) s**, $BR_{\alpha} = 0.1$	$8^{+1.1}_{-0.5}$ %.				

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{108}\text{Te})$	coincident γ-rays	R ₀ (fm)	HF
3.335(7)	3.216(7)	100%	$0.8^{+1.1}_{-0.5}~\%$	$0^+$	0.0		1.6671(75)	$2^{+4}_{-1}$

* All Values from [1994Pa11], except where noted.

** [1979Sc22].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +2 nuclei.

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z$ = +2 nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein. $J^{\pi}$ values for 66 Ga. 70 As. 74 Br. 78 Rb. 82 Y. 86 Nb 90 Tc. are taken from ENSDF.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta\alpha}$	Experimental
((					·			·	
66Ga	$0^+$	9.57(6) h	5.1755(8)	-3.7490(12)		-11.203(1)	0.598(1)		[1956Ru45]
⁷⁰ As	$4^{+}$	52.5(3) m	6.2281(16)	-2.295(2)		-8.905(2)	2.140(2)		[1968Bo40]
⁷⁴ Br	$(0^{-})$	11.5(1) m	6.925(6)	-1.624(7)		-7.280(6)	2.849(6)		[1975Sc07]
⁷⁸ Rb	$0^+$	17.66(3) m	7.243(3)	-0.990(4)		-6.261(3)	2.853(3)		[1981Ba40]
⁸² Y	$1^{+}$	8.3(2) s	7.946(8)	0.104(7)		-4.749(5)	3.689(5)		[1998Oi02]
⁸⁶ Nb	(6+)	88(1) s	8.835(7)	1.419(20)		-3.062(5)	4.451(8)		[1985Wa10]
⁹⁰ Tc	$(8^+)$	49.2(4) s	9.448(4)	2.612(24)		-1.674(5)	4.819(4)		[1981Ox01]
⁹⁴ Rh	$(4^{+})$	70.6(6) s	9.676(5)	3.410(4)	1.8(5)%	-0.677(3)	4.840(4)		[1982Ku15]
⁹⁸ Ag	(6+)	47.5(3) s	8.250(30)	2.240(50)	0.0011(5)%	-1.568(30)	7.089(30)		[1996He25, 1997Ra22,
U									1982Ku15]
¹⁰² In	(6 ⁺ )	23.3(1) s	8.965(5)	3.351(7)	0.0093(13)%	-0.060(19)	8.201(7)		[1995Sz01]
¹⁰⁶ Sb	$(1^+, 2^+)$	0.6(2) s	10.880(9)	5.878(13)		2.917(7)	10.76(7)		[2005So06]
$^{110}I$	$(1^+)$	664(24) ms	11.760(60)	8.490(60)	11(3)%	7.022(60)	14.459(60)	1.1(3)%	[1977Ki11, 1981Sc17,
									1994Pa11, 1985Ti02]
114Cs	$(1^{+})$	0.57(2) s	12.400(90)	9.140(90)	8.7(13)%	8.300(90)	15.115(90)	0.16(6)%	[1985Ti02, 1978Ro19]
¹¹⁸ La			12.58(36)#	9.58(31)#		8.85(30)#	15.04(30)#		
¹²² Pr			13.09(64)#	10.12(58)#		9.53(58)#	15.00(54)#		
¹²⁶ Pm			13.63(5)#	11.03(58)#		10.59(58)#	15.70(64)#		
¹³⁰ Eu		$0.90^{+0.49}_{-0.29} \mathrm{~ms}$	14.19(67)#	12.38(62)#		12.44(58)#	17.45(62)#		[2004Da04]

### Table 2

Particle emission from the odd-Z,  $T_z = +2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	S _p	$BR_{1p}$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
⁶⁶ Ga	5.101(1)		12.877(1)	-3.361(1)		
⁷⁰ As	7.781(1)		17.921(2)	-5.077(1)		
⁷⁴ Br	4.350(9)		11.636(7)	-3.379(6)		
⁷⁸ Rb	4.055(4)		11.224(10)	-4.072(7)		
⁸² Y	3.825(6)		10.467(6)	-3.554(6)		
⁸⁶ Nb	3.248(8)		9.818(7)	-3.495(8)		
⁹⁰ Tc	2.999(4)		9.130(60)	-4.015(6)		
⁹⁴ Rh	2.980(4)		8.560(5)	-4.608(4)		
⁹⁸ Ag	2.550(30)		7.960(30)	-2.580(30)		
¹⁰² In	2.147(5)		7.135(7)	-0.050(30)		
¹⁰⁶ Sb	0.424(8)		4.869(9)	1.797(9)		
$^{110}I$	0.040(60)		2.600(50)	3.536(10)*	17(4)%	[1981Sc17, 1991He21, 1978Ro19, 1994Pa11, 1985Ti02]
¹¹⁴ Cs	-0.230(90)		2.200(90)	3.360(60)	0.018(6)%	[1994Pa11, 1985Ti02, 1981Sc17, 1980Ro04, 1978Ro19, 1996He25]
¹¹⁸ La	-0.55(39)#		2.16(32)#	2.64(31)#		
¹²² Pr	-0.62(64)#		1.79(58)#	2.42(58)#		
¹²⁶ Pm	-1.03(64)#		1.18(64)#	2.610(71)#		
¹³⁰ Eu	-1.028(15)**	100%	-0.13(62)#	3.81(74)#		[ <b>2004Da04</b> , 2003SeZZ, 2002Ma61]

* From  $\alpha$  decay to ground state of ¹⁰⁶Sb [1991He21, 1978Ro19], 3.580(50) in [2021Wa16]. ** From p emission to the ground state of ¹²⁹Sm [2004Da04], -1.53(20)# in [2021Wa16].

#### Table 3

direct  $\alpha$  emission from ¹¹⁰I, J^{$\pi$} = (1⁺), T_{1/2} = 664(24) ms^{*}, BR_{$\alpha$} = 17(4)%^{**}.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{106}\mathrm{Sb})$	coincident $\gamma$ -rays
3.536(10)	3.447(10)***	100%	17(4)%**	$(1^+, 2^+)$	0.0	

*Weighted average of 0.69(4) s [1977Ki11] and 0.65(3) s [1981Sc17].

** [1981Sc17]

*** Weighted average of 3.457(10) [1991He21], and 3.424(15) [1978Ro19].

direct $\alpha$ emission	h from ¹¹⁴ Cs, $J^{\pi} = (1^+)$ ,	$T_{1/2} = 0.57(2) s^*, BR_{\alpha} =$	0.018(6)%*			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{110}\mathrm{I})$	coincident γ-rays
3.351(30)**	3.233(30)	100%	0.018(6)%***	(1 ⁺ )	0.0	
* [1978Ro19 ** Weighted *** [1994Pa	9].   average of 3.239(30) [1  11]	981Sc17], and 3.226(30)	MeV [1980Ro04].			
<b>Table 5</b> $\beta$ -p emission from	m ¹¹⁴ Cs*, $BR_{\beta p} = 8.7(1$	3)%.				
$E_p(\text{c.m.})$	$I_p(rel)$	$I_p(abs)$	$E_{emitter}$ ( ¹¹⁴ Xe)	Edaughter	r( ¹¹³ I) co	incident γ-rays
	14.4(43)% 11.7(1.2)% 7.5(8)% 3.2(8)% 3.9(10)%	1.25(19)% 1.02(15)% 0.65(10)% 0.28(14)% 0.34(5)%			0.0 0. 0.4 0.4 0.4	0307(5) 121.2(5) 2388(5) 4004(5) 4035(5)
* All values	from [1985Ti02].					
<b>Table 6</b> $\beta$ - $\alpha$ emission from $\beta$ - $\alpha$	om ¹¹⁴ Cs*, $BR_{\beta p} = 0.16$	(6)%.				
$E_{\alpha}(c.m.)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$E_{emitter}$ ( ¹¹⁴ Xe)	$E_{daughter}($	¹¹⁰ Te) co	incident γ-rays
	17(8)%	0.027(10)%		0.6572(3)	0.0	6572(3)
* All values	from [1985Ti02].					
Table 7     direct proton emi	ssion from ¹³⁰ Eu*, J ^{$\pi$} =	$T_{1/2} = 0.90^{+0.49}_{-0.29}$ ms, <i>BR</i>	$_{p} = 100\%.$			
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(abs)$	${\sf J}_f^\pi$	i	$E_{daughter}(^{129}\mathrm{Sm})$	coincident $\gamma$ -rays
1.028(15)	1.020(15)	100%	(1/2 ⁺ , 3/2 ⁺ )	(	).0	
*All values f	from [2004Da04].					

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Fig. 1: Known experimental values for heavy particle emission of the even-Z,  $T_z = +5/2$  nuclei.

Last updated 3/21/23

Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +5/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{$\pi$} values for ⁸⁵Zr, ⁸⁹Mo, ⁹³Ru, ⁸¹Y, ⁹⁷Pd, ¹⁰¹Cd, ⁹³Rh, ¹²⁵Nd, ¹²⁹Sm are taken from ENSDF.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\epsilon 2p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta\alpha}$	Experimental
857r	$(7/2^{+})$	7.85(4) m	4 667(20)	0.185(7)		-8 682(6)	-0.1/3(8)		[ <b>1072Tu07</b> ]
89Ma	$(1/2^{+})$	1.09(14) m	5.611(24)	1.225(7)		-0.002(0) 6 575(4)	-0.1+3(0)		[1972]u07]
93 D.u	$(9/2^+)$	1.96(14) III 50 7(6) a	5.011(24)	1.323(7)		-0.373(4)	0.402(19)		[1965De12]
97 D 1	$(9/2^+)$	39.7(0) s	0.589(2)	2.505(2)		-3.137(4)	0.984(24)		[1970De57]
101 C 1	(5/2 ')	3.1(1) m	4.790(40)	0.986(5)		-6.363(7)	3.375(5)		[1980G011]
Cd	(5/2+)	1.37(5) m	5.498(5)	2.087(18)		-4.830(19)	4.339(40)		[1980Ka05]
¹⁰⁵ Sn	$(5/2^+)$	32.7(5) s	6.303(11)	3.341(4)	0.011(4)%	-3.113(6)	5.571(6)		[2006Ka44]
¹⁰⁹ Te	$(5/2^+)$	4.3(1) s	8.536(7)	7.066(7)	9.4(31)%	1.274(11)	9.501(11)	< 0.00443%	[1985Ti02, 2002Re28,
									1977Bo15, 1977Ki11,
									1967Ka01, 2019Xi06,
									1981Sc17, 1979Sc22,
									1977Ki11, 1973Bo20]
¹¹³ Xe	$(5/2^+)$	2.74(8) s	8.916(11)	8.075(11)	7(4)%	4.055(11)	11.622(9)	0.007(4)%	[1985Ti02, 2005Ja10,
									2013Pr01, 1981Sc17,
									1979Sc22, 1978Ro19]
¹¹⁷ Ba	(3/2)	1.75(7) s	9.04(26)	8.30(25)	13(3)%	4.30(25)	11.24(25)	0.011-0.038%	[1997Ja12, 1985Ti02,
									1978Bo20]
¹²¹ Ce	$5/2^{+}$	1.1(1) s	9.50(50)#	8.91(50)#	$\approx 1\%$	5.04(40)#	11.38(40)#		[2005Xu04, 1997Li19.
									2002XuZZ1
¹²⁵ Nd	(5/2)	0.60(15) s	10.00(50)#	9.56(50)#	obs	6.00(45)#	11.70(50)#		[ <b>1999Xu05</b> 2005Xu04]
¹²⁹ Sm	$(1/2^+ 3/2^+)$	0.55(10) s	10.85(58)#	10.91(54)#	obs	7 63(54)#	13 32(58)#		[ <b>1999Xu05</b> , 2005Xu04]
¹³³ Gd	(112,512)	0.00(10)3	11.18(58)#	11.79(58)#	005	9.13(54)#	14.70(58)#		[177711000, 200571004]

# Table 2

Particle emission from the even-Z,  $T_z = +5/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
857.	( 5780(5)	10.05((0)	4.072(7)		
89 <b>N</b>	(120(0))	10.930(9)	-4.072(7)		
⁵⁵ MO	0.130(00)	10.240(0)	-4.203(8)		
⁹⁵ Ru	5.580(4)	9.586(7)	-4.627(4)		
⁹⁷ Pd	5.407(11)	8.926(11)	-3.014(5)		
¹⁰¹ Cd	4.987(5)	8.32(5)	-0.456(5)		
¹⁰⁵ Sn	4.444(7)	7.264(4)	0.074(4)		
¹⁰⁹ Te	2.559(7)	3.781(7)	3.198(6)	3.9(13)%	[1985Ti02, 1981Sc17, 1979Sc22]
¹¹³ Xe	2.429(12)	3.194(9)	3.087(8)	$\approx 0.011\%$	[1985Ti02]
¹¹⁷ Ba	2.70(27)	8.30(25)	2.32(25)		[1997Ja12, 1985Ti02]
¹²¹ Ce	2.41(50)#	8.91(50)#	2.34(47)#		
¹²⁵ Nd	2.21(57)#	2.36(50)#	2.22(57)#		
¹²⁹ Sm	1.40(58)#	1.00(58)#	3.32(64)#		
¹³³ Gd	1.15(64)#	0.36(64)#	3.85(71)#		

# Table 3

direct  $\alpha$  emission from ¹⁰⁹Te,  $J^{\pi} = (5/2^+)$ ,  $T_{1/2} = 4.3(1) \text{ s}^*$ ,  $BR_{\alpha} = 3.9(13)\%$ .**

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{105}\mathrm{Sn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
3.197(15)	3.080(15)***	100%	3.9(13)%	(5/2+)	0.0		1.650(60)	$0.8^{+1.2}_{-0.5}$

* Weighted average of 4.2(2) s [1967Ka01], 4.9(4) s [1977Bo15], 4.1(2) s [1977Ki11], and 4.6(3) s [2002Re28].

** From 1981Sc17].

*** From [1979Sc22].

# Table 4

$\frac{\text{direct } \alpha \text{ emiss}}{\alpha \text{ emiss}}$	rect $\alpha$ emission from ¹¹⁵ Xe*, J ^{$\pi$} = (5/2 ⁺ ), T _{1/2} = 2.74(8) s, BR _{$\alpha$} = $\approx$ 0.011%.													
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	$E_{daughter}(^{109}\text{Te})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF						
3.095(16)	2.985(15)	100%	≈0.011%	(5/2+)	0.0		1.68(12)	$3^{+11}_{-2}$						

* All values from [1985Ti02].

# Table 5

 $\beta$ -p emission from ¹¹³Xe*,  $BR_{\beta p} = 7(4)\%$ .

$E_p(\text{c.m.})$	$I_p(\text{rel})$	$E_{emitter}$ ( ¹¹³ I)	$E_{daughter}(^{112}\text{Te})$	coincident $\gamma$ -rays	
	32(2)%		0.0		
	60(3)%		0.689	0.689	
	pprox 4%		1.476	0.787, 0.689	
	pprox 4%		1.484	0.794, 0.689	

* All values from [2005Ja10].

## Table 6

 $\beta$ -p emission from ¹¹⁷Ba*, T_{1/2} = 1.75(7) s,  $BR_{\beta p} = 13(3)\%$ .

$E_p(\text{c.m.})$	$I_p(\text{rel})$	$E_{emitter}$ ( ¹¹⁷ I)	$E_{daughter}(^{116}\mathrm{Xe})$	coincident γ-rays
	51(4))0		0.0	
	51(4))%		0.0	
	41(4)%		0.394	0.394
	8(2)%		1.016	0.622. 0.394

* All values from [1985Ti02].

# Table 7

 $\beta$ -p emission from ¹²¹Ce*, T_{1/2} = 1.1(1) s**,  $BR_{\beta p} = \approx 1\%$ .

$E_p(c.m.)$	$I_p(\text{rel})$	$E_{emitter}$ ( ¹²¹ La)	$E_{daughter}(^{120}\mathrm{Ba})$	coincident $\gamma$ -rays	
2.5-6.0 2.5-6.0 2.5-6.0	80%		0.0 0.1858 0.5438	 0.1858 0.3578, 0.1858	

* All values from [2005Xu04] except where noted.

** [1997Li19]

#### Table 8

 $\beta$ -p emission from ¹²⁵Nd*, T_{1/2} = 0.60(15) s, *BR*_{$\beta p$} = obs.

$E_p(c.m.)$	$I_p(rel)$	$E_{emitter}$ ( ¹²⁵ Pr)	$E_{daughter}(^{124}\text{Ce})$	coincident γ-rays	
2.5-6.5 2.5-6.5 2.5-6.5	100% 26(6)% <3%		0.1419 0.4478 0.8919	0.1419 0.3059, 0.1419 0.4441, 0.3059, 0.1419	

* All values from [1999Xu05].

# Table 9

β-p emission from ¹²⁹ Sm*, $T_{1/2} = 0.55(10)$ s, $BR_{\beta p} = \text{obs.}$									
$E_p(\text{c.m.})$	$I_p(\text{rel})$	$E_{emitter}$ ( ¹²⁹ Pm)	$E_{daughter}(^{128}\text{Nd})$	coincident γ-rays					
2.0-6.0	100%		0.1337	0.1337					
2.0-6.0	$<\!10\%$		0.44245	0.2908, 0.1337					

* All values from [1999Xu05].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +5/2 nuclei.

Last updated 12/11/23

Table 1
Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +5/2$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	$BR_{\varepsilon\alpha}$	Experimental
07									
87Nb	$(1/2)^{-}$	3.7(1) m	5.473(8)	-1.880(16)		-7.349(8)	0.499(10)		[1974Vo03]
⁹¹ Tc	$(9/2)^+$	3.14(2) m	6.222(7)	-0.614(4)		-5.887(4)	0.953(5)		[1976De37]
⁹⁵ Rh	9/2+	5.02(10) m	5.117(10)	-1.471(6)		-6.112(4)	1.443(7)		[1975We03]
⁹⁹ Ag	$(9/2)^+$	124(3) s	5.470(8)	-0.826(13)		-5.169(7)	4.322(12)		[1981Hu03]
¹⁰³ In	$(9/2^+)$	65(7) s	6.019(9)	0.325(12)		-3.778(10)	5.126(10)		[1978Lh01]
¹⁰⁷ Sb	5/2+	4.0(2) s	7.859(7)	2.666(13)		-0.897(4)	7.574(4)		[2002Re14]
$^{111}I$		2.5(2) s	8.634(8)	5.207(8)		3.098(9)	11.133(7)		[1977Ki11]
115Cs		1.03(10) s	8.96(10)#	5.65(10)#	0.2(1)%	4.07(10)#	11.46(10)#	0.010(5)%	[2023DaXX, 2020DaZX, 1978Da07]
¹¹⁹ La			9.57(36)#	5.10(30)#		4.59(30)#	11.21(30)#		
¹²³ Pr			10.06(50)#	7.02(50)#		5.93(42)#	11.94(45)#		
¹²⁷ Pm			10.60(50)#	7.73(45)#		6.77(45)#	12.56(50)#		
¹³¹ Eu	$3/2^{+}$	17.8(19) ms	10.82(57)#	8.72(45)#		8.34(45)#	14.03(50)#		[1999So17]
¹³⁵ Tb	$(7/2^{-})$	$0.94^{+0.33}_{-0.22}$ ms	11.20(57)#	9.46(50)#		9.60(50)#	14.81(57)#		[2004Wo07]

Particle emission from the odd-Z,  $T_z = +5/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$BR_{1p}$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
⁸⁷ Nb	3.194(8)		10.610(20)	-4.094(20)		
⁹¹ Tc	3.103(4)		9.939(24)	-4.537(7)		
⁹⁵ Rh	3.046(5)		9.312(4)	-4.779(5)		
⁹⁹ Ag	2.680(8)		8.690(40)	-0.797(7)		
¹⁰³ In	2.262(9)		7.876(10)	-0.345(11)		
¹⁰⁷ Sb	0.589(7)		5.591(11)	1.554(10)		
$^{111}I$	0.013(8)		4.192(12)	3.270(10)*	0.088%	[1979Sc22, 1978Ro19, 1977Ki11, 1993HaZS, 1981Sc17]
¹¹⁵ Cs	-0.10(10)#		3.16(10)#	2.83(10)#		
¹¹⁹ La	0.11(36)#		3.10(31)#	2.26(32)#		
¹²³ Pr	-0.36(57)#		2.62(50)#	2.37(50)#		
¹²⁷ Pm	-0.78(50)#		1.82(50)#	2.50(57)#		
¹³¹ Eu	-0.947(5)	89(9)%	0.86(50)#	3.42(57)#		[1999So17, 1998Da03, 2000SeZX]
¹³⁵ Tb	-1.188(7)	$\approx 100\%$	0.40(50)#	3.99(57)#		[2004Wo07, 2005Se21, 2003SeZZ, 2002DaZV]

* Deduced from  $\alpha$ -decay; 2.957(12) MeV in [2021Wa16].

## Table 3

direct $\alpha$ emission from ¹¹¹ I*, J ^{$\pi$} = , T _{1/2} = 2.5(2) s**, BR _{$\alpha$} = $\approx$ 0.088%.									
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{107}\mathrm{Sb})$	coincident y-rays	$R_0$ (fm)	HF	

0

 $5/2^{+}$ 

0.088%

* All values from [1979Sc22], except where noted.

3.152(10)

** [1977Ki11]

# Table 4

3.270(10)

direct p emission from ¹³¹Eu*,  $T_{1/2} = 17.8(19)$  ms,  $BR_p = 89(9)\%$ .

100%

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(abs)$	$E_{daughter}(^{130}\mathrm{Sm})$	coincident $\gamma$ -rays
0.817(7)	0.811(7)	32(6)%	28(7)%	0.212	0.212
0.939(7)	0.932(7)	100(6)%	89(11)%	0.0	

 $20^{+5}_{-2}$ 

1.655(91)

* All values from [1999So17].

# Table 5 direct p emission from ¹³⁵Tb*, $T_{1/2} = 0.94^{+0.33}_{-0.22}$ ms, $BR_p = \approx 100\%$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(abs)$	$E_{daughter}(^{134}\text{Gd})$	coincident $\gamma$ -rays
1.188(7)	1.179(7)	100%	pprox 100%	0.0	

* All values from [2004Wo07].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +3 nuclei.

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +3$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
⁹⁸ Pd	$0^+$	17.7(4) m	1.854(13)	-2.489(5)		-10.077(7)	0.412(6)	[1972Ga12]
¹⁰² Cd	$0^+$	5.5(5) m	2.587(8)	-1.517(5)		-8.647(18)	1.091(12)	[1969Ha03]
¹⁰⁶ Sn	$0^+$	115(5) s	3.254(13)	-0.309(5)		-6.816(6)	2.468(10)	[1988Ba10]
¹¹⁰ Te	$0^+$	18.4(8) s	5.220(9)	3.111(10)		5.953(14)	5.953(14)	[1977Ki11]
¹¹⁴ Xe	$0^+$	10.0(4) s	5.553(23)	3.970(30)		7.939(13)	7.939(13)	[1977Ki11]
¹¹⁸ Ba	$0^{+}$	5.5(2) s	6.21(20)#	4.70(20)#		8.01(20)#	8.01(20)#	[1997Ja12]
¹²² Ce			6.67(50)#	5.58(43)#		8.1140)#	8.11(40)#	
¹²⁶ Nd	$0^+$	> 200 ns	6.94(36)#	5.99(36)#		8.74(42)#	8.74(42)#	[2000So11]
¹³⁰ Sm			7.77(45)#	7.39(45)#		10.20(45)#	10.20(44)#	
¹³⁴ Gd			8.27(50)#	8.41(50)#		11.52(45)#	11.52(44)#	
¹³⁸ Dy			8.67(59)#	8.99(59)#		12.45(58)#	12.45(58)#	
¹⁴² Er			9.32(64)#	10.16(58)#		13.25(58)#	13.25(58)#	

Table 2

Particle emission from the even-Z,  $T_z = +3$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
08- 4					
²⁰ Pd	6.012(36)	9.819(5)	-1.162(6)		
¹⁰² Cd	5.614(5)	9.025(18)	-0.764(5)		
¹⁰⁶ Sn	5.002(11)	7.963(5)	-0.119(5)		
¹¹⁰ Te	3.268(8)	4.738(8)	2.723(15)*	$\approx 0.00076\%$	[1981Sc17, 1977Ki11, 2000De11]
¹¹⁴ Xe	3.255(14)	4.096(14)	2.719(13)		
¹¹⁸ Ba	3.00(21)#	3.73(20)#	2.46(20)#		
¹²² Ce	2.97(50)#	3.56(50)#	1.90(45)#		
¹²⁶ Nd	2.60(42)#	3.04(42)#	2.07(50)#		
¹³⁰ Sm	1.81(50)#	1.75(45)#	3.26(50)#		
¹³⁴ Gd	1.58(50)#	0.97(50)#	3.75(57)#		
¹³⁸ Dy	1.25(64)#	0.42(59)#	4.17(64)#		
¹⁴² Er	0.86(64)#	-0.32(64)#	4.58(71)#		

* Deduced from  $\alpha$  energy, 2.699(8) MeV in [2021Wa16].

# Table 3

direct	$\alpha$ emission	from 110	⁾ Te*, J ^{$\pi$}	$= 0^+,$	$T_{1/2} =$	18.4(8) s,	$BR_{\alpha} = \approx 0.00076\%.$
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{106}\mathrm{Sn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
2.723(15)	2.624(15)	0.00076%	$0^+$	0.0		1.64(11)	≈2.5	

* All values from [1981Sc17].

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +3$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein. $J^{\pi}$ values for 80 Rb, 84 Y, 88 Nb, 92 Tc, 96 Rh, 100 Ag, 104 In, 108 Sb, are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta\alpha}$	Experimental
8051			22.4/7	5 54 6 (2)	2 20 ( (2)		0.500(0)	0.650(0)		54000 H 1001
^{oo} Rb		1+	33.4(7) s	5.718(2)	-3.396(2)		-9.728(2)	0.652(2)		[1993Al03]
⁸⁴ Y		$(6^{+})$	39(1) m	6.755(4)	-2.113(5)		-7.880(4)	1.574(4)		[1981DeZD]
⁸⁸ Nb		$(8^+)$	14.56(11) m	7.46(60)	-0.442(58)		-6.225(60)	2.053(58)		[2009Ga02]
⁹² Tc		$(8^{+})$	4.5(1) m	7.883(3)	0.423(4)		-4.781(3)	2.278(6)		[1985Be12]
⁹⁶ Rh		$6^+$	9.9(1) m	6.393(10)	-0.955(11)		-5.852(10)	4.696(10)		[1975Gu01]
¹⁰⁰ Ag		$(5)^{+}$	2.0(1) m	7.075(18)	0.158(20)		-4.491(8)	5.517(5)		[1980Ha20]
¹⁰⁴ In		(5,6)	1.80(3) m	7.786(6)	1.331(7)		-2.858(6)	6.605(19)		[1995Sz01]
¹⁰⁸ Sb		$(4^{+})$	7.6(3) s	9.625(8)	3.832(11)		0.109(5)	9.098(6)		[1997Sh13]
$^{112}I$		$(1^+)$	3.42(11)s	10.504(13)	6.484(14)	0.88(10)%	4.201(17)	12.582(11)	0.104(12)%	[1985Ti02]
¹¹⁶ Cs		$(1^+)$	0.70(4) s	11.00(10)#	7.01(10)#	0.28(7)%**	5.27(10)#	13.10(10)#	0.049(25)%**	[1977Bo28 1985Ti02
00		(1)	01/0(1)0	11100(10)#	,101(10)	0120(1)/0	0.27(10)	10110(10)#	01017(20)/0	1978Da07 1978Ka17
										1976Bo36, 1975Bo111
^{116m} Cs	0.10(6)*		3.85(13) s	11.08(10)#	7.11(10)#	0.66(13)%**	5.37(10)#	13.18(12)#	< 0.0033%**	[ <b>1977Bo28</b> , 1985Ti02,
										1978Da07, 1978Ka171
¹²⁰ La			2.8(2) s	11.32(42)#	7.45(30)#	obs	5.93(30)#	13.05(30)#		[1984Ni03]
¹²⁴ Pr			1.2(2) s	11.77(50)#	8.21(45)#	obs	6.88(40)#			[1986Wi15]
¹²⁸ Pm			1.0(3) s	12.31(36#)	9.04(36)#	$\approx 6\%$	8.02(30)#	13.31(50)#	14.27(42)#	[2005Xu04, 1999Xu05]
¹³² Eu				12.94(50)#	10.28(45)#		9.82(40)#	15.91(45)#		
¹³⁶ Tb				13.19(58)#	10.96(54)#		10.90(54)#	16.82(58)#		
¹⁴⁰ Ho			6(3) ms	13.51(64)#	11.52(58)#		11.76(54)#	17.35(58)#		[1999Rv04]
¹⁴⁴ Tm		$9^{+***}$	$1.9^{+1.2}_{-0.5} \mu s$	14.45(45)#	12.60(50)#		18.25(57)#	13.38(83)#		[2005Gr32]

* Excitation energy is unknown, Estimated from systematics to be 100(60) keV [2003Au02].

** There are large discrepancies between the three studies [1985Ti02], [1978Da07] and [1977Bo28]. The  $\beta$ -p to  $\beta$ - $\alpha$  ratios reported for the 3.85 s isomer are 200(80), 47(20 and > 200 respectively. For the 0.7 s isomer, the ratio is 16(4) [1985Ti02], 4.7(18) [1977Bo28], and no value is reported by [1978Da07]. This is somewhat consistent if the value reported by [1978Da07] arises from a combination of the 0.7 and 3.8 s isomers. Individual branching ratios for  $\beta$ -p and  $\beta$ - $\alpha$  are not reported by [1985Ti02].

*** [2022Si09]

### Table 2

Particle separation and emission from the odd-Z,  $T_z = +3$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$BR_{1p}$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
⁸⁰ Rb	5.022(4)		13.301(4)	-4.311(10)		
⁸⁴ Y	4.386(8)		12.285(5)	-4.144(5)		
⁸⁸ Nb	4.113(58)		11.466(60)	-4.702(58)		
⁹² Tc	4.006(7)		10.842(5)	-5.179(58)		
⁹⁶ Rh	3.519(14)		10.107(11)	-3.187(10)		
¹⁰⁰ Ag	3.244(7)		9.541(13)	-0.875(11)		
¹⁰⁴ In	2.820(6)		8.514(10)	-0.470(8)		
¹⁰⁸ Sb	1.222(8)		6.415(13)	1.312(8)		
$^{112}I$	0.765(12)		4.192(12)	2.957(12)	≈0.0012%	[ <b>1985Ti02</b> , 1978Ro19]
¹¹⁶ Cs	0.68(10)#		3.98(18)#	2.60(10)#		[1985Ti02, 1978Da07, 1977Bo28, 1978Ka17]
^{116m} Cs	0.60(12)#		3.90(33)#	2.70(12)#		[1985Ti02, 1978Da07, 1977Bo28,1978Ka17]
¹²⁰ La	0.27(36)#		3.74(30)#	2.05(32)#		
¹²⁴ Pr	0.15(50)#		3.19(50)#	1.99(50)#		
¹²⁸ Pm	-0.40(42)#		2.47(36)#	2.51(50)#		
¹³² Eu	-0.79(57)#		1.310(45)#	3.59(50)#		
¹³⁶ Tb	-1.06(64)#		0.68(58)#	3.88(64)#		
¹⁴⁰ Ho	-1.094(10)	100%	0.30(58)#	4.16(71)#		[1999Ry04, 1999BaZR, 1999RyZZ, 1998BaZU]
¹⁴⁴ Tm	-1.712(16)	100%	-0.51(57)#	4.73(64)#		[ <b>2005Gr32</b> , 2005Bi24]

direct $\alpha$ emission	a from ¹¹² I*, $J^{\pi} = (1^+), T^{\pi} = (1^+), T^{$	$\Gamma_{1/2} = 3.42(11)s^{**}, BR_{\alpha}$	=≈0.0012%***.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	Edaughte	r( ¹³⁹ Dy)	coincide	nt γ-rays
2.987(30)	2.880(30)	≈0.0012%***	(5/2+)	0.0			
* All values ** [1985Ti0] *** [1978Ro	from [1981Sc17], excep 2]. 019].	ot where noted.					
Table 4     direct p emission	from ¹⁴⁰ Ho*, $J^{\pi} = T_{1/2}$	$= 6(3) \text{ ms}, BR_p = 100\%.$					
$E_p(\text{c.m.})$	$E_p(lab)$	$I_p(\text{rel})$	$I_p(abs)$	${\sf J}_f^{\pi}$	$E_{daughter}(^{139}\mathrm{I}$	Dy)	coincident $\gamma$ -rays
1.094(10)	1.086(10)	100%	100%	(7/2+)	0.0		
* All values	from [1999Ry04].						
Table 5     direct p emission	from ¹⁴⁴ Tm*, $J^{\pi} = 9^+$ ,	$T_{1/2} = 1.9 {+1.2 \atop -0.5} \mu s, BR_p =$	= 100%.				
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(rel)$	$I_p(absb)$	${f J}_f^{m \pi}$	$E_{daughter}(^{143}$	Er)	coincident γ-rays
1.430(25) 1.700(16)	1.440(25) 1.712(16)	pprox 29% pprox 71%	pprox 29% pprox 71%				

* All values from [2005Gr32].

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Observed and predicted $\beta$ -delayed particle emission from the even-Z, $T_z = +7/2$ nuclei.	Unless otherwise stated, all Q-values are taken from [2021Wa16] or
deduced from values therein. All $J^{\pi}$ values are taken from ENSDF	

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon_P}$	$BR_{\beta p}$	$Q_{\epsilon 2p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta\alpha}$	Experimental
⁹⁵ D.	5/2+	1 64(1) h*	2 564(11)	2222(10)		10,822(10)	0.755(10)		[1069D:02 1070D-22]
99 D 1	5/2	$1.04(1) II^{*}$	2.304(11)	-2.355(10)		-10.825(10)	0.733(10)		[1908F105, 1970B022]
102 m 1	(5/2 )	21.4(2) m	3.402(19)	-1.24/(8)		-9.536(7)	1.414(7)		[1969Ph01]
¹⁰³ Cd	$(5/2^+)$	7.3(1) m	4.151(4)	-0.038(2)		-7.817(6)	2.508(20)		[1969Ha03]
¹⁰⁷ Sn	$(5/2^+)$	2.90(5) m	5.054(11)	1.331(5)		-6.019(7)	3.866(7)		[1976Hs01, 1974Ho17]
¹¹¹ Te	$(5/2)^+$	26.2(6) s	7.249(11)	4.966(15)	obs	-1.676(8)	7.554(12)		[1967Ka01, 2005Sh24,
									1967Bo41, 1967Bo43]
¹¹⁵ Xe	$(5/2^+)$	18(4) s	7.680(30)	5.944(27)	obs	1.182(21)	9.755(15)	0.0003(1)%	[1971Ho07, 1972Ho18]
¹¹⁹ Ba	$(5/2^+)$	5.4(3) s	7.71(20)	6.20(20)	25(2)%	1.27(20)	9.32(20)		[ <b>1975Bo11</b> ,1976Bo36,
									1978Bo20], 1979Ew02
¹²³ Ce	(5/2)	3.8(2) s	8.37(36)#	7.03(30)#	obs	2.24(30)#	9.59(30)#		[1984Ni03, 1988WiZN]
¹²⁷ Nd		1.8(4) s	8.63(36)#	7.62(30)#	obs	3.27(30)#	10.32(36)#		[1987WiZM, 1983Ni05,
									1986Wi15]
¹³¹ Sm		1.2(2) s	9.49(45)#	9.03(40)#	obs	4.92(40)#	13.10(45)#		[1986Wi15, 1987WiZM]
¹³⁵ Gd	$(5/2^+)$	1.1(2) s	9.9(45)#	9.84(45)#	$\approx 18\%$	6.58(40)#	14.02(54)#		[2005Xu04, 1996Xu07]
¹³⁹ Dy	$(7/2^+)$	0.6(2) s	10.43(58)#	10.67(54)#	$\approx 2\%$	7.87(50)#	14.55(50)#		[2005Xu04, 2002XuZZ,
2	. /								1996Xu07]
¹⁴³ Er			10.89(50)#	11.67(83)#		8.80(41)#			-

* Weighted average of 1.65(2) h [1968Pi03] and 1.63(2) h [1970Bo22].

#### Table 2

Particle emission from the even-Z,  $T_z = +7/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental	
⁹⁵ Ru	6.588(10)	11.229(10)	-3.674(11)			
⁹⁹ Pd	6.297(13)	10.640(6)	-1.150(11)			
¹⁰³ Cd	5.694(8)	9.797(5)	-0.894(5)			
¹⁰⁷ Sn	5.193(13)	8.756(5)	-0.286(6)			
¹¹¹ Te	3.427(9)	5.535(10)	2.500(8)			
¹¹⁵ Xe	3.307(23)	4.888(31)	2.506(14)			
¹¹⁹ Ba	3.47(20)	4.98(20)	1.64(20)			
¹²³ Ce	3.03(42)#	4.12(33)#	1.88(36)#			
¹²⁷ Nd	2.88(36)#	3.83(36)#	1.95(42)#			
¹³¹ Sm	2.10(45)#	2.48(45)#	3.21(50)#			
¹³⁵ Gd	1.74(50)#	1.60(50)#	3.61(57)#			
¹³⁹ Dy	1.39(58)#	1.07(58)#	4.12(64)#			
¹⁴³ Er	1.20(56)#	0.36(50)#	4.12(64)#			

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +7/2 nuclei.

Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +7/2$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein. $J^{\pi}$ values for 97 Rh, 101 Ag, 105 In, 109 Sb, 113 I, 117 Cs, 129 Pm are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\epsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
9751		0. <b>12</b> ±	20.0(0) +	2.52(10)	1005000		0.464(25)		
²⁷ Rh		9/2+	30.8(6) s*	3.52(40)	-4.065(36)		-9.464(35)	1.785(35)	[1975P105, 1974Oh07]
¹⁰¹ Ag		$9/2^{+}$	11.2(1) m	4.098(7)	-3.032(19)		-8.287(5)	2.361(6)	[1966Pa14]
¹⁰⁵ In		$9/2^{+}$	5.07(7) m	4.693(10)	-1.813(11)		-6.762(10)	3.367(11)	[1984Ve01]
¹⁰⁹ Sb		$(5/2^+)$	16.67(15) s	6.379(9)	0.580(10)		-3.839(6)	5.658(5)	[1982Jo03]
$^{113}I$		$(5/2^+)$	6.6(2) s	7.228(29)	3.190(20)	≈3.3e-5%	0.241(10)	9.086(11)	[1981Sc17, 1977Ki11]
¹¹⁷ Cs		$(9/2^+)$	8.4(6) s	7.690(60)	3.639(98)		0.992(68)	9.429(68)	[1986Ma41]
¹²¹ La			5.3(2) s	8.56(33)#	4.41(30)#		2.03(30)#	9.57(30)#	[1988Se08]
¹²⁵ Pr			3.3(7) s	8.59(36)#	4.90(31)#		3.01(30)#	10.25(33)#	[1995Os03]
¹²⁹ Pm		$(5/2^{-})$	2.4(9) s	9.2(36)#	5.86(30)#		4.22(30)#	11.05(36)#	[2004Xu05]
¹³³ Eu				10(42)#	7.10(33)#		5.95(30)#	12.71(36)#	
¹³⁷ Tb				10.25(50)#	7.99(45)#		7.31(43)#	13.84(50)#	
¹⁴¹ Ho			4.1(1) ms	11.02(50)#	8.83(90)#		8.69(45)#	14.42(50)#	[2008Ka16]
^{141m} Ho	0.066(12)		7.4(3) μs	11.09(50)#	8.90(90)#		14.49(50)#	8.76(45)#	[2008Ka16]
¹⁴⁵ Tm		$(11/2^{-})$	3.17(20) µs	11.66(28)#	9.74(20)#		10.01(20)#	15.38(36)#	[2007Se06
¹⁴⁹ Lu			$0.45^{+0.17}_{-0.10}\mu{ m s}$	12.32(30)#**	10.47(30)#**		11.02(40)#**	15.81#**	[2022Au01]

* Weighted average of 30.3(9) m [1975Pl05] and 31.1(8) m [1974Oh07].

** Deduced from proton energy and daughter values from [2021Wa16].

### Table 2

Particle separation and  $\beta$ - $\alpha$  emission from the odd-Z,  $T_z = +7/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	Sa	BR _n	S2n	Оa	Experimental
	<i>p</i>	<i>p</i>	~2p	₹u	
⁹⁷ Rh	3.806(35)		11.154(36)	-1.416(35)	
¹⁰¹ Ag	3.411(18)		10.328(20)	-1.162(36)	
¹⁰⁵ In	2.961(10)		9.416(11)	-0.731(11)	
¹⁰⁹ Sb	1.470(8)		7.262(11)	0.965(12)	
$^{113}I$	0.841(12)		4.861(12)	2.707(10)	
¹¹⁷ Cs	0.735(64)		4.733(69)	2.202(63)	
¹²¹ La	0.59(42)#		4.46(30)#	1.88(31)#	
¹²⁵ Pr	0.44(42)#		4.00(36)#	1.70(42)#	
¹²⁹ Pm	-0.06(36)#		3.22(39)#	2.47(42)#	
¹³³ Eu	-0.62(42)#		2.04(36)#	3.52(42)#	
¹³⁷ Tb	-0.83(50)#		1.40(45)#	3.84(60)#	
¹⁴¹ Ho	-1.177(7)	100%	0.81(50)#	4.18(57)#	[1998Da03, 1999Ry04, 2008Ka16, 2007KaZO,
					2005Bi24, 2003BaZZ, 2002Kr04, 2001Se03,
					2000SeZW, 1999BaZR, 1999RyZZ, 1999SeZY]
^{141m} Ho	-1.243(14)	100%	0.74(50)#	4.25(57)#	*
¹⁴⁵ Tm	-1.736(7)	100%	0.11(36)#	4.36(45)#	[2007Se06, 2003Ka04, 2001Ry02, 1998Ba13,
					2007SeZR, 2005Bi24, 2005RoZY, 2005Se26,
					2004SeZW, 2003BaZZ, 2001Ry01, 2001Ry02,
					1999BaZR]
¹⁴⁹ Lu	-1.933(20)	100%	0.388(29)#**	4.15(20)#**	[2022Au01]

* References for  141m Ho are the same as  141 Ho.

** Deduced from proton energy and daughter values from [2021Wa16].

# Table 3

direct p emission from ¹⁴¹Ho*,  $J^{\pi} = T_{1/2} = 4.1(1)$  ms,  $BR_p = 100\%$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(rel)$	$I_p(absb)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{140}\mathrm{Dy})$	coincident $\gamma$ -rays
0.975(10) 1.177(8)	0.968(10) 1.169(8)	0.9(2)% 100%	0.9(2)% 99.1(2)%	$(2^+) \\ 0^+$	0.202(2) 0.0	0.202(2)

* All vaues from [2008Ka16].

Table 4			
direct p emission from ^{141m}	Ho*, $Ex = 66(12)$ keV, J	$\pi = T_{1/2} = 7.4(3) \ \mu s$	$BR_{p} = 100\%$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(rel)$	$I_p(absb)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{140}\mathrm{Dy})$	coincident $\gamma$ -rays
1.037(10)	1.030(10)	$\approx 1\%$	≈1%	$(2^{+})$	0.202(2)	0.202(2)
1.244(9)	1.235(9)	100%	$\approx 99\%$	$0^+$	0.0	

* All values from [2008Ka16].

#### Table 5

lirect p emission from	145 Tm*, J ^{$\pi$} =	$=(11/2^{-}), T_1$	$_{/2} = 3.17(20) \ \mu s^{**}$	$BR_p = 100\%$
------------------------	-----------------------------------------------	--------------------	---------------------------------	----------------

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(absb)$	${f J}_f^{m \pi}$	$E_{daughter}(^{144}\mathrm{Er})$	coincident γ-rays
1.410(10)	1.400(10)	10.6(15)%	9.6(15)%	$2^{+}$	0.330	0.330
1.740(8)	1.728(10)	100%	90.4(15)%	$0^+$	0.0	

* Values from [2003Ka04] except where noted.

** [2007Se06]

#### Table 6

direct p emission fron	$1^{149}$ Lu*, J ^{$\pi$} =	$T_{1/2} = 0.45^{+0.17}_{-0.10}$	$\mu s, BR_p = 100\%.$

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(rel)$	$I_p(absb)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{148}\mathrm{Yb})$	coincident $\gamma$ -rays
1.933(20)	1.920(20)	100%	100%	$0^+$	0.0	

* All values from [2022Au01].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z,  $T_z$  = +4 nuclei.

Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +4$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. All  $J^{\pi}$  values are taken from ENSDE.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental	
108 Sp		$0^+$	10.30(8) m	2.05(10)	-2 369(6)		-9 705(6)	0.622(7)	[1978Hc01]
112Te		$0^+$	20(2) m	4.031(20)	1.082(10)		-5 675(14)	4.127(12)	[1976Wi11]
116Xe		$0^+$	60(2) s	4 37(80)	1.002(10)		-3.128(24)	6 127(22)	[1974Ha10]
¹²⁰ Ba		$\overset{0}{0^+}$	24(2) s	5.00(30)	2.62(30)		-2.50(30)	6.11(31)	[1992Xu04]
¹²⁴ Ce		$0^{+}$	6(2) s	5.34(30)#	3.45(30)#		-1.35(30)#	6.55(30)#	[1978Bo32]
¹²⁸ Nd		$0^{+}$	4(2) s	5.8(20)#	4.16(20)#	obs?*	-0.13(22)#	7.30(21)#	[1983Ni05]
¹³² Sm		$0^+$	4.0(3) s	6.49(34)#	5.34(30)#		1.46(31)#	8.77(30)#	[1989McZU]
¹³⁶ Gd		$0^+$	$\geq 200 \text{ ns}$	7.15(36)#	6.48(34)#		3.10(30)#	10.11(33)#	[2000So11]
¹⁴⁰ Dy		$0^{+}$		7.65(90)#	7.51(45)#		4.34(40)#	10.99(45)#	
¹⁴⁴ Er		$0^+$	≥200 ns	8.00(20)#	8.27(20)#		5.37(73)#	11.45(82)#	[2000So11]
¹⁴⁸ Yb		$0^{+}$		8.54(40)#	9.09(40)#		6.43(40)#	11.96(40)#	
¹⁵² Hf		$0^+$							
¹⁵⁶ W		$0^+$	$157^{+57}_{-34}$ ms						[2023Br10]
¹⁶⁰ Os		$0^+$	$97^{+97}_{-32}\mu s$						[2023Br10]
^{160m} Os	1.844(18)	(8 ⁺ )	$41^{+15}_{-9}$ µs						[2023Br10]

* Uncertain, may be from ¹²⁸Pr [1983Ni05]

# Table 2

Particle emission from the even-Z,  $T_z = +4$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nt 11 . J .	C	DD	C	0	DD	E	
Nuchde	$\mathbf{s}_p$	вкр	$\mathfrak{S}_{2p}$	Qα	Βκα	Experimental	
¹⁰⁸ Sn	5.792(11)		9.516(5)	-0.526(6)			
¹¹² Te	4.020(12)		6.303(16)	2.078(10)			
¹¹⁶ Xe	3.998(32)		5.735(27)	2.096(15)			
¹²⁰ Ba	3.87(30)		5.39(30)	1.73(30)			
¹²⁴ Ce	3.55(36)#		4.89(30)#	1.55(42)#			
¹²⁸ Nd	3.28(28)#		4.29(20)#	1.96(36)#			
¹³² Sm	2.66(36)#		3.12(30)#	2.97(36)#			
¹³⁶ Gd	2.23(36)#		2.29(36)#	3.63(42)#			
¹⁴⁰ Dy	1.99(50)#		1.75(45)#	3.84(50)#			
¹⁴⁴ Er	1.85(36)#		1.07(75)#	3.80(45)#			
¹⁴⁸ Yb	1.54(40)#		0.49(40)#	3.95(45)#			
¹⁵² Hf							
¹⁵⁶ W							
¹⁶⁰ Os				7.724(15)*	100%	[2023Br10]	
^{160m} Os				9.18(10)*	100%	[2023Br10]	
* Deduce	ed from $\alpha$ energy [202	23Br10].					
Table 3							

direct $\alpha$ emis	lirect $\alpha$ emission from ¹⁶⁰ Os*, J ^{$\pi$} = 0 ⁺ , T _{1/2} = 97 ⁺⁹⁷ ₋₃₂ $\mu$ s, BR $_{\alpha}$ = 100%.									
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)\%$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{156}\mathrm{W})$	coincident $\gamma$ -rays	R ₀ (fm)]	HF			
7.274(15)	7.092(15)	100%	$0^+$	0.0		1.5597(29)	$1.8^{+1.8}_{-0.6}$			
* All value $Table 4$ direct $\alpha$ emission	ues from [2003Br sion from ^{160m} Os ³	XX]. *, Ex. = 1.844(18)	) MeV, $J^{\pi}$ =	$ = 8^+, T_{1/2} = 41^{+15}_{-9}, BR_{0}$	_α = 100%.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)\%$	${ m J}_f^{\pi}$	$E_{daughter}(^{156}W)$	coincident $\gamma$ -rays	R ₀ (fm)]	HF			
9.118(10)	8.890(10)	100%	$0^+$	0.0		1.5597(29)	$2.6(10) \times 10^4$			

* All values from [2003BrXX].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +4 nuclei.

Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +4$ nuclei	Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein. $J^{\pi}$	

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
94 <b>T</b> c		7+	203(1) m	4 256(4)	1 234(4)		10.277(4)	2.180(4)	[1063Ma21]
98 Ph		$(2)^{+}$	293(1) m	4.230(4)	-4.234(4)		-10.277(4) 8.058(12)	2.109(4) 2.814(12)	[1905]v1a21]
102 A g		(2) 5+	120(4) m	5.656(8)	-3.240(13)		-0.930(12)	2.014(12) 2.552(10)	[1950Ka25] [1067Cb05]
1061.p		3+ 7+	13.0(4) III	5.030(8)	-2.123(10)		-7.397(6)	3.333(10) 4.870(12)	[1907CH05]
110 ch		$(2^+)$	0.2(1) III 24.0(2) a	0.324(12) 8 202(15)	-0.820(13)		-3.791(12)	4.870(12)	[1976HU00] [1076O::01]
1141		(3)	24.0(5) 8	0.392(13)	1.731(7)		-2.773(0)	10.778(24)	[1970UX01]
1180		1'	2.1(2) s	9.25(30)	4.489(26)	0.0540(().01*	1.438(20)	10.778(24)	[19//Kill]
11°Cs		2	14(2) s	9.67(16)	4.740(29)	0.0542(6)%*	2.276(27)	11.055(28)	[1995Ki07, 1977Bo28,
118m a		(=_)	17/0	0.4544.0	1 = 10(20)	0.0540(0.01)		11.055(20)	<b>1977Ge03</b> , 1978Da07]
^{110m} Cs	х	(7 ⁻ )	17(3) s	9.67(16)+x	4.740(29)+x	0.0542(6)%*	2.276(27)+x	11.055(28)+x	[1995Ki07, 1977Bo28,
122-									<b>1977Ge03</b> , 1978Da07]
¹²² La			8.7(7) s	10.07(30)#	5.27(30)#	obs	3.05(30)#	11.11(30)#	[ <b>1984Ni03</b> , 1988WiZN]
¹²⁶ Pr			3.14(22) s	10.50(20)#	6.15(20)#	obs	4.19(20)#	11.86(20)#	[2002Ka66, 1983Ni05]
¹³⁰ Pm			2.6(2) s	11.13(20)#	7.02(20)#	obs	5.49(20)#	12.93(20)#	[1999Xi03, 1985Wi07]
¹³⁴ Eu			0.5(2) s	11.58(36)#	8.32(30)#		7.05(31)#	14.37(30)#	[1989Vi04]
¹³⁸ Tb				12.06(36)#	9.26(30)#		8.63(30)#	15.35(36)#	
¹⁴² Ho		$(7^{-}, 8^{+})$	0.4(1) s	12.87(83)#	10.00(41)#		15.98(45)#	9.95(40)#	[ <b>2005Xu04</b> , 2002Xu11, 2001Xu02]
¹⁴⁶ Tm		(5 ⁻ )	68(3) ms	13.27(20)#	10.78(20)#		10.94(20)#	16.64(76)#	[2006Ta08, 2005Bb02, 2003Gi10, 2001Ry01, 2001Ry02, 2005Ro40, 2005Se26, 2007BaZQ, 2007DaZU, 2005Bi24, 2005RoZY, 1995PeZY, 1993Ji18, 1993WoZY1
146 <i>m</i> Tm***	0.182(4)	$(10^{+})$	108(3) ms	13 45(20)#	10.96(20)#		11 12(20)#	16.82(76)#	[ <b>2006Ta08</b> ]
150 [ 11	0.102(4)	(2+)	45(3) ms**	13.+5(20)# 14.06(42)#	11.88(36)#		$\frac{11.12(20)\#}{12.13(30)\#}$	17.13(30)#	[2003Gi10_2000Gi01]
Lu		(2)	ч <i>э</i> ( <i>э)</i> шз	17.00(42)#	11.00(30)#		1993WoZY]	17.15(50)#	[20030110, 20000101]
^{150m} Lu	0.022(6)***	$(1^-, 2^-)$	$39^{+8}_{-6}\mu s$	14.09(42)#	11.91(36)#		12.16(30)# 1993WoZY]	17.15(30)#	[2003Gi10, 2000Gi01]

* Mixture of ground state and isomer [1995Ki07, 1977Ge03].
** Weighted average of 43(5) ms [2003Ro21], 49(5) ms [2000Gi01].
*** Excitation Energy = 22(6) keV, deduced from the weighted average of the difference in energies of the protons feeding the ground state of ¹⁴⁹Yb; 16(9) keV [2000Gi10] and 25(7) keV [2003Ro21].

Particle emission from the odd-Z,  $T_z = +4$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	Sp	$BR_p$	$S_{2p}$	Qα	Experimental
04-					
⁹⁴ Tc	4.640(4)		12.283(4)	-3.922(5)	
⁹⁸ Rh	4.344(12)		11.932(13)	-1.442(13)	
¹⁰² Ag	4.104(9)		11.234(20)	-1.496(14)	
¹⁰⁶ In	3.563(12)		10.070(13)	-0.786(15)	
¹¹⁰ Sb	2.109(10)		7.908(10)	0.733(14)	
$^{114}I$	1.581(34)		5.618(27)	2.386(21)	
¹¹⁸ Cs	1.513(16)		5.567(76)	1.805(24)	
^{118m} Cs	1.513(16)-x		5.567(76)-x	1.805(24)+x	
¹²² La	1.087(33)#		5.23(23)#	1.44(30)#	
¹²⁶ Pr	0.96(28)#		4.64(20)#	1.80(36)#	
¹³⁰ Pm	0.38(28)#		3.72(20)#	2.43(28)#	
¹³⁴ Eu	-0.14(42)#		2.71(34)#	3.24(36)#	
¹³⁸ Tb	-0.32(42)#		1.94(36)#	3.78(42)#	
¹⁴² Ho	-0.84(50)#		1.35(90)#	3.93(50)#	
¹⁴⁶ Tm	-0.896(6)#	100%	1.02(20)#	3.77(45)#	[2006Ta08, 2005Bb02, 2003Gi10, 2001Ry01,
					2001Ry02, 2005Ro40, 2005Se26, 2007BaZQ,
					2007DaZU, 2005Bi24, 2005RoZY, 1995PeZY,
					1993Li18, 1993WoZY]
^{146m} Tm	-1.078(7)#	71%	0.84(20)#	3.95(45)#	*
¹⁵⁰ Lu	-1.270(2)	**	0.58(30)#	3.86(36)#	[2003Ro21, 2003Gi10, 2000Gi01, 1999BaZR,
					1993Se04, 1993WoZY]
^{150m} Lu	-1.292(2)#	100%***	0.60(30)#	3.88(36)#	**

* References for the isomer are the same as the ground state. **  $\beta$ -decay from ¹⁵⁰Lu not measured. Using the calculated  $\beta$ -decay T_{1/2} = 155 ms from [1997Mo25], I_p = 71(2) %.

*** Implied from the short  $T_{1/2}$ .

#### Table 3

direct p emission from ¹⁴⁶Tm*,  $J^{\pi} = (5^{-})$ ,  $T_{1/2} = 68(3)$ ms,  $BR_p = 100\%$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})\%$	$I_p(absb)\%$	${f J}_f^{\pi}$	$E_{daughter}(^{145}\mathrm{Er})$	coincident γ-rays
0.938(4)	0.932(4)	20.0(13)%	13.6(9)%	(11/2 ⁻ )	0.253	
1.016(4)	1.009(4)	26.8(16)%	18.3(12)%	$(3/2^+)$	0.175	
1.191(1)	1.18391)	100(3)%	68.1(27)%	$(1/2^+)$	0.0	

* All values from [2006Ta08].

#### Table 4

direct p emission from ^{146m}Tm*, Ex = 0.182(4) MeV,  $J^{\pi} = (10^+)$ ,  $T_{1/2} = 198(3)$ ms,  $BR_p = 100\%$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(absb)$	${f J}_f^{m \pi}$	$E_{daughter}(^{145}\mathrm{Er})$	coincident $\gamma$ -rays
0.889(8)	0.883(8)	1.0(4)%	1.0(4)%	$(13/2^{-})$	0.484	
1.120(1)	1.112(1)	100(1)%	99(1)%	$(11/2^{-})$	0.253	

* All values from [2006Ta08].

#### Table 5

direct p emission from ¹⁵⁰Lu*,  $J^{\pi} = (2^+)$ ,  $T_{1/2} = 45(3)$ ms**,  $BR_p = ***$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(rel)$	$I_p(absb)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{149}\mathrm{Yb})$	coincident γ-rays
1.261(4)	1.253(4)	100%	71(2)%***	(1/2+)	0.0	

* All values from [2000Gi01], except where noted.

** Weighted average of 43(5) ms [2003Ro21], 49(5) ms [2000Gi01]. ***  $\beta$ -decay from ¹⁵⁰Lu not measured. Using the calculated  $\beta$ -decay T_{1/2} = 155 ms from [1997Mo25], I_p = 71(2) %.

## Table 6 direct p emission from ^{150m}Lu*, $J^{\pi} = (1^{-}, 2^{-}), T_{1/2} = 39^{+8}_{-6}, BR_p = 100\%$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(absb)$	${ m J}_f^{\pi}$	$E_{daughter}(^{149}\mathrm{Yb})$	coincident γ-rays
1.277(8)	1.268(8)	100%	100%	$(1/2^+)$	0.0	

* All values from [2000Gi01].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z,  $T_z$  = +4 nuclei.

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +4$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. All J^{$\pi$} values are taken from ENSDE.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\epsilon_{2p}}$	$Q_{\varepsilon \alpha}$	Experimental	
¹⁰⁸ Sn		$0^+$	10 30(8) m	2.05(10)	-2 369(6)		-9 705(6)	0.622(7)	[1978Hs01]
¹¹² Te		$0^{+}$	2.0(2) m	4.031(20)	1.082(10)		-5.675(14)	4.127(12)	[ <b>1976Wi11</b> ]
¹¹⁶ Xe		$0^+$	60(2) s	4.37(80)	1.727(31)		-3.128(24)	6.127(22)	[1974Ha10]
¹²⁰ Ba		$0^{+}$	24(2) s	5.00(30)	2.62(30)		-2.50(30)	6.11(31)	[1992Xu04]
¹²⁴ Ce		$0^{+}$	6(2) s	5.34(30)#	3.45(30)#		-1.35(30)#	6.55(30)#	[1978Bo32]
¹²⁸ Nd		$0^{+}$	4(2) s	5.8(20)#	4.16(20)#	obs?*	-0.13(22)#	7.30(21)#	[1983Ni05]
¹³² Sm		$0^+$	4.0(3) s	6.49(34)#	5.34(30)#		1.46(31)#	8.77(30)#	[1989McZU]
¹³⁶ Gd		$0^+$	>200 ns	7.15(36)#	6.48(34)#		3.10(30)#	10.11(33)#	[2000So11]
¹⁴⁰ Dy		$0^+$	—	7.65(90)#	7.51(45)#		4.34(40)#	10.99(45)#	. ,
¹⁴⁴ Er		$0^+$	>200 ns	8.00(20)#	8.27(20)#		5.37(73)#	11.45(82)#	[2000So11]
¹⁴⁸ Yb		$0^{+}$	_	8.54(40)#	9.09(40)#		6.43(40)#	11.96(40)#	
¹⁵² Hf		$0^+$			. ,		. ,	. ,	
¹⁵⁶ W		$0^+$	$157^{+57}_{24}$ ms						[2023BrXX]
¹⁶⁰ Os		$0^+$	$97^{+97}_{22}$ µs						[2023BrXX]
^{160m} Os	1.844(18)	(8 ⁺ )	$41^{+15}_{-9}$ µs						[2023BrXX]

* Uncertain, may be from ¹²⁸Pr [1983Ni05]

### Table 2

Particle emission from the even-Z,  $T_z = +4$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

		22	<i>.</i>	0		
Nuclide	$S_p$	$BR_p$	$S_{2p}$	$Q_{\alpha}$	Experimental	
108 <b>S</b> m	5 702(11)		0.516(5)	0.526(6)		
¹¹² Te	4.020(12)		6.303(16)	2.078(10)		
¹¹⁶ Xe	3.998(32)		5.735(27)	2.096(15)		
¹²⁰ Ba	3.87(30)		5.39(30)	1.73(30)		
¹²⁴ Ce	3.55(36)#		4.89(30)#	1.55(42)#		
¹²⁸ Nd	3.28(28)#		4.29(20)#	1.96(36)#		
¹³² Sm	2.66(36)#		3.12(30)#	2.97(36)#		
¹³⁶ Gd	2.23(36)#		2.29(36)#	3.63(42)#		
¹⁴⁰ Dy	1.99(50)#		1.75(45)#	3.84(50)#		
¹⁴⁴ Er	1.85(36)#		1.07(75)#	3.80(45)#		
¹⁴⁸ Yb	1.54(40)#		0.49(40)#	3.95(45)#		
¹⁵² Hf						
¹⁵⁶ W						
¹⁶⁰ Os			7.724(15)*	100%	[2023BrXX]	
^{160m} Os			9.18(10)*	100%	[2023BrXX]	

* Deduced from  $\alpha$  energy [2023BrXX].

### Table 3

$\frac{\text{direct } \alpha \text{ emiss}}{E_{\alpha}(\text{c.m.})}$	sion from ¹⁶⁰ Os*, J Ea(lab)	$\pi = 0^+, T_{1/2} = 97^+$	$J_{32}^{\pi}$ $\mu$ s, $BR_{\alpha}$	= 100%.	coincident <i>Y</i> -rays	Ro (fm)]	HF
20(000)	$\Sigma_{u}(\mathbf{m} \mathbf{c})$	14(400)/0	• _f			110 (111)]	
7.274(15)	7.092(15)	100%	$0^+$	0.0		1.5597(29)	$1.8^{+1.8}_{-0.6}$
* All valu	ies from [2003BrX	X].					
Table 4	160			15			
direct $\alpha$ emiss	sion from ^{160m} Os*,	Ex. = 1.844(18) M	IeV, $J^{\pi} = 8^+$	$T_{1/2} = 41^{+15}_{-9}$ , $BR_{\alpha} = 1$	00%.		

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)\%$	${ m J}_f^\pi$	$E_{daughter}(^{156}\mathrm{W})$	coincident $\gamma$ -rays	$R_0$ (fm)]	HF
9.118(10)	8.890(10)	100%	$0^+$	0.0		1.5597(29)	$2.6(10)  imes 10^4$

* All values from [2003BrXX].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +4 nuclei.

Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +4$ nuclei	Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein. $J^{\pi}$	

	Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon_{2p}}$	$Q_{\varepsilon \alpha}$	Experimental
	94 <b>T</b> a		$\tau^+$	202(1) m	1 256(1)	4 224(4)		10.277(4)	2 180(4)	[1062Ma21]
	98 DL		$(2)^+$	295(1) III 8 7(1)	4.230(4)	-4.254(4)		-10.277(4)	2.169(4)	[1905]V1a21]
	102 A		(2)	8./(1) m	5.05(10)	-3.240(13)		-8.958(12)	2.814(12)	[1950Ka25]
	102 Ag		5+	13.0(4) m	5.656(8)	-2.123(10)		-7.597(8)	3.553(10)	[1967Ch05]
	100 In		7+	6.2(1) m	6.524(12)	-0.826(13)		-5.791(12)	4.870(12)	[1978Hu06]
	110Sb		(3+)	24.0(3) s	8.392(15)	1.751(7)		-2.775(6)	7.257(6)	[1976Ox01]
	¹¹⁴ I		$1^{+}$	2.1(2) s	9.25(30)	4.489(26)		1.438(20)	10.778(24)	[1977Ki11]
	¹¹⁸ Cs		2	14(2) s	9.67(16)	4.740(29)	0.0542(6)%*	2.276(27)	11.055(28)	[1995Ki07, 1977Bo28,
										1977Ge03, 1978Da07]
	118m Cs	х	(7 ⁻ )	17(3) s	9.67(16)+x	4.740(29)+x	0.0542(6)%*	2.276(27)+x	11.055(28)+x	[1995Ki07, 1977Bo28,
										1977Ge03, 1978Da07]
	¹²² La			8.7(7) s	10.07(30)#	5.27(30)#	obs	3.05(30)#	11.11(30)#	[1984Ni03, 1988WiZN]
	¹²⁶ Pr			3.14(22) s	10.50(20)#	6.15(20)#	obs	4.19(20)#	11.86(20)#	[2002Ka66, 1983Ni05]
	¹³⁰ Pm			2.6(2) s	11.13(20)#	7.02(20)#	obs	5.49(20)#	12.93(20)#	[1999Xi03, 1985Wi07]
	¹³⁴ Eu			0.5(2) s	11.58(36)#	8.32(30)#		7.05(31)#	14.37(30)#	[1989Vi04]
	¹³⁸ Tb				12.06(36)#	9.26(30)#		8.63(30)#	15.35(36)#	
	¹⁴² Ho		$(7^{-}, 8^{+})$	0.4(1) s	12.87(83)#	10.00(41)#	15.98(45)#	9.95(40)#		[2005Xu04, 2002Xu11,
										2001Xu02]
1	¹⁴⁶ Tm		(5 ⁻ )	68(3) ms	13.27(20)#	10.78(20)#		10.94(20)#	16.64(76)#	[2006Ta08, 2005Bb02,
										2003Gi10, 2001Rv01,
										2001Ry02, 2005Ro40,
										2005Se26, 2007BaZO,
										2007DaZU, 2005Bi24,
										2005RoZY, 1995PeZY,
										1993Li18, 1993WoZY1
	^{146m} Tm***	0.182(4)	$(10^{+})$	198(3) ms	13.45(20)#	10.96(20)#		11.12(20)#	16.82(76)#	[2006Ta08]
1	¹⁵⁰ Lu		(2+)	45(3) ms**	14.06(42)#	11.88(36)#		12.13(30)#	17.13(30)#	[2003Gi10, 2000Gi01]
			. /	. /	. ,	× /		1993WoZY]	× /	. ,
	^{150m} Lu	0.022(6)***	$(1^{-}, 2^{-})$	$39^{+8}_{6}\mu s$	14.09(42)#	11.91(36)#		12.16(30)#	17.15(30)#	[2003Gi10, 2000Gi01]
		. /	/	-04	. ,	× /		1993WoZY]	× /	. ,

* Mixture of ground state and isomer [1995Ki07, 1977Ge03].
** Weighted average of 43(5) ms [2003Ro21], 49(5) ms [2000Gi01].
*** Excitation Energy = 22(6) keV, deduced from the weighted average of the difference in energies of the protons feeding the ground state of ¹⁴⁹Yb; 16(9) keV [2000Gi10] and 25(7) keV [2003Ro21].

Particle emission from the odd-Z,  $T_z = +4$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$BR_p$	$S_{2p}$	Qα	Experimental
04-					
⁹⁴ Tc	4.640(4)		12.283(4)	-3.922(5)	
⁹⁸ Rh	4.344(12)		11.932(13)	-1.442(13)	
¹⁰² Ag	4.104(9)		11.234(20)	-1.496(14)	
¹⁰⁶ In	3.563(12)		10.070(13)	-0.786(15)	
¹¹⁰ Sb	2.109(10)		7.908(10)	0.733(14)	
$^{114}I$	1.581(34)		5.618(27)	2.386(21)	
¹¹⁸ Cs	1.513(16)		5.567(76)	1.805(24)	
^{118m} Cs	1.513(16)-x		5.567(76)-x	1.805(24)+x	
¹²² La	1.087(33)#		5.23(23)#	1.44(30)#	
¹²⁶ Pr	0.96(28)#		4.64(20)#	1.80(36)#	
¹³⁰ Pm	0.38(28)#		3.72(20)#	2.43(28)#	
¹³⁴ Eu	-0.14(42)#		2.71(34)#	3.24(36)#	
¹³⁸ Tb	-0.32(42)#		1.94(36)#	3.78(42)#	
¹⁴² Ho	-0.84(50)#		1.35(90)#	3.93(50)#	
¹⁴⁶ Tm	-0.896(6)#	100%	1.02(20)#	3.77(45)#	[2006Ta08, 2005Bb02, 2003Gi10, 2001Ry01,
					2001Ry02, 2005Ro40, 2005Se26, 2007BaZQ,
					2007DaZU, 2005Bi24, 2005RoZY, 1995PeZY,
					1993Li18, 1993WoZY]
^{146m} Tm	-1.078(7)#	71%	0.84(20)#	3.95(45)#	*
¹⁵⁰ Lu	-1.270(2)#	**	0.58(30)#	3.86(36)#	[2003Ro21, 2003Gi10, 2000Gi01, 1999BaZR,
					1993Se04, 1993WoZY]
150mLu	-1.292(2)#	100%***	0.60(30)#	3.88(36)#	**

* References for the isomer are the same as the ground state. **  $\beta$ -decay from ¹⁵⁰Lu not measured. Using the calculated  $\beta$ -decay T_{1/2} = 155 ms from [1997Mo25], I_p = 71(2) %.

*** Implied from the short  $T_{1/2}$ .

#### Table 3

direct p emission from ¹⁴⁶Tm*,  $J^{\pi} = (5^{-})$ ,  $T_{1/2} = 68(3)$ ms,  $BR_p = 100\%$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})\%$	$I_p(absb)\%$	${f J}_f^{\pi}$	$E_{daughter}(^{145}\mathrm{Er})$	coincident γ-rays
0.938(4)	0.932(4)	20.0(13)%	13.6(9)%	(11/2 ⁻ )	0.253	
1.016(4)	1.009(4)	26.8(16)%	18.3(12)%	$(3/2^+)$	0.175	
1.191(1)	1.18391)	100(3)%	68.1(27)%	$(1/2^+)$	0.0	

* All values from [2006Ta08].

#### Table 4

direct p emission from ^{146m}Tm*, Ex = 0.182(4) MeV,  $J^{\pi} = (10^+)$ ,  $T_{1/2} = 198(3)$ ms,  $BR_p = 100\%$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(absb)$	${f J}_f^{m \pi}$	$E_{daughter}(^{145}\mathrm{Er})$	coincident $\gamma$ -rays
0.889(8)	0.883(8)	1.0(4)%	1.0(4)%	$(13/2^{-})$	0.484	
1.120(1)	1.112(1)	100(1)%	99(1)%	$(11/2^{-})$	0.253	

* All values from [2006Ta08].

#### Table 5

direct p emission from ¹⁵⁰Lu*,  $J^{\pi} = (2^+)$ ,  $T_{1/2} = 45(3)$ ms**,  $BR_p = ***$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(rel)$	$I_p(absb)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{149}\mathrm{Yb})$	coincident γ-rays
1.261(4)	1.253(4)	100%	71(2)%***	(1/2+)	0.0	

* All values from [2000Gi01], except where noted.

** Weighted average of 43(5) ms [2003Ro21], 49(5) ms [2000Gi01]. ***  $\beta$ -decay from ¹⁵⁰Lu not measured. Using the calculated  $\beta$ -decay T_{1/2} = 155 ms from [1997Mo25], I_p = 71(2) %.

## Table 6 direct p emission from ^{150m}Lu*, $J^{\pi} = (1^{-}, 2^{-}), T_{1/2} = 39^{+8}_{-6}, BR_p = 100\%$ .

$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(absb)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{149}\mathrm{Yb})$	coincident γ-rays
1.277(8)	1.268(8)	100%	100%	$(1/2^+)$	0.0	

* All values from [2000Gi01].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +9/2 nuclei.

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +9/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. All J^{$\pi$} values taken from ENSDE.

		-		_					
Nuclide	Ex	$J^{n}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
105 - 4		1		/ 0					
¹⁰⁵ Cd		5/2+	55.4(4) m*	2.737(4)	-2.228(2)		-10.880(3)	0.654(6)	[1953Jo20, 1968Bo25, 1969St18]
¹⁰⁹ Sn		$5/2^{+}$	18.1(2) m**	3.859(9)	-0.667(8)		-8.801(8)	2.016(9)	[1969Ba04, 1972Ba41, 1956Pe56]
¹¹³ Te		$(7/2^+)$	1.6(2) m	6.07(30)	3.019(28)		-4.533(28)	5.718(28)	[1976Wi11]
¹¹⁷ Xe		$5/2(^+)$	61(2) s	6.253(28)	3.789(26)	0.0029(6)%	-1.760(19)	7.807(20)	[1971Ho07]
¹²¹ Ba		$5/2(^+)$	29.7(15) s	6.36(14)	4.14(14)	obs	-1.545(144)	7.27(14)	[1974Ka31]
¹²⁵ Ce		$(7/2^{-})$	9.9(5) s***	7.10(20)#	5.14(20)#	obs	-0.19(20)#	8.02(20)#	[1998Be64, 1983Ni05, 1986Wi15]
¹²⁹ Nd		$(5/2^+)$	6.7(4) s	7.40(20)#	5.87(20)#	obs	0.94(20)#	8.96(20)#	[2010Xu12, 1985Wi07, 2011MaZL,
									1977Bo02]
¹³³ Sm	y@	$(1/2^{-})$	$3.4(5) s^a$	8.18(30)#	6.91(30)#	obs	2.49(30)#	10.12(30)#	[2006Xu07,2001Xu04, 1993BrZU,
	-								1985Wi07, 1977Bo02]
133mSm@	x@	$(5/2^+)$	2.8(5) s	8.18(30)#+x	6.91(30)#+x	obs	2.49(30)#+x	10.12(30)#+x	[2006Xu07, 2001Xu04, 1985Wi07,
		. ,						× /	1977Bo02]
¹³⁷ Gd		(7/2)	2.2(2) s	8.93(30)#	8.301(30)#	obs	4.27(31)#	11.77(30)#	[2005Xu04]
¹⁴¹ Dy		$(9/2^{-})$	0.9(2) s	9.16(32)#	9.11(30)#	obs	5.44(30)#	12.34(30)#	[2006Xu03, 1984Ni03, 1986Wi15]
¹⁴⁵ Er		$(1/2^+)$		9.88(20)#	10.04(20)#	obs	6.60(21)#	12.88(23)#	[2010Ma20]
^{145m} Er ^{@@}	0.253(1)	$(1/2^+)$	0.9(3) s	10.13(20)#	10.29(20)#	obs	6.86(21)#	13.13(23)#	[2010Ma20, 2006Ta08, 1989Vi02,
									1988WiZN]
¹⁴⁹ Yb		$(1/2^+)$	0.7(2) s	10.61(36)#	10.86(30)#	$\approx 6\%$	7.849(30)#	13.37(30)#	[2005Xu04]
¹⁵³ Hf			> 200 ns	11.08(34)#	11.68(34)#		8.89(30)#	14.22(36)#	[2006Xu07]
$^{157}W$		$(7/2^{-})$	275(40) ms	9.91(43)#	10.84(43)#		8.28(40)#	6.26(423)#	[2019Hi06, 2010Bi03, 2008PaZV]
¹⁶¹ Os		$(7/2^{-})$	640(60) µs	10.65(43)#	11.84(43)#		9.67(40)#	16.97(43)#	[2010Bi03, 2019Hi06, 2008BiZT,
		` '							2008PaZV]
¹⁶⁵ Pt		(7/2 ⁻ )	$0.26^{+26}_{-9}$ ms	11.28(43)#	12.82(43)#		11.11(40)#	18.10(43)#	[2019Hi06]

* Weighted average of 54.7(8) m [1953Jo20], 57.0(6) m [1968Bo25] and 56.0(5) [1969St18].

** Weighted average of 518.0(2) m [1969Ba04], 18.3(3) m [1972Ba41] and 18.1(3) m [1956Pe56].

*** Weighted average of 10.5(5) s [1998Be64], 8.9(7) s [1983Ni05] and 9.2(10 s [1986Wi15].

^a Weighted average of 3.2(7) s [2006Xu07], 3.4(5) s [2001Xu04], 3.7(7) s [1993BrZU].

[@] The relative energy placement of the two isomers is unknown.

#### Table 2

Particle separation and emission from the even-Z,  $T_z = +9/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$BR_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
¹⁰⁵ Cd	6.506(4)		11.455(2)	-1.327(5)		
¹⁰⁹ Sn	5.799(12)		10.218(8)	-0.721(8)		
¹¹³ Te	4.037(33)		6.986(28)	1.858(29)		
¹¹⁷ Xe	4.054(76)		6.701(30)	1.737(30)		
¹²¹ Ba	4.15(142)		6.53(14)	1.02(14)		
¹²⁵ Ce	3.69(20)#		5.58(20)#	1.66(24)#		
¹²⁹ Nd	3.33(20)#		4.97(20)#	1.86(28)#		
¹³³ Sm	2.89(33)#		4.04(30)#	2.72(36)#		
133mSm*	2.89(33)#-x		4.04(30)#-x	2.72(36)#+x		
¹³⁷ Gd	2.26(36)#		2.93(34)#	3.59(42)#		
¹⁴¹ Dy	2.19(85)#		2.33(36)#	3.41(42)#		
¹⁴⁵ Er	1.92(20)#		1.65(20)#	3.72(36)#		
145mEr**	1.67(20)#		1.90(20)#	3.97(36)#		
¹⁴⁹ Yb	1.85(30)#		1.30(30)#	3.49(36)#		
¹⁵³ Hf	1.17(36)#		0.34(43)#	3.61(42)#		
¹⁵⁷ W	0.98(50)#		-0.04(50)#	5.19(50)#		
¹⁶¹ Os	0.61(50)#		-0.66(50)#	7.069(11)#	5.9(27)%	[2010Bi03, 2019Hi06, 2008BiZT]
¹⁶⁵ Pt	0.12(51) #		-1.44(50)#	7.453(14)#	100%	[2019Hi06]

	3001110111 03 ,	J = (112), I	$1/2 = 0.40(00) \mu$	$5, BR_{\alpha} = 5.7(2$	7)70.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	)	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs$	sb) $J_f^{\pi}$		$E_{daughter}(^{15}$	⁷ W)	coincident γ-rays
6.747(30) 7.066(12)	6.580(3 6.890(1	30) (2)	100% 100%	5.9(27 5 9(27	7)% (9)	$(2^{-})$	0.318		
* All val <b>Table 4</b> direct p emiss	ues from [2010Bit sion from ¹⁶⁵ Pt*, J	)3]. $\pi = (7/2^{-}), T_1$	$_{/2}=0.26^{+26}_{-9}\ \mu s,$	$BR_{\alpha} = 100\%.$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	<i>I_p</i> (abs)	$\mathrm{J}_f^\pi$	$E_{daughter}(^{161}\mathrm{Os})$	) coi	ncident γ-rays	R ₀ (fm)	HF
7.453(14)	7.272(14)	100%	100%	$(7/2^{-})$	0.0		_	1.551(19)	$2.6^{+1.5}$

* All values from [2019Hi06].

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#### Table 3 direct $\alpha$ emission from $\frac{161}{0}$ s* $I^{\pi} = (7/2^{-})$ T₁ = 640(60) us BR = 5.9(27)%

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +9/2 nuclei.
Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +9/2$ nuclei. Unless otherwise stated, all Q-values are take	n from [2021Wa16] or deduced
from values therein. $J^{\pi}$ values for ¹⁰³ Ag, ¹⁰⁷ in, ¹¹¹ Sb, ¹¹⁵ I, ¹¹⁹ Cs, ¹²³ La, ¹²⁷ Pr, ¹³¹ Pm, ¹³⁵ Eu, ¹³⁹ Tb, ¹⁴³ Ho are taken from ENSDF	۰. ۲.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
102 .									
¹⁰⁵ Ag		7/2+	65.7(7) m	2.654(4)	-5.308(8)		-11.423(4)	0.398(4)	[1975Di09]
¹⁰⁷ In		$9/2^{+}$	32.4(3) m	3.424(10)	-3.913(10)		-9.727(10)	1.465(10)	[1973Ny03]
¹¹¹ Sb		$(5/2^+)$	73(1) s	5.102(10)	-1.656(15)		-6.910(9)	3.729(9)	[1976Wi10]
$^{115}I$		$(5/2^+)$	1.3(2) m	5.72(40)	0.870(35)		-2.588(29)	7.176(29)	[1969Ha03]
¹¹⁹ Cs		$9/2^{+}$	43.0(2) s	6.489(17)	1.377(24)		-1.788(19)	7.333(31)	[1984IcZY]
¹²³ La			16.3(3) s	7.00(20)#	2.21(20)#		-0.75(20)#	7.72(20)#	[1992Ic02]
¹²⁷ Pr			4.2(3) s	7.44(20)#	3.14(22)#		0.55(20)#	8.69(20)#	[1995Gi12]
¹³¹ Pm		$(11/2^{-})$	6.3(8) s	8.00(20)#	4.12(21)#		1.94(20)#	9.78(20)#	[1999Ga41]
¹³⁵ Eu				8.71(25)#	5.327(20)#		3.61(20)#	11.20(20)#	
¹³⁹ Tb			1.6(2) s	9.50(36)#	6.33(30)#		5.28(30)#	12.30(34)#	[1999Xi04]
¹⁴³ Ho				10.12(30)#	7.22(76)#		6.60(30)#	13.16(36)#	
¹⁴⁷ Tm		$11/2^{-}$	615(45) ms	10.63(40)	7.975(9)		7.690(9)	13.770(15)	[1993Se04, 1993To02]
^{147m} Tm	0.068(6)*	$3/2^{+}$	375(5) µs	10.70(40)	8.043(11)		7.758(11)	13.838(16)	[2023Au03]
¹⁵¹ Lu		$11/2^{-}$	78(1) ms	11.24(43)#	8.90(36)#		8.86(30)#	13.88(30)	[2015Ta12]
^{151<i>m</i>} Lu	0.078(10)*	3/2+	17(1) μs	11.32(43)#	8.98(36)#		8.894(30)#	13.96(32)	[2015Ta12
¹⁵⁵ Ta		$(1/2^+)$	$2.9^{+1.5}_{-1.1}$ ms	10.32(42)#	8.39(36)#		8.59(36)#	15.13(43)	[2007Pa27]
^{155m} Ta	х	$11/2^{-}$	$12^{+4}_{-3} \mu s$	10.32(42)#+x	8.39(36)#+x		8.59(36)#+x	15.13(43)+x	[1999Uu01]
¹⁵⁹ Re		$(1/2^+)$	5.	10.63(43)#	9.02(37)#		9.47(37)#	17.08(43)#	
^{159m} Re	х	11/2-	21(4) µs	10.63(43)#+x	9.02(37)#+x		9.47(37)#+x	17.08(43)#+x	[2006.Jo10]
¹⁶³ Ir				11.03(50)#	9.85(45)#		10.62(45)#	17.70(50)#	L <b>-</b>

* From difference in Sp.

#### Table 2

Particle separation and emission from the odd-Z,  $T_z = +9/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$BR_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
103 .	4 100(4)		11.0(0(7)	1 ( 12 ( 20 )		
¹⁰⁵ Ag	4.189(4)		11.968(7)	-1.643(20)		
¹⁰⁷ In	3.723(10)		11.074(11)	-1.189(10)		
111Sb	2.284(16)		8.925(10)	0.305(13)		
115I	1.737(38)		6.499(34)	2.074(30)		
¹¹⁹ Cs	1.515(17)		6.444(29)	1.608(32)		
¹²³ La	1.33(20)#		6.13(13)#	1.23(20)#		
¹²⁷ Pr	1.01(20)#		5.36(20)#	1.68(28)#		
¹³¹ Pm	0.46(20)#		4.58(20)#	2.35(28)#		
¹³⁵ Eu	0.06(28)#		3.32(20)#	3.20(28)#		
¹³⁹ Tb	-0.24(36)#		2.56(30)#	3.59(36)#		
¹⁴³ Ho	-0.78(79)#		2.09(32)#	3.66(42)#		
¹⁴⁷ Tm	-1.059(3)	15(5)%	1.432(10)	3.65(30)		[1993Se04, 1993To02, 2023Au03, 2008Ra03,
						2007Ra37, 2007HeZV, 2007RaZZ, 2004SeZW,
						1997Se03, 1995Ho26, 1995PeZY, 1993WoZY,
						1988ToZW, 1984HoZN, 1983La27, 1982Kl03]
^{147m} Tm	-1.127(7)	100%	1.500(12)	3.72(31)		[1993Se04, 2023Au03, 1993To02, 1997Se03,
						1995PeZY, 1995Ho26, 1995PeZY, 1993WoZY]
¹⁵¹ Lu	-1.232(4)*	**	0.94(36)	3.25(30)		[2015Ta12, 1999Bi14, 1997Mo25, 1993Se04,
						1982Ho04, 2017Wa18, 2017Wa47, 2013Pr05,
						2007LiZR, 2003Pr05, 2003YuZW, 1999BaZR,
						1998BaZU, 1982Ho04]
$^{151m}Lu$	-1.319(10)	100%	1.02(37)	3.33(32)		[2015Ta12, 2017Wa18, 2017Wa47, 1999Bi14,
						1997Mo25, 1993Se04, 2013Pr05, 2007LiZR,
						2003YuZW, 1999BaZR, 1999BaZZ]
¹⁵⁵ Ta	-1.453(15)	100%	0.19(334)	3.89(42)		[2007Pa27]
^{155m} Ta	-1.453(15)-x	100%	0.19(33)-x	3.89(42)+x		[1999Uu01]
¹⁵⁹ Re	-1.599(53)#		-0.21(34)#	6.76(55)#		
^{159m} Re	-1.599(53)#-x	92.5(35)%	-0.21(34)#-x	6.76(55)#+x	7.5(35)%	[2007Pa27, 2006Jo10, 2007JoZX, 2007PaZT]
¹⁶³ Ir	-1.90(50)#		-0.95(43)#	7.07(50)#	× /	

* Deduced from proton energy, -1.241(2) MeV in [2021Wa16]. **  $\beta$ -decay branch not measured.

Table 3direct p emission	n from ¹⁴⁷ Tm*, $J^{\pi} = 11/2^{-1}$	$T_{1/2} = 615(45) \text{ ms}^{*}$	*, $BR_p = 15(5)\%$ .			
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(absb)$	${\rm J}_f^\pi$	$E_{daughter}(^{146}\mathrm{Er})$	coincident γ-rays
1.071(33)	1.0510(33)***	100%	15(5)%	$0^+$	0.0	
* All values ** Weighter *** [1993So	from [1993To02], except v d average of 580(70) ms [19 e04].	where noted. 993Se04], and 640(60	)) ms [1993To02].			
direct p emission	147mTm*, Ex = 68(6	) keV, $J^{\pi} = 3/2^+$ , $T_{1/2}$	$B_2 = 360(40) \text{ ms}, BR_p =$	100%.		
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(rel)$	$I_p(absb)$	${\sf J}_f^{\pi}$	$E_{daughter}(^{146}{\rm Er})$	coincident γ-rays
1.1315(39)	1.1108(39)	100%	100%	$0^+$	0.0	
* All values	from [1993Se04].					
Table 5     direct p emission	n from ${}^{151}Lu^*$ , $J^{\pi} = 11/2^-$ ,	$T_{1/2} = 78(1)$ ms.				
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(absb)$	$\mathbf{J}_f^{\pmb{\pi}}$	$E_{daughter}(^{150}\mathrm{Yb})$	coincident $\gamma$ -rays
1.240(4)	1.232(4)			0+	0.0	
* All values	from [2015Ta12].					
Table 6     direct p emission	h from ${}^{151m}Lu^*$ , Ex = 78(10)	)) keV, $J^{\pi} = 3/2^+$ , $T_{1/2}$	$\mu_2 = 17(1) \ \mu \text{s}, BR_p = 10$	0%.		
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(absb)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{150}\mathrm{Yb})$	coincident γ-rays
1.294(4)	1.285(4)	100%	100%	0+	0.0	
* All values	from [2015Ta12].					
Table 7     direct p emission	n from ¹⁵⁵ Ta*, $J^{\pi} = (1/2^+)$ ,	$T_{1/2} = 2.9^{+15}_{-11} \text{ ms}, BR$	$_{p} = 100\%.$			
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(rel)$	<i>I</i> _p (absb)	$\mathrm{J}_f^\pi$	<i>E</i> _{daughter} ( ¹⁵⁴ Hf)	coincident $\gamma$ -rays
1.453(15)	1.444(15)	100%	100%	$0^+$	0.0	
* All values	from [2007Pa27].					
Table 8           direct p emission	1 from 155m Ta*, Ex = unk.,	$J^{\pi} = 11/2^{-}, T_{1/2} = 12$	$^{+4}_{-3} \mu \text{s}, BR_p = 100\%.$			
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(absb)$	${\rm J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{154}\mathrm{Hf})$	coincident $\gamma$ -rays	
1.776(10)	1.765(10)	100%				
* All values	from [1999Uu01].					
Table 9         direct p emission	a from 159m Re*, Ex = unk.,	$J^{\pi} = 11/2^{-}, T_{1/2} = 21$	(4) $\mu$ s, $BR_p = 92.5(35)$	%.		
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(\text{rel})$	$I_p(absb)$	$\mathrm{J}_{f}^{\pi}$	$E_{daughter}(^{158}W)$	coincident $\gamma$ -rays
1.816(20)	1.805(20)	100%	92.5(35)%	0+	0.0	

* All values from [2006Jo10].

#### **Table 10** direct $\alpha$ emission from ^{159m}Re* Ex = unk. $I^{\pi} = 11/2^{-1}$ T_{1/2}= 21(4) $\mu$ s** $BR_{\alpha} = 7.5(35)\%$

	rte ; En anni, e	11/2 , 11/2 =						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_p(absb)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{155}\mathrm{Ta})$	coincident $\gamma$ -rays		
6.950(26)	6.776(26)	100%	7.5(35)%	$0^+$	0.0			

* All values from [2007Pa27], except where noted.

** [2006Jo10]

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +5$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

NT	E	τπ	T	0	0	ממ	0	0	E
Nuclide	EX	J	1 _{1/2}	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	Βκβρ	$Q \epsilon_{2p}$	$Q_{\varepsilon \alpha}$	Experimental
¹¹⁴ Te		$0^+$	15.2(7) m	2.610(30)	-0.851(24)		-8.477(25)	2.155(27)	[ <b>1976Wi11</b> ]
¹¹⁸ Xe		$0^{+}$	3.8(9) m	2.892(22)	-0.273(17)		-5.835(12)	3.993(22)	[1976Be61]
¹²² Ba		$0^{+}$	1.95(15) m	3.540(40)	0.583(30)		-5.440(32)	3.937(34)	[1978Bo32]
¹²⁶ Ce		$0^+$	51.0(4) s	4.150(90)	1.559(30)		-3.657(29)	4.899(44)	[2002Ko02]
¹³⁰ Nd		$0^+$	13(3) s	4.580(70)	2.402(40)		-2.549(61)	5.952(95)	[2000Xu08]
¹³⁴ Sm		$0^{+}$	9.3(8) s	5.39(20)#	3.67(20)#		-0.73(20)#	7.37(21)#	[1990Ko25]
138Gd		$0^+$	4.7(9) s	6.09(20)#	5.04(20)#		0.93(21)#	8.68(21)#	[1999Xi04]
¹⁴² Dy		$0^+$	2.3(3) s	6.44(20)#	5.82(73)#	0.06(3) %	2.29(73)#	9.20(73)#	[1991Fi03, 1986Wi15]
¹⁴⁶ Er		$0^+$	1.7(6) s	6.916(9)	6.632(9)		3.468(29)	9.813(70)	[1993To05]
¹⁵⁰ Yb		$0^+$	$\geq$ 200 ns	7.66(36)#	7.62(30)#		4.58(31)#	9.98(30)#	[2000So11]
¹⁵⁴ Hf		$0^{+}$	2(1) s	6.94(36)#	7.14(36)#		4.41(31)#	11.34(36)#	[1981Ho10]
¹⁵⁸ W		$0^+$	1.5(2) ms	7.43(36)#	7.87(36)#		5.43(31)#	13.55(36)#	[2000Ma95]
$^{158m}W$	1.888(8)	$(8^+)$	143(19) µs	9.32(36)#	9.76(36)#		7.32(31)#	15.44(36)#	[2000Ma95]
¹⁶² Os		$0^{+}$	2.05(10) ms	7.95(36)#	8.72(36)#		6.75(31)#	14.19(36)#	[2000Mu95]
¹⁶⁶ Pt		$0^+$	$260^{+100}_{-60} \ \mu s$	8.52(36)#	9.68(36)#		8.11(31)#	15.25(36)#	[2019Hi06]
¹⁷⁰ Hg		$0^+$	$80^{+40}_{-4}\mu\mathrm{s}$	9.12(36)#	10.59(36)#		9.504(31)#	16.30(36)#	[2019Hi06]

#### Table 2

Particle emission from the even-Z,  $T_z = +5$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	S	BR	Sa	0	BR	Experimental
Ruenue	$S_p$	DRp	$S_{2p}$	Qα	Βια	Experimental
¹¹⁴ Te	4.762(30)		7.813(24)	1.527(28)		
¹¹⁸ Xe	4.929(28)		7.393(26)	1.386(27)		
¹²² Ba	4.796(31)		7.014(308)	1.045(30)		
¹²⁶ Ce	4.350(38)		6.309(31)	1.363(40)		
¹³⁰ Nd	4.112(41)		5.640(40)	1.799(40)		
¹³⁴ Sm	3.26(20)#		4.53(20)#	2.80(20)#		
¹³⁸ Gd	2.80(20)#		3.43(20)#	3.29(28)#		
¹⁴² Dy	2.87(74)#		2.92(73)#	3.12(76)#		
¹⁴⁶ Er	2.49(10)		2.330(10)	3.37(73)		
¹⁵⁰ Yb	2.18(36)#		1.93(30)#	3.07(30)#		
¹⁵⁴ Hf	1.64(34)#		1.04(34)#	3.68(42)#		
$^{158}W$	1.39(34)#		0.45(34)#	6.612(3)	100 %	[2000Ma95, 2005Se11, 1996Pa01, 1989Ho12]
$^{158m}W$	-0.50(34)#		-1.44(34)#	8.503(8)	100 %	[2000Ma95, 2005Se11, 2017Jo09, 1996Pa01, 1989Ho12]
¹⁶² Os	0.95(34)#		-0.25(34)#	6.768(3)	100 %	[2000Mu95, 2004Jo12, 1996Bi07, 1989Ho1]
¹⁶⁶ Pt	0.48(34)#		-1.06(34)#	7.292(7)	100 %	[ <b>2019Hi06</b> , 1996Bi07]
¹⁷⁰ Hg	0.09(42)#		-1.85(34)#	7.773(30)*	100 %	[2019Hi06]

* From [2019Hi06], 7.77(31)# in [2021Wa16].

#### Table 3

direct $\alpha$ emiss	emission from ¹⁵⁸ W*, $J^{\pi} = 0^+$ , $T_{1/2} = 1.5(2)$ ms, $BR_{\alpha} = 100 \%$ .							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_p(absb)$	${\sf J}_f^\pi$	$E_{daughter}(^{154}\mathrm{Hf})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
6.612(3)	6.445(3)	100%	$0^+$	0.0		1.557(10)	1.0	

* All values from [2000Ma95].

### Table 4

direct $\alpha$ emissio	on from ^{158m} W*, E	Ex = 1.888(8) MeV,	$J^{\pi} = 0^+, T_{1/2}$	= 143(19) $\mu$ s, $BR_{\alpha}$ = 100 %	ю.		
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_p(absb)$	${ m J}_f^{\pi}$	$E_{daughter}(^{154}\mathrm{Hf})$	coincident γ-rays	R ₀ (fm)	HF
8.501(7)	8.286(7)	100%	$0^+$	0.0		1.557(10)	1.0

* All values from [2000Ma95].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_p(absb)$	$\mathbf{J}_f^{m{\pi}}$	$E_{daughter}(^{158}\mathrm{W})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.767(3)	6.600(3)	100%	$0^+$	0.0		1.561(3)	1.0
* All valu	es from [2000Ma95	].					
Table 6direct $\alpha$ emission	on from ¹⁶⁶ Pt*, J ^{$\pi$}	$= 0^+, T_{1/2} = 260^{+100}_{-60}$	0 $\mu$ s, $BR_{\alpha}$ = 1	00 %.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	<i>I_p</i> (absb)	$\mathbf{J}_{f}^{m{\pi}}$	$E_{daughter}(^{162}\mathrm{Os})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.294(8)	7.118(8)	100%	0+	0.0		1.555(26)	1.0
* All valu	es from [2019Hi06]						
Table 7 direct $\alpha$ emission	on from ¹⁷⁰ Hg*, J ^π	$T = 0^+, T_{1/2} = 80^{+40}_{-4}$	us, $BR_{\alpha} = 10$	0 %.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	<i>I_p</i> (absb)	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{168}\mathrm{Pt})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.773(30)	7.590(30)	100%	$0^+$	0.0		1.532(38)	1.0

direct  $\alpha$  emission from ¹⁶²Os*, J^{$\pi$} = 0⁺, T_{1/2}= 2.05(10) ms, BR_{$\alpha$} = 100 %.

* All values from [2019Hi06].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +5 nuclei.

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +5$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced or delayed particle emission from the odd-Z, $T_z = +5$ nuclei.	ced
from values therein. All $J^{\pi}$ values are taken from ENSDE.	

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta P}$	$Q_{\varepsilon_{2p}}$	$Q_{\varepsilon \alpha}$	$BR_{\varepsilon\alpha}$	Experimental
⁹⁶ Tc		$7^{+}$	4.20(4) d	0.259(5)	-6.324(5)		-13.130(5)	0.212(5)		[1950Co69]
¹⁰⁰ Rh		$1^{-}$	20.2(1) h	3.636(18)	-5.552(18)		-12.053(18)	0.779(18)		[1995KeZZ]
¹⁰⁴ Ag		$5^{+}$	89.2(10) m	4.279(4)	-4.374(5)		-10.588(4)	1.686(4)		[1971Mu22]
¹⁰⁸ In		$7^{+}$	58.0(12) m	5.133(9)	-3.002(9)		-8.790(9)	2.850(9)		[1975Fl01]
¹¹² Sb		(3+)	53.5(5) s	7.056(18)	-0.496(18)		-5.829(18)	5.229(18)		[1972Si28]
$^{116}I$		$1^{+}$	2.91(15) s	7.840(80)	2.294(77)		-1.439(75)	8.809(75)		[1976Go02]
¹²⁰ Cs		$2(^{+})$	61.3(14) s	8.284(15)	2.600(24)	$7(3) \times 10^{-6}\%$	-0.776(21)	8.950(26)	$2.0(4) \times 10^{-5}\%$	[1975Ho09, 1969Ch18]
¹²⁴ La*			21(4) s	8.830(60)	3.496(58)		0.518(58)	9.489(58)		[1997As05]
¹²⁸ Pr			3.1(3) s	9.200(40)	4.276(40)	obs	1.761(32)	10.334(32)		[1985Wi07]
¹³² Pm		(3 ⁺ )	6.2(6) s	9.8(150)#	5.38(156)#	obs	3.22(15)#	11.48(15)#		[1988WiZN]
¹³⁶ Eu		$(7^{+})$	3.3(3) s	10.57(20)#	6.53(21)#	obs	4.82(20)#	12.76(20)#		[1989Vi04]
^{136m} Eu	х	$(3^{+})$	3.8(3) s	10.57(20)#+x	6.53(21)#+x	obs	4.82(20)#+x	12.76(20)#+x		[1989Vi04]
¹⁴⁰ Tb		$7^{+}$	2.0(5) s	11.30(80)	7.63(80)	obs	6.44(80)	13.90(80)#		[2006Xu03, 1991Fi03,
									1986Wi15]	
¹⁴⁴ Ho		(5 ⁻ )	0.7(1) s	11.961(11)	8.521(52)	obs	7.772(29)	14.748(29)		[1986Wi15]
¹⁴⁸ Tm		$(10^{+})$	0.7(2) s	12.714(14)	9.703(11)		9.212(12)	15.380(13)		[1982No08]
¹⁵² Lu			0.7(1)s	12.85(25)#	10.06(20)#	obs	9.83(20)#	15.63(20)#		[1988Ni02]
¹⁵⁶ Ta		$(2^{-})$	106(4) ms	11.82(34)#	9.26(30)#		9.35(30)#	17.84(34)		[2011Da12
^{156m} Ta	0.10	(2(7))	$9^+)$ 333 ⁺²⁵	ms 11.92(34)#	ŧ 9.36(30)#	ŧ	9.45(30)#	# 17.94(34)	)	[2023Br10]
¹⁶⁰ Re			611(7)	μs 12.45(34)‡	ŧ 10.27(30)	#	10.65(30)	)# 8.52(34)		[2011Da12]
¹⁶⁴ Ir				12.94(35)#	11.23(32)	#	11.94(32)	)# 19.42(35)	)#	
164m Ir	,	x (	$(9^+)$ 70(10)	us 12.94(35)#	+x 11.23(32)	#+x	11.94(32	)#+x 19.42(35)	)#+x	[2014Dr02]
¹⁶⁸ Au		(	,(10)	13.54(43)#	t 12.31(40)	#	13.38(40)	)# 20.53(43)	)#	
¹⁶⁸ Au			· · · ·	13.54(43)‡	ŧ 12.31(40)	#	13.38(40)	)# 20.53(43)	)#	

* Possibly not the ground state

#### Table 2

Particle separation and emission from the odd-Z,  $T_z = +5$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$BR_p$	$S_{2p}$	Qα	I	BRα	Experimental
⁹⁶ Tc	5.399(5)		14.031(	5.) -1.793(5	) -		
¹⁰⁰ Rh	5.255(18)		13.737(	18) -2.194(1	9) -		
¹⁰⁴ Ag	4.948(4)		12.911(	8) -1.950(1	9) -		
¹⁰⁸ In	4.418(9)		11.755(	9) -1.428(1	0) -		
¹¹² Sb	2.949(19)		9.707(2)	1) 0.096(20	))		
¹¹⁶ I	2.647(80)		7.502(7	8) 1.753(77	7)		
¹²⁰ Cs	2.383(14)		7.496(22	2) 1.107(76	5)		
¹²⁴ La	1.893(58)		6.692(6	6) 1.205(58	3)		
¹²⁸ Pr	1.640(42)		5.935(9)	5) 1.503(64	4)		
¹³² Pm	1.15(15)#		5.03(16)	)# 2.28(15)	#		
¹³⁶ Eu	0.68(25)#		4.06(20)	)# 2.96(25)	#		
^{136m} Eu	0.68(25)#-x		4.06(20)	)#-x 2.96(25)	#+x		
¹⁴⁰ Tb	0.14(82)#		3.31(80)	)# 3.34(82)	#		
¹⁴⁴ Ho	-0.27(16)		2.63(70)	) 3.45(80)	1		
¹⁴⁸ Tm	-0.55(40)		2.105(12	2) 3.420(13	3)		
¹⁵² Lu	-0.83(36)#		1.51(28)	)# 2.92(20)	#		
¹⁵⁶ Ta	-1.020(4)	71(3)	% 0.91(36)	) 5.00(36)	1		[2011Da12, 2023Br10, 1996Pa01, 1992Pa05, 1993Li34,
							1993WoZY]
^{156m} Ta	-1.122(4)	4.2(9) %	0.90(36)	5.10(36)		[1996	Pa01, 1993Li34, 2023Br10, 2011Da12, 1992Pa05]
¹⁶⁰ Re	-1.267(7)	89(1) %	0.34(36)	6.698(4)	11(1)%	[201]	Da12, 2001Ke05, 1996Pa01, 1995PeZY, 1993WoZY, 1992Pa05]
¹⁶⁴ Ir	-1.56(10)#		-0.39(38)#	6.97(10)#		_	
164m Ir	-1.56(10)#-x*	96(2) %	-0.39(38)#-x	6.97(10)#+x**	4(2) %	[2014	Dr02, 2002Ma61, 2001Ke05, 2001DaZU]
¹⁶⁸ Au	-1.99(50)#	. /	-1.26(45)#	7.59(51)#		-	

*  $Q_p$  from the isomer is 1.825(5) MeV, suggesting the the isomer excitation = 265(100) keV assuming decay to the ground state of ¹⁶³Os. **  $Q_{\alpha}$  from the isomer is 7.052(14) MeV, and assuming decay to the 184(1) keV (9⁺) level of ¹⁶⁰Re would give an isomer excitation = -102(100) keV. This suggests that the value given for  $Q_{\alpha}$  from [2021Wa19] is too small.

direct p emission	n from ¹⁵⁶ Ta*, $J^{\pi} = (2^{-}),$	$T_{1/2} = 106(4) \text{ ms}, BR_{\mu}$	y = 71(3)%.			
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(absb)$	$J_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{155}\mathrm{Hf})$	coincident $\gamma$ -rays	
1.018(5)	1.011(5)(14)	71(3) %	(7/2 ⁻ )	0.0		
* All values	s from [2011Da12].					
Table 4       direct p emission	n from 156m Ta*, Ex = 102	(7) keV, $J^{\pi} = (9^+), T_1$	_{/2} = 358(45) ms**,	$BR_p = 4.2(9)\%.$		
$E_p(c.m.)$	$E_p(\text{lab})$	$I_p(absb)$	${\sf J}_f^\pi$	$E_{daughter}(^{155}\mathrm{Hf})$	coincident $\gamma$ -rays	
1.113(8)	1.106(8)***	4.2(9)%	(7/2-)	0.0		
* All values ** Weighter ** Weighter <b>Table 5</b> direct p emission	s from [1996Pa01], excep d average of 320(80) ms [ d average of 1.108(8) Me n from ¹⁶⁰ Re*, J ^{$\pi$} = , T _{1/2}	t where noted. [1993Li34] and 375(54 V [1996Pa01] and 1.1 $g = 611(7) \ \mu s, BR_p = 8$	4) ms [1996Pa01]. 03(12) MeV [1993] 9(1) %.	Li34].		
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(absb)$	$\mathbf{J}_f^{m{\pi}}$	$E_{daughter}(^{159}W)$	coincident $\gamma$ -rays	
1.272(6)	1.264(6)	89(1) %		0.0		
* All values	s from [2011Da12].					
Table 6direct $\alpha$ emissio	n from ¹⁶⁰ Re*, J ^{$\pi$} = , T _{1/}	$_2 = 611(7) \ \mu s, BR_{\alpha} = 3$	11(1) %.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$J_f^\pi$	$I_p(absb)$	$E_{daughter}(^{156}\mathrm{Ta})$	coincident γ-rays	
6.697(4)	6.530(4)	100%	(2 ⁻ )	((1/2 ⁺ )0.0		
* All values	s from [2011Da12].					
Table 7         direct p emission	n from 164m Ir*, Ex = unk,	$J^{\pi} = (9^+), T_{1/2} = 70(1$	0) $\mu$ s, $BR_{\alpha} = 96(2)$	)%.		
<i>E_p</i> (c.m.)	$E_p(\text{lab})$	<i>I_p</i> (absb)	${ m J}_f^\pi$	$E_{daughter}(^{163}\mathrm{Os})$	coincident $\gamma$ -rays	
1.826(6)	1.814(6)	96(2) %	(7/2–)	0.0		
* All values	s from [2014Dr02].					
Table 8direct $\alpha$ emissio	n from 164m Ir*, Ex = unk	, $\mathbf{J}^{\pi} = (9^+),  \mathbf{T}_{1/2} = 70($	10) $\mu$ s, $BR_{\alpha} = 4(2)$	%.		
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_p(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{160}\mathrm{Re})$	coincident $\gamma$ -rays	
7.052(10)	6.550(10)	100%		0.184**	0.096, 0.038, 0.050?***	
· ·						

* All values from [2014Dr02], except where noted.

** [2014Dr02] assign the  $\alpha$  decay as L=0, populating the  $\pi h_{11/2}$  state in ¹⁶⁰Re (from [2011Da01]. *** Existence of this  $\gamma$  is implied but not observed in [2011Da01]

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +11/2 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +11/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{$\pi$} values for ¹¹¹Sn, ¹¹⁵Te, ¹¹⁹Xe, ¹²³Ba, ¹²⁷Ce are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
1110		7/0+	25.0(0)	0.452(6)	0.000(5)		11 707(5)	0.042(6)	[10/00] 11]
115m		7/2 '	35.8(8) m	2.453(6)	-2.880(5)		-11./9/(5)	0.043(6)	[1969Sh11]
110 Te		112+	6.0(1) m	4.940(30)	1.208(28)		-7.274(28)	3.904(28)	[1972Sh37]
¹¹ / ₁₂₂		(5/2+)	5.8(3) m	4.983(24)	1.607(21)		-4.733(13)	5.784(19)	[1976Be61]
¹²⁵ Ba		(5/2+)	2.4(4) m*	5.389(17)	2.411(16)		-3.987(13)	5.698(25)	[1975Ar31, 1962Pr09]
¹² /Ce		$(1/2^+)$	34(2) s	5.920(40)	3.402(31)		-2.468(30)	6.639(31)	[1996Ge07]
¹³¹ Nd		$(5/2^+)$	25.5(10) s**	6.530(50)	4.366(39)	obs	-1.022(35)	7.703(38)	[1986Wi15, 1999Ga41,
									1993Al03,1977Bo02]
¹³⁵ Sm		$(3/2^+, 5/2^+)$	10.3(5) s	7.21(18)	5.50(16)	0.02(1)%	0.50(16)	9.02(16)	[ <b>1989Vi04</b> , 1977Bo02]
¹³⁹ Gd			5.8(9) s	7.77(20)#	6.58(20)#	obs	1.86(20)#	10.01(21)#	[1999Xi04, 1983Ni05]
139mGd	Х		4.8(9) s	7.77(20)#+x	6.58(20)#+x	obs	1.86(20)#+x	10.01(21)#+x	[1999Xi04, 1983Ni05]
¹⁴³ Dy		$(1/2^+)$	5.6(10) s	8.250(50)	7.502(31)	obs	3.179(18)	10.804(19)	[2003Xu04, 1984Ni03,
2									1983Ni05]
^{143m} Dy	0.3107(6)	$(11/2^{-})$	3.0(3) s	8.561(50)	7.833(31)	obs	3.1490(18)	11.115(19)	[2003Xu04]
¹⁴⁷ Er		$(1/2^+)$	≈2.5 s	9.150(40)	8.658(39)	obs	5.21(12)	11.386(64)	[2010Ma20, 2011MaZL
									2010Ma27,1988WiZN,
									1987ToZU, 1984ScZT]
147m Er	х	$(11/2^{-})$	2.5(2) s	9.150(40)+x	8.658(39)+x	obs	5.21(12)+x	11.386(64)+x	[2010Ma20, 2011MaZL,
		· · ·							2010Ma27, 1988WiZN,
									1987ToZU, 1984ScZT]
¹⁵¹ Yb		$(1/2^+)$	1.6(1) s	9.23(30)	9.00(30)	obs	5.53(30)	11.79(30)	[1989Ni02, 1986To12]
^{151m} Yb	х	$(11/2^{-})$	1.6(1) s	9.23(30)+x	9.00(30)+x	obs	5.53(30)+x	11.79(30)+x	[1989Ni02, 1986To12]
¹⁵⁵ Hf		$(7/2^{-})$	840(30) ms	8.24(30)#	8.33(30)#		5.09(30)#	14.04(30)#	[1981HoZM, 2011Sa59]
¹⁵⁹ W		$(7/2^{-})$	8.2(7) ms	9.01(30)#	9.38(30)#		6.43(30)#	14.69(30)	[1996Pa01]
¹⁶³ Os		(7/2-)	$6.2^{+1.3}$ ms	9.67(30)#	10.37(30)#		7.86(30)#	15.68(30)#	[2019Hi06
¹⁶⁷ Pt		. ,	$0.90(13) \text{ ms}^{***}$	10.32(31)#	11.39(31)#		9.33(31)#	16.82(31)	2019Hi06, 1996Pa01.
- •				=()"					1996Bi07]
¹⁷¹ Hg			$59^{+36}_{-16}\mu{ m s}$	10.90(31)#	12.35(31)#		10.86(31)#	17.99(31)	[2004Ke06]

* Weighted average of 2.7(4) m [1975Ar31] and 2.0(5) m [1962Pr09].

** Weighted average of 26.6(17) s [1999Ga41], and 25.0(12) s [1993Al03].

*** Weighted average of 1.1(2) ms [2019Hi06], 0.9(3) ms [2004Ke06], and 0.91(16) ms [1996Bi07].

#### Table 2

Particle emission from the even-Z,  $T_z = +11/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
111.0	( 750/10)	10.010(6)	1.052(6)		
¹¹¹ Sn	6./58(13)	12.012(6)	-1.3/3(6)		
TTSTe	4.855(34)	8.313(28)	1.451(28)		
¹¹⁹ Xe	5.112(22)	8.277(17)	0.843(30)		
¹²³ Ba	4.799(36)	7.752(16)	0.715(16)		
¹²⁷ Ce	4.295(95)	6.888(31)	1.251(31)		
¹³¹ Nd	3.882(70)	6.058(39)	1.786(40)		
¹³⁵ Sm	3.38(16)	5.10(16)	2.49(16)		
¹³⁹ Gd	3.17(20)#	4.22(20)#	2.80(25)#		
139mGd	3.17(20)#-x	4.22(20)#-x	2.80(25)#+x		
¹⁴³ Dy	2.90(70)	3.52(24)	3.04(20)#		
143m Dy	2.59(70)	3.21(24)	3.35(20)#		
¹⁴⁷ Er	2.659(39)	2.94(39)	3.136(40)		
^{147m} Er	2.659(39)-x	2.94(39)-x	3.136(40)+x		
¹⁵¹ Yb	2.34(36)#	2.38(30)	2.64(30)		
^{151m} Yb*	2.34(36)#-x	2.38(30)-x	2.64(30)+x		
¹⁵⁵ Hf	1.93(36)#	1.73(36)#	4.81(43)#	0.06%	[1981HoZM]
¹⁵⁹ W	1.605(36)#	1.16(36)#	6.451(4)	$92^{+8}_{-23}\%$	[1996Pa01, 1981Ho10, 2019Hi06, 2011Sa59, 1981HoZM]
¹⁶³ Os	1.17(36)#	0.41(36)#	6.673(7)	100%	[2019Hi06, 1996Pa01, 1996Bi07, 1981Ho10, 2004Ke06]
¹⁶⁷ Pt	0.74(37)#	-0.42(37)#	7.160(60)	100%	[ <b>2019Hi06, 1996Pa01, 1996Bi07</b> , 1981Ho10
¹⁷¹ Hg	0.245(37)#	-1.23(37)#	7.668(15)	100%	[2004Ke06]

direct $\alpha$ emiss	sion from ¹⁵⁵ Hf*, J ^{$\pi$}	$=(7/2^{-}), T_{1/2} = 3$	840(30) ms**, <i>E</i>	$BR_{\alpha} = 0.06 \%.$			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{151}\mathrm{Yb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.900	4.774	0.06%	(1/2 ⁺ )	0.0			
* All valu ** [2011]	ues from [1981HoZM Sa59].	M], except where r	noted.				
<b>Fable 4</b> direct $\alpha$ emiss	sion from ¹⁵⁹ W*, J ^{$\pi$}	$=(7/2^{-}), T_{1/2}=8$	$B.2(7)$ ms, $BR_{\alpha}$ =	$=92^{+8}_{-23}$ %.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	<i>I_p</i> (abs)	${\rm J}_f^\pi$	$E_{daughter}(^{155}\mathrm{Hf})$	coincident γ-rays	R ₀ (fm)	HF
6.457(5)	6.295(5)**	$92^{+8}_{-23}$ %	(7/2 ⁻ )	0.0		1.5566(82)	$2.2_{-0.4}^{+0.5}$
** Weigh Table 5 direct α emiss	sion from ¹⁶³ Os*, J ^{$\pi$}	(5)  MeV  [1996Pa] = $(7/2^{-}), \text{ T}_{1/2} = 0$	01] and 6.299(6 $6.2^{+1.3}_{-0.9}$ ms, $BR_{\alpha}$	) MeV [1981Ho10]. = 100%.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_p(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{159}W)$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
6.666(12)	6.503(12)	100%	(7/2-)	0.0		1.5537(37)	1.28(31)
* All valu ** Weigh	ues from [2019Hi06] tted average of 6.512	. 2(19) MeV [1996F	a01] and 6.499(	(12) keV [2019Hi06].			
direct $\alpha$ emiss	sion from ¹⁶⁷ Pt, $J^{\pi}$ =	$T_{1/2} = 0.90(13)$	ms**, $BR_{\alpha} = 1$	00%.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_p(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{163}\mathrm{Os})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.163(7)	6.983(7)**	100%	(7/2-)	0.0		1.555(10)	$1.5^{+0.4}_{-0.3}$
* Weight ** Weigh Fable 7	ed average of 1.1(2) ted average of 6.985	ms [2019Hi06], 0 5(8) MeV [2019Hi	.9(3) ms [2004k 06], 6.979(7) [2	Xe06], and 0.91(16) ms [15 004Ke06], and 6.988(10)	996Bi07]. MeV [1996Bi07].		
direct $\alpha$ emiss	sion from 171Hg*, J [#]	$T = , T_{1/2} = 59^{+50}_{-16}$	$\mu$ s, $BR_{\alpha} = 100$	%.			

* All values from [2004Ke06].

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7.667(12)

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +1/2 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z = +11/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{$\pi$} values for ¹¹³Sb, ¹¹⁷I ¹²¹Cs, ¹²⁵La, ¹¹⁹Pr, ¹³³Pm, ¹³⁷Eu, ¹⁴¹Tb, ¹⁴⁵Ho, ¹⁴⁹Tm are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon_P}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
¹¹³ Sb		5/2+	6.67(7) m	3.911(17)	-3.716(18)		-9.743(17)	1.662(17)	[1976Wi10]
$^{117}I$		$(5/2^+)$	22.2(4) m	4.657(28)	-0.906(26)		-4.983(26)	5.465(26)	[1985Le10]
¹²¹ Cs		3/2+	155(4) s	5.379(14)	-0.644(21)		-4.498(16)	5.568(20)	[1991Ge02]
¹²⁵ La		$(3/2^+)$	64.8(12) s	5.909(28)	0.693(28)		-3.089(28)	6.297(28)	[1992Ic02]
¹²⁹ Pr		$(3/2^+)$	~ /	6.510(40)	1.563(62)		-1.534(32)	7.470(32)	. ,
¹³³ Pm		$(3/2^+)$	13.5(3) s*	6.920(70)	2.531(58)		-0.277(60)	8.455(58)	[1995Br21, 1977Bo02]
¹³⁷ Eu		$(11/2^{-})$	11(2) s	7.846(29)	3.735(69)		1.490(20)	9.762(47)	[1982No15]
¹⁴¹ Tb		$(5/2^{-})$	3.5(2) s	8.68(11)	5.16(12)		3.26(11)	11.03(11)	[1989Gi06]
¹⁴⁵ Ho		$(11/2^{-})$	2.4(1) s	9.122(10)	5.959(29)		4.53(20)	11.679(21)	[1989Vi02]
¹⁴⁹ Tm		$(11/2^{-})$	0.9(2) s	9.80(20)#	6.76(22)#	obs	5.68(20)#	11.88(20)#	[1987To12]
¹⁵³ Lu		$11/2^{-}$	0.9(2) s	8.78(25)#	6.06(14)#		5.31(15)#	12.94(15)#	[1989Ni04]
¹⁵⁷ Ta		$1/2^{+}$	10.1(4) ms	9.26(25)#	6.82(14)#		6.33(15)#	15.14(25)#	[1997Ir01]
^{157m1} Ta	0.022(5)	$11/2^{-}$	4.3(1) ms	9.28(25)#	6.84(14)#		6.35(15)#	15.16(25)#	[1996Pa01, 1997Ir01]
^{157m2} Ta	1.589(10)	$(25/2^{-})$	1.7(1) ms	10.85(25)#	8.41(14)#		7.92(15)#	16.73(25)#	[1996Pa01]
¹⁶¹ Re		$1/2^{+}$	0.44(1) ms	9.66(25)#	7.69(14)#		7.43(15)#	15.59(25)#	[1997Ir01]
161m Re	0.1238(13)	$11/2^{-}$	14.8(3) ms	9.78(25)#	7.81(14)#		7.55(15)#	15.71(28)#	[2006La16]
¹⁶⁵ Ir		$(1/2^+)$		10.15(26)#	8.59(15)#		8.74(17)#	16.49(26)#	
165mIr	0.18(5)	$(11/2^{-})$	340(40) µs	10.33(26)#	8.77(15)#		8.92(17)#	16.67(26)#	[2014Dr02]
¹⁶⁹ Au			<5 µs	10.68(36)#	9.59(30)#		10.13(31)#	17.53(36)#	[2019Uu01]

* Weighted average of 15(3) s [1995Br21] and 12(3) s [1977Bo02].

#### Table 2

Particle emission from the odd-Z,  $T_z = +11/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$BR_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
112 01	2.051(15)		10 (00 (10)	0.050(10)		
115Sb	3.051(17)		10.603(18)	-0.352(18)		
117I	2.464(35)		8.013(30)	1.553(31)		
¹²¹ Cs	2.219(19)		7.903(26)	0.911(29)		
¹²⁵ La	1.959(29)		7.294(29)	0.918(30)		
¹²⁹ Pr	1.529(41)		6.455(40)	1.561(40)		
¹³³ Pm	1.271(56)		5.685(69)	1.941(58)		
¹³⁷ Eu	0.624(13)		4.662(83)	2.837(50)		
¹⁴¹ Tb	0.05(11)		3.72(11)	3.18(11)		
¹⁴⁵ Ho	-0.161(10)		3.279(52)	3.00(11)		
¹⁴⁹ Tm	-0.25(20)#		2.76(20)#	2.76(20)#		
¹⁵³ Lu	-0.606(10)		2.18(15)	3.14(25)#		
¹⁵⁷ Ta	-0.935(10)	3.4(12) %	1.63(15)	6.355(6)	96.6(12)%	[ <b>1997Ir01</b> , 1996Pa01]
^{157m1} Ta	-0.957(11)		1.41(16)	6.377(8)	$95^{+5}_{-12}\%$	[1997Ir01, 1996Pa01, 1981HoZM, 1979Ho10]
^{157m2} Ta	-2.524(140)		0.04(18)	7.944(12)	100%	[1996Pa01]
¹⁶¹ Re	-1.197(5)	100%	0.98(15)	6.328(7)		<b>1997Ir01</b> , 2006La16, 1996Pa01, 2011Sa59,
						2001Ke05, 1979Ho10]
^{161m} Re	-1.300(14)	7.0(3) %	0.86(15)	6.162(15)	93.0(3)%	2006La16, 1997Ir01, 1996Pa01, 2011Sa59,
						2001Ke05, 1995DeZY, 1981HoZM, 1979Ho10]
¹⁶⁵ Ir	-1.541(50)#		0.17(16)#	6.823(50)#		· · · •
165mIr	-1.721(71)#	88(2)%	-0.10(17)#	7.003(71)#	12(2)%	[2014Dr02, 1997Da07]
¹⁶⁹ Au	-1.93(33)#	$\approx 100\%$	-0.71(30)#	7.382(34)#		[2019Uu01]

#### Table 3

direct p emission	from ¹⁵⁷ Ta*, $J^{\pi} = 1/2^+$	$T_{1/2} = 10.1(4) \text{ ms}, BR_p$	, = 3.4(12) %.			
$E_p(\text{c.m.})$	$E_p(\text{lab})$	<i>I_p</i> (absb)	${\sf J}_f^{{m \pi}}$	$E_{daughter}(^{156}\mathrm{Hf})$	coincident γ-rays	
0.933(7)	0.927(7)	3.4(12)%	$0^+$	0.0		

* All values from [1997Ir01], except where noted.

direct $\alpha$ emis	ssion from ¹⁵⁷ Ta*,	$J^{\pi} = 1/2^+, T_{1/2}$	= 10.1(4)  ms,	$BR_{\alpha} = 96.6(12) \%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{m{\pi}}$	$E_{daughter}(^{153}\mathrm{Lu})$	coincident γ-rays	R ₀ (fm)	HF	
6.277(4)	6.117(4)	96.6(12)%	1/2+	80(5)	?	1.5551(66)	$0.73\substack{+0.11 \\ -0.10}$	
* All val	lues from [1997Ir0	)1].						
Table 5 direct $\alpha$ emission	ssion from ^{157m1} Ta	[*] , Ex = 22(5) ke	$V^{**}, J^{\pi} = (11)$	$(2^{-}), T_{1/2} = 4.3(1) \text{ ms}, B$	$R_{\alpha} = 95^{+5}_{-12}\%.$			
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{153}\mathrm{Lu})$	coincident γ-rays	R ₀ (fm)	HF	
6.375(4)	6.213(4)	$95^{+5}_{-12}\%$	11/2-	0.0		1.5551(66)	$1.56^{+0.23}_{-0.20}$	
* All oth ** [1997	ner values from [19 7Ir01]	996Pa01], except	where noted.					
Table 6 direct $\alpha$ emis	ssion from ^{157m2} Ta	u*, Ex = 1.589(10	)) MeV, $J^{\pi} = (2)$	25/2 ⁻ ), $T_{1/2} = 1.7(1)$ ms	$, BR_{\alpha} = 100\%.$			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pmb{\pi}}$	$E_{daughter}(^{153}Lu)$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
7.946(8)	7.744(8)	100%	11/2-	0.0		1.5551(66)	2.07(29)×10 ⁴	
* All val	lues from [1996Pa	01].						
Table 7     direct p emiss	sion from ¹⁶¹ Re*,	$J^{\pi} = 1/2^+, T_{1/2}$	= 0.44(1)  ms, 1	$BR_p = 100 \%.$				
$E_p(\text{c.m.})$	$E_{\alpha}(\operatorname{lat}$	))	$I_p(abs)$	$J_f^{m{\pi}}$	$E_{daughter}(^{160}W)$	coincide	coincident γ-rays	
1.199(6)	1.192(	(6)	100%	$0^+$	0.0			
* All val	lues from [1997Ir0	)1].						
Table 8     direct p emiss	sion from ^{161m} Re*	^c , Ex = 123.8(13)	keV**, $J^{\pi} =$	$1/2^+$ , $T_{1/2} = 14.8(3)$ ms,	$BR_p = 7.0(3) \%.$			
$E_p(\text{c.m.})$	$E_p(\text{lab})$	)	<i>I_p</i> (abs)	$\mathbf{J}_{f}^{\boldsymbol{\pi}}$	$E_{daughter}(^{160}W)$	coincide	ent γ-rays	
1.199(2)	1.192(2	2)**	7.0(3)%	$0^{+}$	0.0			
* All val ** [1997	lues from [2006La 7Ir01].	16], except wher	e noted.					
<b>Table 9</b> direct $\alpha$ emission	ssion from ^{161m} Re	*, Ex = 123.8(13	) keV**, $J^{\pi} = 1$	$1/2^-$ , $T_{1/2} = 14.8(3)$ ms	$BR_{\alpha} = 93.0(3) \%.$			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{157}\mathrm{Ta})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
6.429(6)	6.269(6)***	93.0(3)%	11/2-	0.022		1.5580(46)	1.30(13)	

* All values from [2006La16], except where noted. ** [1997Ir01]. *** Weighted average of 6.265(6) MeV [1996Pa01], and 6.272(6) MeV [2006Pa01].

Table	10
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$E_p(c.m.)$	$E_p(\text{lab})$	$I_p(abs)$	$\mathbf{J}_{j}^{\pi}$	$E_{daughter}$	( ¹⁶⁴ Os) coinciden	t γ-rays	
1.733(7)	1.707(7)**	88(2)%	* 0	+ 0.0			
* [2014]	Dr02]						
** [1997] able 11	Da07]						
Table 11 lirect α emis	sion from ^{165m} Ir, Ex	= 180(50) keV*,	$J^{\pi} = (11/2^{-}), T$	$\Gamma_{1/2} = 340(40) \ \mu s^*, B_{1/2}$	$R_{\alpha} = 12(2)\%^*.$		
<b>Fable 11</b> direct $\alpha$ emis $\Sigma_{\alpha}(c.m.)$	Sion from ^{165m} Ir, Ex $E_{\alpha}(lab)$	= 180(50) keV*, $I_{\alpha}(abs)$	$J^{\pi} = (11/2^{-}), T$ $J_{f}^{\pi}$	$\Gamma_{1/2} = 340(40) \ \mu s^*, B_{1/2}$ $E_{daughter}(^{161} \text{Re})$	$R_{\alpha} = 12(2)\%^*.$ coincident $\gamma$ -rays	R ₀ (fm)	HF

direct p emission from ^{165m}Ir, Ex = 180(50) keV*,  $J^{\pi} = 11/2^{-}$ ,  $T_{1/2} = 340(40) \ \mu s^{*}$ ,  $BR_{p} = 88(2)\%^{*}$ .

* [2014Dr02]

** [1997Da07]

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +6 nuclei.

Last updated 3/21/23

Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +6$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\epsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
¹¹⁶ Te		$0^{+}$	2 50(2) h	1 558(25)	-2 519(24)		-11 272(24)	0 301(25)	[1961Fi05]
¹²⁰ Xe		$0^{+}$	40(1) m	1.575(19)	-2.279(14)		-8.754(12)	2.225(13)	[1965An05]
¹²⁴ Ba		$\overset{\circ}{0^+}$	10.5(5) m	2.651(15)	-1.130(16)		-7.588(14)	2.232(20)	[1975Ra03]
¹²⁸ Ce		$0^{+}$	4.0(1) m	3.090(60)	-0.005(30)		-5.761(30)	3.782(29)	[2000Li08]
¹³² Nd		$0^{+}$	94(6) s*	3.800(40)	0.994(41)		-4.376(35)	4.775(60)	[1992Le09, 1995Bu11]
¹³⁶ Sm		$0^{+}$	47(2) s	4.360(70)	2.114(23)		-2.861(24)	5.992(31)	[1988Ke03]
¹⁴⁰ Gd		$0^{+}$	15.8(4) s	5.200(60)	3.309(30)		-1.446(30)	6.963(75)	[1991Fi03]
¹⁴⁴ Dy		$0^+$	9.1(5) s	5.798(29)	4.37(20)	obs	0.161(31)	7.991(52)	[1986Wi05]
¹⁴⁸ Er		$0^+$	4.6(2) s	6.510(80)	5.428(14)	obs	1.707(46)	8.464(30)	[1988To03]
¹⁵² Yb		$0^+$	3.03(6) s	5.45(14)	4.71(15)		1.010(15)	9.30(17)	[1987To02]
¹⁵⁶ Hf		$0^{+}$	23(1) ms	5.88(14)	5.39(15)		2.03(15)	11.48(16)	[1996Pa01]
^{156m} Hf	1.952(6)**	$8^+$	520(10) µs	7.83(15)	7.34(16)		3.98(16)	13.43(17)	[2018Pa37]
$^{160}W$		$0^+$	91(5) ms	6.49(14)	6.24(15)		3.31(15)	11.95(16)	[1996Pa01]
¹⁶⁴ Os		$0^+$	21(1) ms	7.05(14)	7.20(16)		4.78(16)	12.97(16)	[1996Pa01]
¹⁶⁸ Pt		$0^+$	2.04(16) ms***	7.66(14)	8.20(17)		6.25(17)	14.04(16)	[2009Gi06, 2004Ke06, 1998Ki20, 1996Bi07]
¹⁷² Hg		$0^+$	231(9) µs	8.26(14)	9.12(17)		7.54(18)	15.18(16)	[2009Sa27]

* Weighted average of 105(10) s [1992Le09] and 88(7) s [1995Bu11].

** Deduced from  $\alpha$  center of mass energies of the isomer (7980(5) MeV) [2018Pa37] and ground state (6.028(4)MeV) [1996Pa01] decays, that both feed the ground state of ¹⁵²Yb.

*** Weighted average of 1.98(16) ms [2009Gi06], 2.1(2) ms [2004Ke06], 2.0(2) ms [1998Ki20], and 2.0(4) ms [1996Bi07].

#### Table 2

Particle separation and emission from the even-Z,  $T_z = +6$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$BR_p$	$S_{2p}$	Qα	BRα	Experimental
117			-			
¹¹⁶ Te	5.549(29)		9.282(248)	0.966(24)		
¹²⁰ Xe	5.684(25)		9.060(22)	0.666(27)		
¹²⁴ Ba	5.335(17)		8.313(17)	0.658(17)		
¹²⁸ Ce	4.927(38)		7.442(31)	1.131(31)		
¹³² Nd	4.414(53)		6.581(37)	1.683(37)		
¹³⁶ Sm	4.038(84)		5.742(17)	2.190(27)		
140Gd	3.673(31)		4.862(30)	2.604(31)		
¹⁴⁴ Dy	3.440(52)		4.189(29)	2.787(29)		
¹⁴⁸ Er	3.011(11)		3.502(12)	2.666(13)		
¹⁵² Yb	2.79(15)		3.02(15)	2.78(15)		
¹⁵⁶ Hf	2.56(15)		2.47(15)	6.026(3)	100%	[1996Pa01, 2018Pa37, 2011Da12, 1981HoZM, 1979Ho10, 1978ReZZ]
^{156m} Hf	0.61(16)		0.52(16)	7.978(7)	100%	2018Pa37, 1996Pa01, 2011Da12, 1981HoZM]
$^{160}W$	2.18(15)		1.81(15)	6.066(5)	87(8)%	[1996Pa01, 1981Ho10, 1979Ho10, 1978ReZZ]
¹⁶⁴ Os	1.71(15)		1.00(15)	6.479(5)	$96^{+4}_{-5}\%$	[2008Bi15, 1996Pa01, 1996Bi07, 1981Ho10]
¹⁶⁸ Pt	1.23(15)		0.16(15)	6.990(3)	$\approx 100\%^*$	[2009Gi06, 2004Ke06, 1998Ki20, 1996Bi07, 1981Ho10]
¹⁷² Hg	0.79(15)		-0.66(15)	7.524(6)	100%*	[2009Sa27, 2004Ke06, 1999Se14, 1998NiZW]

* Not measured, deduced from half-life.

#### Table 3

direct $\alpha$ emission	arect α emission from ¹⁵⁰ Hf*, $J^{\pi} = 0^+$ , $T_{1/2} = 23(1)$ ms, $BR_{\alpha} = 100\%$ .											
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${\rm J}_f^\pi$	$E_{daughter}(^{152}\mathrm{Yb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF					
6.028(4)	5.873(4)	100%	$0^+$	0.0		1.5536(31)	0.99(4)					

* All values from [1996Pa01].

-				/				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{152}\mathrm{Y})$	o)*** coincident γ-rays	*** R ₀ (fm)	HF
6.098(15) 6.439(15) 7.980(5)	5.942(15) 6.274(15) 7.775(5)	0.0038(23)% 0.0064(30)% 100%	0.0038(23)% 0.0064(30)% 99.990(4)%	$3^{-}$ $2^{+}$ $0^{+}$	1.8901(6) 1.5314(5) 0.0	1.531, 0.359 1.531 —	1.5536(31) 1.5536(31) 1.5536(31)	$\begin{array}{c} 1.0^{+1.6}_{-0.4}{\times}10^3 \\ 1.1^{+1.0}_{-0.4}{\times}10^4 \\ 1.65(3){\times}10^4 \end{array}$
* All v ** Ded ground state *** Va	values from [201 duced from $\alpha$ ce e of ¹⁵² Yb. dues taken from	8Pa37], unless oth enter of mass energ [2013Ma77].	nerwise noted. gies of the isome	er (7980(	5) MeV) [1996Pa	37] and ground state (6.028	(4)MeV) [1996Pa01	] decays, that both feed th
Table 5 direct $\alpha$ em	hission from ¹⁶⁰	W*, $J^{\pi} = 0^+$ , $T_{1/2}$	$= 91(5) \text{ ms}, BR_{0}$	$\alpha = 87(8)$	)%.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	) $J_f^{\pi}$	$E_{dd}$	nughter ( ¹⁵⁶ Hf)	coincident γ-rays	R ₀ (fm)	HF
6.072(10)	5.920(10	0) 100%	$0^+$	0.0	I		1.5533(77)	1.06(11)
* All v	alues from [199	6Pa01].						
Table 6 direct $\alpha$ em	hission from ¹⁶⁴ C	$Ds^*, J^{\pi} = 0^+, T_{1/2}$	g = 21(1)  ms, BR	$\alpha = 96^{+4}_{-4}$	5%**.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{dd}$	ughter ( ¹⁶⁰ W)	coincident γ-rays	R ₀ (fm)	HF
6.479(7)	6.321(7)	$96^{+4}_{-5}\%$	$0^+$	0.0			1.5504(56)	0.95(6)
* All v ** [200	alues from [199 08Bi05].	6Pa01], except wl	nere noted.					
<b>Table 7</b> direct $\alpha$ em	nission from ¹⁶⁸ I	Pt, $J^{\pi} = 0^+$ , $T_{1/2} =$	= 2.04(16) ms*, <i>i</i>	$BR_{\alpha} = \approx$	100%***.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^*$	** $I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	E	daughter( ¹⁶⁴ Os)	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.987(3)	6.821(3)	$\approx 1009$	<i>‰</i> 0 ⁺	0.	0		$1.5578^{+45}_{-42}$	0.97(8)
* Weig ** Wei *** No	thed average of ighted average of ot measured, dec	1.98(16) ms [200 of 6.823(3) MeV [2 duced from half-life	9Gi06], 2.1(2) n 2009Gi06], and ( fe.	ns [2004] 6.820(4)	Ke06], 2.0(2) ms   MeV [2004Ke06]	1998Ki20], and 2.0(4) ms [	1996Bi07].	
Table 8 direct $\alpha$ em	hission from ¹⁷² H	Hg*, $J^{\pi} = 0^+$ , $T_{1/2}$	$p_2 = 231(9) \ \mu s, B_2$	$R_{\alpha} = 100$	)%**.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^{\pi}$	$E_{dd}$	uughter ( ¹⁶⁸ Pt)	coincident γ-rays	R ₀ (fm)	HF
7.523(7)	7.348(7)	100%	$0^+$	0.0			1.5574(32)	0.99(4)

direct  $\alpha$  emission from ^{156m}Hf*, Ex = 1.952(6) MeV**, J^{$\pi$} = 8⁺, T_{1/2} = 520(10)  $\mu$ s, BR $_{\alpha}$  = 100%.

* All values from [2009Sa27].

7.348(7)

7.523(7)

** Not measured, deduced from half-life.

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1.5574(32)

0.99(4)

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Last updated 3/22/23

Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +6$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein. $J^{ p }$ values for ¹¹⁰ In, ¹¹⁴ Sb, ¹¹⁸ I, ¹²² Cs, ¹²⁶ La, ¹³⁰ Pr, ¹³⁴ Pm, ¹³⁸ Eu are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\epsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
110-		-		2 0 5 0 (1 2)	5.04044.0		11.50.((10))		
110 In		7+	4.9(1) h	3.878(12)	-5.040(12)		-11.524(12)	1.013(12)	[1975Bu24]
114Sb		3+	3.51(4) m	6.063(20)	-2.418(20)		-8.500(20)	3.426(20)	[1976Wi10]
118I		$2^{-}$	14.3(1) m	6.720(27)	0.380(21)		-4.023(20)	7.164(20)	[1969Ha03]
$^{122}Cs$		$1^{+}$	21.18(19) s	7.210(40)	0.812(34)		-3.361(34)	7.121(38)	[1993Al03]
¹²⁶ La			54(2) s	7.700(90)	1.827(91)		-1.884(91)	7.957(91)	[2002Ko02]
¹³⁰ Pr		$(5^+)$	40.0(4) s	8.250(70)	2.859(68)		-0.384(64)	9.070(65)	[1988Ba42]
¹³⁴ Pm		$(2^{+})$	$\approx 5 \text{ s}$	8.880(40)	3.885(44)		1.127(47)	10.234(50)	[1988KeZX]
¹³⁸ Eu		(6-)	12.1(6) s	9.750(30)	5.034(31)		2.872(30)	11.472(30)	[1985Ch25]
¹⁴² Tb		$1^{+}$	597(17) ms	10.40(70)	6.08(70)	0.0022(11)%	4.32(70)	12.51(70)	[1991Fi03]
¹⁴⁶ Ho		(6-)	2.8(5) s	11.317(9)	7.87(11)	obs	5.943(29)	13.296(29)	[2010Ma37, 2011MaZL,
									1986Wi05, 1988ToZW,
									1988WiZN, 1986Wi15,
									1987WiZM]
¹⁵⁰ Tm		(6 ⁻ )	2.20(7) s	11.34(20)#	7.87(20)#	1.2(3)%	6.79(20)#	13.64(20)#	[1988Ni02]
¹⁵⁴ Lu		$(2^{-})$		10.27(20)#	7.02(20)#		6.26(20)#	15.74(20)#	
^{154m} Lu	х	$(9^{+})$	1.16(5) s	10.27(20)#+x	7.02(20)#+x	$\approx 0.06\%$	6.26(20)#+x	15.74(20)#+x	[1988Vi02]
¹⁵⁸ Ta		$(2^{-})$	46(4) ms	10.98(20)#	8.03(20)#		7.57(20)#	16.39(20)#	[2014Ca03]
^{158m1} Ta	0.1408(87)	$(9^{+})$	35(1) ms	11.12(20)#	8.17(20)#		7.74(20)#	16.53(22)#	[1996Pa01]
^{158m2} Ta	2.8055(4)	(19 ⁻ )	6.1(1) μs	13.79(20)#	10.84(20)#		10.38(20)#	19.20(20)#	[2014Ca04]
¹⁶² Re		$(2^{-})$	107(13) ms	11.55(20)#	9.04(20)#		8.91(20)#	17.22(20)	[1997Da07]
^{162m} Re	0.1723(80)	$(9^{+})$	76(6) ms*	11.72(20)#	9.21(20)#		9.08(20)#	17.39(22)	[2016Ca15]
¹⁶⁶ Ir		$(2^{-})$	10.5(22) ms	12.13(20)#	10.07(20)#		10.35(20)#	18.27(20)	[1997Da07]
^{166m} Ir	0.1715(61)	(9+)	15.1(9) ms	12.30(20)#	10.24(20)#		10.52(20)#	18.44(20)	[1997Da07]
¹⁷⁰ Au		$(2^{-})$	$286^{+50}_{-40} \mu s$	12.60(20)#	11.10(20)#		11.71(20)#	19.30(20)	[2004Ke06]
^{170m} Au	0.282(10)	(9 ⁺ )	$617^{+50}_{-40} \ \mu s$	12.82(20)#	11.38(20)#		11.99(20)#	19.58(20)	[2004Ke06]

* Weighted average of 66(7) ms [1996Pa01] and 84.6(62) ms [1997Da07].

#### Table 2

Particle emission from the odd-Z,  $T_z = +6$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	S _p	$BR_p$	$S_{2p}$	Qα	BRα	Experimental
	-	-	•			
¹¹⁰ In	5.255(12)		13.44(11)	-1.952(12)		
¹¹⁴ Sb	3.457(20)		11.084(20)	-0.452(23)		
$^{118}I$	3.165(24)		8.727(20)	1.101(28)		
¹²² Cs	2.953(35)		8.976(37)	0.401(39)		
¹²⁶ La	2.593(91)		7.810(91)	0.746(97)		
¹³⁰ Pr	2.177(70)		7.128(84)	1.37(11)		
¹³⁴ Pm	1.720(63)		6.114(51)	1.987(77)		
¹³⁸ Eu	1.047(40)		5.158(75)	2.589(50)		
¹⁴² Tb	0.62(70)		4.15(70)	2.77(70)		
¹⁴⁶ Ho	0.285(9)		3.448(29)	2.90(70)		
¹⁵⁰ Tm	0.04(20)#		3.08(21)#	2.32(20)#		
¹⁵⁴ Lu	-0.204(14)#		2.52(21)#	4.40(28)#		
^{154m} Lu	-0.204(14)#-x		2.52(21)#-x	4.40(28)#+x		
¹⁵⁸ Ta	-0.448(13)		2.00(21)#	6.124(4)	$\approx 100\%$	[2014Ca03, 1997Da07, 1996Pa01, 1981HoZM, 1978ReZZ]
^{158m1} Ta*	-0.4589(16)		2.14(23)#	6.265(10)	$\approx 100\%$	[2019Pa27, 1996Pa01, 2014Ca03, 1997Da07, 2015Ca04, 2016Ca15,
						1981HoZM]
^{158m2} Ta**	-3.254(13)		-0.67(21)#	8.930(4)	1.4(2)%	2016Ca15, 2014Ca03, 1997Da07, 1996Pa01, 1979Ho10, 1981HoZM,
						1978ReZZ]
¹⁶² Re	-0.765(11)		1.21(21)#	6.240(5)	$\approx 100\%*$	[1997Da07]
^{162m} Re***	-0.937(19)		1.04(22)#	6.412(9)	91(5)%**	[2016Ca15, 1997Da07, 1996Pa01, 1979Ho10, 1981HoZM, 1978ReZZ]
¹⁶⁶ Ir	-1.152(8)	6.9(29)%	0.41(21)#	6.722(6)	93.1(29)%	[1997Da07, 1996Pa01, 2004Ke06, 1981Ho10, 1995DaZX, 1981HoZM]
166mIr ^a	-1.324(10)	1.76(58)%	0.24(21)#	6.894(8)	98.24(58)%	[1997Da07, 1996Pa01, 2004Ke06, 1981Ho10, 1995DaZX, 1981HoZM]
¹⁷⁰ Au	-1.472(12)	89(10)%	-0.39(21)#	7.177(15)	11(10)%	[ <b>2004Ke06</b> , 2002LeZZ]
$^{170m}Au^b$	-1.754(16)	58(5)%	-0.67(21)#	7.459(18)	42(5)%	[2004Ke06, 2002Ma61, 2002LeZZ, 2003SeZZ, 2001DaZU]

* No evidence for  $\alpha$ -decay from ¹⁶²W (arising from the  $\beta$ -decay of ¹⁶²Re were observed [1997Da07]. ** Weighted average of 85(9)% [1996Pa01] and 94(6)% [1997Da07].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(absb)$	$J_f^{\pi}$	$E_{daughter}(^{154}L$	u) coincide	ent γ-rays	R ₀ (fm)*	**	HF
6.123(5)	5.968(5)	100%	(2 ⁻ )	0.0			1.5534(8	33)	1.76(34)
* All va ** Inter	lues from [2014 polated between	Ca03] 1.5535(31) fm ¹⁵⁶ I	Hf and 1.5533(77)	) fm ¹⁶⁰ W.					
<b>Fable 4</b> lirect α emi	ssion from ^{158m1}	Ta*, Ex = 140.8(87	$V$ ) keV, $J^{\pi} = , T_{1/2}$	$= 35(1) \text{ ms}^{**}, BR_{c}$	$\alpha \approx 100\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{m{\pi}}$	E _{daughter} ( ¹⁵⁴ Lu)	coincident γ	-rays	$R_0 (fm)^@$	HF
6.136(4) 6.177(4)	5.981(4) 6.021(4) 6.041(4)	0.1031(25)% 2.8(5)%	0.099(24)% 2.7(5)% 06 ⁺² %	$(8,9,10^+)$ $(8^+)$ $(0^+)$	0.126(11)*** 0.088(11)*** 0.066(11)***	0.060 0.022		1.5534(83) 1.5534(83)	$1.5^{+0.7}_{-0.5} \times 10$ $78^{+27}_{-21}$ $2.7^{+0.8}$
[@] Interj	polated between	ergy. 1.5535(31) fm ¹⁵⁶ H	If and 1.5533(77)	fm ¹⁶⁰ W.					
lirect $\alpha$ emi	ssion from 158m2	$Ta^*, Ex = 2805.5(4)$	) keV, $J^{\pi} = (19^{-})$	$T_{1/2} = 6.1(1) \ \mu s$	$BR_{\alpha} = 1.4(2)\%.$				
lirect $\alpha$ emi $E_{\alpha}(\text{c.m.})$	ssion from $158m^2$ $E_{\alpha}(\text{lab})$	$\frac{\text{Ta}^*, \text{Ex} = 2805.5(4)}{I_{\alpha}(\text{abs})}$	$J_{f}^{\pi} = (19^{-}),$	$T_{1/2} = 6.1(1) \ \mu s,$ $E_{daughter}(^{154}Lu$	$BR_{\alpha} = 1.4(2)\%.$ () coincident	γ-rays	R ₀ (fm)***	Н	F
lirect $\alpha$ emi $E_{\alpha}(\text{c.m.})$ 3.869(11)	$\frac{E_{\alpha}(\text{lab})}{8.644(11)}$	$Ta^*, Ex = 2805.5(4$ $I_{\alpha}(abs)$ 1.4(2)%	$J_{f}^{\pi}$ (9 ⁺ )	$T_{1/2} = 6.1(1) \ \mu s,$ $E_{daughter}(^{154}Lu$ $0.066(11)^{**}$	$BR_{\alpha} = 1.4(2)\%.$ ) coincident	γ-rays	R ₀ (fm)*** 1.5534(83)	HI 6.:	F 5(11)×10 ³
lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 3.869(11) * All va ** Dedu *** Inte	$\frac{E_{\alpha}(\text{lab})}{E_{\alpha}(\text{lab})}$ 8.644(11) ulues from [2014) uced from $\alpha$ energy	Ta*, Ex = 2805.5(4 $I_{\alpha}(abs)$ 1.4(2)% Ca03]. rgy. n 1.5535(31) fm ¹⁵⁰	b) keV, $J^{\pi} = (19^{-})$ . $J_{f}^{\pi}$ (9 ⁺ ) ⁵ Hf and 1.5533(77)	$\frac{T_{1/2} = 6.1(1) \ \mu s,}{E_{daughter}}$ $\frac{E_{daughter}}{154}$ $\frac{154}{100}$ $\frac{100}{100}$ $\frac{160}{100}$	$BR_{\alpha} = 1.4(2)\%.$	γ-rays	R ₀ (fm)*** 1.5534(83)	HI 6.:	F 5(11)×10 ³
lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 3.869(11) * All va ** Dedu *** Inte fable 6 lirect $\alpha$ emi	$\frac{E_{\alpha}(\text{lab})}{E_{\alpha}(\text{lab})}$ 8.644(11) ulues from [20144 uced from $\alpha$ ener erpolated betwee ssion from ¹⁶² Re	Ta*, Ex = 2805.5(4 $I_{\alpha}(abs)$ 1.4(2)% Ca03]. rgy. n 1.5535(31) fm ¹⁵⁰ *, J ^{$\pi$} = (2 ⁻ ), T _{1/2}	b) keV, $J^{\pi} = (19^{-})$ . $J_{f}^{\pi}$ (9 ⁺ ) ⁵ Hf and 1.5533(77) = 107(13) ms, <i>BR</i> .	$\frac{F_{1/2} = 6.1(1) \ \mu s,}{E_{daughter}(^{154}Lu}$ $0.066(11)^{**}$ $7) \ fm^{160}W.$ $\alpha = \approx 100\%.$	BR _α = 1.4(2)%.	γ-rays	R ₀ (fm)*** 1.5534(83)	HI 6.3	F 5(11)×10 ³
lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 3.869(11) * All va ** Dedu *** Inte Fable 6 lirect $\alpha$ emi $E_{\alpha}(c.m.)$	$\frac{E_{\alpha}(\text{lab})}{E_{\alpha}(\text{lab})}$ 8.644(11) ulues from [20144 uced from $\alpha$ enere- erpolated betwee ssion from ¹⁶² Re $E_{\alpha}(\text{lab})$	Ta*, Ex = 2805.5(4 $I_{\alpha}(abs)$ 1.4(2)% Ca03]. rgy. n 1.5535(31) fm ¹⁵⁰ *, J ^{$\pi$} = (2 ⁻ ), T _{1/2} : $I_{\alpha}(abs)$	$J_{f}^{\pi} = (19^{-})$ $J_{f}^{\pi}$ $(9^{+})$ 5 Hf and 1.5533(77) $= 107(13) \text{ ms, } BR$ $J_{f}^{\pi}$	$f(1) = 6.1(1) \ \mu s,$ $E_{daughter}(^{154}Lu)$ $0.066(11)^{**}$ $f(1) \ fm^{160}W.$ $\alpha = \approx 100\%.$ $E_{daughter}(^{158}T)$	$BR_{\alpha} = 1.4(2)\%.$ ) coincident (a) coincid	γ-rays ent γ-rays	R ₀ (fm)*** 1.5534(83) R ₀ (fm)	HI 6.: **	F 5(11)×10 ³ HF
lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 3.869(11) * All va ** Dedu *** Inte Fable 6 lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 6.239(5)	$\frac{E_{\alpha}(\text{lab})}{E_{\alpha}(\text{lab})}$ 8.644(11) 4.000 from [20144 4.000 from $\alpha$ energy 4.000 energ	Ta*, Ex = 2805.5(4 $I_{\alpha}(abs)$ 1.4(2)% Ca03]. rgy. a 1.5535(31) fm ¹⁵⁰ , J ^{$\pi$} = (2 ⁻ ), T _{1/2} : $I_{\alpha}(abs)$ 100%	$J_{f}^{\pi} = (19^{-})$ $J_{f}^{\pi}$ $(9^{+})$ 5 Hf and 1.5533(77) $= 107(13) \text{ ms, } BR$ $J_{f}^{\pi}$ $(2^{-})$	$\frac{F_{daughter}(^{154}Lu}{0.066(11)^{**}}$ $\frac{E_{daughter}(^{154}Lu}{0.066(11)^{**}}$ $\frac{160}{M}$ $\frac{\alpha}{\alpha} = \approx 100\%.$ $\frac{E_{daughter}(^{158}T)}{0.0}$	BR _α = 1.4(2)%. ) coincident Ga) coincid	γ-rays ent γ-rays	R ₀ (fm)*** 1.5534(83) R ₀ (fm) 1.5519(i	HI 6.: ** 83)	$\frac{F}{5(11) \times 10^3}$ $\frac{HF}{1.7^{+0.4}_{-0.3}}$
lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 3.869(11) * All va ** Dedu *** Inte Fable 6 lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 6.239(5) * All va ** Inter	$\frac{E_{\alpha}(\text{lab})}{E_{\alpha}(\text{lab})}$ $\frac{E_{\alpha}(\text{lab})}{8.644(11)}$ $\frac{E_{\alpha}(\text{lab})}{1000}$ $\frac{E_{\alpha}(\text{lab})}{6.086(5)}$ $\frac{E_{\alpha}(\text{lab})}{1000}$	Ta*, Ex = 2805.5(4 $I_{\alpha}(abs)$ 1.4(2)% Ca03]. rgy. n 1.5535(31) fm ¹⁵⁰ *, J ^{$\pi$} = (2 ⁻ ), T _{1/2} : $I_{\alpha}(abs)$ 100% Da07]. 1.5533(77) fm ¹⁶⁰	$J_{f}^{\pi} = (19^{-})$ $J_{f}^{\pi}$ $(9^{+})$ $= 107(13) \text{ ms, } BR$ $J_{f}^{\pi}$ $(2^{-})$ W and 1.5504(56)	$\frac{F_{daughter}(^{154}Lu}{0.066(11)^{**}}$ $\frac{E_{daughter}(^{154}Lu}{0.066(11)^{**}}$ $\frac{160}{M}$ $\frac{E_{daughter}(^{158}T)}{0.0}$ $\frac{164}{M}$ Os.	BR _α = 1.4(2)%. ) coincident (a) coincid (b) coincid	γ-rays ent γ-rays	R ₀ (fm)*** 1.5534(83) R ₀ (fm) 1.5519(i	HI 6.: ** 83)	F $5(11) \times 10^{3}$ HF $1.7^{+0.4}_{-0.3}$
lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 3.869(11) * All va ** Dedu *** Inte <b>Fable 6</b> lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 6.239(5) * All va ** Inter <b>Fable 7</b> lirect $\alpha$ emi	$\frac{E_{\alpha}(\text{lab})}{E_{\alpha}(\text{lab})}$ $\frac{E_{\alpha}(\text{lab})}{8.644(11)}$ $\frac{E_{\alpha}(\text{lab})}{1000}$ $\frac{E_{\alpha}(\text{lab})}{6.086(5)}$ $\frac{E_{\alpha}(\text{lab})}{1000}$ $\frac{E_{\alpha}(\text{lab})}{1000}$ $\frac{E_{\alpha}(\text{lab})}{1000}$ $\frac{E_{\alpha}(\text{lab})}{1000}$ $\frac{E_{\alpha}(\text{lab})}{1000}$	Ta*, Ex = 2805.5(4 $I_{\alpha}(abs)$ 1.4(2)% Ca03]. rgy. n 1.5535(31) fm ¹⁵⁰ *, J ^{$\pi$} = (2 ⁻ ), T _{1/2} : $I_{\alpha}(abs)$ 100% Da07]. 1.5533(77) fm ¹⁶⁰ ref. Ex = 172.3(80)	$J_{f}^{\pi} = (19^{-})$ $J_{f}^{\pi} = (9^{+})$ $(9^{+})$ $= 107(13) \text{ ms, } BR$ $J_{f}^{\pi} = (2^{-})$ W and 1.5504(56) $keV^{***}, J^{\pi} = , T$	$\frac{F_{daughter}(^{154}Lu}{0.066(11)^{**}}$ $\frac{E_{daughter}(^{154}Lu}{0.066(11)^{**}}$ $\frac{160}{M}$ $\frac{\alpha}{164}$ $\frac{E_{daughter}(^{158}T)}{0.0}$ $\frac{164}{M}$ $\frac{164}$	$BR_{\alpha} = 1.4(2)\%.$ ) coincident Ta) coincid Ta) coincid BR_{\alpha} = 91(5) \%^{@}.	γ-rays	R ₀ (fm)*** 1.5534(83) R ₀ (fm) 1.5519(i	HI 6.: ** 83)	$\frac{F}{5(11) \times 10^{3}}$ $\frac{HF}{1.7^{+0.4}_{-0.3}}$
lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 3.869(11) * All va ** Dedu *** Inte Fable 6 lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 6.239(5) * All va ** Inter Fable 7 lirect $\alpha$ emi E_{\alpha}(c.m.)	$\frac{E_{\alpha}(\text{lab})}{E_{\alpha}(\text{lab})}$ $\frac{E_{\alpha}(\text{lab})}{8.644(11)}$ $\frac{E_{\alpha}(\text{lab})}{1000}$ $\frac{E_{\alpha}(\text{lab})}{6.086(5)}$ $\frac{E_{\alpha}(\text{lab})}{1000}$ $\frac{E_{\alpha}(\text{lab})}{1000}$ $\frac{E_{\alpha}(\text{lab})}{1000}$	Ta*, Ex = 2805.5(4 $I_{\alpha}(abs)$ 1.4(2)% Ca03]. gy. n 1.5535(31) fm ¹⁵⁰ *, J ^{$\pi$} = (2 ⁻ ), T _{1/2} : $I_{\alpha}(abs)$ 100% Da07]. 1.5533(77) fm ¹⁶⁰ ee*, Ex = 172.3(80) $I_{\alpha}(rel)$	$J_{f}^{\pi} = (19^{-})$ $J_{f}^{\pi} = (9^{+})$ $J_{f}^{\pi} = 107(13) \text{ ms}, BR$ $J_{f}^{\pi} = (2^{-})$ W and 1.5504(56) $keV^{***}, J^{\pi} = , T$ $I_{\alpha}(abs)$	$\frac{F_{daughter}(^{154}Lu}{0.066(11)^{**}}$ $\frac{E_{daughter}(^{154}Lu}{0.066(11)^{**}}$ $\frac{160}{M}$ $\frac{\alpha}{\alpha} = \approx 100\%.$ $\frac{E_{daughter}(^{158}T)}{0.0}$ $\frac{164}{M}$ $\frac{164}{M}$ $\frac{J_f^{\pi}}{M}$	$BR_{\alpha} = 1.4(2)\%.$ ) coincident $\overline{fa}$ coincid $\overline{fa}$ coincid $BR_{\alpha} = 91(5) \%^{@}.$ $E_{daughter}(^{158}Ta)$	γ-rays	R ₀ (fm)*** 1.5534(83) R ₀ (fm) 1.5519(i γ-rays	HI 6.: ** 83) R ₀ (fm) ⁶	F 5(11)×10 ³ HF 1.7 ^{+0.4} 1.7 ^{-0.3}

*** Deduced by evaluator from Fig 2 in [2016Ca15]. ^(a) Weighted average of 85(9)% [1996Pa01] and 94(6)% [1997Da07]. ^(a) ^(a) ^(a) ^(a) ^(a) ^(a) ^(b) ^(b)

direct p emiss	ion from ¹⁶⁶ Ir*, $J^{\pi}$ =	$(2^{-}), T_{1/2} = 10.5(22)$	) ms, $BR_p = 6$	5.9(29)%.			
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daugi}$	_{tter} ( ¹⁶⁵ Os) coir	ncident γ-rays	
1.152(8)	1.145(8)	6.9(29)%	(7/2-	-) 0.0			
* All valu	ues from [1997Da07].						
Table 9 direct $\alpha$ emiss	sion from ¹⁶⁶ Ir*, J ^{$\pi$} =	, $T_{1/2} = 10.5(22)$ ms	$BR_{\alpha} = 93.1$	(29)%.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^{{m \pi}}$	$E_{daughter}(^{162}\mathrm{Re})$	coincident $\gamma$ -rays	$R_0 (fm)^{**}$	HF
6.724(6)	6.562(6)	93.1(29)%	(2 ⁻ )	0.0		1.5541(72)	1.6(4)
* All valu ** Interp	ues from [1997Da07]. olated between 1.550	4(56) ¹⁶⁴ Os and 1.55	78(45) ¹⁶⁸ Pt.				
direct p emiss	ion from ^{166m} Ir*, Ex :	$= 171.5(61) \text{ keV}, \text{ J}^{\pi} =$	$= (9^+), T_{1/2} =$	= 15.1(9) ms, $BR_p$ =	1.76(58)%.		
$E_p(c.m.)$	$E_p(\text{lab})$	<i>I_p</i> (abs)	$E_{d}$	_{aughter} ( ¹⁶⁵ Os)	coincident γ-rays		
1.340(8)	1.316(8)	1.76(58)%	(2-	-)	0.0		
* All valu	ues from [1997Da07].						
Table 11 direct $\alpha$ emiss	sion from ^{166m} Ir*, Ex	$= 171.5(61) \text{ keV}, \text{ J}^{\pi}$	$= (9^+), T_{1/2} =$	= 15.1(9) ms, $BR_{\alpha}$ =	98.24(58)%.		
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{162}\mathrm{Re})$	coincident γ-ray	s R ₀ (fm)**	HF
6.723(5)	6.561(5)	98.24(58)%	(9+)	0.172(8)		1.5541(72)	2.2(4)
* All valu	ues from [1997Da07].	4(56) 164 Op and 1 55	79(45) 1680+				
Table 12       direct p emiss	ion from ¹⁷⁰ Au*, J ^{$\pi$} =	$= (2^{-}), T_{1/2} = 286^{+50}_{-40}$	$\frac{1}{2}\mu s, BR_p = 8$	39(10)%.			
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(abs)$		$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{169}\mathrm{Pt})$	coincident γ-rays	
1.472(12)	1.463(12)	89(10)%	1	(7/2-)	0.0		
* All valu	ues from [2004Ke06].						
Table 13 direct $\alpha$ emiss	sion from ¹⁷⁰ Au*, J ^{$\pi$} :	= (2 ⁻ ), $T_{1/2} = 286^{+5}_{-4}$	$_{0}^{0} \mu s, BR_{\alpha} =$	11(10)%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{166}\mathrm{Ir})$	coincident γ-ray	s R ₀ (fm)**	HF
7.170(10)	7.001(10)	89(10)%	(2 ⁻ )	0.0		1.5576(55)	$2^{+25}_{-1}$
* All valu ** Interp	nes from [2004Ke06]. olated between 1.557	8(45) ¹⁶⁸ Pt and 1.557	74(32) ¹⁷² Hg.				
Table 14 direct p emiss	ion from ^{170m} Au*, Ex	$x = 282(10) \text{ keV}, J^{\pi} =$	$(9^+), T_{1/2} =$	$617^{+50}_{-40} \ \mu s, BR_p = 5$	8(5)%.		
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(abs)$	J	f	$E_{daughter}(^{169}\mathrm{Pt})$	coincident $\gamma$ -rays	
1.753(6)	1.743(6)	58(5)%	(	7/2-)	0.0		

* All values from [2004Ke06].

#### Table 15

direct $\alpha$ emission from ^{170m} Au*, Ex = 282(10) keV, J ^{$\pi$} = (9 ⁺ ), T _{1/2} = 617 ⁺⁵⁰ ₋₄₀ $\mu$ s, BR _{$\alpha$} = 42(5)%.	
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{166}\mathrm{Ir})$	coincident γ-rays	R ₀ (fm)**	HF
7.278(6)	7.107(6)	42(5)%	(9 ⁺ )	0.172(6)		1.5576(55)	1.2(4)

* All values from [2004Ke06].

** Interpolated between 1.5578(45) ¹⁶⁸Pt and 1.5574(32) ¹⁷²Hg.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +13/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\epsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
¹¹⁷ Te		$1/2^{+}$	61(2) m	3.544(13)	-0.858(13)		-10.137(13)	1.847(13)	[1961Fi05]
¹²¹ Xe		$(5/2^+)$	38.8(6) m	3.765(11)	-0.408(10)		-7.583(12)	3.734(13)	[1969Bu07]
¹²⁵ Ba		$1/2^{+}$	3.3(4) m*	4.421(13)	0.709(11)		-6.304(12)	4.152(12)	[1975Ar31, 1968Da09]
¹²⁹ Ce		$(5/2^+)$	3.5(3) m	5.040(40)	1.793(28)		-4.625(28)	5.377(29)	[1993Al03]
¹³³ Nd		$(7/2^+)$	70(10) s	5.610(50)	2.847(51)		-3.141(54)	6.566(51)	[1977Bo02]
¹³⁷ Sm		$(9/2^{-})$	45(1) s	6.080(30)	3.919(31)		-1.634(31)	7.521(31)	[1983AlZO]
¹⁴¹ Gd		$1/2^{+}$	14(4) s	6.701(23)	4.943(23)	0.3(1)%	-0.301(24)	8.424(24)	[ <b>1989Gi06</b> , 1986Wi15]
¹⁴⁵ Dy		$(1/2^+)$	6(2) s	8.16(11)	6.228(29)	$\approx 50\%$	1.421(13)	9.258(14)	[1993To04, 1984ScZT]
¹⁴⁹ Er		$(1/2^+)$	4(2) s	7.900(30)	6.829(29)	7(2)%	2.423(29)	10.23(11)	[1989Fi01, 1984ScZT]
149mEr*	0.7418(2)	$(11/2^{-})$	8.9(2) s	8.642(30)	7.571(29)	0.18(7)%	3.165(29)	10.97(11)	[1989Fi01, 1984To07, 1984ScZT]
¹⁵³ Yb		7/2-	4.2(2) s	6.81(20)#	6.05(20)#	0.008(2)%	1.89(20)#	12.06(20)#	[1988Wi05]
¹⁵⁷ Hf		$(7/2^{-})$	115(1) s	7.59(20)#	7.12(20)#		3.19(20)#	12.69(20)#	[1996Pa01]
$^{161}W$			409(18) ms	8.27(20)#	8.14(20)#		4.62(20)#	13.51(20)#	[1996Pa01]
165Os		$(7/2^{-})$	21(1) ms	8.91(20)#	9.20(20)#		6.21(20)#	14.61(20)#	[1996Pa01]
¹⁶⁹ Pt		$(7/2^{-})$	7.0(2) ms	9.63(20)#	10.24(20)#		7.79(20)#	15.77(20)#	[2004Ke04]
¹⁷³ Hg		(7/2-)	0.80(8) ms	10.17(20)#	11.16(20)#		9.17(20)#	17.001(20)#	[2012Od01]

* Weighted average of 3.5(4) m [1975Ar31] and 3.0(5) m 1968Da09].

#### Table 2

Particle emission from the even-Z,  $T_z = +13/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	S _{2p}	Qα	BRα	Experimental	
¹¹⁷ Te	5 562(14)	9,640(13)	0.808(14)			
¹²¹ Xe	6.023(18)	9.876(13)	0.000(17)			
125 Ba	5.023(10)	8 999(15)	0.190(17) 0.387(15)			
129 Co	4.051(61)	8.047(30)	0.057(10)			
133 N.J	4.951(01)	7.047(30)	1.520(54)			
137 0	4.394(33)	(25((37)	1.330(34)			
141 Sm	4.111(/5)	6.356(34)	1.916(55)			
¹⁴¹ Gd	3.527(55)	5.422(23)	2.343(35)			
¹⁴⁵ Dy	3.163(29)	4.59(20)	2.557(21)			
¹⁴⁹ Er	3.039(88)	4.12(29)	2.076(29)			
^{149m} Er	3.781(88)	4.86(29)	2.818(29)			
¹⁵³ Yb	2.73(21)#	3.47(20)#	4.16(20)#			
¹⁵⁷ Hf	2.44(21)#	2.93(20)#	5.880(3)	94(5)%*	[1996Pa01. 1979Ho10, 1989Wo02, 1981HoZM]	
					1973Ea01, 1965Ma14]	
¹⁶¹ W	1.972(208)#	2.23(20)#	5.923(4)	73(3)%	[1996Pa01. 1981Ho10, 1989Ho02, 1981HoZM]	
¹⁶⁵ Os	1.563(208)#	1.42(21)#	6.335(6)	90(2)%	[2008Bi15, 1996Pa01. 2013Dr06, 2002Pa03	
					[1997Da07, 1991Se01, 1981Ho10, 1978Ca11,	
					1978CaZF, 1977Ca23]	
¹⁶⁹ Pt	1.087(208)#	0.54(22)#	6.858(5)	$\approx 100\%$	[2004Ke06, 1999Se14, 2012Od01, 2009Go16]	
					[2008Bi15, 1996Pa01, 1981Ho10]	
¹⁷³ Hg	0.632(208)#	-0.23(22)#	7.378(4)	100%	[2012Od01, 2009Sa27, 2004Ke04, 1999Se14]	
U	· · · ·				[1998NiZW]	

* Weighted average of 95(5)% [1996Pa01] and 91(7)% [1979Ho10].

## Table 3

<u>direct</u> $\alpha$ emission from ¹⁵⁷ Hf, T _{1/2} = 115(1) s*, <i>BR</i> _{$\alpha$} = 94(5)%**.										
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{153}\mathrm{Yb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF				
5.881(4)	5.731(4)***	94(5)%**	0.0		1.5573(31)	1643(14)				

* [1996Pa01]

** Weighted average of 95(5)% [1996Pa01] and 91(7)% [1979Ho10].

** Weighted average of 5.729(4) MeV [1996Pa01] and 5.735(5) MeV [1979Ho10].

direct $\alpha$ emis	sion from ¹⁶¹ W*, T	$_{1/2}$ = 409(18) ms, <i>E</i>	$BR_{\alpha} = 73(3)\%.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$E_{daughter}(^{157}\mathrm{Hf})$	coincident γ-rays	R ₀ (fm)	HF	
5.923(5)	5.776(5)**	73(3)%	0.0		1.5636(62)	$1.80\substack{+0.28\\-0.24}$	
* All val ** Weigh	ues from [1996Pa01 nted average of 5.77	], except where no 5(5) MeV [1996Pa	oted. 101] and 5.777(5) MeV [1	979Ho10], adjusted to 5.77	6(5) in [1991Ry01].		
Table 5direct $\alpha$ emiss	sion from ¹⁶⁵ Os*, T	$T_{1/2} = 21(1) \text{ ms}, BR$	$\alpha = 90(2)\%^{**}.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{161}W)$	coincident $\gamma$ -ray	R ₀ (fm)	HF	
6.342(7)	6.188(7)	90(2)%**	0.0		1.5570(38)	0.41(4)	
* All val ** [2008 Table 6 direct $\alpha$ emis	Bil5]. sion from ¹⁶⁹ Pt*, T ₁	$_{1/2} = 7.0(2) \text{ ms}, BR$	$\alpha = \approx 100\%^{**}.$	coincident % rays	P _o (fm)	НЕ	
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(1ab)$	$I_{\alpha}(abs)$	E _{daughter} ( ^a Os)	concident y-rays	<b>K</b> ₀ (III)	1 27(9)	
* All val. ** [1999 <b>Table 7</b> direct α emis	ues from [2004Ke00 Se14]. sion from ¹⁷³ Hg*, T	$\approx 100\%^{+10}$ 6], except where no $\Gamma_{1/2} = 800(80) \ \mu s$ , $\mu$	bted. BR $_{\alpha} = 100\%^{**}$ .		1.3002(24)	1.57(8)	
E(am)	F (lab)	L (abs)	$E_{\rm res}$ (169 $\mathbf{p}_{\rm t}$ )	opingidant w rays	$\mathbf{P}_{\mathbf{r}}$ (fm)	ПЕ	
<u>7.379(5)</u>	7.208(5)	100%	0.0		1.5524(75)	$1.22^{+0.23}_{-0.21}$	

* All values from [2010Od01].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +13/2 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z = +13/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{|pi} values for ¹¹⁹I, ¹²³Cs, ¹²⁷La, ¹³¹Pr, ¹³⁵Pm, ¹³⁹Eu, ¹⁴³Tb, ¹⁴⁷Ho, ¹⁵¹Tm are taken from ENSDF

Nuclide	Fv	īπ	Tere	0.	0.	BRo	0.2	0	Experimental
Nucliue	LA	5	11/2	Qε	$\mathcal{Q}\varepsilon p$	DR _B p	$Q \epsilon 2p$	Qεα	Experimental
¹¹⁹ I		5/2+	19.0(2) m*	3.405(23)	-3.070(22)		-7.958(22)	3.831(22)	[1968Se05, 1969La33]
¹²³ Cs		$1/2^{+}$	5.87(5) m	4.205(15)	-2.253(13)		-7.078(29)	3.714(14)	[1993Al03]
¹²⁷ La		$(11/2^{-})$	5.1(1) m	4.922(28)	-0.834(28)		-5.275(26)	4.927(28)	[1992Ic02]
¹³¹ Pr		$(3/2^+)$	1.48(2) m	5.410(60)	0.038(54)		-3.818(48)	6.092(48)	[1983AkZZ]
¹³⁵ Pm			49(3) s	6.150(90)	1.177(85)		-2.222(85)	7.221(89)	[1989Ko07]
¹³⁹ Eu		$(11/2^{-})$	17.9(6) s	6.982(17)	2.227(18)		-0.392(18)	8.391(23)	[1986De35]
¹⁴³ Tb		$(11/2^{-})$	12(1) s	7.81(21)	3.601(59)		0.937(52)	9.536(52)	[1986Re11]
¹⁴⁷ Ho		$(11/2^{-})$	5.8(4) s	8.439(10)	4.718(45)		2.592(20)	10.05(20)	[1982No08]
¹⁵¹ Tm		$(11/2^{-})$	4.13(11) s	7.495(25)	3.885(16)		2.344(21)	11.000(21)	[1988Ba02]
¹⁵⁵ Lu		$(11/2^{-})$	70(1) ms	7.958(25)	4.593(16)		3.344(21)	13.296(25)	[1996Pa01]
^{155m1} Lu	0.199(62)	$(1/2^+)$	136(9) ms	7.978(25)	4.613(16)		3.364(21)	13.316(25)	1996Pa01, 1997Da07]
^{155m2} Lu	1.781(2)	$(25/2^{-})$	2.71(3) ms	9.739(25)	6.374(16)		5.125(21)	15.097(25)	1996Pa01]
¹⁵⁹ Ta		$(1/2^+)$	1.10(10) s	8.413(26)	5.484(17)		4.403(23)	13.639(26)	1996Pa01]
^{159m} Ta	0.0637(52)	$(11/2^{-})$	514(9) ms**	8.477(26)	5.548(18)		4.467(24)	13.703(26)	1997Da07, 1996Pa01]
¹⁶³ Re		$(1/2^+)$	390(72) ms	8.910(60)	6.490(64)		5.736(30)	14.425(25)	[1997Da07]
^{163m} Re	0.1151(40)	$(11/2^{-})$	214(5) ms	9.025(60)	6.605(64)		5.851(30)	14.540(25)	[1997Da07]
¹⁶⁷ Ir		$(1/2^+)$	29.3(6) ms	9.430(80)	7.476(88)		7.211(32)	15.411(61)	[2005Sc22]
^{167m} Ir	0.1753(22)	$(11/2^{-})$	28.5(6) ms***	9.650(80)	7.651(88)		7.386(32)	15.586(61)	[2005Sc22, 2004Ke06,
									1997Da07]
¹⁷¹ Au		$(1/2^+)$	$22^{+3}_{-2} \ \mu s$	9.900(80)#	8.33(10)#		8.583(33)#	16.512(84)	[2004Ke06]
171m Au	0.258(13)	$(11/2^{-})$	1.09(3) ms	10.158(81)#	8.59(10)#		8.5841(35)#	16.770(85	[2004Ke06]
	× /	. /		~ /	. /		× /		

* Weighted average of 19.3(2) m [1968Se05] and 18.2(3) m [1969La33].

** Weighted average of 500(11) ms [1997Da07], and 544(16) ms [1996Pa01].

*** Weighted average of 30.0(6) ms [1997Da07], 25.7(8) ms [2004Ke06], and 28.7(33) ms [2005Sc22].

#### Table 2

Particle emission from the odd-Z,  $T_z = +13/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$BR_p$	$S_{2p}$	Qα	BRα	Experimental
110-						
119	3.376(28)		9.716(23)	0.801(27)		
$^{123}Cs$	2.978(16)		9.376(13)	0.309(25)		
¹²⁷ La	2.515(29)		8.384(27)	0.723(29)		
¹³¹ Pr	2.167(55)		7.555(52)	1.171(54)		
¹³⁵ Pm	1.705(84)		6.703(84)	1.813(95)		
¹³⁹ Eu	1.189(18)		5.903(19)	2.239(84)		
¹⁴³ Tb	0.749(58)		5.071(53)	2.554(53)		
¹⁴⁷ Ho	0.491(8)		3.94(11)	2.237(51)		
¹⁵¹ Tm	0.229(9)		3.704(23)	2.561(20)		
¹⁵⁵ Lu	-0.098(8)		3.150(23)	5.802(2)	90(2)%	[2016Ca42, 1997Da01, 1996Pa01, 1979Ho10, 2018Pa37, 1998DiZY,
						1993Li34, 1993ToZX,1991To09, 1990AbZW, 1989Ho12, 1989HoZX,
						1984Gr14, 1981HoZM]
^{155m1} Lu	-0.078(10)		3.130(23)	5.822(6)	76(16)%	[2016Ca42, 1997Da07, 1996Pa01, 1991To09]
^{155m2} Lu	1.683(12)		1.369(23)	7.583(6)	obs	[1996Pa01, 2016Ca42, 1993Li34 1981HoZM]
¹⁵⁹ Ta	-0.374(9)		2.578(23)	5.681(6)	34(5)%	1997Da07, 1996Pa01]
^{159m} Ta	-0.438(10)		2.514(24)	5.745(8)	55(1)%	1997Da07, 1996Pa01, 2002Ro17, 1979Ho10]
¹⁶³ Re	-0.708(6)		1.802(31)	6.012(8)	32(3)%	[1997Da07]
^{163m} Re	-0.823(7)		1.687(31)	6.127(9)	66(4)%	[ <b>1997Da07</b> , 1996Pa01, 1979Ho10]
¹⁶⁷ Ir	-1.070(4)	39.3(13)%	0.991(30)	6.505(3)	43(2)%	[2005Sc22, 1997Da07, 2001Ke05, 1996Pa01, 1995DaZX, 1981Ho10]
^{167m} Ir	-1.185(6)	0.42(8)%	0.876(30)	6.620(5)	90(3)%	2005Sc22, 2004Ke06, 1997Da07, 1995DaZX, 1981Ho10]
¹⁷¹ Au	-1.448(10)	100%	0.047(31)	7.085(11)		[2004Ke06, 1999Po09, 2003Bb21]
171m Au	-1.706(16)	40(4)%*	-0.211(34)	7.343(17)	60(4)%*	[2004Ke06, 1999Po09, 1997Da07, 2003Bb21, 1995DaZX]

* Weighted average from [2004Ke06]  $BR_p = 34(4)\%$  and [1997Da07].  $BR_p = 46(4)\%$ .

		(11/2), 11/2 = 70(1)	$1 / \ln 3$ , $DR_{\alpha} = 70$	2) // :			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{151}\mathrm{Tm})$	coincident $\gamma$ -rays		
5.809(5)	5.659(5)***	90(2)%**	(11/2 ⁻ )	0.0		1.5533(22)	1.38(9)
* [1996Pa ** [1997I *** Weig <b>Table 4</b> direct α emiss	01] Da07] hted average of 5.661 ion from ^{155m1} Lu, Ex	(5) MeV [2016Ca42 = 19.9(62) keV*, J ²	2], 5661(4) MeV [ $\pi = (1/2^+), T_{1/2} =$	1997Da07], 5.655(5) [199 136(9) ms**, $BR_{\alpha} = 76(1)$	96Pa01], and 5.656(6) Me [*] 16)%*.	V [1979Ho10].	
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{151}\mathrm{Tm})$	coincident $\gamma$ -rays		
5.732(4)	5.584(4)***	76(16)%**	(1/2+)	0.096(9)@		1.5533(22)	$1.6\substack{+0.6 \\ -0.4}$
* [1997Da ** [1996F *** Weigl @ Deduce Table 5 direct α emiss	a07] 2a01] hted average of 5.586 d from isomer energ ion from ^{155m2} Lu*, E	5(5)  MeV  [2016 Ca42] y, and $\alpha$ energies of 5x = 1.781(2)  MeV, J	2], 5.586(4) MeV   ground state and i $t^{\pi} = (25/2^{-}), T_{1/2}$	[1997Da07], 5.584(5) [19 somer. = 2.71(3) ms, $BR_{\alpha}$ = obs.	96Pa01], and 5.579(5) Me	V [1991To09].	
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{151}\mathrm{Tm})$	coincident γ-rays		
7.586(5)	7.390(5)	(11/2 ⁻ )	(11/2-)	0.0?		1.5533(22)	
* All valu <b>Table 6</b> <u>direct $\alpha$ emiss</u>	ion from ¹⁵⁹ Ta, $J^{\pi} =$	$, T_{1/2} = 1.10(10) s^*,$	$BR_{\alpha} = 34(5) \%^{**}$	*.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$J_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{155m}$	Lu) coincident	γ-rays	
5.660(4)	5.518(4)***	34(5) %	19.9(62)	1			
* [1996Pa ** [1997I *** Weigl <b>Table 7</b> direct α emiss	01]. Da07]. hted average of 5.519 ion from ^{159m} Ta*, Ex	$P(4) \text{ MeV } [1997\text{Da0}^{\circ}]$ = 63.7(52) keV, J ^{$\pi$}	7] and 5.516(5) M = , $T_{1/2} = 514(9)$	eV [1996Pa01]. ms**, $BR_{\alpha} = 55(1)$ %.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{m{\pi}}$	Edaughter( ¹⁵⁵ Lu)	coincident γ-ra	iys	
5.746(3)	5.600(3)	55(1)%	0.0				
* All valu ** Weight Table 8	es from [1997Da07], ted average of 500(1)	except where noted 1) ms [1997Da07], a	nd 544(16) ms [19	996Pa01].			
direct $\alpha$ emiss	10n from ¹⁰³ Re*, $J^{\pi}$ =	$=, T_{1/2} = 390(72) \text{ m}$	$BR_{\alpha} = 32(3) \%$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{159}\mathrm{Ta})$	coincident γ-ra	ays	
6.018(4)	5.870(4)	32(30%	0.0				

* All values from [1997Da07].

direct $\alpha$ emissi	on from ^{163m} Re*, Ex	$= 115.1(40)$ keV, J ^{$\pi$} =	$=, T_{1/2} = 214(5) \text{ ms}, B_{1/2}$	$R_{\alpha} = 66(4)\%.$		
$E_{\alpha}(c m)$	$E_{\alpha}(lab)$	<i>L</i> _c (abs)	Iπ	$E_{d=1}$	coincident <i>Y</i> -rays	
6 069(3)	5 920(3)	66(4)%	0.0637(52)		concluent / rugo	
* All volu	os from [1007De07]	00(1)//	0.0037(32)			
* All valu	es from [1997Da07].					
direct p emissi	on from ¹⁶⁷ Ir*, J ^{$\pi$} = , ⁷	$\Gamma_{1/2} = 29.3(6) \text{ ms}, B_{1/2}$	$R_p = 39.3(13)\%.$			
$E_p(\text{c.m.})$	$E_p(\text{lab})$	<i>I_p</i> (abs)	$E_{daughter}(^{166}$	Os) coincid	lent γ-rays	
1.068(6)	1.062(6)	39.3(13)%	0.0			
* All valu	es from [2015Sc22], e	xcept where noted.				
<b>Table 11</b>	for from $167$ tr* 1 $\pi$ –	$T_{c} = 29.3(6) ms^{-1}$	3R - 43(2)%			
uncer a ennissi	ion noni in , y = ,	$1_{1/2} - 20.5(0) \text{ ms}$ , 1	$5R_{\alpha} = 45(2)/0.$	162 -		
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{n}$	$E_{daughter}(^{103}\mathrm{Re})$	coincident $\gamma$ -rays	
6.504(3)	6.348(3)	43(2)%	0.0			
* All valu	es from [2005Sc22].					
Table 12direct p emission	on from 167m Ir*, Ex =	175.3(22) keV, $J^{\pi} = 1$	$T_{1/2} = 28.5(6) \text{ ms}^{**},$	$BR_p = 0.42(8)\%.$		
$E_p(c.m.)$	$E_p(\text{lab})$	$I_p(abs)$	$E_{daughter}(^{1}$	⁵⁶ Os) coinci	ident γ-rays	
1.251(7)	1.243(7)***	0.42(8)%	0.0			
* All valu ** Weight ** Weight	es from [2005Sa22], e ed average of 30.0(6) ed average of 1.238(7	xcept where noted. [1997Da07], 25.7(8) ) MeV [1997Da07], a	ms [2004Ke06], and 2 and 1.248)7) MeV [200	8.7(33) ms [2005Sc22]. 5Sc22].		
Table 13direct $\alpha$ emission	fon from 167m Ir, Ex = 1	175.3(22) keV*, $J^{\pi} =$	, T _{1/2} = 28.5(6) ms**,	$BR_{\alpha} = 90(3) \%^{***}.$		
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\rm J}_f^\pi$	$E_{daughter}(^{163m}\mathrm{Re})$	coincident γ-rays	
6.556(3)	6.399(3)***	90(3)%	0.1151(40)			
* [1997Da ** Weight *** [2005 *** Weigh Table 14 direct p amissi	a07]. ed average of 30.0(6) Sc22]. tted average of 6.410( $\frac{1}{2}$	ms [1997Da07], 25.7 3) MeV [1997Da07] T. a = 22 ⁺³ us <i>BB</i>	(8) ms [2004Ke06], an and 6.394(2) MeV [200 – 100%	d 28.7(33) ms [2005Sc2 )4Ke06].	2].	
	E (1)	$r_{1/2} - 22_2 \mu s, BK$	p = 100 m.			
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(abs)$	$E_{daughter}(170)$	Pt) coincide	ent γ-rays	
1.448(12)	1.439(12)	100%	0.0			
* All volu	as from $[2004 Ke06]$	weent where noted				

* All values from [2004Ke06], except where noted. ** Weighted average of 1.437(12) MeV [2004Ke06] and 1.444(17) MeV [1999Po09].

$E_p(c.m.)$	$E_p(\text{lab})$	$I_p(abs)$	$E_{daughter}(^{170}\mathrm{Pt})$	coincident γ-rays	
1.703(6)	1.693(6)***	40(4)%	0.0		
** Weight	ed average of 34(4)% [20	04Ke06], and 46(4)%	[1997Da07].		
** Weight *** Weigh Table 16 direct α emissi	ed average of $34(4)\%$ [20 ted average of $1.694(6)$ M on from 171m Au*, Ex = 2	04Ke06], and 46(4)% AeV [2004Ke06], and 58(13) keV, $J^{\pi} = , T_{1/2}$	[1997Da07]. 1.692(6) MeV [1999Po09, 1] $r_2 = 1.09(3) \text{ ms}, BR_{\alpha} = 60(4)\%$	997Da07]. "**.	

0.1753(22)

direct p emission from  171m Au, Ex = 258(13) keV*, J^{$\pi$} = , T_{1/2} = 1.09(3) ms*, BR_p = 40(4)%**.

* [2004Ke06].

7.162(4)

** Weighted average from [2004Ke06] BR_{$\alpha$} = 66(4)% and [1997Da07]. BR_{$\alpha$} = 54(4) %.

60(4)%

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Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +7$  nuclei. Unless otherwise stated, all Q-values and separation energies values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\epsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
¹²² Xe	$0^+$	20.1(1) h	0.724(12)	-4.101(28)		-11.516(13)	0.216(12)	[1965An05]
¹²⁶ Ba	$0^+$	100(2) m	1.681(16)	-2.760(13)		-9.883(13)	0.984(14)	[1976Pa11]
¹³⁰ Ce	$0^+$	22.9(5) m	2.200(40)	-1.651(30)		-8.069(28)	2.503(30)	[1996Xu04]
¹³⁴ Nd	$0^+$	8.5(15) m	2.882(24)	-0.517(20)		-6.501(38)	3.556(29)	[1970Ab07]
¹³⁸ Sm	$0^+$	3.1(2) m	3.417(17)	0.797(17)		-4.735(16)	4.605(24)	[1983GaZT]
¹⁴² Gd	$0^{+}$	70.2(6) s	4.350(40)	1.685(29)		-3.325(37)	5.530(30)	[1991Fi03]
¹⁴⁶ Dy	$0^+$	33.2(7) s	5.210(50)	3.083(21)		-1.514(13)	6.329(31)	[1993Al03]
¹⁵⁰ Er	$0^+$	18.5(7) s	4.115(14)	2.574(19)		-1.872(21)	7.507(48)	[1981NoZY]
¹⁵⁴ Yb	$0^+$	409(2) ms	4.495(14)	3.246(20)		-0.905(21)	9.589(22)	[1996Pa01]
¹⁵⁸ Hf	$0^+$	2.85(7) s	5.110(15)	4.029(21)		0.154(23)	9.900(23)	[1996Pa01]
¹⁶² W	$0^{+}$	1.13(3) s*	5.780(60)	5.028(29)		1.693(60)	10.788(23)	[1981Ho10, 2015Li24]
¹⁶⁶ Os	$0^+$	214(6) ms**	6.410(90)	6.141(31)		3.273(33)	11.925(66)	[1996Pa01, 2015Li24]
¹⁷⁰ Pt	$0^+$	13.9(2) ms***	6.88(10)#	7.135(32)#		4.918(36)#	13.113(90)#	[2004Ke06, 1998Ki20, 1996Bi07]
¹⁷⁴ Hg	$0^+$	$1.9^{+0.4}_{0.3}$ ms	7.42(10)#	8.007(66)#		6.160(38)#	14.12(10)#	[1999Se14, 1997Uu01]
¹⁷⁸ Pb	$0^+$	$180^{+130}_{-50} \ \mu s^{@}$	8.19(10)#	9.060(88)#		7.516(40)#	15.21(10)#	[2016Ba60, 2003BaZO]

* Weighted average of 1. 39(4) s [1981Ho10] and 0. 99(3) s [2015Li24].

** Weighted average of 220(7) ms [1996Pa01] and 210(6) ms [2015Li24].

*** Weighted average of 14. 0(2) ms [2004Ke06], 13. 5(3) ms [1998Ki20], 14. 7(5) ms [1996Bi07].

[@] Value from maximum likelihood method combining 2 events (147, 202 µs) from [2003BaZO] and 4 events (127, 166, 365, 588 µs) from [2016Ba60].

## Table 2

Particle emission from the even-Z,  $T_z = +7$  nuclei. Unless otherwise stated, all Q-values and separation energies values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	$Q_{\alpha}$	$BR_{\alpha}$	Experimental
100					
¹²² Xe	6.398(12)	10.571(11)	-0.089(21)		
¹²⁶ Ba	5.869(15)	9.580(13)	0.260(17)		
¹³⁰ Ce	5.388(35)	8.632(28)	0.822(31)		
¹³⁴ Nd	4.998(17)	7.756(24)	1.352(30)		
¹³⁸ Sm	4.714(18)	6.876(17)	1.724(17)		
¹⁴² Gd	4.323(31)	6.082(31)	2.113(30)		
¹⁴⁶ Dy	3.44(11)	5.373(29)	1.980(29)		
¹⁵⁰ Er	3.474(21)	4.550(19)	2.299(18)		
¹⁵⁴ Yb	3.248(21)	4.010(19)	5.474(2)	92.6(20)%*	[1996Pa01, 1988Vi02, 1979Ho10, 1989Wo02, 1988KaZK,
			. ,		1981HoZM, 1978AfZZ, 1977Ha48, 1964Ma45]
¹⁵⁸ Hf	2.952(21)	3.415(20)	5.405(3)	45(3)%	[1996Pa01, 1979Ho10, 2000Di18, 1996HiZX, 1989Wo02,
					1981HoZM, 1965Ma14]
$^{162}W$	2.510(30)	2.638(20)	5.678(2)	44(2)%	[1996Pa01, 1981Ho10, 2015Li24, 1989Wo02, 1982De11,
					1981HoZM, 1979Ho10, 1975To05, 1974Sc35]
¹⁶⁶ Os	2.061(30)	1.774(20)	6.143(3)	84(4)%**	[2015Li24, 2008Bi15, 1996Pa01, 1981Ho10, 1991Se01,
					1978Ca11, 1978ReZZ, 1977Ca23]
¹⁷⁰ Pt	1.495(30)	0.882(21)	6.707(3)	pprox 100%	[2004Ke06, 1998Ki20, 1996Bi07, 2004GoZZ, 1997Uu01,
	. ,		. ,		1993ToZY, 1982En03, 1981Ho10]
¹⁷⁴ Hg	1.098(30)	0.112(22)	7.233(6)	100%***	[1999Se14, 1997Uu01, 2016Ba60, 2004GoZZ, 1998NiZW]
¹⁷⁸ Pb	0.375(32)	-0.780(26)	7.789(13)	100%***	[2016Ba60, 2003BaZO]

* Weighted average of 92(2)% [1996Pa01], 92.8(20)% [1988Vi02], and 93(2)% [1979Ho10].

** [2008Bi15].

*** Not measured, inferred from  $T_{1/2}$ .

## Table 3

direct $\alpha$ emission from ¹⁵⁴ Yb, J ^{$\pi$} = 0 ⁺ , T _{1/2} = 409(2) ms*, BR _{$\alpha$} = 90(3) %**:	*.	
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{150}\mathrm{Er})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.474.4(21)**	5.332.2(21)	92.6(20)%***	$0^+$	0.0		1.5559(33)	1.0

* [1996Pa01].

** [1988Vi02].

*** Weighted average of 92(2)% [1996Pa01], 92.8(20)% [1988Vi02], and 93(2)% [1979Ho10].

- u ( • • • • • • )	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{154}\mathrm{Yb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.406(4)	5.269(4)	45(3)%	$0^+$	0.0		1.5615(46)	1.0
* All val	ues from [1996Pa01]	l.					
Table 5							
lirect $\alpha$ emis	sion from ¹⁶² W, $J^{\pi}$ =	$0^+, T_{1/2} = 1.13(3)$	)s*, $BR_{\alpha} = 4$	4(2) %**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{m \pi}$	$E_{daughter}(^{158}\mathrm{Hf})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.679(5)	5.539(5)***	44(2)%**	$0^+$	0.0		1.5712(39)	1.0
* Weight ** [1996 *** Weig Fable 6	ted average of 1.39(4 Pa01]. ghted average of 5.54	) s [1981Ho10] and 11(5) MeV [1996Pa = 0 ⁺ T _e in = 214(6	d 0.99(3) s [2 a01] and 5.53	2015Li24]. 38(5) MeV [1981Ho10] ac - 84(4) %**	ljusted to 5.537(5) MeV in	[1991Ry01].	
		-0,1]/2-214(0	$\frac{1}{1}$ $\frac{1}$	- 04(4) // .			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{162}W)$	coincident γ-rays	R ₀ (fm)	HF
6.138(6)	5.991(6)***	44(2)%**	$0^+$	0.0		1.5690(43)	1.0
* Weight ** [2008 *** Weig	ted average of 220(7) Bi15]. ghted average of 6.00	) ms [1996Pa01] an 00(6) MeV [1996Pa	ad 210(6) ms a01] and 5.98	[2015Li24]. 81(6) MeV [1981Ho10].			
* Weight ** [2008 *** Weig Table 7 direct $\alpha$ emis $E_{\alpha}(c.m.)$	ted average of 220(7) Bi15]. ghted average of 6.00 sion from ¹⁷⁰ Pt, $J^{\pi} = E_{\alpha}(lab)$	$ms [1996Pa01] an 00(6) MeV [1996Pa : 0^+, T_{1/2} = 13.9(2)I_{\alpha}(abs)$	ad 210(6) ms a01] and 5.98 ) ms*, $BR_{\alpha} = J_{f}^{\pi}$	[2015Li24]. 81(6) MeV [1981Ho10]. = $\approx 100\%^{**}$ . $E_{daughter}$ ⁽¹⁶⁶ Os)	coincident γ-rays	R ₀ (fm)	HF
* Weight ** [2008 *** Weight <b>Fable 7</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.707(2)	ted average of 220(7) Bi15]. ghted average of 6.00 sion from ¹⁷⁰ Pt, $J^{\pi} = \frac{E_{\alpha}(lab)}{6.549(2)^{***}}$	ms [1996Pa01] and $00(6) MeV [1996Pa01]$ and $00(6) MeV [1996Pa01]= 0^+, T_{1/2} = 13.9(2)I_{\alpha}(abs)\approx 100\%^{**}$	and 210(6) ms (a01] and 5.98 (b) ms*, $BR_{\alpha} = \frac{J_f^{\pi}}{0^+}$	[2015Li24]. 81(6) MeV [1981Ho10]. = $\approx 100\%^{**}$ . <u>$E_{daughter}(^{166}Os)$</u> 0.0	coincident γ-rays	R ₀ (fm)	HF 1.0
* Weight ** [2008 *** Weight Table 7 direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.707(2) * Weight ** Not n *** [2007 Table 8 direct $\alpha$ emiss	ted average of 220(7) Bi15]. ghted average of 6.00 sion from ¹⁷⁰ Pt, J ^{$\pi$} = <u>E_a(lab)</u> 6.549(2)*** ted average of 14.0(2 heasured, inferred from 4Ke06]. sion from ¹⁷⁴ Hg, J ^{$\pi$}	$ms [1996Pa01] an 00(6) MeV [1996Pa c0^+, T_{1/2} = 13.9(2)I_{\alpha}(abs)\approx 100\%^{**}) ms [2004Ke06], T_{1/2}= 0^+, T_{1/2} = 1.9^{+0}_{-0}$	ad 210(6) ms a01] and 5.98 a01] and 5.98 and 5.99 and 5.98 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.9888 and 5.98888 and 5.988888 and 5.9888888888888888888888888888888888888	[2015Li24]. 81(6) MeV [1981Ho10]. = $\approx 100\%^{**}$ . <u>Edaughter</u> ( ¹⁶⁶ Os) 0.0 1998Ki20], 14.7(5) ms [19 = 100\%^{**}.	coincident γ-rays  96Bi07].	R ₀ (fm) 1.5648(11)	HF 1.0
* Weight ** [2008 *** Weight Table 7 direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.707(2) * Weight ** Not n *** [2007 Table 8 direct $\alpha$ emiss $E_{\alpha}(c.m.)$	ted average of 220(7) Bi15]. ghted average of 6.00 sion from ¹⁷⁰ Pt, J ^{$\pi$} = $E_{\alpha}$ (lab) 6.549(2)*** ted average of 14.0(2 heasured, inferred from 4Ke06]. sion from ¹⁷⁴ Hg, J ^{$\pi$} = $E_{\alpha}$ (lab)	$\frac{1996Pa01}{1} \text{ an}$ $\frac{1996Pa01}{1} \text{ an}$ $\frac{1006}{1} \text{ MeV} [1996Pa]$ $\frac{1006}{1} \text{ me} (1996Pa]$ $\frac{I_{\alpha}(abs)}{\alpha} = 100\%^{**}$ $\frac{100\%^{**}}{1} \text{ ms} [2004Ke06], T_{\alpha}$ $\frac{100\%^{**}}{1} \text{ ms} [2004Ke06], T_{\alpha}$	ad 210(6) ms a01] and 5.98 a01] and 5.98 and 5.99 and 5.98 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.9888 and 5.9888 and 5.9888 and 5.9888 and 5.98888 and 5.988888 and 5.9888888888888888888888888888888888888	$[2015Li24].$ $B1(6) MeV [1981Ho10].$ $= \approx 100\%^{**}.$ $E_{daughter}(^{166}Os)$ $0.0$ $1998Ki20], 14.7(5) ms [19]$ $= 100\%^{**}.$ $E_{daughter}(^{170}Pt)$	coincident γ-rays  96Bi07]. coincident γ-rays	R ₀ (fm) 1.5648(11) R ₀ (fm)	HF 1.0 HF
* Weight ** [2008 *** Weight Table 7 direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.707(2) * Weight ** Not n *** [2007 Table 8 direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 7.233(6)	ted average of 220(7) Bi15]. ghted average of 6.00 sion from ¹⁷⁰ Pt, J ^{$\pi$} = $E_{\alpha}$ (lab) 6.549(2)*** ted average of 14.0(2 heasured, inferred from 4Ke06]. sion from ¹⁷⁴ Hg, J ^{$\pi$} = $E_{\alpha}$ (lab) 7.067(6)***	$\frac{1996Pa01}{1} \text{ an}$ $\frac{1996Pa01}{1} \text{ an}$ $\frac{100(6) \text{ MeV } [1996Pa]}{I_{\alpha}(abs)}$ $\frac{1}{\alpha}(abs)$ $\approx 100\%^{**}$ $\frac{100\%^{**}}{I_{\alpha}(abs)}$ $\frac{1}{\alpha}(abs)$ $100\%^{**}$	ad 210(6) ms a01] and 5.98 a01] and 5.98 and 5.99 and 5.98 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.988 and 5.9888 and 5.9888 and 5.9888 and 5.98888 and 5.9888888 and 5.9888888888888888888888888888888888888	$[2015Li24].$ $B1(6) MeV [1981Ho10].$ $= \approx 100\%^{**}.$ $E_{daughter}(^{166}Os)$ $0.0$ $1998Ki20], 14.7(5) ms [19]$ $= 100\%^{**}.$ $E_{daughter}(^{170}Pt)$ $0.0$	coincident γ-rays  96Bi07]. coincident γ-rays 	$R_0 (fm)$ 1.5648(11) $R_0 (fm)$ 1.549 ⁺¹³ 1.549 ⁺¹³	HF 1.0 HF 1.0
* Weight ** [2008 *** Weight <b>Table 7</b> direct $\alpha$ emise $E_{\alpha}(c.m.)$ 6.707(2) * Weight ** Not n *** [200 <b>Table 8</b> $E_{\alpha}(c.m.)$ 7.233(6) * [1999S ** Not n *** Weight *** Weight *** [200 <b>Table 9</b> direct $\alpha$ emise	ted average of 220(7) Bi15]. ghted average of 6.00 sion from ¹⁷⁰ Pt, J ^{$\pi$} = <u>E_a(lab)</u> 6.549(2)*** ted average of 14.0(2 heasured, inferred from 4Ke06]. sion from ¹⁷⁴ Hg, J ^{$\pi$} : <u>E_a(lab)</u> 7.067(6)*** Se14]. heasured, inferred from ghted average of 7.06 sion from ¹⁷⁸ Pb, J ^{$\pi$} =	$\begin{array}{l} \text{ms} [1996\text{Pa01}] \text{ an} \\ 00(6) \text{ MeV} [1996\text{Pa}0] \\ \hline 00(6) \text{ MeV} [1996\text{Pa}0] \\ \hline 00(6) \text{ MeV} [1996\text{Pa}0] \\ \hline 100\%^{**} \\ \hline Iangle I \\ \hline Iangle I \\ \hline 1angle I \\ \hline 1angl$	ad 210(6) ms a01] and 5.98 a01] and 5.98 a01] and 5.98 $J_{f}^{\pi}$ 0+ 13.5(3) ms [1 $\frac{.4}{.3}$ ms*, $BR_{\alpha}$ $J_{f}^{\pi}$ 0+ e14], 7.069(1 $\frac{.30}{.0}$ $\mu$ s*, $BR_{\alpha}$	[2015Li24]. 81(6) MeV [1981Ho10]. = $\approx 100\%^{**}$ . <u>Edaughter</u> ( ¹⁶⁶ Os) 0.0 1998Ki20], 14.7(5) ms [19 = $100\%^{**}$ . <u>Edaughter</u> ( ¹⁷⁰ Pt) 0.0 1) MeV [1997Uu01]. = $100\%^{**}$ .	coincident γ-rays 96Bi07]. coincident γ-rays	$R_0 (fm)$ 1.5648(11) $R_0 (fm)$ 1.549 ⁺¹³ ₋₁₀	HF 1.0 HF 1.0
* Weight ** [2008 *** Weight Table 7 direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.707(2) * Weight ** Not n *** [200 Table 8 direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 7.233(6) * [1999S ** Not n *** Weight *** Weight *** [200 Table 9 direct $\alpha$ emiss $E_{\alpha}(c.m.)$	ted average of 220(7) Bi15]. ghted average of 6.00 sion from ¹⁷⁰ Pt, J ^{$\pi$} = $E_{\alpha}$ (lab) 6.549(2)*** ted average of 14.0(2 heasured, inferred from 4Ke06]. sion from ¹⁷⁴ Hg, J ^{$\pi$} = $E_{\alpha}$ (lab) 7.067(6)*** Se14]. heasured, inferred from ghted average of 7.00 sion from ¹⁷⁸ Pb, J ^{$\pi$} = $E_{\alpha}$ (lab)	$\begin{array}{l} \text{ms} [1996\text{Pa01}] \text{ an} \\ 00(6) \text{ MeV} [1996\text{Pa}0] \\ \hline 00(6) \text{ MeV} [1996\text{Pa}0] \\ \hline 00(6) \text{ MeV} [1996\text{Pa}0] \\ \hline I_{\alpha}(\text{abs}) \\ \hline I_{\alpha}(\text{abs}) \\ \hline 00\%^{**} \\ \hline 00\% \text{ T}_{1/2}. \\ \hline 00\% \text{ T}_{1/2}. \\ \hline 00\%^{**} \\ \hline 100\%^{**} \\ \hline 00\%^{**} \\ \hline 00\%^{**} \\ \hline 00\%^{**} \\ \hline 00\%^{**} \\ \hline 100\%^{**} \\ \hline 00\%^{**} \\ \hline 100\%^{**} \\ \hline 00\%^{**} \\ \hline 00\%^{**} \\ \hline 00\%^{**} \\ \hline 00\%^{*} \\ \hline 100\%^{**} \\ \hline 00\%^{**} \\ \hline 00\%^{*} \\ \hline 100\%^{**} \\ \hline 00\%^{*} \\ \hline 100\%^{**} \\ \hline 100\%^{**} \\ \hline 00\%^{*} \\ \hline 100\%^{**} \\ \hline $	ad 210(6) ms a01] and 5.98 a01] and 5.98 and 5.99 and 5.	[2015Li24]. 81(6) MeV [1981Ho10]. = $\approx 100\%^{**}$ . <u>Edaughter</u> ( ¹⁶⁶ Os) 0.0 1998Ki20], 14.7(5) ms [15 = $100\%^{**}$ . <u>Edaughter</u> ( ¹⁷⁰ Pt) 0.0 1) MeV [1997Uu01]. = $100\%^{**}$ . <u>Edaughter</u> ( ¹⁷⁴ Hg)	coincident γ-rays 96Bi07]. coincident γ-rays coincident γ-rays	$     R_0 (fm)     1.5648(11)      R_0 (fm)     1.549^{+13}_{-10}      R_0 (fm)     $	HF 1.0 HF 1.0

* Value from maximum likelihood method combining 2 events (147, 202  $\mu$ s) from [2003] ** Not measured, inferred from T_{1/2}. *** Weighted average of 7.615(30) MeV [2003BaZO], and 7.610(30) MeV [2016Ba60].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +7 nuclei.

Last updated 3/23/23

Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z$ = +7 nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduce	ed
from values therein. All $J^{\pi}$ values are taken from ENSDF.	

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Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon_P}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
¹¹⁶ Sb		3+	16.2(12) m	4.704(5)	-4.575(5)		-11.385(5)	1.328(5)	[1967Ha27]
$^{120}I$		$2^{-}$	81.7(2) m	5.615(15)	-1.561(17)		-6.672(15)	5.354(15)	[2000Ho19]
¹²⁴ Cs		$1^{+}$	30.9(5) m	5.926(9)	-1.087(10)		-6.006(9)	5.196(9)	[1993Al03]
¹²⁸ La*		$(5^+)$	5.2(4) m	6.740(50)	0.326(55)		-4.057(54)	6.617(54)	[1977Zo02]
¹³² Pr		$(2^{-})$	1.6(3) m	7.240(40)	1.253(40)		-2.549(29)	7.717(29)	[1987Ko24]
¹³⁶ Pm*		$(2^+)$	30-150 s	8.030(70)	2.477(70)		-0.915(72)	8.874(72)	[1989Vi04]
¹⁴⁰ Eu		$1^{+}$	1.51(2) s	8.470(50)	3.226(53)		0.453(53)	9.788(53)	[1991Fi03]
¹⁴⁴ Tb			1.5(10) s	9.390(40)	4.584(30)		2.036(28)	10.663(31)	[1982No08]
¹⁴⁸ Ho		$(1^{+})$	2.2(1) s	9.870(80)	5.463(84)		3.517(84)	11.343(88)	[1982No08]
^{148m} Ho	х	(5 ⁻ )	9.59(15) s	9.870(80)+x	5.463(84)+x	0.08(1)%	3.517(84)+x	11.343(88)+x	[1988To03]
¹⁵² Tm		$(2^{-})$	8.0(10) s	8.780(50)	4.613(55)		3.011(54)	13.714(55)	[1982No13]
¹⁵⁶ Lu		$(2^{-})$	494(12) ms	9.570(50)	5.637(55)		4.327(54)	14.376(55)	[1996Pa01]
^{156m} Lu	х	$(10^{+})$	198(2) ms	9.570(50)+x	5.637(55)+x		4.327(54)+x	14.376(55)+x	[1996Pa01]
¹⁶⁰ Ta*			1.7(2) s	10.120(60)	6.596(66)		5.608(55)	15.017(55)	[1996Pa01]
^{160m} Ta	х		1.55(4) s	10.120(60)+x	6.596(66)+x		5.608(55)+x	15.017(55)+x	[1996Pa01]
¹⁶⁴ Re			$848^{+140}_{-105}$ ms	10.760(60)	7.773(67)		7.118(55)	16.041(55)	[2009Ha42]
^{164m} Re	х		$864^{+150}_{-110}$ ms	10.760(60)+x	7.773(67)+x		7.118(55)+x	16.041(55)+x	[2009Ha42]
¹⁶⁸ Ir			155(40) ms**	11.330(60)#	8.879(68)#		8.643(56)#	17.144(56)	[2009Ha42, 1996Pa01]
^{168m} Ir	х		161(21) ms	11.330(60)#	8.879(68)#		8.643(56)#	17.144(56)+x	[2009Ha42, 1996Pa01]
¹⁷² Au			$22^{+6}_{-4}$ ms	11.790(60)	9.805(68)		10.030(57)	18.252(57)	[2009Ha42]
^{172m} Au	х		5(1) ms***	11.790(60)	9.805(68)		10.030(57)	18.252(57)+x	2009Ha42, 1996Pa01, 1993Se09]
¹⁷⁶ Tl			$5.2^{+3.0}_{-1.4}$ ms	12.370(80)	10.699(92)		11.324(84)	19.266(84)	[2004Ke06]

* Possibly isomeric state. ** Weighted average of  $222_{-45}^{+60}$  ms [2009Ha42] and 125(40) ms [1996Pa01].

*** Weighted average of  $9^{+2}_{-1}$  ms [2009Ha42], 6.3(15) ms [1996Pa01], and 4(1) ms [1993Se09].

## Table 2

Particle emission from the odd-Z, Tz = +7 nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$BR_p$	$S_{2p}$	Qα	BRα	Experimental
¹¹⁶ Sb	4.077(5)		12.830(5)	-1.257(7)		
¹²⁰ I	3.854(17)		10.329(15)	0.650(16)		
¹²⁴ Cs	3.782(13)		10.240(11)	-0.419(18)		
¹²⁸ La*	3.096(56)		8.853(55)	0.691(55)		
¹³² Pr	2.808(44)		8.178(39)	0.973(62)		
¹³⁶ Pm*	2.245(72)		7.220(72)	1.633(75)		
¹⁴⁰ Eu	1.895(53)		6.650(53)	1.759(86)		
¹⁴⁴ Tb	1.43(20)		5.637(41)	2.193(59)		
¹⁴⁸ Ho	1.084(84)		4.805(95)	1.952(88)		
^{148m} Ho	1.084(84)-x		4.805(95)-x	1.952(88)+x		
¹⁵² Tm	0.743(56)		4.352(56)	3.85(10)		
¹⁵⁶ Lu	0.486(57)		3.850(56)	5.596(3)	$\approx 100\%$	[1996Pa01, 1991PoZZ, 1981HoZM, 1979Ho10]
^{156m} Lu**	0.486(57)-x		3.850(56)-x	5.596(3)+x	$98^{+2}_{-9}\%$	[2019Pa27, 1996Pa01, 1991PoZZ, 1981HoZM, 1979Ho10]
¹⁶⁰ Ta	0.260(57)		3.189(56)	5.451(5)	obs	[1996Pa01]
^{160m} Ta	0.260(57)-x		3.189(56)-x	5.451(5)+x	obs	[1996Pa01, 1992Ha10, 1988MeZY, 1987HaZO, 1987ScZH,
						1986Ru05, 1981HoZM, 1979Ho10
¹⁶⁴ Re	-0.147(80)		2.269(84)	5.926(5)	obs	[2009Ha42, 1996Pa01, 1979Ho10, 1981Ho10, 1979Ho10]
164mRe**	-0.147(80)-x		2.269(84)-x	5.926(5)+x	3(1)%	[2009Ha42]
¹⁶⁸ Ir	-0.544(98)		1.41(10)	6.381(9)	obs	[2009Ha42, 1996Pa01, 1982De11, 1981DeZA, 1981DeZL,
						1978Ca11, 1978CaZF]
168mIr	-0.544(98)-x		1.41(10)-x	6.381(9)+x	78(11)%**	[2009Ha42, 1996Pa01]
¹⁷² Au	-0.860(99)		0.71(12)	6.923(10)	100%	[2009Ha42]
^{172m} Au	-0.860(99)-x	$<\!\!2\%$	0.71(12)-x	6.923(10)+x	100%	[2009Ha42, 1996Pa01, 1993Se09]
¹⁷⁶ Tl	-1.265(18)	100%	-0.07(13)	7.48(10)		[2004Ke06]

* Possibly isomeric state.

** Weighted average of 75(11)% [2009Ha42] and 82(14)% [1996Pa01].

direct $\alpha$ emiss	sion from ¹⁵⁶ Lu*, J ^{$\pi$} =	$(2^{-}), T_{1/2} = 494(12)$	) ms, $BR_{\alpha} = \approx 100^{\circ}$	%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{152}\mathrm{Tr})$	n) coincide	ent γ-rays	
5.593(10)	5.450(10)	$\approx 100\%$	(2 ⁻ )	0.0			
* All valu	ues from [1996Pa01].						
<b>Table 4</b> direct $\alpha$ emiss	ion from ^{156m} Lu*. Ex	$=$ unk., J ^{$\pi$} = (10 ⁺ ), 7	$\Gamma_{1/2} = 198(2) \text{ ms. } B$	$R_{\alpha} = 98^{+2}\%^{**}.$			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_{f}^{\pi}$	$E_{daughter}(^{152}\mathrm{Tm})$	coincident $\gamma$ -rays	
5.589(5) 5.707(4)	5.446(5) 5.561(4)	0.057(10)% 100%	0.056(10)% $98^{+2}_{-9}\%$	(9 ⁺ )	0.1148(5) 0.0	0.115	
* All valu ** [1996]	ues from [2019Pa27], o Pa01].	except where noted.					
Table 5 direct $\alpha$ emiss	sion from ¹⁶⁰ Ta*, $J^{\pi}$ =	, $T_{1/2} = 1.7(2)$ s, <i>BR</i>	$\alpha = \text{obs.}$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${f J}^{\pi}_f$	Edaughter( ¹⁵⁶ Lu)	coinciden	tγ-rays	
5.449(5)	5.313(5)	obs					
<b>Table 6</b> direct $\alpha$ emiss	ion from ^{160m} Ta*, Ex	= unk., $J^{\pi}$ = , $T_{1/2}$ =	198(2) ms, $BR_{\alpha} = 0$	obs.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{156}Lu)$	coinciden	tγ-rays	
5.552(5)	5.413(5)	obs		**			
* All valu ** α-α ce	nes from [1996Pa01]. oincident with 5.561 M	MeV $\alpha$ from ^{156m} Lu.					
<b>Table 7</b> direct $\alpha$ emiss	sion from ¹⁶⁴ Re*, $J^{\pi}$ =	$T_{1/2} = 848^{+140}_{-105} \text{ ms}$	**, $BR_{\alpha}$ = obs.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{160}\mathrm{Ta})$	) coincide	nt γ-rays	
5.926(7)	5.781(7)***	obs					
* All valu ** Other *** Weig	ues from [2009Ha42], values: 38(16) ms [19 hted average of 5.780	except where noted. 96Pa01], 880(240) m (10) MeV [2009Ha42	s [1979Ha10]. 2], 5.784(7) MeV [1	996Pa01], and 5.778(	10) MeV [1979H010]		
<b>Table 8</b> direct $\alpha$ emiss	ion from ^{164m} Re*, Ex	= unk., $J^{\pi}$ = , $T_{1/2}$ =	$864^{+150}_{-110}$ ms, $BR_{\alpha}$ =	= 3(1)%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{160}$ Ta)	coincider	t γ-rays	
5.764(10)	5.623(10)	3(1)%		**			
5.764(10)	5.623(10)	3(1)%		**			

* All values from [2009Ha421]. **  $\alpha$ - $\alpha$  coincident with 5.413 MeV  $\alpha$  from ^{160m}Ta.

direct $\alpha$ emission	on from ¹⁶⁸ Ir, $J^{\pi} = , T_1$	$_{/2} = 155(40) \text{ ms}^*, BH$	$R_{\alpha} = \text{obs.}$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^{\pi}$	$E_{daughter}(^{164}\mathrm{F})$	Re) coir	ncident γ-rays	
6.381(10)	6.229(10)**	obs					
* Weighted ** Weighte	l average of $222^{+60}_{-45}$ ms ed average of 6.230(10)	5 [2009Ha42] and 12: ) MeV [2009Ha42], a	5(40) ms [1996Pa0 and 6.227(15) MeV	1]. [1996Pa01].			
Table 10 direct $\alpha$ emission	on from 168m Ir*, Ex = u	ank., $J^{\pi} = , T_{1/2} = 16$	$1(21) \text{ ms}^{**}, BR_{\alpha} =$	= 78(11)%***.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{m{\pi}}$	$E_{daughter}(^{164}\mathrm{Re})$	coincident γ-rays	
6.474(10) 6.413(10)	6.320(10) 6.260(10)	42(11)% 100%	22(10)% 53(5)%		@ @	0.069	
* All value ** [1996Pa *** Weigh @ α-α coi <b>Table 11</b> direct α emissio	s from [2009Ha421], e a01]. ted average of 75(11)% ncident with 5.623 Me on from ¹⁷² Au, $J^{\pi} = , T$	except where noted. (b) [2009Ha42] and 82 V $\alpha$ from ^{164m} Re. $\Gamma_{1/2} = 22^{+6}_{-4}$ ms, $BR_{\alpha}$	(14)% [1996Pa01]. = 100%.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${ m J}^{\pi}_{f}$	$E_{daughter}(^{168}$ Ir	) coinc	ident γ-rays	
6.923(10)	6.762(10)	100%					
* All value	s from [2009Ha42].						
Table 12direct $\alpha$ emission	on from ^{172m} Au*, Ex =	unk., J $^{\pi}$ = , T $_{1/2}$ = 5	(1) ms**, $BR_{\alpha} = 1$	00%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\mathrm{rel})^{***}$	$I_{\alpha}(abs)^{***}$	$\mathbf{J}_{f}^{\boldsymbol{\pi}}$	$E_{daughter}(^{168}\mathrm{Ir})$	coincident $\gamma$ -rays	
6.962(10) 7.034(10)	6.800(10) 6.870(10)	18(8)% 100%	15(7)% 85(7)%		@ @	0.073, 0.065	
* All value ** Weighte *** Based @ α-α coi <b>Table 13</b>	s from [2009Ha421], e ed average of $9^{-1}_{-1}$ ms [2 on Fig. 2e of [2009Ha ncident with 6.260 Me	except where noted. 009Ha42], 6.3(15) m 42]. V $\alpha$ from ^{168m} Ir.	us [1996Pa01], and	4(1) ms [1993Se09	9].		
unect p emissio	$11, J^{"} = , I_{1}$	$/2 = 3.2_{-1.4}$ ms, $BR_p$	= 100%.				
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(abs)$	${f J}_f^{\pi}$	$E_{daughter}(^{175}\mathrm{Hg}$	g) coind	cident γ-rays	
1.265(18)	1.258(18)	100%		0.0			
* All value	s from [2004Ke06].						

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Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +15/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J|*pi* values for ¹²³Xe, ¹²⁷Ba, ¹³¹Ce, ¹³⁵Md ¹³⁹Sm, ¹⁴³Gd, ¹⁴⁷Dy, ¹⁵¹Er are taken from ENSDF

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\epsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
100								
¹²³ Xe	$1/2^{+}$	2.040(9) h	2.694(10)	-2.224(10)		-10.227(10)	1.802(12)	[2021Ze01]
¹²⁷ Ba	$1/2^{+}$	12.7(4) m	3.422(13)	-0.961(11)		-8.560(11)	2.700(12)	[1976Be11]
¹³¹ Ce	$7/2^{+}$	10.5(6) m	4.060(40)	0.259(33)		-6.787(33)	4.107(33)	[1966No05]
¹³⁵ Nd	9/2-	12.4(6) m	4.722(22)	1.330(28)		-5.297(34)	5.131(34)	[1975Wi11]
¹³⁹ Sm	$1/2^{+}$	2.57(10) m	5.121(17)	2.348(16)		-3.756(14)	6.131(16)	[1982De06]
¹⁴³ Gd	$(1/2^+)$	39(2) s	6.01(20)	3.46(20)		-2.29(20)	6.85(20)	[1978Fi02]
¹⁴⁷ Dy	$(1/2^+)$	67(7) s	6.547(12)	4.601(10)	$\approx 0.05\%$	-0.782(9)	7.620(14)	[ <b>1984To07</b> , 1988WiZN]
¹⁵¹ Er	$(7/2^{-})$	23.8(20) s*	5.356(18)	3.754(17)		-1.356(17)	10.051(18)	[1988Ba02, 1970To16
¹⁵⁵ Yb	$(7/2^{-})$	1.79(2) s**	6.123(19)	4.813(17)		-0.068(17)	10.695(19)	[1991To08, 1996Pa01]
¹⁵⁹ Hf	$(7/2^{-})$	5.2(1) s	6.860(40)	5.868(19)		1.279(33)	11.348(20)	[1996Pa01]
¹⁶³ W	7/2-	2.7(1) s***	7.630(70)	6.971(59)		3.076(65)	12.375(70)	[2010Sc02, 1979Ho10, 1973Ea01]
¹⁶⁷ Os	$(7/2^{-})$	839(5) ms	8.340(90)	8.100(81)		4.771(82)	13.611(89)#	[2010Sc02]
¹⁷¹ Pt	$(7/2^{-})$	43(3) ms	8.950(90)	9.170(82)		6.365(82)	14.943(90)	[1996Pa01]
¹⁷⁵ Hg	$(7/2^{-})$	10.2(4) ms@	9.430(90)	10.059(82)		7.721(82)	16.018(90)	[2017Ba46, 2002Ro17]
¹⁷⁹ Pb	(9/2-)	2.7(2) ms	10.320(90)	11.078(82)		9.019(82)	17.030(90)	[2017Ba46]

* Weighted average of 23(2) s [1970To16] and 24.6(20)s [1988Ba02].

** Weighted average of 1.75(5) s [1991To08] and 1.80(2) s [1996Pa01].

*** Weighted average of 2.6(1) s [2010Sc02], 3.0(2) s [1979Ho10] and 2.5(3) s [1973Ea01].

[@] Weighted average of 9.6(4) ms [2017Ba46], and 10.8(4) ms [2002Ro17].

## Table 2

Particle separation and emission from the even-Z,  $T_z = +15/2$  nuclei. Unless otherwise stated, all Q-values and separation energies values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	BRα	Experimental
123	( 450(11)	11.000(20)	0.401/(10)		
¹²⁵ Xe	6.458(11)	11.283(28)	-0.491(12)		
¹²⁷ Ba	5.756(15)	10.197(11)	0.005(15)		
¹³¹ Ce	5.370(42)	9.226(34)	0.685(35)		
¹³⁵ Nd	4.975(28)	8.373(25)	1.070(38)		
¹³⁹ Sm	4.755(16)	7.374(16)	1.408(22)		
¹⁴³ Gd	4.211(203)	6.88(20)	1.72(20)		
¹⁴⁷ Dy	3.721(46)	5.847(22)	1.61(20)		
¹⁵¹ Er	3.609(22)	5.150(19)	3.505(19)		
¹⁵⁵ Yb	3.364(22)	4.614(19)	5.339(2)	90(5)%	[ <b>1996Pa01, 1991To08, 1979Ho10, 1977Ha48</b> , 1992A118,
					1992AIZM, 1992AIZY, 1990KaZM, 1990Po13, 1989KaYU,
					1988KaZK, 1987KaZI, 1982Bo04, 1981HoZM, 1980Da09,
					1978AfZZ, 1973BoXL, 1973BoXW, 1964Ma45]
¹⁵⁹ Hf	2.929(23)	4.011(20)	5.225(3)	12(1)%	[1996Pa01, 1992Ha10, 1979Ho10, 1983Fa03, 1996HiZX,
					1981HoZM, 1978Ca11, 1973To02, 1973ToZU, 1972ToZC,
					1996HiZX, 1996HiZX, 1972ToZL]
$^{163}W$	2.416(86)	3.171(63)	5.519(5)*	14(2)%**	[2010Sc02, 1996Pa01, 1979Ho10, 1975To01, 1973Ea01,
					1978Ca11, 1982De11, 1981DeZA, 1981DeZL, 1981HoZM,
					1973Ea011975To05, 1972EaZU]
¹⁶⁷ Os	1.95(12)#	2.215(85)#	5.978(5)***	58(7)% [@]	[2010Sc22, 1996Pa01, 1982En03, 1981Ho10, 2009Od02,
	× /	~ /			1978Ca11, 1978ReZZ, 1977Ca13]
¹⁷¹ Pt	1.57(13)	1.322(85)	6.607(3)	$\approx 100\%$ [@] @	[1996Pa01, 1981De22, 1981Ho10, 2010Sc02, 2006Jo04,
	× /				2005Jo18, 2003Ba32, 2002Ro17, 1997Uu01, 1993ToZY,
					1982En03, 1981DeZB]
¹⁷⁵ Hg	1.20(13)	0.61(10)	7.008(4)@@@	$\approx 100\%^{@@}$	[2017Ba46, 2002Ro17, 1997Uu01, 1996Pa01, 1984ScZO,
U	× /	× /	× /		1983Sc24]
¹⁷⁹ Pb	0.62(13)	-0.25(12)	7.516(4) ^a	$\approx 100\%$ [@] @	[ <b>2017Ba46</b> , 2010An01]

* Deduced from  $\alpha$  energy, 5.520(60) in [2021Wa16].

** Weighted average of 15(2)% [2010Sc22], and 13(2)% [1996Pa01].

*** Deduced from  $\alpha$  energy, 5.985(56)# in [2021Wa16].

[@] Weighted average of 58(12)% [1981Ho10], 76(10% [1982En03], and 49(7)% [1996Pa01].

@@ Inferred from half-life.

^{@@@} Deduced from  $\alpha$  energy, 7.072(5) in [2021Wa16].

^{*a*} Deduced from  $\alpha$  energy, 7.596(5) in [2021Wa16].

direct $\alpha$ emis	sion from ¹⁵⁵ Yb, $T_{1/}$	$_{2} = 1.79(2) \text{ s}^{*}, BR_{\alpha} =$	= 90(5)%**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)^{***}$	$E_{daughter}(^{151}\mathrm{Er})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.341(4)	5.203(4)**	90(5)%**	0.0		1.5767(66)	$1.79\substack{+0.26\\-0.24}$
* Weight ** [1991 *** Weiş Table 4	ted average of 1.75(5 To08]. ghted average of 5.20	) s [1991To08] and 1 )2 MeV [1991To08],	1.80(2) s [1996Pa01]. , 5.206(5) MeV [1979Ho1	0], and 5.202(10) MeV [19	977Ha48] (adjusted	to 5.203(10) MeV in [1991Ry01]).
direct $\alpha$ emis	sion from ¹⁵⁹ Hf, $T_{1/2}$	$_{2}=5.2(1) \text{ s}^{*}, BR_{\alpha}=$	12(1)%**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)^{***}$	$E_{daughter}(^{155}\mathrm{Yb})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
5.226(5)	5.094(5)***	12(1)%**	0.0		1.5552(96)	$0.96^{+0.21}_{-0.19}$
*** Weiş Table 5 direct α emis	ghted average of 5.09 sion from ¹⁶³ W, T _{1/2}	$p_2 = 2.7(1) \text{ s*}, BR_{\alpha} = 3$	10] (adjusted to 5.094(10) 14(2)%**.	MeV in [1991Ry01]), 5.0	88(6) MeV [1992Ha	10], and 5.098(5) MeV [1996Pa01]
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)^{***}$	$E_{daughter}(^{159}\mathrm{Hf})$	coincident γ-rays	R ₀ (fm)	HF
5.519(5)	5.383(5)***	14(2)%**	0.0		1.568(13)	$1.5^{+0.5}_{-0.4}$
* Weight ** Weig *** Weig MeV in [199] Table 6	ted average of 2.6(1) hted average of 15(2) ghted average of 5.38 [Ry01]).	s [2010Sc02], 3.0(2) % [2010Sc22], and 5(5) MeV [1973Ea0	) s [1979Ho10] and 2.5(3) 13(2)% [1996Pa01]. 1], 5.383(6) MeV [2010Sc	o s [1973Ea01] 02], 5383(6) MeV [1996Pa	01] and 5.384(5) Mo	eV [1979Ho10] (adjusted to 5.382(5)
direct $\alpha$ emis	sion from ¹⁰⁷ Os, $T_{1/}$	$_2 = 839(5) \text{ ms}^*, BR_{\alpha}$	= 58(7)%**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)^{***}$	$E_{daughter}(^{163}W)$	coincident γ-rays	$R_0$ (fm)	HF
5.978(5)	5.835(5)***	58(7)%**	0.0		1.5653(46)	$1.30\substack{+0.23\\-0.19}$
* [2010S ** Weigl *** [199	c02]. hted average of 58(12 6Pa01].	2)% [1981Ho10], 76	(10% [1982En03], and 49	(7)% [1996Pa01].		
<b>Table 7</b> direct $\alpha$ emis	sion from 171 Pt, T $_{1/2}$	$p_2 = 43(3) \text{ ms}^*, BR_{\alpha} =$	÷≈ 100%**.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)^{***}$	$E_{daughter}(^{167}\mathrm{Os})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
6.607(4)	6.453(4)***	$pprox 100\%^{**}$	0.0		1.5607(30)	1.34(13)
* [1996P	Pa01].					

*** Inferred from half-life. *** Weighted average of 6.453(4) MeV [1981De22] and 6.448(5) MeV [1981Ho10], (adjusted to 6452(5) MeV in [1991Ry01]).

direct $\alpha$ emis	lirect $\alpha$ emission from ¹⁷⁵ Hg, T _{1/2} = 10.2(4) ms*, $BR_{\alpha} = \approx 100\%$ **.										
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)^{***}$	$E_{daughter}(^{171}\mathrm{Pt})$	coincident $\gamma$ -rays	R ₀ (fm)	HF					
7.008(4)	6.848(4)***	$\approx 100\%^{**}$	0.0		1.5469(98)	$1.02\substack{+0.22\\-0.19}$					
* Weight ** Inferr *** [201 <b>Table 9</b> direct <i>α</i> emis	ted average of 9.6(4) ed from half-life. 7Ba46]. ssion from ¹⁷⁹ Pb*, T	ms [2017Ba46], and $_{1/2}$ = 2.7(2) ms, $BR_{\alpha}$	d 10.8(4) ms [2002Ro17]. = ≈ 100%**.								
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)^{***}$	$E_{daughter}(^{175}\mathrm{Hg})$	coincident γ-rays	R ₀ (fm)	HF					
7.516(4)	7.348(5)	$\approx 100\%^{**}$	0.0		1.532(20)	$1.6^{+0.8}_{-0.5}$					

* All values from [2017Ba46].

** Inferred from half-life.

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +15/2 nuclei.

Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z = +15/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{|pi} values for ¹²¹I, ¹²⁵Cs, ¹²⁹La, ¹³³Pr, ¹³⁷Pm, ¹⁴¹Eu, ¹⁴⁵Tb, ¹⁴⁹Ho, are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
121 -		5/0+	0.10(1).1	2 207/20	5 117(0)		10 750(5)	1 222(2)	
1211		5/2	2.12(1) h	2.297(26)	-5.117(9)		-10./59(5)	1.727(5)	[1965An05]
¹²⁵ Cs		1/2+	49(5) m	3.110(8)	-4.014(8)		-9.497(8)	2.028(27)	[1962Pr09]
¹²⁹ La		$(3/2^+)$	7(3) s	3.737(22)	-2.681(22)		-7.581(21)	3.451(21)	[1970Ab07]
¹³³ Pr		$(3/2^+)$	6.5(3) m	4.481(21)	-1.500(40)		-5.837(13)	4.698(16)	[1972ArZP]
¹³⁷ Pm		$11/2^{-}$	2.4(1) m	5.511(18)	-0.021(17)		-4.034(17)	5.920(21)	[1975No08]
¹⁴¹ Eu		5/2+	41.4(7) s	6.008(14)	0.997(27)		-2.487(30)	7.233(17)	[1993Al03]
¹⁴⁵ Tb*		$(11/2^{-})$	31.6(6) s	6.53(11)	1.93(11)		-1.460(111)	7.11(11)	[1992Al03]
¹⁴⁹ Ho		$(11/2^{-})$	21.1(2) s	6.048(13)	1.602(15)		-0.867(12)	8.856(23)	[1993Al03]
¹⁵³ Tm		$(11/2^{-})$	1.7(2) s	6.494(13)	2.343(16)		0.202(12)	11.296(15)	[1989Ko02]
^{153m} Tm	0.0432(2)	$(1/2^+)$	2.5(2) s	6.537(13)	2.386(16)		0.245(12)	11.337(15)	[1988ScZV, 1989Ko02]
¹⁵⁷ Lu		$(1/2^+, 3/2^+)$	6.8(5) s**	7.012(14)	3.138(17)		1.191(14)	11.602(15)	[1991Le15, 1991To09]
^{157m} Lu	0.032(2)	$(11/2^{-})$	4.75(10) s	7.044(14)	3.170(17)		1.223(14)	11.634(15)	[1991Le15]
¹⁶¹ Ta		$(1/2^+)$		7.540(30)	4.202(62)		2.477(30)	12.216(27)	
^{161m} Ta	0.096(28)***	$(11/2^{-})$	$3157^{+74}_{-79}$ ms	7.636(41)	4.298(68)		2.573(41)	12.312(39)	[2005Sc22]
¹⁶⁵ Re		$(1/2^+)$	1.6(6) s	8.248(30)	5.334(37)		4.032(35)	13.232(33)	[2012Th13]
^{165m} Re	0.048(26)	$(11/2^{-})$	1.74(6) s	8.200(40)	5.382(45)		4.080(44)	13.280(42)	[2012Th13, 1999Po09]
¹⁶⁹ Ir		$(1/2^+)$	3.53(4) s	8.630(30)	6.413(39)		5.422(30)	14.343(35)	[2005Sc22]
^{169m} Ir	0.153(24)	$(11/2^{-})$	280(3) ms	8.783(38)	6.567(46)		5.575(38)	14.496(42)	[2005Sc22, 1999Po09]
¹⁷³ Au		$(1/2^+)$	26.3(12) ms	9.100(70)	7.258(40)		6.887(29)	15.466(35)	[2012Th13]
^{173m} Au	0.214(23)	$(11/2^{-})$	12.2(1) ms	9.314(74)	7.472(46)		7.101(37)	15.680(42)	[2012Th13, 1999Po09]
¹⁷⁷ Tl		$(1/2^+)$	18(5) ms	9.440(90)	7.892(40)		7.791(29)	16.172(67)	[1999Po09]
177m Tl	0.807(18)	(11/2-)	230(40) µs	10.247(92)	8.699(44)		8.598(34)	16.979(69)	[1999Po09]

* Possibly not the ground state. ** Weighted average of 9.6(8) s [1991Le5] and 5.7(5) s [1991To09]. *** From  $Q_{\alpha}$  values for ^{161,161m}Ta [2012Th13] and 32(3) keV for the excitation energy of ^{157m}Lu.

Particle separation and emission from the odd-Z,  $T_z = +15/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$BR_p$	$S_{2p}$	Qα	BRα	Experimental
121-			11.010(0)	0.001/10		
¹²¹	4.172(4)		11.348(8)	-0.031(10)		
¹²⁵ Cs	3.711(8)		10.725(9)	-0.269(9)		
¹²⁹ La	3.243(21)		9.661(22)	0.341(23)		
¹³³ Pr	2.758(24)		8.746(31)	0.961(25)		
¹³⁷ Pm	2.163(18)		7.715(18)	1.440(18)		
¹⁴¹ Eu	1.759(18)		7.003(19)	1.722(18)		
¹⁴⁵ Tb*	1.929(114)		6.74(11)	1.10(11)		
¹⁴⁹ Ho	1.075(12)		5.481(14)	2.33(11)		
¹⁵³ Tm	0.761(12)		4.928(15)	5.248(1)	91(3)%	[1989Ko02, 1982De11, 1982Bo04, 1996Pa01, 1989Wo02, 1988To13,
						1988ScZW, 1988ScZO, 1988ScZV, 1979Be52, 1979Ho10, 1978AfZZ,
						1973BoXL, 1973BoXW]
^{153m} Tm	0.718(12)		4.885(15)	5.291(1)	92(3)%	[1988To13, 1988ScZV, 1989Ko02, 1996Pa01, 1989Wo02, 1988ScZW,
						1988ScZO, 1982Bo04, 1982De11, 1979Be52, 1979Ho10, 1978AfZZ,
						1973BoXL, 1973BoXW]
¹⁵⁷ Lu	0.463(12)		4.392(16)	5.108(3)	obs	[1991Le15, 1991To09, 1993ToZY]
^{157m} Lu	0.431(12)		4.360(16)	5.140(3)	6(2)%	[1996Pa01, 1991Le15, 1992Ha10, 1983To01, 1979Ho10, 1991Le15,
						1991To09, 1993ToZY, 1981HoZM, 1979A116, 1979Be52, 1979BeYR,
						1978AfZZ, 1977Ha49, 1972GaZR]
¹⁶¹ Ta	0.129(23)		3.648(45)	5.406(28)**		
^{161m} Ta	0.031(36)		3.552(53)	5.332(37)	7(3)%	[2012Th13, 2005Sc22, 1996Pa01, 1992Ha10, 1979Ho10, 1986Ru05,
						1988MeZY, 1987HaZO, 1984Gr14, 1981HoZM]
¹⁶⁵ Re	-0.287(23)		2.703(45)	5.694(6)	14(8)%	[ <b>2012Th13</b> ], 2005Sc22]
^{165m} Re	-0.335(35)		2.655(52)	5.742(27)	13(1)%	[ <b>2012Th13</b> , 2005Sc22, 1996Pa01, 1981Ho10]
¹⁶⁹ Ir	-0.613(22)		1.838(46)	6.141(4)	53(9)%***	[2012Th13, 2005Sc22, 1999Po05, 1996Pa01, 1984ScZQ, 1981DeZA,
						1978Ca11, 1978CaZF, 1978ReZZ]
^{169m} Ir	-0.766(33)		1.685(52)	6.294(24)	68(4)% [@]	[2012Th13, 2005Sc22, 1999Po05, 1996Pa01]
¹⁷³ Au	-0.986(21)		0.998(45)	6.891(4) ^{@@}	$94^{+6}_{-19}$ %	[2012Th13, 1999Po09, 2001Ko14, 1996Pa01, 1984ScZQ, 1983Sc24]
^{173m} Au	-1.200(31)		0.784(51)	7.105(23)	$92^{+8}_{-13}$ %	[2012Th13, 1999Po09, 2001Ko14]
¹⁷⁷ Tl	-1.156(19)	27(13)%	0.51(44)	7.067(7)	73(13)%	[1999Po09]
177m Tl	-1.963(26)	51(8)%	-0.30(44)	7.874(19)	49(8)%	[ <b>1999Po09</b> , 2004Ke04]

* Possibly not the ground state.

** Deduced from  $\alpha$  energy, 5.236(24) in [2021Wa16].

*** Weighted average of 50(18)% [1999Po09], 57(9)% [2012Th13], and 42(15)% [2005Sc22].

[@] Weighted average of 84(8)% [1999Po09], 78(6)% [2012Th13], 72(13)% [1996Pa01], and 59(4)% [2005Sc22].

^{@@} Deduced from  $\alpha$  energy, 6.836(5) in [2021Wa16].

# Table 3

direct $\alpha$ emission	from ¹⁵³ Tm, $T_{1/2} = 1$	$.7(2)  s^*, BR_{\alpha} = 91$	(3)%*.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)^*$	$E_{daughter}(^{149}\mathrm{Ho})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.247(2)	5.110(2)**	91(3)%	0.0		1.5621(20)	1.40(18)

* [1989Ko02]

** Weighted average of 5.111(2) MeV [1982De11], 5.103(3) MeV [1982Bo04] (adjusted to 5.108(3) in [1991Ry02]), and 5.112(5) MeV [1996Pa01].

**Table 4** direct  $\alpha$  emission from ^{153m}Tm*, Ex = 43.2(2) keV**, T_{1/2}= 2.5(2) s***, BR_{$\alpha$} = 92(3)%**.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)^{***}$	<i>E</i> _{daughter} ( ¹⁴⁹ Ho)	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.709(10) 5.034(15)	4.586(10) 4.902(15)	@ @ @	@ @ @	0.564 0.220	0.344, 0.171 0.171	1.5621(20) 1.5621(20)	$<\!\!6.4\! imes\!10^3$ $<\!\!1.6\! imes\!10^4$
5.233(4)	4.902(15) 5.096(4)	100%	$\approx 100\%$	0.220	0.171	1.5621(20) 1.5621(20)	<1.6×10 ⁻¹

* All values from [1988To13], unless otherwise stated.

** [1989Ko02].

*** [1988ScZV].

@ [1988To13] lists this transition as a possible doublet to the  $5/2^+$  564 keV state from both the  $11/2^-$  ground state and  $1/2^+$  isomer, however the change in spin greatly favors decay from the  $1/2^+$  isomer. I_{$\alpha$}4.586/I_{$\alpha$}(5.096 + 5.108) = 4.5(6)×0⁻⁵ [1988To13].

@ @ [1988To13] lists this transition as a possible doublet to the  $3/2^+$  220 keV keV state from both the  $11/2^-$  ground state and  $1/2^+$  isomer, however the change in spin greatly favors decay from the  $1/2^+$  isomer. I_{$\alpha$}4.902/I_{$\alpha$}(4.586 + 5.108) =  $1.8(4) \times 10^{-5}$  [1988To13].

#### Table 5

direct  $\alpha$  emission from ¹⁵⁷Lu*, T_{1/2}= 6.8(5) s**, BR_{$\alpha$} = obs.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{153}\mathrm{Tm})$	coincident $\gamma$ -rays
5.054(5)	4.925(5)	obs	0.043	

* All values from [1991Le15], except where noted.

** Weighted average of 9.6(8) s [1991Le5] and 5.7(5) s [1991To09].

#### Table 6

direct	α	emission	from	^{157m} Lu,	Ex =	= 32(2) 1	keV*,	$T_1$	$_{/2} = 4.75($	(10) s	*, $BR_{\alpha}$	$= 6(2)\%^{**}.$
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{153}\mathrm{Tm})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.129(2)	4.998(2)***	6(2)%	0.0		1.5787(76)	$2.7^{+1.5}_{-0.8}$

* [1991Le15].

** [1979Ho10].

*** Weighted average of 4.997(4) MeV [1996Pa01], 4.998(5) MeV [1991Le15], 4.995(6) MeV [1992Ha10], 4.999(5) MeV [1983To01] (adjusted to 5.003(3) in [1991Ry02]), and 4.994(5) MeV [1979Ho10] (adjusted to 4.999(3) in [1991Ry02]).

#### Table 7

direct $\alpha$ emission	from 161m Ta, Ex = 96(2	8) keV, $T_{1/2} = 315^{\circ}$	$7^{+74}_{-79}$ ms*, $BR_{\alpha} = 7(3)\%$ **.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{157}Lu)$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
5.278(2)	5.147(2)***	6(2)%	0.032		1.560(11)	$0.7^{+0.7}_{-0.3}$

* [2005Sc22].

** [2012Th13].

*** Weighted average of 5.140(7) MeV [1996Pa01], 5.149(5) MeV [1992Ha10], 5.142(6) MeV [2012Th13], 5.151(4) MeV [2005Sc22], and 5.148(5) MeV [1996Ru05].

#### Table 8

direct $\alpha$ emiss	ion from ¹⁶⁵ Re*, T ₁	$_{/2} = 1.6(6) \text{ s}, BR_{\alpha} =$	14(8)%.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{161}\mathrm{Ta})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
5.694(6)	5.556(6)	14(8)%	0.0		1,566(11)	$2^{+4}$	

* All values from [2012Th13].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{161}\mathrm{Ta})$	coincident γ-rays	R ₀ (fm)	HF
5.657(6)	5.520(6)	13(1)%	0.096		1.566(11)	$1.5 \ ^{+0.4}_{-0.3}$
* All val ** [1999	ues from [2012Th13], Po09].	except where noted				
Table 10 irect $\alpha$ emission	sion from ¹⁶⁹ Ir, $T_{1/2}$ =	$353(4) \text{ ms*}, BR_{\alpha} =$	53(9)%**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{165}\mathrm{Re})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.141(4)	5.995(4)***	53(9)%**	0.0		1.5639(39)	$1.0 \ ^{+0.6}_{-0.3}$
** Weigh *** Weig F <b>able 11</b> lirect α emis	hted average of 50(18) ghted average of 6.005 sion from ^{169m} Ir*, Ex	% [1999Po09], 57(9 5(8) MeV [1999Po09 = 153(24) keV**, T	1)% [2012Th13], and 42(1 1), and 5.993(4) MeV [200 $_{1/2}$ = 280(3) ms***, $BR_{\alpha}$ =	5)% [2005Sc22]. )5Sc22]. = 68(4)%* [@] .		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{165}\mathrm{Re})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.263(3) * All val ** [1999 *** [200 @ Weigh @@ Weig	6.114(3) ^{@@} ues from [2012Th13], P009]. 55c22]. ted average of 84(8)% ghted average of 6.106	68(4)%*** except where noted [1999Po09], 78(6) (5) MeV [1999Po09]	0.048 % [2012Th13], 72(13)% [1 ], 6.119(9) MeV [1996Pat	1996Pa01], and 59(4)% [200 01], and 6.117(3) MeV [200:	1.5639(39) 58c22]. 58c22].	1.85(18)
5.263(3) * All vali ** [1999 *** [200 @ Weigh @@ Weigh @@ Weig fable 12 lirect α emis	6.114(3) ^{@@} ues from [2012Th13], P009]. 55C22]. ted average of 84(8)% ghted average of 6.106 sion from ¹⁷³ Au, T _{1/2}	$68(4)\%^{***}$ except where noted (1999Po09], 78(6) (5) MeV [1999Po09] = 26.3(12) ms*, <i>BR</i>	0.048 (2012Th13], 72(13)% [1 (19), 6.119(9) MeV [1996Pat $\alpha = 94^{+6}_{-19}$ %*.	1996Pa01], and 59(4)% [200 01], and 6.117(3) MeV [200:	1.5639(39) 5\$c22]. 5\$c22].	1.85(18)
5.263(3) * All val. ** [1999 *** [200 @ Weigh @@ Weig fable 12 lirect $\alpha$ emis $E_{\alpha}(c.m.)$	$6.114(3)^{@@}$ ues from [2012Th13], P009]. 15Sc22]. ted average of 84(8)% ghted average of 6.106 sion from ¹⁷³ Au, T _{1/2} $E_{\alpha}(\text{lab})$	$68(4)\%^{***}$ except where noted 0 [1999Po09], 78(6) 0(5) MeV [1999Po09] = 26.3(12) ms*, <i>BR</i> $I_{\alpha}(abs)$	0.048 % [2012Th13], 72(13)% [1] % [2012Th	1996Pa01], and 59(4)% [200 01], and 6.117(3) MeV [200: coincident γ-rays	1.5639(39) 5Sc22]. 5Sc22]. R ₀ (fm)	1.85(18) HF
5.263(3) * All values ** [1999 *** [200 @ Weigh @@ Weigh @@ Weigh irect $\alpha$ emise $S_{\alpha}(c.m.)$ 5.891(4)	$\frac{6.114(3)^{@@}}{1000}$ ues from [2012Th13], P009]. 15Sc22]. ted average of 84(8)% ghted average of 6.106 sion from ¹⁷³ Au, T _{1/2} <u>E_{\alpha}(lab)</u> 6.732(4)**	$\frac{68(4)\%^{***}}{68(4)\%^{***}}$ except where noted (1999Po09], 78(6) (5) MeV [1999Po09] = 26.3(12) ms*, BR I _{\alpha} (abs) 94 ⁺⁶ ₋₁₉ \%	0.048 % [2012Th13], 72(13)% [1] % [2012Th	1996Pa01], and 59(4)% [200 01], and 6.117(3) MeV [200: 	1.5639(39) 55Sc22]. 5Sc22]. R ₀ (fm) 1.5529(80)	$\frac{1.85(18)}{\text{HF}}$
5.263(3) * All vali ** [1999 *** [200 @ Weigh @@ Weig fable 12 lirect $\alpha$ emis $E_{\alpha}(c.m.)$ 5.891(4) * [2012T ** [1999	$\frac{6.114(3)^{@@}}{1000}$ ues from [2012Th13], P009]. 15Sc22]. ted average of 84(8)% ghted average of 6.106 sion from ¹⁷³ Au, T _{1/2} <u>E_{\alpha}(lab)</u> 6.732(4)** Th13]. P009].	$\frac{68(4)\%^{***}}{68(4)\%^{***}}$ except where noted (1999Po09], 78(6) (5) MeV [1999Po09] = 26.3(12) ms*, BR I _{\alpha} (abs) 94 ⁺⁶ ₋₁₉ \%*	$0.048$ % [2012Th13], 72(13)% [1] ], 6.119(9) MeV [1996Pat $x = 94^{+6}_{-19} \%^*.$ $E_{daughter}(^{169} \text{Ir})$ 0.0	1996Pa01], and 59(4)% [200 01], and 6.117(3) MeV [200: 	1.5639(39) 558c22]. 58c22]. R ₀ (fm) 1.5529(80)	1.85(18) HF 2.9 ^{+0.6} _{-0.5}
5.263(3) * All vali ** [1999 *** [200 @ Weigh @@ Weig fable 12 lirect $\alpha$ emis 5.891(4) * [2012T ** [1999 Fable 13 lirect $\alpha$ emis	$\frac{6.114(3)^{@@}}{1000}$ ues from [2012Th13], P009]. 15Sc22]. ted average of 84(8)% ghted average of 6.106 sion from ¹⁷³ Au, T _{1/2} <u>Ea(lab)</u> 6.732(4)** Th13]. P009]. sion from ^{173m} Au, Ex	$\frac{68(4)\%^{***}}{68(4)\%^{***}}$ except where noted (1999Po09], 78(6) (5) MeV [1999Po09] = 26.3(12) ms*, BR I _{\alpha} (abs) 94 ⁺⁶ ₋₁₉ \%* = 214(23) keV*, T ₁	0.048 % [2012Th13], 72(13)% [1] % [2012Th13], 72(13)% [1] % [1996Pat a) (1996Pat a) (19	1996Pa01], and 59(4)% [200 01], and 6.117(3) MeV [200: coincident γ-rays 	1.5639(39) 558c22]. 58c22]. R ₀ (fm) 1.5529(80)	1.85(18) HF 2.9 ^{+0.6} _{-0.5}
5.263(3) * All vali ** [1999 *** [200 @ Weigh @@ Weig irect $\alpha$ emis 5.891(4) * [2012T ** [1999 Fable 13 firect $\alpha$ emis $E_{\alpha}(c.m.)$	$\frac{6.114(3)^{@@}}{1000}$ ues from [2012Th13], P009]. 15Sc22]. ted average of 84(8)% ghted average of 6.106 sion from ¹⁷³ Au, T _{1/2} <u>Ea(lab)</u> 6.732(4)** Th13]. P009]. sion from ^{173m} Au, Ex <u>Ea(lab)</u>	$\frac{68(4)\%^{***}}{68(4)\%^{***}}$ except where noted (1999Po09], 78(6) (5) MeV [1999Po09] = 26.3(12) ms*, BR I _{\alpha} (abs) 94 ⁺⁶ ₋₁₉ \%* = 214(23) keV*, T ₁ I _{\alpha} (abs)	$0.048$ % [2012Th13], 72(13)% [1] % [2012Th13], 72(13)% [1] % [1996Pat y], 6.119(9) MeV [1996Pat y], 6.119(9) MeV [1996Pat y], 6.119(9) MeV [1996Pat g] $\chi = 94^{+6}_{-19}$ %*. $E_{daughter}(^{169}\text{Ir})$ 0.0 $\frac{1}{2} = 12.2(1) \text{ ms}^{**}, BR_{\alpha} = 92$ $E_{daughter}(^{169}\text{Ir})$	1996Pa01], and 59(4)% [200 01], and 6.117(3) MeV [200: 	1.5639(39) 558c22]. 58c22]. R ₀ (fm) 1.5529(80)	1.85(18) HF 2.9 ^{+0.6} -0.5
5.263(3) * All vali ** [1999 *** [200 @ Weigh @@ Weig irect $\alpha$ emis $F_{\alpha}(c.m.)$ 5.891(4) * [2012T ** [1999 <b>Yable 13</b> irect $\alpha$ emis $F_{\alpha}(c.m.)$ 5.891(4)	$\frac{6.114(3)^{@@}}{1000}$ ues from [2012Th13], P009]. 15Sc22]. ted average of 84(8)% ghted average of 6.106 sion from ¹⁷³ Au, T _{1/2} <u>Ea(lab)</u> 6.732(4)** Th13]. P009]. sion from ^{173m} Au, Ex <u>Ea(lab)</u> 6.732(4)* [@]	$\frac{68(4)\%^{***}}{68(4)\%^{***}}$ except where noted (1999Po09], 78(6) (5) MeV [1999Po09] = 26.3(12) ms*, BR I _{\alpha} (abs) 94 ⁺⁶ ₋₁₉ %* = 214(23) keV*, T ₁ I _{\alpha} (abs) 92 ⁺⁸ ₋₁₃ %**	0.048 % [2012Th13], 72(13)% [1] % [20	1996Pa01], and 59(4)% [200 01], and 6.117(3) MeV [200: 	1.5639(39) 5Sc22]. 5Sc22]. R ₀ (fm) 1.5529(80) 1.5529(80)	$\frac{\text{HF}}{2.9^{+0.6}_{-0.5}}$
5.263(3) * All vali ** [1999 *** [200 @ Weigh @@ Weig fable 12 lirect $\alpha$ emis 5.891(4) * [2012T ** [1999 fable 13 lirect $\alpha$ emis $\overline{E_{\alpha}(c.m.)}$ 5.891(4) * [2012T ** [1999P ** [2012	$\frac{6.114(3)^{@@}}{1000}$ ues from [2012Th13], P009]. 15Sc22]. ted average of 84(8)% ghted average of 6.106 sion from ¹⁷³ Au, T _{1/2} <u>Ea(lab)</u> 6.732(4)** Th13]. P009]. sion from ^{173m} Au, Ex <u>Ea(lab)</u> 6.732(4)* [@] P009]. Th13].	$\frac{68(4)\%^{***}}{68(4)\%^{***}}$ except where noted (1999Po09], 78(6) (5) MeV [1999Po09] = 26.3(12) ms*, BR I _{\alpha} (abs) 94 ⁺⁶ ₋₁₉ %* = 214(23) keV*, T ₁ I _{\alpha} (abs) 92 ⁺⁸ ₋₁₃ %**	0.048 % [2012Th13], 72(13)% [1] % [20	1996Pa01], and 59(4)% [200 01], and 6.117(3) MeV [200: 	1.5639(39) 558c22]. 58c22]. R ₀ (fm) 1.5529(80) 1.5529(80)	$\frac{\text{HF}}{2.9^{+0.6}_{-0.5}}$
5.263(3) * All vali ** [1999 *** [200 @ Weigh @@ Weigh @@ Weig fable 12 lirect $\alpha$ emis 5.891(4) * [2012T ** [1999 Fable 13 lirect $\alpha$ emis 5.891(4) * [2012T ** [2012T *	$\frac{6.114(3)^{@@}}{1000}$ ues from [2012Th13], P009]. 15Sc22]. ted average of 84(8)% ghted average of 6.106 sion from ¹⁷³ Au, T _{1/2} <u>Ea(lab)</u> 6.732(4)** Th13]. P009]. sion from ^{173m} Au, Ex <u>Ea(lab)</u> 6.732(4)* [@] P009]. Th13].	$\frac{68(4)\%^{***}}{except where noted}$ except where noted o [1999Po09], 78(6) o(5) MeV [1999Po09] = 26.3(12) ms*, BR Ia(abs) 94 ⁺⁶ ₋₁₉ %* = 214(23) keV*, T ₁ Ia(abs) 92 ⁺⁸ ₋₁₃ %**	0.048 % [2012Th13], 72(13)% [1] % [2012Th13], 72(13)% [1] % [2012Th13], 72(13)% [1] % [2012Th13], 72(13)% [1996Pathered scale="block" style="text-align: center;"> % [2012Th13], 72(13)% [1996Pathered scale="text-align: center;"> % [2012Th13], 72(13) % [1996Pathered scale="text-align: center;"] % [2012Th13], 1000 [1996Pathered scale="text-align: center;"]	1996Pa01], and 59(4)% [200 01], and 6.117(3) MeV [200: 	1.5639(39)         5Sc22].         SSc22].         R ₀ (fm)         1.5529(80)	$HF$ $2.9^{+0.6}_{-0.5}$ $1.43^{+0.27}_{-0.24}$
5.263(3) * All valu ** [1999 *** [200 @ Weigh @@ Weigh @@ Weig fable 12 lirect $\alpha$ emis 5.891(4) * [2012T ** [1999 fable 13 lirect $\alpha$ emis $\overline{\mathcal{E}_{\alpha}}(c.m.)$ 5.891(4) * [2012T ** [1999 fable 13 lirect $\alpha$ emis $\overline{\mathcal{E}_{\alpha}}(c.m.)$ 5.891(4) * [2012 fable 14 lirect $\alpha$ emis $\overline{\mathcal{E}_{\alpha}}(c.m.)$	$\frac{6.114(3)^{@@}}{6.114(3)^{@@}}$ ues from [2012Th13], Po09]. 15Sc22]. ted average of 84(8)% ghted average of 6.106 sion from ¹⁷³ Au, T _{1/2} <u>Ea(lab)</u> 6.732(4)** Th13]. Po09]. sion from ^{173m} Au, Ex <u>Ea(lab)</u> 6.732(4)* [@] Po09]. Th13]. sion from ¹⁷⁷ Tl*, T _{1/2} <u>Ea(lab)</u>	$\frac{68(4)\%^{***}}{except where noted}$ except where noted $\frac{0}{2} [1999Po09], 78(6)\%$ $= 26.3(12) \text{ ms}^*, BR_{0}$ $\frac{I_{\alpha}(abs)}{94^{+6}_{-19}\%^*}$ $= 214(23) \text{ keV}^*, T_{1}$ $\frac{I_{\alpha}(abs)}{92^{+8}_{-13}\%^{**}}$ $= 18(5)\text{ ms}, BR_{\alpha} = 7$ $I_{\alpha}(abs)$	0.048 % [2012Th13], 72(13)% [1] % [2012Th13], 72(13)% [1] % [2012Th13], 72(13)% [1] % [1996Pather] % [19	1996Pa01], and 59(4)% [200 01], and 6.117(3) MeV [200: 	1.5639(39)         558c22].         58c22].         R0 (fm)         1.5529(80)         1.5529(80)         R0 (fm)	HF 2.9 ^{+0.6} 2.9 ^{-0.5} 1.43 ^{+0.27} -0.24

* All values taken from [1999Po09].

direct p emissio	on from 177 Tl*, T $_{1/2}$ =	18(5)ms, BR _p = 27	(13)%.				
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(abs)$	Edaughter( ¹⁷⁶ Hg)	coincident	γ-rays		
1.163(20)	1.156(20)	27(13)%	0.0				
* All value	es taken from [1999Po	09].					
Table 16 direct $\alpha$ emission	on from ^{177m} Tl*, Ex =	807(18) keV, T _{1/2} =	= 230(40) $\mu$ s, $BR_{\alpha}$ = 49(8)%				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{173}\mathrm{Au})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
7.660(13)	7.487(13)	49(8)%	0.214		1.545(21)	$2.2^{+1.4}_{-1.0}$	
* All value	es taken from [1999Po	09].					
Table 17     direct p emission	on from ^{177m} Tl*, Ex =	807(18) keV, T _{1/2} =	= 230(40) $\mu$ s, BR _p = 51(8)%.				
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p(abs)$	$E_{daughter}(^{176}\mathrm{Hg})$	coincident $\gamma$	-rays		
1.969(10)	1.958(10)	51(8)%	0.0				

* All values taken from [1999Po09].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +8 nuclei.

Last updated 3/23/23

α
Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +8$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\epsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
¹³² Ce	$0^{+}$	3.51(11) h	1.250(40)	-3.079(20)		-10.147(22)	1.038(21)	[1976Ge10]
¹³⁶ Nd	$0^+$	50.65(33) m	2.141(16)	-1.872(16)		-8.559(23)	2.099(38)	[1975Br16]
¹⁴⁰ Sm	$0^+$	14.82(10) m	2.756(27)	-0.728(30)		-6.905(16)	3.460(17)	[1972De23]
¹⁴⁴ Gd	$0^+$	4.47(6) m	3.860(30)	0.469(28)		-5.196(37)	4.028(37)	[1991Tu01]
¹⁴⁸ Dy	$0^+$	3.1(1) m	2.678(10)	0.209(9)		-5.320(11)	5.335(14)	[1975To03]
¹⁵² Er	$0^+$	10.3(1) s	3.104(10)	0.963(9)		-3.972(12)	7.612(15)	[1982Bo04]
¹⁵⁶ Yb	$0^+$	25.3(5) s*	3.569(13)	1.655(11)		-3.204(12)	7.914(16)	[2011Es03, 1983Mi01, 1982To14,
								1979Ho10, 1970To16]
¹⁶⁰ Hf	$0^+$	13.6(2) s	4.330(60)	2.606(20)		-1.813(27)	8.471(17)	[1995Hi12]
$^{164}W$	$0^+$	6.0(3) s**	5.047(30)	3.745(27)		0.018(76)	9.609(58)	[[1979Ho10, 1975To05, 1973Ea01]
¹⁶⁸ Os	$0^{+}$	2.2(1)*** s	5.800(30)	4.809(21)		1.525(30)	10.863(30)	[1996Pa01, 1982En03]
¹⁷² Pt	$0^+$	96(3) ms	6.270(30)	5.902(21)		3.219(15)	12.263(33)	[1996Pa01]
¹⁷⁶ Hg	$0^+$	21.3(8) ms@	6.740(30)	6.635(22)		4.423(16)	13.170(34)	[2009An20, 2004GoZZ, 2002Ro17,
C								1999To11, 1999Po09]
¹⁸⁰ Pb	$0^+$	4.1(3) ms	7.450(70)	7.703(31)		5.784(16)	14.155(35)	[2010Ra12]

* Weighted average of 24(1) s[1970To16], 26.1(7) s [2011Es03], 25.8(10) s [1977Ha48], 26.0(5) s [1978AfZZ], 23.6(13) s [1983Mi01], and 23(1) s [1982To14]. ** Weighted average of 6.3(5) s [1973Ea01], 5.5(5) s [1975To05], 6.4(8) s [1979Ho10].

*** Weighted average of 2.2(1) s [1982En03], and 2.1(1) s [1996Pa01].

[@] Weighted average of 20(3) ms [2009An20], 22(1) ms [2004GoZZ], 20(2) ms [2002Ro17], 20(3) ms [1999To11], and 21(4) ms [1999Po09].

# Table 2

Particle separation and emission from the even-Z,  $T_z = +8$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
132 <b>C</b> a	5 (199(25))	0.700(20)	0.476(20)		
136 11	5.966(55)	9.790(20)	0.470(20)		
130 Nd	5.552(17)	8.944(24)	0.844(24)		
¹⁴⁰ Sm	5.244(18)	8.017(17)	1.318(17)		
¹⁴⁴ Gd	4.807(30)	7.356(28)	1.272(31)		
¹⁴⁸ Dy	4.406(12)	6.352(10)	1.475(29)		
¹⁵² Er	4.166(12)	5.769(10)	4.934(2)	92(4)%*	[1982Bo04, 1982De11, 1987To02, 1979Ho10, 1982Ba75, 1982To14,
					1981HoZM, 1977Ha48, 1970To16
¹⁵⁶ Yb	3.929(14)	5.239(11)	4.810(4)	9(2)%	[1996Pa01, 1983Mi01, 1982To14, 1979Ho10, 1978AfZZ, 1977Ha48,
				(_),-	<b>1979To16</b> , 2011Es03, 1970ToZS, 1970ToZU]
¹⁶⁰ Hf	3.519(39)	4.507(12)	4.902(3)	0.7(2)%	[1995Hi12, 1992Ha10, 1996Pa01, 1996HiZX, 1979Ho10, 1973To02,
			, 0=(0)		1970ToZU, 1970ToZY]
$^{164}W$	2,990(39)	3.645(13)	5.278(2)	4.4(9)%**	[1996Pa01, 1979Ho10, 1975To05, 1973Ea01, 1994TeZZ, 1982De11,
			0.2.0(2)		1981DeZA, 1976ToZP, 1974Sc35, 1972EaZU]
¹⁶⁸ Os	2.450(41)#	2.685(14)	5.816(3)	43(3)%***	[2004GoZZ, 1996Pa01, 1995Hi02, 1984Sc06, 1982De11, 1982En03,
					1978Ca11, 1978Sc26, 1977Ca231
¹⁷² Pt	1.984(40)#	1.759(14)	6463(4)	94(6)%	[2004GoZZ, 1996Pa01, 1981De22, 2002Ro17, 1993ToZY, 1984ScZO
	1001(10)	11/05(11)	01.000(1)	1.(0)/0	1982En03]
¹⁷⁶ Hg	1.670(40)#	1.045(15)	6.897(6)	98(2)%	[2004GoZZ, 1999Po09, 2010Ju02, 2009An02, 2002Ro17, 1999To11,
0					1998Mu25, 1996Pa01, 1993ToZY, 1990SeZW, 1984ScZO, 1983Sc241
¹⁸⁰ Ph	0.960(41)	0 204(16)	7 419(5)	$\approx 100\%^{@}$	[2010Ra12, 2009An20, 2010Iu02, 1999To11, 1998ToZW, 1996To08]
10	5.700(11)	5.20 ((10)		010070	[

* Weighted average of 93(4)% [1979Ho10] and 90(4)% , 94(4)% [1987To01].

** Weighted average of 5(1)% [1996Pa01] and 2.6(17)% [1979Ho10].

*** Weighted average of 36(4)% [2004GoZZ], 40(3)% [1996Pa01], and 49(3)% [1982En03].

[@] Deduced from short half-life.

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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{148}\mathrm{Dy})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.935(2)	4.805(2)***	92(4)%**	$0^+$	0.0		1.5668(28)	1.00(5)
* [1982B ** Weigh *** Weig	004]. tted average of 93(4) [,] thted average of 4.79	% [1979Ho10] and 9(3) MeV [1982Bo	90(4)% , 94( 04] (adjustec	(4)% [1987To01]. 1 to 4.805(3) in [1991Ry02	2]), 4.804(2) MeV [1982De	11], and 4.808(5) Me	eV [1979Ho10].
<b>Table 4</b> lirect $\alpha$ emiss	sion from ¹⁵⁶ Yb*, J ^{$\pi$}	$= 0^+, T_{1/2} = 25.3(2)$	5) s**, $BR_{\alpha}$	= 9(2)%***.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{152}\mathrm{Er})$	coincident γ-rays	$R_0$ (fm)	HF
4.810(4)	4.687(4)	9(2)%	$0^+$	0.0		1.592(15)	$1.09\substack{+0.34\\-0.22}$
irect $\alpha$ emiss	sion from ¹⁶⁰ Hf*, J $\pi$	$= 0^+, T_{1/2} = 13.6(2)$	2) s, $BR_{\alpha} = 0$	.7(2)%.	coincident 4-rays	$\mathbf{R}_{0}$ (fm)	HF
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{156}\mathrm{Yb})$	coincident γ-rays	R ₀ (fm)	HF
1.902(6)	4.779(6)**	0.7(2)%	$0^+$	0.0		1.549(19)	$1.0\substack{+0.4\\-0.2}$
* All valu ** [1992] F <b>able 6</b> lirect α emiss	tes from [1995Hi12] Ha10] sion from ¹⁶⁴ W, J $\pi$ =	, except where note $0^+$ , $T_{1/2} = 6.0(3)$ s	d. *, $BR_{\alpha} = 4.4$	(9)%**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{160}\mathrm{Hf})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.278(3)	5.140(3)***	4.4(9)%	$0^+$	0.0		1.576(15)	$0.8\substack{+0.3\\-0.2}$
* Weight ** Weigh *** Weig able 7 lirect α emiss	ed average of 6.3(5) s ted average of 5(1)% thed average of 5.14 sion from ¹⁶⁸ Os, J ^{$\pi$} =	s [1973Ea01], 5.5(5 b [1996Pa01] and 2. 8(6) MeV [1996Pa0 e 0 ⁺ , T _{1/2} = 2.2(1) s	b) s [1975Tot 6(17)% [197 b)1], 5.153(5) s*, $BR_{\alpha} = 43$	05], 6.4(8) s [1979Ho10]. 9Ho10]. MeV [1973Ea01], 5.146( (3)%**.	5) MeV [1975To05], and 5.	148(5) MeV [1979H	io10].
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{m \pi}$	$E_{daughter}(^{164}W)$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.817(3)	5.678(3)***	43(4)%	$0^{+}$	0.0		1.5627(48)	1.03(11)

* Weighted average of 2.2(1) s [1982En03], and 2.1(1) s [1996Pa01].
** Weighted average of 36(4)% [2004GoZZ], 40(3)% [1996Pa01], and 49(3)% [1982En03].
*** Weighted average of 5.674(8) MeV [1995Hi02], 5.662(8) MeV [1984Sc06], and 5.680(3) MeV [1982De11].

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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{168}\mathrm{Os})$	coincident γ-rays	R ₀ (fm)	HF
6.466(3)	6.315(3)***	43(4)%	$0^+$	0.0	_	1.5583(40)	0.99(7)
* [1996Pa ** [20040 *** Weig <b>Table 9</b> direct α emiss	a01]. GoZZ]. hted average of 6.317 sion from 176 Hg, J $^{\pi}$ =	(5) MeV [2004Gc 0 ⁺ , T _{1/2} = 21.3(8	ZZ], and 6.3 ) ms*, $BR_{\alpha}$ =	14(4) MeV [1982De11]. = 98(2)%**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{172}\mathrm{Pt})$	coincident γ-rays	R ₀ (fm)	HF
6.906(5)	6.749(5)***	98(2)%	$0^+$	0.0		1.5446(30)	1.02(4)
* Weighta ** [20040 *** Weig <b>Table 10</b> direct α emiss	ed average of 20(3) m GoZZ]. thed average of 6.755 sion from ¹⁸⁰ Pb*, $J^{\pi}$ =	s [2009An20], 220 (5) MeV [2004Go $= 0^+, T_{1/2} = 4.1(3)$	(1) ms [2004) ZZ], and 6.7 ms, $BR_{\alpha} = 2$	GoZZ], 20(2) ms [2002Ro 40(6) MeV [1999Po09]. ≈100%.	17], 20(3) ms [1999To11],	and 21(4) ms [1999P	009].
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{176}\mathrm{Hg})$	coincident $\gamma$ -rays	R ₀ (fm)	HF

* All values from [2010Ra12].

7.254(7)

7.419(7)

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 $0^{+}$ 

0.0

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≈100%

direct  $\alpha$  emission from ¹⁷²Pt, J^{$\pi$} = 0⁺, T_{1/2} = 96(3) ms^{*}, BR_{$\alpha$} = 94(6)%^{**}.

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Last updated 12/12/22

Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z$  = +8 nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{[pi} values for ¹²²I, ¹²⁶Cs, ¹³⁰La, ¹³⁴Pr, ¹³⁸Pm, ¹⁴²Eu, ¹⁴⁶Tb, ¹⁵⁰Ho, are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$Q_{\varepsilon 2p}$	$Q_{\varepsilon \alpha}$	$BR_{\varepsilon F}$	Experimental
100									
$^{122}I$		$1^{+}$	3.63(6) m	4.234(5)	-3.769(5)	-9.559(5)	3.149(5)		[1970LaZX]
¹²⁶ Cs		$1^{+}$	98.6(10) s	4.796(10)	-2.804(10)	-8.404(10)	3.538(10)		[1969Ch18]
¹³⁰ La		3+	8.7(1) m	5.629(26)	-1.417(26)-	-6.345(26)	5.094(26)		[1963Ya05]
¹³⁴ Pr		$2^{-}$	17(2) m	6.305(29)	-0.323(35)	-4.671(20)	6.304(20)		[1967Cl02]
¹³⁸ Pm		$(1^{+})$	10(2) s	7.103(16)	0.998(14)	-2.984(12)	7.494(23)		[1983Al06]
¹⁴² Eu		$1^{+}$	2.34(12) s	7.673(30)	1.925(33)	-1.630(30)	8.283(32)		[1991Fi03]
¹⁴⁶ Tb		$1^{+}$	8(4) s	8.320(40)	2.939(45)	-0.376(45)	8.793(45)		[1982No08]
¹⁵⁰ Ho		$(2^{-})$	72(4) s	7.364(14)	2.254(15)	-0.254(14)	11.715(15)		[1982No08]
¹⁵⁴ Tm		$(2^{-})$	8.3(3) s	8.178(15)	3.296(15)	1.113(15)	12.458(15)		[1982Bo04]
^{154m} Tm	х	(9+)	3.35(5) s	8.178(15)+x	3.296(15)+x	1.113(15)+x	12.458(15)+x		[1982Bo04]
¹⁵⁸ Lu		(2 ⁻ )	10.6(3) s	8.797(17)	4.208(32)	2.422(29)	12.968(16)		[1983Ge08]
¹⁶² Ta			3.60(15) s	9.390(60)	5.492(69)	3.804(64)	13.803(64)		[1992Ha10]
¹⁶⁶ Re		(3 ⁻ )*	2.4(2) s**	10.050(90)	6.722(89)	5.403(90)	14.906(89)		[1992Me10, 1984Sc06, 1978Sc26]
¹⁷⁰ Ir		(3-)	$870^{+180}_{-120}$ ms	10.74(10)#	7.94(10)#	7.13(10)#	16.28(10)		[2002Ro17]
170m Ir	х	$(8^+)$	811(18) ms	10.74(10)#+x	7.94(10)#+x	7.13(10)#+x	16.28(10)+x		[2007Ha45]
¹⁷⁴ Au		$(2^{-})$	120(20) ms	11.26(10)#	8.92(10)#	8.61(10)#	17.44(10)		[1983Sc24]
^{174m} Au	х	$(9^{+})$	162(3) ms	11.26(10)#+x	8.92(10)#+x	8.61(10)#+x	17.44(10)+x		[2004GoZZ]
¹⁷⁸ Tl		(4 ⁻ , 5 ⁻ )	252(20) ms	11.70(10)#	9.64(10)#	9.74(10)#	18.28(10)	0.15(6)%	[2013Li49]

* [2004GoZZ]

** Weighted average of 2.3(2) [1992Me10], 2.8(3) s [1984Sc06] and 2.2(4) s [1978Sc26].

#### Table 2

Particle separation and emission from the odd-Z,  $T_z = +8$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	Experimental
¹²² I	4.825(26)	12.240(9)	-0.508(6)		
¹²⁶ Cs	4.440(10)	11.564(11)	-0.696(12)		
¹³⁰ La	3.855(28)	10.274(26)	0.298(28)		
¹³⁴ Pr	3.399(26)	9.382(42)	0.674(33)		
¹³⁸ Pm	2.619(16)	8.152(16)	1.189(23)		
¹⁴² Eu	2.664(31)	7.675(39)	1.181(32)		
¹⁴⁶ Tb	2.126(49)	6.722(46)	1.120(54)		
¹⁵⁰ Ho	1.541(17)	5.987(19)	3.393(47)		
¹⁵⁴ Tm	1.249(17)	5.400(19)	5.094(3)	54(5)%	[1997To12, 1982Bo04, 1979Ho10, 1995Wa32, 1995WaZN, 1995WaZR,
					1993ToZX, 1992Po14, 1981De22, 1981HoZM, 1979Be52, 1973BoVZ,
					1973BoXW, 1973BoXL, 1964Ma45, 1963Ma13]
^{154m} Tm*	1.249(17)-x	5.400(19)-x	5.094(3)+x	58(5)%	[1997To12, 1982Bo04, 1982De11, 1979Ho10, 1995Wa32, 1995WaZN,
					1995WaZR, 1993ToZX, 1992Po14, 1991VaZZ, 1989KaYU, 1984ToZT,
					1981De22, 1981HoZM, 1979Be52, 1973BoVZ, 1973BoXW, 1973BoXL,
					1964Ma45, 1963Ma13]
¹⁵⁸ Lu	1.081(19)	4.956(21)	4.790(5)	0.91(20)%	[1992Ha10, 1983Ge08, 1983To01, 1992Po14, 1982RaZZ, 1981RaZH,
					1980A114, 1980AIZN, 1979A116, 1979AIZM, 1979Be52]
¹⁶² Ta	0.755(68)	4.089(85)	5.008(5) [@]	0.074(13)%**	[1992Ha10, 1986Ru05, 2011Gh08, 1988MeZY, 1987HaZO, 1987ScZH,
					1987ScZL]
¹⁶⁶ Re	0.265(92)#	3.132(93)	5.663(4)@@	obs	[1996Pa01, 1992Me10, 1984Sc06, 1982De11, 1978Sc26, 1992MeZW,
					1984Gr14, 1981DeZA, 1981DeZL]
¹⁷⁰ Ir	-0.25(11)	1.97(11)#	5.955(5)***	5.2(17)%	[2004GZZ, 2002Ro17, 1996Pa01]
^{170m} Ir*	-0.25(11)-x	1.97(11)#-x	5.955(5)+x	39(6)%	[2004GoZZ, 2002Ro17, 1996Pa01, 1984Gr14, 1982De11, 1978ReZZ,
					1978Sc26, 1978Ca11, 1977Ca23, 1977ScYH
¹⁷⁴ Au	-0.59(12)	1.26(11)#	6.699(7)	90(6)%	[2002Ro17, 2004GoZZ]
^{174m} Au	-0.59(12)-x	1.26(11)#-x	6.699(7)+x	obs	[2004GoZZ, 2002Ro17, 1996Pa01, 1992Ha10, 2000KoZN, 1984ScZQ,
					1983Sc24]
¹⁷⁸ Tl	-0.87(13)	0.67(11)#	7.020(10)	62(2)%	[2013Li49, 2002Ro17, 2001RoZW, 1997Ca13]

* Excitation is unknown.

** Weighted average of 0.081(13)% [1992Ha10] and 0.065(14)% [1986Ru05].

*** Deduced from  $\alpha$  energy, 6.230(50)# in [2021Wa16].

[@] Deduced from  $\alpha$  energy, 5.010(60) in [2021Wa16].

^{@@} Deduced from  $\alpha$  energy, 5.520(60) in [2021Wa16].

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$E_{daughter}(^{150}\mathrm{Ho})$	coincident γ-rays	R ₀ (fm)	HF
4.975(15)	4.846(15) [@]	0.45(20)%**	0.24(11)%**	0.131	0.131	$1.5815(15)^{@@}$	$180^{+16}_{-6}$
5.093(3)	4.961(3)***	100%**	58(5)%**	0.0		$1.5815(15)^{@@}$	3.4(4)

* All values from [1997To12], except where noted.

direct  $\alpha$  emission from ¹⁵⁴Tm*, T_{1/2}= 8.3(3) s**, BR_{$\alpha$} = 54(5)%.

** [1982Bo04].

*** Weighted average of 4.959(5) MeV [1979Ho10] (adjusted to 4.964(5) MeV in [1999Ry01]) and 4.955(3) MeV [1982Bo04] (adjusted to 4.960(3) MeV in [1999Ry01])

[@] Reported as 4.825(15) MeV in [1997To12], which lists the 100% peak as 4.956(3) MeV based on data that was not adjusted in [1991Ry01]. The value adopted here is 5 keV higher, therefore the energy of the fine structure peak was adjusted accordingly.

[@] Interpolated between 1.567(3) fm  152 Er and 1.596(15) fm  156 Yb.

#### Table 4

direct $\alpha$ emission from 154m	Tm*, Ex = unk,	$T_{1/2} = 3.35(5) s^{**},$	$BR_{\alpha} = 58(5)\%$
-----------------------------------------	----------------	-----------------------------	-------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$E_{daughter}(^{150}\text{Ho})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.975(15)	4.846(15) [@]	0.24(5)%**	0.14(3)%**	0.197 + x	0.197	$1.5815(15)^{@@}$	$150^{+50}_{-30}$
5.172(2)	5.037(2)***	100%**	58(5)%**	x		$1.5815(15)^{@@}$	2.98(28)

* All values from [1997To12], except where noted.

** [1982Bo04].

*** Weighted average of 5.035(5) MeV [1979Ho10] (adjusted to 5.040(5) MeV in [1999Ry01]), 5.037(2) MeV [1981De22] and 5.030(3) MeV [1982Bo04] (adjusted to 5.036(3) MeV in [1999Ry01]).

[@] Reported as 4.840(15) MeV in [1997To12], which lists the 100% peak as 5.031(3) MeV based on data that was not adjusted in [1991Ry01]. The value adopted here is 6 keV higher, therefore the energy of the fine structure peak was adjusted accordingly.

^{@@} Interpolated between 1.567(3) fm  152 Er and 1.596(15) fm  156 Yb.

Table 5 direct $\alpha$ emis	<b>Fable 5</b> lirect $\alpha$ emission from ¹⁵⁸ Lu, T _{1/2} = 10.6(3) s*, $BR_{\alpha} = 0.91(20)\%$ **.								
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{154}\mathrm{Tm})$	coincident $\gamma$ -rays	R ₀ (fm)	HF			
4.789(5)	4.668(5)***	0.91(20)%**	0.0		1.573(24)@	$0.7^{+0.5}_{-0.3}$			

*	Γ1	0	83	Ge	03.	1
				<b>、</b> IX /	.,,	

** [1992Ha10].

*** Reported as 4.666(5) MeV [1983To01] (adjusted to 4.668(5) MeV in [1999Ry01]).

[@] Interpolated between 1.596(15) fm  156 Yb, and 1.549(19) fm  160 Hf.

## Table 6

Table 0			
direct $\alpha$ emission from	¹⁶² Ta*, T ₁	$_{/2}$ = 3.60(15) s,	$BR_{\alpha} = 0.074(13)\%^{**}.$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{158}Lu)$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
5.008(5)	4.884(5)	0.074(13)%**	0.0		1.563(24)***	$3.8^{+2.4}_{-1.6}$

* All values from [1992Ha10], unless otherwise noted.

** Weighted average of 0.081(13)% [1992Ha10] and 0.065(14)% [1986Ru05].

*** Interpolated between 1.549(19) fm  160  Hf and 1.576(15) fm  164 W,

# Table 7

direct  $\alpha$  emission from ¹⁶⁶Re, T_{1/2}= 2.4(2) s*, BR_{$\alpha$} =obs.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{162}\text{Ta})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.663(4)	5.527(4)**	obs	0.0		1.569(16)	$5^{+5}_{-3}$

* Weighted average of 2.3(2) [1992Me10], 2.8(3) s [1984Sc06] and 2.2(4) s [1978Sc26].

** [1982De11].

*** Interpolated between 1.576(15) fm  $^{164}\mathrm{W}$  and 1.5627(48) fm  $^{168}\mathrm{Os}.$ 

$z_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$		$E_{daughter}(^{166}\mathrm{Re})$	coincident $\gamma$ -rays	R ₀ (fr	n)	HF	
5.955(5)	5.815(5)**	5.2(17)%	*	0.0		1.560	5(62)	$4.5^{+3.1}_{-1.7}$	
* [2002F ** [2004 *** Inter	Ro17]. GoZZ]. polated between 1.	5627(48) fm ¹⁶⁸ O	9s and1.558.	3(40) fm ¹⁷² Pt.					
Table 9 irect $\alpha$ emis	sion from ^{170m} Ir*,	Ex. = unk., T _{1/2} =	811(18) ms	$BR_{\alpha} = 39(6)\%^{**}.$					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$E_{daughter}(^{166}\mathrm{Re})$	coincident $\gamma$ -rays	8		R ₀ (fm)	Н
5.094(10) 5.152(10) 5.199(10) 5.268(10)	5.951(10) 6.007(10) 6.053(10) 6.121(10)	$\approx 30^{***}$ $\approx 80^{***}$ $100^{***}$ $\sim 25^{***}$	$\approx 5^{***}$ $\approx 14^{***}$ $\approx 17^{***}$ $\approx 4^{***}$	0.175+x 0.122+x 0.075+x	0.175, 0.122, 0.1 0.122, 0.069, 0.0 0.075	10, 0.075, 0.06 53	9, 0.053		
* All val ** [2004 *** Rela able 10 irect α emis	ues from [2007Ha4 GoZZ]. tive intensities not sion from ¹⁷⁴ Au, T	[45], except where a given in [2007Hash $r_{1/2} = 120(20) \text{ ms}^*$	noted. 45], estimat , $BR_{\alpha} = 90($	ed by evaluator from Fi 6)%**.	g 5b.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$		$E_{daughter}(^{170}\mathrm{Ir})$	coincident γ-rays	R ₀ (fm	.)	HF	
5.701(5)	6.547(5)***	90(6)%*	k*	0.0		1.5525	(50)@	3.3(7)	
5.701(5) * [1983S ** [2002 ** [2004 @ Interpo Fable 11	6.547(5)*** c24]. Ro17]. GoZZ]. olated between 1.52	90(6)%3 583(40) fm ¹⁷² Pt a	** and 1.5466()	0.0 30) fm ¹⁷⁶ Hg.		1.5525	(50) [@]	3.3(7)	
5.701(5) * [19835 ** [2002 ** [2004 @ Interpo Table 11 lirect α emis	6.547(5)*** c24]. GoZZ]. Dated between 1.5: sion from ^{174m} Au,	90(6)% ³ 583(40) fm ¹⁷² Pt a $T_{1/2}$ = 162(3) ms,	** and 1.5466( $BR_{\alpha} = \text{obs.}$	0.0 30) fm ¹⁷⁶ Hg.		1.5525	(50) [@]	3.3(7)	
5.701(5) * [19835 ** [2002 ** [2004 @ Interp Table 11 lirect $\alpha$ emis $E_{\alpha}(c.m.)$	$6.547(5)^{***}$ cc24]. GoZZ]. Dated between 1.5: sion from ^{174m} Au, $E_{\alpha}(\text{lab})$	90(6)% ³ 583(40) fm ¹⁷² Pt a $T_{1/2}$ = 162(3) ms, $I_{\alpha}$ (rel)	** and 1.5466( $BR_{\alpha} = obs.$ $I_{\alpha}($	0.0 30) fm ¹⁷⁶ Hg. abs) <i>E_{daughte}</i>	 r( ¹⁷⁰ Ir) coir	1.5525 ncident γ-rays	(50) [@] R ₀ (fi	3.3(7) m)	HF
5.701(5) * [1983S ** [2002 ** [2004 @ Interper- Fable 11 lirect $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.584(5) 6.623(5) 5.773(15)	$\frac{6.547(5)^{***}}{6.24].}$ Ro17]. GoZZ]. blated between 1.52 sion from ^{174m} Au, <u>E_{\alpha}(lab)</u> 6.433(5) 6.471(5) 6.618(15)	90(6)% ³ 583(40) fm ¹⁷² Pt a $T_{1/2}$ = 162(3) ms, $I_{\alpha}$ (rel)	** and 1.5466( $BR_{\alpha} = obs.$ $I_{\alpha}($	0.0 30) fm ¹⁷⁶ Hg. <u>abs) <i>E</i>daughte</u> 0.191+x 0.153+x x	$r_{\rm r}^{(170}{\rm Ir})$ coir coir c 0.19 c 0.15	<u>1.5525</u> <u>acident γ-rays</u> 21 33	(50) [@] R ₀ (f	3.3(7) m)	HF
6.701(5) * [1983S ** [2002 ** [2004 @ Interp Fable 11 lirect $\alpha$ emis $E_{\alpha}(c.m.)$ 6.584(5) 6.623(5) .773(15) * All val	$\frac{6.547(5)^{***}}{6.24].}$ Ro17]. GoZZ]. blated between 1.53 sion from ^{174m} Au, <u>E_a(lab)</u> <u>6.433(5)</u> <u>6.471(5)</u> <u>6.618(15)</u> ues from [2004GoZ	$\frac{90(6)\%^3}{583(40) \text{ fm }^{172}\text{Pt }z}$ $\frac{T_{1/2} = 162(3) \text{ ms,}}{I_{\alpha}(\text{rel})}$ $ZZ].$	** and 1.5466( $BR_{\alpha} = obs.$ $I_{\alpha}($	0.0 30) fm ¹⁷⁶ Hg. abs) <u>E_{daughte}</u> 0.191+x 0.153+x x	$r_{r}(^{170}\text{Ir})$ coir coir c 0.15	1.5525 acident γ-rays 21 33	(50) [@] R ₀ (f	3.3(7) m)	HF
6.701(5) * [19835 ** [2002 ** [2004 @ Interp Fable 11 lirect $\alpha$ emis $E_{\alpha}(c.m.)$ 6.584(5) 6.623(5) 5.773(15) * All val Fable 12 lirect $\alpha$ emis	$\frac{6.547(5)^{***}}{6.24].}$ Ro17]. GoZZ]. blated between 1.5: sion from ^{174m} Au, <u>E_{\alpha}(lab) 6.433(5) 6.471(5) 6.618(15) ues from [2004GoZ sion from ¹⁷⁸Tl*, 7</u>	$90(6)\%^{3}$ 583(40) fm ¹⁷² Pt a $T_{1/2} = 162(3) \text{ ms},$ $I_{\alpha}(\text{rel})$ ZZ]. $T_{1/2} = 252(20) \text{ ms},$	** and 1.5466(1) $BR_{\alpha} = \text{obs.}$ $I_{\alpha}(1)$ $BR_{\alpha} = 62(2)$	0.0 30) fm ¹⁷⁶ Hg. abs) E _{daughte} 0.191+x 0.153+x x 2)%.	r ⁽¹⁷⁰ Ir) coir . 0.15 . 0.15	1.5525 acident γ-rays	(50) [@] R ₀ (fi	3.3(7) m)	HF
5.701(5) * [19835 ** [2002 ** [2004 @ Interp <b>Fable 11</b> lirect $\alpha$ emis E_{\alpha}(c.m.) 6.584(5) 6.623(5) * All val Fable 12 lirect $\alpha$ emis E_{\alpha}(c.m.)	$\frac{6.547(5)^{***}}{6.24].}$ Ro17]. GoZZ]. blated between 1.5: sion from ^{174m} Au, <u>E_{\alpha}(lab)</u> 6.433(5) 6.471(5) 6.618(15) ues from [2004GoZ sion from ¹⁷⁸ Tl*, 7 <u>E_{\alpha}(lab)</u>	$90(6)\%^{3}$ 583(40) fm ¹⁷² Pt a T _{1/2} = 162(3) ms, <i>I</i> _{\alpha} (rel) <i>ZZ</i> ]. <i>T</i> _{1/2} = 252(20) ms, <i>I</i> _{\alpha} (rel)	** and 1.5466() $\frac{BR_{\alpha} = \text{obs.}}{I_{\alpha}}$ $\frac{BR_{\alpha} = 62(2)}{I_{\alpha}(\text{abs})}$	$\begin{array}{c} 0.0 \\ \hline \\ 30) \text{ fm} \ ^{176} \text{Hg.} \\ \hline \\ abs) & E_{daughte} \\ 0.191 + x \\ 0.153 + x \\ x \\ \hline \\ 2)\%. \\ \hline \\ E_{daughter}(^{174} A) \\ \hline \end{array}$	r ⁽¹⁷⁰ Ir) coir . 0.19 . 0.15 . 0.15	1.5525 acident γ-rays 01 33	(50) [@] R ₀ (fi	3.3(7) m)	HF

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +17/2 nuclei.

Last updated 3/23/23

Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +17/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{|pi} values for ¹²⁹Ba, ¹³³Ce, ¹³⁷Nd, ¹⁴¹Sm, ¹⁴⁵Gd, ¹⁴⁹Dy, are taken from ENSDF

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\epsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
¹²⁹ Ba	$1/2^{+}$	2.23(11) h	2.438(11)	-2.489(11)		-10.656(11)	1.350(11)	[1972Ta02]
¹³³ Ce	$1/2^{+}$	97(4) m	3.080(30)	-1.272(16)		-8.941(16)	2.656(17)	[1967Ge08]
¹³⁷ Nd	$1/2^{+}$	38.5(15) m	3.618(14)	-0.364(12)		-7.518(15)	3.486(30)	[1973Bu18]
¹⁴¹ Sm	$1/2^{+}$	10.2(2) m	4.589(16)	1.034(9)		-5.683(9)	4.843(12)	[1977Ke03]
¹⁴⁵ Gd	$1/2^{+}$	23.0(4) m	5.065(20)	1.750(20)		-4.544(20)	5.171(24)	[1982Fi01]
¹⁴⁹ Dy	7/2-	4.2(2) m	3.795(9)	1.286(9)		-4.727(10)	7.873(10)	[1993Al03]
¹⁵³ Er	$(7/2^{-})$	37.1(2) s	4.545(10)	2.362(10)		-3.421(10)	8.597(10)	[1982Bo04]
¹⁵⁷ Yb	7/2-	37.9(9) s*	5.289(30)	3.503(27)		-1.958(21)	9.167(12)	[1978AfZZ, 1977Ha48, 1970To16]
¹⁶¹ Hf	$(7/2^{-})$	18.7(5) s	6.250(40)	4.558(24)		-0.323(36)	9.969(36)	[1995Hi12]
$^{165}W$	$(5/2^{-})$	5.1(5) s	6.987(29)	5.668(30)		1.352(38)	11.276(38)	[1975To05]
¹⁶⁹ Os	$(5/2^{-})$	3.3(3) s	7.686(28)	6.881(29)		3.050(38)	12.700(29)	[1995Hi02]
¹⁷³ Pt	$(5/2^{-})$	382(2) ms	8.330(60)	8.018(65)		4.736(69)	14.048(64)	[2004GoZZ]
¹⁷⁷ Hg	$(7/2^{-})$	127(2) ms	8.770(90)	8.869(86)		6.041(86)	15.068(85)	[2002Ro17]
¹⁸¹ Pb	(9/2-)	39.0(9) ms**	9.690(90)	9.851(86)		7.300(86)	16.010(86)	2009An20, 2005CaZV]

* Weighted average of 37(2) s [1978AfZZ], 38.6(10) s [1977Ha48], 34(3) s [1970To16].

** Weighted average of 36(2) ms [2009An20] and 39.6(9) ms [2005CaZV].

Table 2

Particle separation and emission from the even-Z,  $T_z = +17/2$  nuclei

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	Experimental
129 0	( 110/10)	11 210(11)	0.00((11))		
127 Ba	6.418(12)	11.318(11)	-0.286(11)		
¹³⁵ Ce	5.984(40)	10.317(16)	0.218(19)		
¹³ /Nd	5.533(16)	9.546(16)	0.409(20)		
¹⁴¹ Sm	5.011(26)	8.495(29)	1.225(15)		
¹⁴⁵ Gd	4.596(22)	7.987(20)	0.582(21)		
¹⁴⁹ Dy	4.446(15)	6.915(9)	2.808(22)		
¹⁵³ Er	4.151(15)	6.292(10)	4.802(1)	53(3)%	1996Pa01, 1982Bo04, 1981De22, 1978Ho10, 1977AfZZ, 1988KaZK,
					1988ScZO, 1981HoZM, 1980Da09, 1977Ha48, 1975ToZT, 1974Sc35,
					1974To07, 1974ToZN, 1973BoXL, 1970To16, 1970Ma18
¹⁵⁷ Yb	3.874(18)	5.789(12)	4.622(6)	obs	[1983Al09, 1979Ho10, 1978AfZZ, 1977Ha48, 1970To16, 1981HoZM,
					1970ToZS, 1970ToZU, 1970ToZY]
¹⁶¹ Hf	3.335(61)	5.060(29)	4.718(7)*	0.30(5)%	[1995Hi12, 1992Ha10, 1973To12, 1996HiZX, 1973ToZU
¹⁶⁵ W	2.867(38)	4.170(36)	5.031(5)	< 1.5%	[1979Ho10, 1975To05, 1981HoZM, 1976ToZP]
¹⁶⁹ Os	2.217(40)	3.208(32)	5.713(3)	13(2)%	[1995Hi02, 2004GoZZ, 1996Pa01, 1984Sc06, 1982En03, 1982De11,
					1981DeZO, 1981DeZL, 1978Sc26, 1972To19]
¹⁷³ Pt	1.846(71)	2.217(66)	6.380(5)***	86(6)%	[2004GoZZ, 2014ThZZ, 2009An20, 2002Ro19, 1996Pa01, 1993ToZY,
					1993ToZX, 1982En03, 1981De22, 1981DeZB, 1979Ha10, 1975Ca39,
					1973Ga08, 1966Si08]
¹⁷⁷ Hg	1.544(91)	1.645(87)	6.731(5) [@]	100%	[2009An20, 2004GoZZ, 1996Pa01. 2003Me20, 2002Ro17, 1991Se01,
-					1990SeZW, 1976HaYQ, 1976HoZD, 1975Ca39]
¹⁸¹ Pb	1.01(11)	0.756(90)	7.240(7)	$\approx 100\%$	2009An20, 2005CaZV, 2005CaZY, 2004CaZW, 1996To01, 1995ToZU,
					1989To01, 1986Ke03]

* Deduced from  $\alpha$  energy, 4.679(25) in [2021Wa16].

** Deduced from  $\alpha$  energy, 5.030(32) in [2021Wa16].

*** Deduced from  $\alpha$  energy, 6.361(58) in [2021Wa16].

[@] Deduced from  $\alpha$  energy, 6.736(56) in [2021Wa16].

### Table 3

direct $\alpha$ emission from ¹⁵³ Er, J ^{$\pi$} = (7/2 ⁻ ), T _{1/2} = 37.1(2) s*, BR _{$\alpha$} = 53(3)%**.										
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${\sf J}_f^{\pi}$	$E_{daughter}(^{149}\mathrm{Dy})$	coincident $\gamma$ -rays	R ₀ (fm)	HF			
4.799(2)	4.674(2)***	53(3)%**	7/2-	0.0		1.5584(94)	$1.21^{+0.23}_{-0.20}$			

* [1982Bo04].

** [1979Но10].

*** Weighted average of 4.674(4) [1996Pa01], 4.676(2) [1981De22], and 4.671(3) [1978AfZZ],

	sion from ¹⁵⁷ Yb, J ^{<i>n</i>}	$T = 7/2^-, T_{1/2} = 37.$	$\Theta(9)$ s*, $BR_{\alpha} =$	obs.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	$E_{daughter}($ ¹⁵³ Er)	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.622(10)	4.504(10)**		(7/2 ⁻ )	0.0		1.563(27	7)
* Weight * Weigh MeV [1970To	ted average of 37(2) ted average of 4.50 p16].	) s [1978AfZZ], 38. 4(10) MeV [1983A	6(10) s [1977H 109], 4.505(10)	a48], 34(3) s [1970To16]. MeV [1979Ho10], 4.504(	10) MeV [1978AfZZ], 4.5	07(10) MeV [19	77Ha48], and 4.500(10
Table 5 direct $\alpha$ emis	sion from ¹⁶¹ Hf, J ^π	$=(7/2^{-}), T_{1/2}=18$	$5.7(5)$ s*, $BR_{\alpha}$ =	= 0.30(5)%*.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}($ ¹⁵⁷ Yb)	coincident γ-rays	R ₀ (fm)	HF
4.718(7)	4.600(7)**	0.30(5)%*	7/2-	0.0		1.567(12)	$0.49_{-0.14}^{+0.17***}$
* [1995F ** Weigl *** This <b>Table 6</b> direct α emis	Ii 12]. Inted average of 4.60 low value for HF n sion from 165 W, J ^{$\pi$}	14(10)  MeV [1995H] may indicate that the = (5/2 ⁻ ), $T_{1/2} = 5.1$	i12], 4.599(7) BR for $\alpha$ -deca (5) s*, $BR_{\alpha} =$	MeV [1992Ha10], and 4.60 y is slightly higher than rep <1.5%**.	0(10) MeV [1973To12]. ported in [1995Hi12].		
* [1995H ** Weigl *** This <b>Table 6</b> direct α emis <i>E</i> _α (c.m.)	Ii12]. hted average of 4.60 low value for HF n sion from ¹⁶⁵ W, J ^{$\pi$} $E_{\alpha}$ (lab)	04(10) MeV [1995H nay indicate that the = (5/2 ⁻ ), $T_{1/2} = 5.1$ $I_{\alpha}(abs)$	i12], 4.599(7) BR for $\alpha$ -deca (5) s*, $BR_{\alpha} =$ $J_{f}^{\pi}$	MeV [1992Ha10], and 4.60 y is slightly higher than report <1.5%**. $E_{daughter}(^{161}\text{Hf})$	0(10) MeV [1973To12]. ported in [1995Hi12]. coincident γ-rays	<b>R</b> ₀ (fm)	HF

* [1975To05]. ** [1979Ho10].

*** This unphysical HF value indicates that the  $\alpha$  branching ratio is much lower. A value of  $BR_{\alpha} = 0.12\%$  gives a value of 1.0.

# Table 7

direct  $\alpha$  emission from ¹⁶⁹Os*, J^{$\pi$} = (5/2⁻), T_{1/2} = 3.3(3) s*, BR_{$\alpha$} = 13(2)%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{165}W)$	coincident γ-rays	$R_0$ (fm)	HF
5.642(8)	5.508(8)	15%	2.0(3)%	(7/2-)	0.072	0.028?, 0.043, 0.072	1.5627(60)	8
5.670(10)	5.536(10)	10%	1.3(2)%	$(3/2^{-})$	0.043	0.043	1.5627(60)	15
5.713(8)	5.578(8)	100%	10(2)%	(5/2-)	0.0		1.5627(60)	2.4

* All values from [1995Hi02].

### Table 8

direct  $\alpha$  emission from ¹⁷³Pt*,  $J^{\pi} = (5/2^{-}), T_{1/2} = 382(2)$  ms,  $BR_{\alpha} = 86(6)\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{169}\mathrm{Os})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.211(5)	6.067(5)	≈1%	≈1%		0.171(7)	0 171	1,5565(36)	$50^{+5}$
6.244(5)	6.100(5)	≈1%	≈1%		0.136(7)	0.136	1.5565(36)	$60^{+7}_{-2}$
6.278(5)	6.133(5)	$\approx 2\%$	$\approx 2\%$		0.102(7)		1.5565(36)	$40^{+5}_{-2}$
6.380(5)	6.232(5)	100%	82(6)%	(5/2-)	0.0		1.5565(36)	2.22(24)

* All values from [2004GoZZ].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{173}\mathrm{Pt})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.731(5)	6.579(5)***	100%	(5/2-)	0.0		1.55433(52)	$1.48\substack{+0.17 \\ -0.16}$
** [2009. *** Weig Table 10 direct α emiss	An20] (hted average of 6.580) (sion from ¹⁸¹ Pb, $J^{\pi} = 1$	(5) MeV [20040 (9/2 ⁻ ), $T_{1/2} = 39$	GoZZ] and 6.57 9.0(9) ms*, <i>BR</i>	7(9) MeV [1996Pa01]. α = ≈100%.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{m \pi}$	$E_{daughter}(^{177}\mathrm{Hg})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.174(10)	7.015(10)**	100%	9/2-	0.077	0.077	1.5139(54)	$1.47^{+0.17}_{-0.16}$

direct  $\alpha$  emission from ¹⁷⁷Hg,  $J^{\pi} = (7/2^{-})$ ,  $T_{1/2} = 127(2)$  ms*,  $BR_{\alpha} = 100\%$ **.

** Weighted average of 36(2) ms [2009An20] and 39.6(9) ms [2005CaZV].

** Weighted average of 7.016(15) MeV [2009An10] and 7.015(10) MeV [2005CaZV].

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**Fig. 1**: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +17/2 nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{|pi} values for ¹²⁷Cs, ¹³¹La, ¹³⁵Pr, ¹³⁹Pm, ¹⁴³Eu, ¹⁴⁷Tb, are taken from ENSDF.

Last updated 3/23/23

Table 1
Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +17/2$ nucle

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\epsilon 2p}$	$Q_{\varepsilon \alpha}$	Experimental
127 <b>C</b> a		1/2+	6 25(10) h	2 081(6)	5 610(6)	11 706(6)	0.506(6)	[1054Ma54]
1311		1/2	0.23(10) 11	2.081(0)	-3.019(0)	-11.790(0)	0.300(0)	[1954][1954]
131 La		3/2	61(2) m	2.910(28)	-4.158(29)	-9.651(28)	2.127(28)	[1960Cr01]
¹⁵⁵ Pr		3/2+	25.4(5) m	3.680(16)	-3.006(23)	-7.960(12)	3.318(12)	[1970Ab07]
¹³⁹ Pm		$(5/2^+)$	4.15(5) m	4.516(26)	-1.661(17)	-6.160(14)	4.690(17)	[1977De06]
¹⁴³ Eu		5/2+	2.57(3) m	5.276(11)	-0.389(26)	-4.628(11)	5.351(30)	[1993Al03]
¹⁴⁷ Tb		$(1/2^+)$	1.64(3) h	4.614(8)	-0.914(10)	-4.669(8)	6.350(9)	[1997Wa04]
¹⁵¹ Ho		$(11/2^{-})$	35.1(2) s	5.130(9)	0.194(11)	-3.074(9)	9.309(9)	[1982Bo04]
^{151m} Ho	0.0411(2)	$(1/2^+)$	47.6(13) s*	5.171(9)	0.265(11)	-3.071(9)	9.350(9)	[1991To08, 1982Bo04, 1982Ba75]
¹⁵⁵ Tm		$(11/2^{-})$	21.6(2) s	5.583(12)	0.724(13)	-2.061(11)	9.702(10)	[1991To08]
^{155m} Tm	0.041(6)	$(1/2^+)$	44(4) s	5.624(13)	0.765(14)	-2.020(12)	9.743(11)	[1991To08, 1990Po13]
¹⁵⁹ Lu			12.1(10) s**	6.120(40)	1.706(45)	-0.873(46)	10.076(38)	[1992Ha10, 1980Al04]
¹⁶³ Ta			10.9(12) s***	6.730(50)	3.008(84)	0.722(41)	10.874(42)	[1992Ha10, 1985Li14]
¹⁶⁷ Re			3.4(4) s	7.260(40)#	3.975(49)#	2.223(49)#	12.010(48)#	[1992Me10]
^{167m} Re	x@		6.1(2) s	7.260(40)#+x	3.975(49)#+x	2.223(49)#+x	12.010(48)#+x	[1992Me10, 1984Sc06]
¹⁷¹ Ir		$(1/2^+)$	$3.2^{+1.7}_{-0.7}$ s	7.890(40)	5.203(40)	3.928(41)	13.256(43)	[2013An01]
171m Ir	х	$(11/2^{-})$	1.24(4) s ^{@@}	7.890(40)+x	5.203(40)+x	3.928(41)+x	13.256(43)+x	[2023Zh03, 2014Pe02, 2013An01]
¹⁷⁵ Au		$(1/2^+)$	200(3) ms	8.300(40)	6.093(40)	5.457(41)	14.469(43)	[2017Ba46]
^{175m} Au	Х	$(11/2^{-})$	137(1) ms ^{@@@}	8.300(40)+x	6.093(40)+x	5.457(41)+x	14.469(43)+x	[2017Ba46, 2011Wa37]
¹⁷⁹ Tl		$(1/2^+)$	426(10) ms	8.660(50)	6.744(40)	6.523(41)	15.014(43)	[2017Ba46]
^{179m} Tl ^a		$(11/2^{-})$	1.42(3) ms ^a	8.660(50)	6.744(40)	6.523(41)	15.014(43)	[2017Ba46, 2010An01]

* Weighted average of 47.9(13) s [1982Bo14], 47(2) s [1982Ba75].

*** Weighted average of 12.3(10)s [1980Al14] and 9.2(35) s [1992Ha10].

^a Weighted average of 1.0.5(10)s [1202214, 1.4.1]
^a Weighted average of 1.14(5) s [2014Pe02], 1.4(1) s [2013An01], and 1.28(4) [2023Zh03].
^a Weighted average of 1.36(1) ms [2017Ba46] and 139(2) ms [2011Wa37].
^a Weighted average of 1.40(3) ms [2017Ba46], and 1.46(4) ms [2010An01].

Particle separation and emission from the odd-Z,  $T_z = +17/2$  nuclei. Unless otherwise stated, all Q-values and separation energies are taken from [2021Wa16] or deduced from values therein.

Nuclide	S.,	BR.	See	0 _a	BRa	Experimental
Tuende	5 <i>p</i>	BRp	02p	₹u	BRa	Ехреттенц
¹²⁷ Cs	4.383(6)		11.982(6)	-0.722(7)		
¹³¹ La	3.801(28)		10.848(28)	0.046(28)		
¹³⁵ Pr	3.392(24)		10.019(30)	0.408(30)		
¹³⁹ Pm	2.773(18)		8.877(16)	1.010(18)		
¹⁴³ Eu	2.548(11)		8.296(18)	0.835(17)		
¹⁴⁷ Tb	1.946(9)		7.329(9)	1.074(14)		
¹⁵¹ Ho	1.602(9)		6.712(9)	4.695(2)	21(2)%	[1987Li09, 1990Po13, 1991To08, 1982Ba75, 1982Bo04, 1982De11,
	. ,					1979Ho10, 1974Sc19, 1963Ma17, 1996Pa01, 1995Wa31, 1995WaZO,
						1995WaZS, 1991VaZY, 1990KaZM, 1990VaZO, 1989KaYU, 1989KaZK,
						1989KaZI, 1989PoZR, 1973BoXL, 1973BoXW, 1970Ma23, 1961Ma40,
						1960Ma47]
^{151m} Ho*	1.561(9)		6.671(9)	4.736(2)	$80^{+15}_{-20}\%$	[1987Li09, 1991To08, 1982Ba75, 1982Bo04, 1981De22, 1979Ho10,
						1963Ma17 1995Wa31, 1995WaZO, 1995WaZS, 1991VaZY, 1990Po13,
						1990KaZM, 1990VaZO, 1989KaYU, 1989KaZK, 1989KaZI, 1989PoZR,
						1974Sc19, 1974ToZN, 1974ToZQ, 1973BoXL, 1973BoXV, 1970Ma23,
						1970To16, 1961Ma40, 1960Ma47]
¹⁵⁵ Tm	1.310(11)		6.192(11)	4.572(5)	0.84(20)%	[ <b>1991To08, 1992Ha10, 1990Po13, 1971To10</b> , 1991VaZT, 1990KaZM,
						1990PoZU, 1989KaYU, 1988KaZK, 1987KaZI, 1988KaZK, 1978AfZZ,
1.5.5						1977Ag01]
^{155m} Tm	1.269(12)		6.151(12)	4.613(8)	obs	[ <b>1991To08, 1992Ha10, 1990Po13, 1971To10</b> , 1991VaZY, 1990KaZM,
						1990PoZU, 1989KaYU, 1988KaZK, 1989KaZI, 1988KaZK, 1978AfZZ,
150						1977Ag01]
¹⁵⁹ Lu	0.988(38)		5.577(47)	4.492(39)	< 0.15(3)%	[ <b>1992Ha10, 1980Al04</b> , 1980AlZN]
¹⁰³ Ta	0.655(39)		4.550(47)	4.749(5)	<0.28(4)%	[ <b>1992Ha10, 1986Ru05</b> , 1988MeZY, 1987HaZO, 1983Sc18]
¹⁶⁷ Re	0.235(41)#		3.564(42)#	5.276(13)#	obs	[ <b>1992Me10</b> , 1992MeZW]
^{10/m} Re***	0.235(41)#-x		3.564(42)#-x	5.276(13)#+x	$\approx 1\%$	[ <b>1992Me10</b> , 1992MeZW, 1984Sc06]
^{1/1} Ir	-0.225(40)		2.581(40)	5.997(12)	15(2)%	[2013An01]
$^{1/1m}$ Ir [@]	-0.225(40)-x		2.581(40)-x	5.997(12)+x	62(6)%	[ <b>2023Zh03</b> , <b>2014Pe02</b> , <b>2013An01</b> , 2010An01, 2002Ro17, 1996Pa01,
175 .						1992Sc16, 1982De11, 1981DeZL, 1978Ca11, 1978Sc26]
175 Mu	-0.625(40)		1.713(40)	6.583(3)	90(7)%	[ <b>2017Ba46</b> , <b>2013An10</b> , 2010An01, 2002Ro17, 1996Pa01, 1983Sc24]
^{175m} Au [@]	-0.625(40)-x		1.713(40)-x	6.583(3)+x	90(3)%	[2017Ba46, 2011Wa37, 2010An01, 2013An10, 2004GoZZ, 2002Ro17,
170-						1996Pa01, 1983Sc24]
179Tl	-0.757(40)		1.302(40)	6.709(3)	60(20)%	[ <b>2017Ba46</b> , <b>2013An10</b> , 2002Ro17, 1998To14, 1996Pa01, 1983Sc24]
179mTI@	-0.757(40)		1.302(40)	6.709(3)	100%	[ <b>2017Ba46, 2010An01</b> , 2002Ro17, 1998To14, 1996Pa01, 1983Sc24]

* Excitation energy = 41.1(2) keV [1991To08].

** Excitation energy = 41(6) keV [1990Po13].

*** Excitation is unknown, may be the ground state.

[@] Excitation is unknown.

# Table 3

Table 5			
direct $\alpha$ emission from	151 Ho, J $^{\pi} = (11/2^{-}),$	$T_{1/2} = 35.1(2) s^*,$	$BR_{\alpha} = 21(2)\%^{**}$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_{f}^{\pi@@@}$	$E_{daughter}(^{147}\mathrm{Tb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.335(6)	$4.220(6)^{@}$	$0.36(4)\%^{@}$	0.076(8)%	$(5/2^+)$ $(3/2^+)$	0.354 [@]	0.101, 0.253	1.5642(20)	$9.3^{+1.7}_{-1.3}$
4.645(2) 4.689	4.522(2)*** 4.565 ^{@@}	< 0.01% $100\%^{@}$ $< 0.7\%^{@}$	< 0.002% 21(2)% < 0.15%	$(3/2^+)$ $(1/2^+)$	0.254 0.0506(9) [@] 0.0	(11/2 ⁻ )	1.5642(20)	1.60(17)

* [1982Bo04].

* [1982Bo04]. ** Weighted average of 28(7)% [1991To08], 22(3)% [1990Po13], 22(3)% [1982Bo75], 18(5)% [1979Ho10], 18(5)% [1974Sc19], and 20(5)% [1963Ma17]. *** Weighted average of 4.523(3) MeV [1982Bo04] (adjusted to 4.529(3) MeV in [1999Ry01]), 4.524(5) MeV [1979Ho10] (adjusted to 4.524(5) MeV in [1999Ry01]), and 4.521(3) MeV [1981De22]. [@] [1987Li09] ^{@@} Transition not observed. ^{@@@@} [2022Ni03].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	J ^{#@@@}	$E_{daughter}(^{147}\mathrm{Tb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.376(6)	4.260(6)@	0.26(4)% [@]	0.076(8)%	$(5/2^+)$	0.354 [@]	0.101, 0.253	1.5642(20)	$7.9^{+2.8}_{-1.8}$
4.478	4.359	< 0.05% @	< 0.01%	$(3/2^+)$	0.254			
4.082	4.558	< 1.1% -	< 0.2%	(11/2)	0.0506(9)		1.5(40(00)	1 7+5
4.736(2)	4.611(2)***	100% @	$80^{+13}_{-20}\%$	$(1/2^+)$	0.0		1.5642(20)	$1.7^{+3}_{-3}$

direct  $\alpha$  emission from ^{151m}Ho, Ex = 41.1(2) keV**, J^{$\pi$} = (1/2⁺), T_{1/2} = 47.6(13) s*, BR_{$\alpha$} = 80⁺¹⁵₋₂₀%**.

** Weighted average of 47.9(13) s [1982Bo14], 47(2) s [1982Ba75].

** [1991To08].

*** Weighted average of 4.523(3) MeV [1982Bo04] (adjusted to 4.529(3) MeV in [1999Ry01]), 4.524(5) MeV [1979Ho10] (adjusted to 4.524(5) MeV in [1999Ry01]), and 4.521(3) MeV [1981De22].

@ [1987Li09]

@ @ Transition not observed.

@@@ [2022Ni03].

### Table 5

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{151}\mathrm{Ho})$	coincident γ-rays	$R_0$ (fm)	HF
4.570(8)	4.452(8)***	0.84(20)%**	(11/2 ⁻ )	0.0	1.573(14)	$1.2^{+0.5}_{-0.4}$	

* [1991To08].

** Weighted average of 1.2(6)% [1990Po13] and 2.1(3)% (adjusted to 0.80(21)% by evaluator in 2009Si01).

*** From [1992Ha10]. [1991To08] report that the ground state and isomer have nearly identical  $\alpha$  energies. Their measured T_{1/2} value of 26(3) s indicates that this value is mostly from the  $11/2^{-}$  ground state decay.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{151}\mathrm{Ho})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.568(10)	4.450(10)***			0.0411(2)		1.573(14)	

blet from [19917608] who report that the ground state and isomer have nearly identical  $\alpha$  energy

## Table 7

direct $\alpha$ emission from ¹⁵⁹ Lu, J ^{$\pi$} =	$T_{1/2} = 12.1(10) \text{ s}^*, BR_{\alpha} = <0.15(3)\%^{**}.$
----------------------------------------------------------------------------------	------------------------------------------------------------------

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{155}\mathrm{Tm})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.533(10)	4.419(10)***	<0.15(3)%**		?		1.539(29)	

* Weighted average of 12.3(10)s [1980A114] and 9.2(35) s [1992Ha10].

** [1992Ha10], based on comparison of the  $\alpha$  intensity to the reported [1980A114] intensities of the 151 keV  $\gamma$ -ray.

*** Weighted average of 4.420(10) MeV [1980A114] and 4.417(10) MeV [1992Ha10].

### Table 8

4.750(10)

direct $\alpha$ emission	direct $\alpha$ emission from ¹⁶³ Ta, J ^{$\pi$} = , T _{1/2} = 10.9(12) s*, <i>BR</i> _{$\alpha$} = <0.28(4)%**.										
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{159}Lu)$	coincident $\gamma$ -rays	$R_0$ (fm)	HF				

1.575(13)

 $0.17^{+0.07\,@}_{-0.05}$ 

0.0

* Weighted average of 10.5(18)s [1985Li14] and 11.2(16) s [1992Ha10].

4.633(10)***

** [1992Ha10], based on comparison of the  $\alpha$  intensity to the reported [1985Li14] intensities of the 449 and 451 keV  $\gamma$  doublet.

*** Weighted average of 4.630(10) MeV [1986Ru05] and 4.635(7) MeV [1992Ha10].

<0.28(4)%**

[@] This unphysical result likely indicaties that the absolute  $\gamma$ -ray intensities are much weaker than the reported relative ones.

	sion nom næ , s							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{163}\mathrm{Ta})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
5.138(10)	5.015(10)			?		1.540(14)	)	
* All val	ues from [1992Me]	10].						
<b>Table 10</b> direct $\alpha$ emission	sion from ^{167m} Re*,	Ex = unk., $J^{\pi}$ = , 7	$\Gamma_{1/2} = 6.1(2)  s^{**}$	$, BR_{\alpha} = \approx 1\%.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{163}\mathrm{Ta})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
5.392(10)	5.263(12)			0.0?		1.540(14)	$2.9^{+3.2}_{-1.3}$	
* All val ** [1984	ues from [1992Me] Sc06].	10], except where r	noted.					
<b>Table 11</b> direct $\alpha$ emis	sion from ¹⁷¹ Ir*, J ⁷	$T = (1/2^+), T_{1/2} = 2$	$3.2^{+1.7}_{-0.7}$ s, $BR_{\alpha} = 1$	15(2)%.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{167}\mathrm{Re})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF	
5.871(7)	5.734(7)	15(2)%		х		1.5595(50)	)	
* All val	ues from [2013An0	01].						
* All value <b>Table 12</b> direct $\alpha$ emission $E_{\alpha}(c.m.)$	ues from [2013An0 sion from 171m Ir, E $E_{\alpha}$ (lab)	1]. $x = \text{unk.}, J^{\pi} = (11/I)$ $I_{\alpha}(\text{rel})$	$2^{-}$ ), $T_{1/2} = 1.24(4)$ $I_{\alpha}(abs)$	4) s**, $BR_{\alpha} = 62(6)\%^{**}$ . J $_{f}^{\pi} \qquad E_{dau}$	_{ghter} ( ¹⁶⁷ Re) coinc	ident γ-rays	R ₀ (fm)	HF
* All value <b>Table 12</b> direct $\alpha$ emission $E_{\alpha}(c.m.)$ 6.061(4) 6.155(5)	ues from [2013An0 sion from 171m Ir, E $E_{\alpha}$ (lab) 5.919(4) 6.011(5)	1]. $x = \text{unk., } J^{\pi} = (11/I)$ $I_{\alpha}(\text{rel})$ $I00\%$ $I5(2)\%$	2 ⁻ ), $T_{1/2} = 1.24(4$ $I_{\alpha}(abs)$ 53(5)%*** 9(1)%	4) s**, $BR_{\alpha} = 62(6)\%^{**}$ . $J_{f}^{\pi} \qquad E_{dau}$ $(11/2^{-}) \qquad 0.0$	$_{ghter}(^{167}\text{Re})$ coinc 21(2) <u>0.092</u>	ident γ-rays 21(2)	R ₀ (fm) 1.5595(50) 1.5595(50)	HF
* All value <b>Table 12</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.061(4) 6.155(5) * All value ** Weigh *** [201	ues from [2013An0 sion from ^{171m} Ir, E $E_{\alpha}$ (lab) 5.919(4) 6.011(5) ues from [2023Zh0 nted average of 1.14 4Pe02].	1]. $x = unk., J^{\pi} = (11/I)$ $I_{\alpha}(rel)$ $I00\%$ $I5(2)\%$ 3]. except where n $I_{4}(5) \text{ s } [2014Pe02],$	$\frac{2^{-}}{I_{\alpha}(abs)}, T_{1/2} = 1.24(4)$ $\frac{I_{\alpha}(abs)}{53(5)\%^{***}}$ $9(1)\%$ oted. $1.4(1) \text{ s } [2013 \text{ Arr}]$	4) s**, $BR_{\alpha} = 62(6)\%^{**}$ . $J_{f}^{\pi} \qquad E_{dat}$ 0.09 (11/2 ⁻ ) 0.0 h01],and 1.28(4) [2023Zh	ghter( ¹⁶⁷ Re) coinc 21(2) 0.092  03].	ident γ-rays 21(2)	R ₀ (fm) 1.5595(50) 1.5595(50)	HF
* All value <b>Table 12</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.061(4) 6.155(5) * All value ** Weighted *** Weighted *** [2013) <b>Table 13</b> direct $\alpha$ emiss	ues from [2013An0 sion from ^{171m} Ir, E $E_{\alpha}(lab)$ 5.919(4) 6.011(5) ues from [2023Zh0 nted average of 1.14 4Pe02]. sion from ¹⁷⁵ Au*, 2	p1]. x = unk., $J^{\pi} = (11/I_{\alpha})^{\pi}$ $I_{\alpha}(rel)$ $I_{00\%}$ $I_{5(2)\%}$ 3]. except where n $I_{4(5)}$ s [2014Pe02], $J^{\pi} = (1/2^+), T_{1/2} =$	2 ⁻ ), $T_{1/2} = 1.24(4$ $I_{\alpha}(abs)$ 53(5)%*** 9(1)% oted. 1.4(1) s [2013Ar = 200(3) ms, $BR_{\alpha}$	4) s**, $BR_{\alpha} = 62(6)\%^{**}$ . $J_{f}^{\pi} \qquad E_{dau}$ 0.09 (11/2 ⁻ ) 0.0 h01],and 1.28(4) [2023Zh =90(7)%**.	ghter ⁽¹⁶⁷ Re) coinc 21(2) <u>0.092</u>  03].	ident γ-rays 21(2)	R ₀ (fm) 1.5595(50) 1.5595(50)	HF
* All value <b>Table 12</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.061(4) 6.155(5) * All value ** Weighted *** [2013] <b>Table 13</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$	ues from [2013An0 sion from ^{171m} Ir, E $E_{\alpha}(lab)$ 5.919(4) 6.011(5) ues from [2023Zh0 nted average of 1.14 4Pe02]. sion from ¹⁷⁵ Au*, $E_{\alpha}(lab)$	b1]. $x = unk., J^{\pi} = (11/100\%)$ $I_{\alpha}(rel)$	2 ⁻ ), $T_{1/2} = 1.24(4)$ $I_{\alpha}(abs)$ 53(5)%*** 9(1)% oted. 1.4(1) s [2013Ar = 200(3) ms, $BR_{\alpha}$ $J_{f}^{\pi}$	4) s**, $BR_{\alpha} = 62(6)\%^{**}$ . $J_{f}^{\pi} E_{dau}$ 0.09 (11/2 ⁻ ) 0.0 h01], and 1.28(4) [2023Zh =90(7)%**. $E_{daughter}(^{171} Ir)$	ghter ⁽¹⁶⁷ Re) coinc 21(2) <u>0.092</u> 	rident γ-rays 21(2) R ₀ (fm)	R ₀ (fm) 1.5595(50) 1.5595(50) HF	HF
* All value <b>Table 12</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.061(4) 6.155(5) * All value ** Weight ** Weight *** [201] <b>Table 13</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.583(4)	ues from [2013An0 sion from ^{171m} Ir, E $E_{\alpha}(lab)$ 5.919(4) 6.011(5) ues from [2023Zh0 nted average of 1.14 4Pe02]. sion from ¹⁷⁵ Au*, $E_{\alpha}(lab)$ 6.433(4)	p1]. x = unk., $J^{\pi} = (11/I_{\alpha})^{\pi}$ $I_{\alpha}(rel)$ 100% 15(2)% 3]. except where n 4(5) s [2014Pe02], $J^{\pi} = (1/2^{+}), T_{1/2} = I_{\alpha}(abs)$ 90(7)%**	2 ⁻ ), $T_{1/2} = 1.24(4)$ $I_{\alpha}(abs)$ 53(5)%*** 9(1)% oted. 1.4(1) s [2013Ar = 200(3) ms, $BR_{\alpha}$ $J_{f}^{\pi}$ (11/2 ⁻ )	4) s**, $BR_{\alpha} = 62(6)\%^{**}$ . $J_{f}^{\pi} E_{dau}$ 0.09 (11/2 ⁻ ) 0.0 h01], and 1.28(4) [2023Zh =90(7)%**. $E_{daughter}(^{171}Ir)$ x	ghter ⁽¹⁶⁷ Re) coinc 21(2) <u>0.092</u> 	ident γ-rays 21(2) 	R ₀ (fm) 1.5595(50) 1.5595(50) HF 4)	HF
* All value <b>Table 12</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.061(4) 6.155(5) * All value ** Weigh *** [2013] <b>Table 13</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.583(4) * All value ** [2013]	ues from [2013An0 sion from ^{171m} Ir, E <u>$E_{\alpha}$(lab)</u> 5.919(4) 6.011(5) ues from [2023Zh0 nted average of 1.14 4Pe02]. sion from ¹⁷⁵ Au*, . <u>$E_{\alpha}$(lab)</u> 6.433(4) ues from [2017Ba4 An10].	p1]. x = unk., $J^{\pi} = (11/I_{\alpha})^{\pi}$ $I_{\alpha}(rel)$ 100% 15(2)% 3]. except where n 4(5) s [2014Pe02], $J^{\pi} = (1/2^{+}), T_{1/2} = I_{\alpha}(abs)$ 90(7)%** 6], except where n	2 ⁻ ), $T_{1/2} = 1.24(4)$ $I_{\alpha}(abs)$ 53(5)%*** 9(1)% oted. 1.4(1) s [2013Ar = 200(3) ms, $BR_{\alpha}$ $J_{f}^{\pi}$ (11/2 ⁻ ) oted.	4) s**, $BR_{\alpha} = 62(6)\%^{**}$ . $J_{f}^{\pi} E_{dau}$ (11/2 ⁻ ) h01], and 1.28(4) [2023Zh =90(7)%**. $E_{daughter}(^{171} Ir)$ x	ghter( ¹⁶⁷ Re) coinc 21(2) 0.092 	rident γ-rays 21(2) R ₀ (fm) 1.5504(5-	R ₀ (fm) 1.5595(50) 1.5595(50) HF 4)	HF
* All value <b>Table 12</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.061(4) 6.155(5) * All value ** Weigh *** [2013 <b>Table 13</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.583(4) * All value ** [2013] <b>Table 14</b> direct $\alpha$ emiss	ues from [2013An0 sion from ^{171m} Ir, E $E_{\alpha}(lab)$ 5.919(4) 6.011(5) ues from [2023Zh0 nted average of 1.14 4Pe02]. sion from ¹⁷⁵ Au*, . $E_{\alpha}(lab)$ 6.433(4) ues from [2017Ba4 An10]. sion from ^{175m} Au, .	b1]. $x = unk., J^{\pi} = (11/2^{-1})^{\pi} = (11/2^{-1})^{\pi} = (1/2^{-1})^{\pi} = (1/2^{+1})^{\pi} = (1/2^{+1})^{$	2 ⁻ ), $T_{1/2} = 1.24(4)$ $I_{\alpha}(abs)$ 53(5)%*** 9(1)% oted. 1.4(1) s [2013Ar = 200(3) ms, $BR_{\alpha}$ $J_{f}^{\pi}$ (11/2 ⁻ ) oted. $I/2^{-}$ ), $T_{1/2} = 1.19$	4) s**, $BR_{\alpha} = 62(6)\%^{**}$ . <u>J_f</u> <u>Edau</u> 0.09 (11/2 ⁻ ) 0.0 h01], and 1.28(4) [2023Zh =90(7)%**. <u>Edaughter(171 Ir)</u> <u>x</u> 9(5) s*, $BR_{\alpha} = 90(3)\%^{**}$ .	ghter( ¹⁶⁷ Re) coinc 21(2) <u>0.092</u> 	ident γ-rays 21(2) R ₀ (fm) 1.5504(5)	R ₀ (fm) 1.5595(50) 1.5595(50) HF 4)	HF
* All value <b>Table 12</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 6.061(4) 6.155(5) * All value ** Weighter ** [2011 <b>Table 13</b> direct $\alpha$ emiss * All value ** [2013] <b>Table 14</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$	ues from [2013An0 sion from ^{171m} Ir, E $E_{\alpha}(lab)$ 5.919(4) 6.011(5) ues from [2023Zh0 nted average of 1.14 4Pe02]. sion from ¹⁷⁵ Au*, . $E_{\alpha}(lab)$ 6.433(4) ues from [2017Ba4 An10]. sion from ^{175m} Au, . $E_{\alpha}(lab)$	b1]. $x = unk., J^{\pi} = (11/12)^{\pi}$ $I_{\alpha}(rel)$ $I_{00\%}$ $I_{5}(2)\%$ 3]. except where n (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/2) (1/	2 ⁻ ), $T_{1/2} = 1.24(4)$ $I_{\alpha}(abs)$ 53(5)%*** 9(1)% oted. 1.4(1) s [2013Ar = 200(3) ms, $BR_{\alpha}$ $J_{f}^{\pi}$ (11/2 ⁻ ) oted. $I/2^{-}$ ), $T_{1/2} = 1.19$ $J_{f}^{\pi}$	4) s**, $BR_{\alpha} = 62(6)\%^{**}$ . <u>J_f</u> <u>Edau</u> 0.09 (11/2 ⁻ ) 0.0 h01],and 1.28(4) [2023Zh =90(7)%**. <u>Edaughter</u> ( ¹⁷¹ Ir) <u>x</u> $D(5)$ s*, $BR_{\alpha} = 90(3)\%^{**}$ . <u>Edaughter</u> ( ¹⁷¹ Ir)	ghter( ¹⁶⁷ Re) coinc 21(2) 0.092 	rident γ-rays 21(2) R ₀ (fm) 1.5504(5) s R ₀ (fm)	R ₀ (fm) 1.5595(50) 1.5595(50) HF 4) HF	

* Weighted average of 136(1) ms [2017Ba46] and 139(2) ms [2011Wa37].
*** [2010An01].
*** Weighted average of 6.433(4) MeV [2017Ba46], 6.430(6) MeV [2011Wa37], and 6.432(5) MeV [2010An01].

Table	15
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	<i>E_{daughter}</i> ( ¹⁷⁵ Au)	coincident γ-ray	rs R ₀ (fm)	HF	
6.709(4)	6.559(4)	60(2)%**	(1/2+)	0.0		1.5297(36)	2.16(19)	
* [2017E ** [2013 <b>Table 16</b> direct α emis	3a46]. 3An10]. sion from ^{179m} Tl, E	$\mathbf{x} = \mathbf{unk.}, \mathbf{J}^{\pi} = (11)$	/2 ⁻ ), T _{1/2} =1.42(	3) ms*, $BR_{\alpha} = 100\%$	ó.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	E _{daughter} ( ¹⁷⁵ Au)	coincident γ-rays	R ₀ (fm)	HF
7.258(10)	7.096(10) @	25(11)%	20(9)% [@]		x + 0.113		1.5297(36)	

 $(11/2^{-})$ 

х

1.5297(36)

direct  $\alpha$  emission from ¹⁷⁹Tl,  $J^{\pi} = (1/2^+)$ ,  $T_{1/2} = 426(10)$  ms*,  $BR_{\alpha} = 60(2)\%$ **.

* Weighted average of 1.40(3) ms [2017Ba46], and 1.46(4) ms [2010An01].

100(25)%

** [2010An01].

7.371(4)

*** Weighted average of 7.206(4) MeV [2017Ba46], and 7.207(5) MeV [2010An01].

80(20)%[@]

[@] [1998To14].

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Observed and predicted $\beta$ -delayed particle emission from the even-Z, $T_z = +9$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduce
from values therein. $J^{\pi}$ values for ¹³⁸ Nd. ¹⁴² Sm, and ¹⁴⁶ Gd are taken from ENSDE.

Nuclide	$J^{\pi}$	$T_{1/2}$	Q _ε	$Q_{\varepsilon p}$	$Q_{\epsilon \alpha}$	$BR_{\beta F}$	Experimental
¹³⁸ Nd	$0^+$	5.04(9) h	1.112(15)	-3.387(12)	0.777(23)		[1970Ho25]
¹⁴² Sm	$0^+$	72.49(5) m	2.160(24)	-2.079(3)	1.722(10)		[1966Ma15]
¹⁴⁶ Gd	$0^+$	48.27(10) d	1.032(7)	-2.723(4)	2.631(24)		[1970Ch09]
¹⁵⁰ Dy	$0^+$	2.17(2) m	1.796(8)	-1.471(5)	5.383(7)		[1973Bi06]
¹⁵⁴ Er	$0^+$	3.75(12) m	2.034(9)	-0.751(6)	6.076(9)		[1974PeZS]
¹⁵⁸ Yb	$0^+$	1.65(20) m	2.694(26)	0.115(28)	6.205(11)		[1977Ha48]
¹⁶² Hf	$0^+$	39.8(4) s	3.660(80)	1.377(17)	7.110(27)		[1995Hi12]
¹⁶⁶ W	$0^+$	18.8(4) s	4.210(30)	2.459(30)	8.519(76)		[1989Hi04]
¹⁷⁰ Os	$0^+$	7.3(2) s*	4.978(15)	3.703(18)	9.747(30)		[2004GoZZ, 1995Hi02, 1982En03]
¹⁷⁴ Pt	$0^+$	866(5) ms**	5.468(15)	4.832(18)	11.161(15)		[2014Pe02, 2004GoZZ, 1996Pa01, 1982En03]
¹⁷⁸ Hg	$0^+$	266(3) ms***	5.988(15)	5.766(18)	12.046(16)		[2002Ro17, 2000Ko01]
¹⁸² Pb	$0^+$	55(5) ms	6.503(17)	6.548(20)	13.054(16)		[1999To11]
¹⁸⁶ Po	$0^+$	$28^{+16}_{-6} \ \mu s$	7.247(25)	8.354(24)	15.004(22)		[2013An13]

* Weighted average of 7.2(2) s [2004GoZZ], 7.9(3) s [1995Hi02], and 7.1(2) s [1982En03],

** Weighted average of 930(30) ms [2014Pe02], 857(5) ms [2004GoZZ], 890(20 ms [1996Pa01], and 900(10) ms [1982En03],

*** Weighted average of 269(3) ms [2002Ro17] and 262(4) ms [2000Ko01].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +9$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
¹³⁸ Nd ¹⁴² Sm ¹⁴⁶ Cd	6.104(14) 5.748(14) 5.383(5)	10.087(12) 9.303(4) 8.698(4)	0.391(23) 0.610(12) 0.471(4)		
¹⁵⁰ Dy	5.110(5)	7.618(4)	4.351(2)	34(3)%*	[ <b>1974To07, 1973Bi06, 1973BoXL, 1968Go32</b> ] 1981HoZM, 1977Ha48, 1974ToZN, 1974ToZQ, 1974PeZS, 1970Ma23, 1968Go13, 1964Ma19, 1960To05]
¹⁵⁴ Er	4.882(7)	7.065(6)	4.280(3)	0.52(13)%**	[ <b>1974To07, 1974PeZS, 1973BoXL, 1968Go13</b> , 1988KaZK, 1982Bo04, 1978AfZZ, 1978VrZY, 1975ToZT, 1974ToZN, 1975ToZT, 1970Ma23, 1963Ma18]
¹⁵⁸ Yb	4.589(29)	6.376(26)	4.170(7)	0.0021(12)%	[ <b>1992Ha10, 1977Ha48</b> , 1979Ho10, 1976Gi15]
¹⁶² Hf	3.895(29)	5.583(11)	4.416(5)	0.008(1)%	[1995Hi12, 1992Ha10, 1983To01, 1982Sc15] 1992HeZV]
¹⁶⁶ W	3.329(17)	4.647(18)	4.856(4)	0.6(2)%	[ <b>1979Ho10, 1975To05</b> , 1987ScZL, 1984ScZQ, 1981HoZM, 1976ToZP]
¹⁷⁰ Os	2.805(15)	3.611(16)	5.537(3)	9.4(6)%***	[2004GoZZ, 1996Pa01, 1995Hi02, 1982De11 1982En03, 2002Ro17, 1984Sc06, 1981DeZA, 1981DeZL, 1978Sc26, 1972To06, 1972ToZC, 1972ToZL, 1972ToZW]
¹⁷⁴ Pt	2.338(15)	2.652(16)	6.183(3)	74(3)%	[ <b>2004GoZZ</b> , <b>2004Go38</b> , <b>1996Pa01</b> , <b>1979Ha10</b> , 2002Ro17, 1982En03, 1981DeZB, 1973Ga08 1966Si08]
¹⁷⁸ Hg	2.059(15)	1.959(17)	6.577(3)	89(4)%	[ <b>2012Ve04, 2004GoZZ, 2000Ko01, 1979Ha10</b> 2019Ma08, 2009An20, 2003An13, 2002Ro17, 1999To11, 1996Pa01, 1991Se01, 1976HaYQ, 1976HoZD, 1971Ha03]
¹⁸² Pb	1.315(15)	1.152(17)	7.066(6)	$\approx 100\%^{@}$	[2000Je09, 1999To11, 1987To09, 1986Ke05, 2013An13, 1988ToZV, 1988ToZW, 1984SeZQ, 1982HeZM]
¹⁸⁶ Po	0.952(83)	-0.575(22)	8.501(14)	100%@	[ <b>2013An13</b> , 2005AnZY]

* Weighted average of 31(3)% and 36(3)% [1974To07].

** Weighted average of 0.59(16)% and 0.47(13)% [1974To07]. *** Weighted average of 10(3)% [2004GoZZ], 8.6(5)% [1996Pa01], 992)% [1995Hi02], and 12(1)% [1982En03].

[@] Inferred from Half-life.

direct $\alpha$ emiss	sion from ¹⁵⁰ Dy, J ^{$\pi$}	$= 0^+, T_{1/2} = 7.17(2)$ r	$m^*, BR_{\alpha} = 3$	34(3)%**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{146}\mathrm{Gd})$	coincident γ-rays	R ₀ (fm)	HF
4.348(3)	4.232(3)	34(3)%**	$0^+$	0.0		1.5648(57)	1.0
* [1973B ** Weigł	i06]. nted average of 31(3	)% and 36(3)% [1974'	Го07].				
Table 4 direct $\alpha$ emiss	sion from 154 Er, J $^{\pi}$ =	$= 0^+, T_{1/2} = 3.75(12)$	$m^*, BR_{\alpha} =$	0.52(13)%**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{150}\mathrm{Dy})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.279(5)	4.168(5)***	5.2(13)%**	$0^+$	0.0		1.556(18)	1.0
* [1974P ** Weigh *** Repo Table 5 direct α emiss	teZS]. Inted average of 5.9(1 ported as 4.166(5) Me sion from 158 Yb, J ^{$\pi$}	16)% and 4.7(13)% [19 eV [1968Go13] (adjust = $0^+$ , $T_{1/2} = 1.65(20)$	974To07]. ted to 4.168 $m^*, BR_{\alpha} =$	<ul><li>(5) MeV in [1999Ry01]).</li><li>0.0021(12)%**.</li></ul>			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{154}\mathrm{Er})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.171(10)	4.065(10)***	0.0021(12)%**	* 0+	0.0		1.523(51)	1.0
<b>Table 6</b> direct $\alpha$ emiss	sion from ¹⁶² Hf*, J ^{$\pi$}	$\tau = 0^+, T_{1/2} = 39.8(4)$	s, $BR_{\alpha} = 0.1$	008(1)%.	coincident %rays	R _o (fm)	НЕ
$\frac{L_{\alpha}(\text{c.m.})}{4.417(0)}$	4 208(0)**	0.009(1)0/	$f_{f}$	L _{daughter} (10)	concluent <i>y</i> -rays	1 592(10)	10
* All valı ** Weigh Table 7 direct α emiss	ues from [1995Hi12 nted average of 4.30' sion from ¹⁶⁶ W, J ^{$\pi$} =	2], except where noted. 7(10) MeV [1995Hi12 = $0^+$ , $T_{1/2} = 18.8(4)$ s ²	[], 4.305(9)	MeV [1992Ha10], 4.311(1 5(2)%**.	0) MeV [1983To01], and 4	4.308(10) MeV [198	32Sc15].
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{162}\mathrm{Hf})$	coincident γ-rays	R ₀ (fm)	HF
4.865(5)	4.739(5)**	0.6(2)%**	$0^+$	0.0		1.660(23)	1.0
* [ 1989] ** [1979 *** [197 <b>Table 8</b> direct α emiss	Hi04]. Ho10]. 5To05]. sion from ¹⁷⁰ Os. Ι ^π	$= 0^+$ T _{1/2} = 7 3(2) s*	$BR_{\alpha} = 9.4$	(6)%**			
E (cm)	F (lab)	$I_{(abc)}$	1π	E. (16611)	coincident & rays	$\mathbf{P}_{\mathbf{r}}$ (fm)	НЕ
5,530(4)	5 400(4)***	$\Omega \Lambda(6)$	0+	D D	concluent y-rays	1 5615(42)	1.0
5.559(4)	5.409(4)****	9.4(0)%**	0 '	0.0		1.3013(43)	1.0

* Weighted average of 7.2(2) s [2004GoZZ], 7.9(3) s [1995Hi02], and 7.1(2) s [1982En03], ** Weighted average of 10(3)% [2004GoZZ], 8.6(5)% [1996Pa01], 992)% [1995Hi02], and 12(1)% [1982En03]. *** Weighted average of 5.410(5) MeV [2004GoZZ], 5.411(4) MeV [1982De11], and 5.405(5) MeV [1982En03].

direct $\alpha$ emiss	sion from ¹⁷⁴ Pt*, $J^{\pi}$ =	$0^+, T_{1/2} = 866(5)$	) ms**, $BR_{\alpha}$	=74(3)%.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi}$ E	daughter( ¹⁷⁰ Os)	coincider	nt γ-rays	R ₀ (fm)	HF
5.898(5) 6.182(5)	5.762(5) 6.040(5)***	<1% 100%	<0.7% 73(1)%	$2^+$ 0. $0^+$ 0.	287 0	0.2867		1.5553(31) 1.5553(31)	>6.6 1.0
* All valu ** Weigh *** [200	ues from [2004GoZZ] nted average of 930(30 4GoZZ] and [2004Go	, except where no )) ms [2014Pe02], 38].	ted. , 857(5) ms [2	004GoZZ], 890(20	ms [1996Pa01], an	d 900(10) ms	[1982En03],		
Table 10direct $\alpha$ emiss	sion from ¹⁷⁸ Hg, $J^{\pi}$ =	$0^+, T_{1/2} = 266(3)$	) ms*, $BR_{\alpha}$ =	89(4)%**.					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	Edaughter( ¹⁷⁴ P	t) coincide	nt γ-rays	R ₀ (fm)	HF	
6.577(3)	6.429(3)***	89(4)%**	$0^+$	0.0	_		1.5422(27)	1.0	
* Weight ** [2012 *** Weig <b>Table 11</b> direct α emiss	ed average of 269(3) r Ve04]. ghted average of 6.429 sion from ¹⁸² Pb, $J^{\pi} =$	ns [2002Ro17] an (5) MeV [2004Go 0 ⁺ , T _{1/2} = 55(5)	and 262(4) ms   DZZ], 6.429(4 $MS^*$ , $BR_{\alpha} = \approx$	2000Ko01]. ) MeV [2000Ko01] 2100%**.	and 6.430(6) MeV	[1979Ha10].			
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{178}\mathrm{H}$	(g) coincide	ent γ-rays	R ₀ (fm)	HF	
7.066(10)	6.910(10)***	≈100%**	$0^+$	0.0			1.5163(61)	1.0	
* [19997 ** Inferm *** Weig <b>Table 12</b> direct α emiss	to 11]. ed from half-life. ghted average of 6.911 sion from 186 Po*, J [#] =	(10) MeV [2000J = $0^+$ , $T_{1/2} = 28^{+1} \epsilon$	e09], 6.895(1) $^{6} \mu s, BR_{\alpha} = 1$	0) MeV [1999To11 00%.	], 6.919(15) MeV [	1987To09] and	1 6.921(10) Me ^v	V [1986Ke05].	
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	<i>E</i> _{daughter} ( ¹⁸² Pb)	coinciden	t γ-rays	R ₀ (fm)	HF	

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +9 nuclei.

last updated 6/1/2025

Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z = +9$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{$\pi$} values for ¹²⁴I, ¹²⁸Cs, ¹³²La, ¹³⁶Pr, ¹⁴⁰Pm, ¹⁴⁴Eu, ¹⁴⁸Tb, ¹⁶⁴Ta, are taken from ENSDF.

	-	<b>-</b> <i>π</i>	-		2			
Nuclide	Ex	J ⁿ	$T_{1/2}$	$Q_{\varepsilon}$	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	$BR_{\varepsilon_F}$	Experimental
124		2-	4.15(0(2)) 1	0.202(1.0)	5 (21/2)	1 200 (2)		[1000W/ 00]
1241		2	4.1760(3) d	0.303(1.9)	-5.431(2)	1.308(2)		[1992/wo03]
¹²⁸ Cs		1+	3.66(2) m	3.929(5)	-4.238(6)	2.167(6)		[1976He04]
¹³² La		$2^{-}$	4.8(2) h	4.710(40)	-2.957(36)	3.712(36)		[1960Wa03]
¹³⁶ Pr		$2^{+}$	13.1(1) m	5.168(11)	-1.986(15)	4.670(12)		[1971Ke07]
¹⁴⁰ Pm			9.2(2) s	6.045(24)	-0.672(24)	5.872(24)		[1968Bl14]
¹⁴⁴ Eu		$1^{+}$	10.1(1) s	6.346(11)	0.053(11)	6.213(11)		[1976Ke01]
¹⁴⁸ Tb		$2^{-}$	60(1) m	5.732(13)	-0.281(13)	9.004(13)		[1975SpZU]
¹⁵² Ho		$2^{-}$	161.8(3) s	6.513(13)	0.730(13)	10.240(13)		[1982Bo14]
^{152m} Ho	0.160(1)	$9^{+}$	49.7(3) s*	6.673(13)	0.890(13)	10.400(13)		[1987LiZY, 1987StZU,
								1982Ba75, 1982Bo04,
								1978AfZZ]
¹⁵⁶ Tm		$2^{-}$	82(3) s**	7.377(27)	1.916(23)	10.859(15)		[1982To14, 1981Ga36]
¹⁶⁰ Lu			34.5(15) s	7.890(60)	3.011(63)	11.517(62)		[1979Al16]
¹⁶⁴ Ta		(3 ⁺ )	13.6(2) s	8.540(30)	4.220(40)	12.456(28)		[1983Sc18]
¹⁶⁸ Re		$(7^{+})$	4.4(1) s	9.100(30)	5.267(42)	13.599(35)		[1992Me10]
¹⁷² Ir		$(3^{-}, 4^{-})$	4.1(2) s	9.860(30)	6.582(43)	15.089(35)		[2023Zh03]
172m Ir	х	(7 ⁺ )	1.89(5) s	9.860(30)+x	6.582(43)+x	15.089(35)+x		[2023Zh03]
¹⁷⁶ Au***	у	$(2^{-},3^{-})$	1.046(11) s	10.410(40)+y	7.585(35)+y	16.298(36)+y		[2021Ha37, 2004GoZZ]
^{176m} Au***	х	$(7^+, 8^+, 9^+)$	1.36(2) s	10.410(40)+x	7.585(35)+x	16.298(36)+x		[2021Ha37, 2004GoZZ]
¹⁸⁰ Tl		(5 ⁻ )		10.860(70)	8.309(71)	17.119(71)	3.2(3)X10 ⁻³ 9	5 [2011El07]
¹⁸⁴ Bi***	v		13(2) ms	12.31(12)#+y	10.55(12)#+y	19.08(12)#+y		[2003An27, 2003AnZZ]
^{184m} Bi***	x		6.6(15) ms	12.31(12)#+x	10.55(12)#+x	19.08(12)#+x		[2003An27, 2003AnZZ]
¹⁸⁸ At			$190^{+350}_{80} \ \mu s$	12.161(54)	10.711(51)	25.094(52)		[2025KhXX]
			-30 1	× ,	, , , , , , , , , , , , , , , , , , ,	. ,		

* Weighted average of 49.5(3) s [1982Ba75], 49.7(4) s [1982Bo04] and 50.0(5) s [1978AfZZ]. ** Weighted average of 80(3) s [1982To14] and 86(4) s 1981Ga36]. *** The relative ordering of the ¹⁷⁶Au and ¹⁸⁴Bi isomers are unknown.
Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +9$  nuclei. Unless otherwise stated, all S and Q-values and separation energies are taken from [2021Wa16].

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BR _α	Experimental
124 -	5 492(2)	12 (00/2)	1.252(0)		
124I	5.483(2)	13.608(3)	-1.372(8)		
¹²⁰ Cs	4.900(7)	12.599(7)	-0.992(6)		
¹³² La	4.334(36)	11.402(37)	-0.217(37)		
¹³⁰ Pr	4.013(15)	10.700(23)	-0.042(38)		
140Pm	3.484(37)	9.661(26)	0.703(27)		
¹⁴⁴ Eu	3.391(11)	9.056(26)	0.168(27)		
¹⁴⁸ Tb	2.469(13)	7.997(14)	2.657(16)		
¹⁵² Ho	2.141(13)	7.077(15)	4.507(1)	11(3)%	[1987LiZY, 1987StZU, 1982Bo14, 1982To14,
					<b>1977Ha48, 1974Sc19</b> , 1983Ml01, 1982Ba75,
					1981De11, 1981Ga36, 1981GaZO, 1983GaZR,
					1980BaYV, 1978AfZZ, 1975ScZG, 1974PeZS,
					1974ToZN, 1974ToZQ, 1973BoXL, 1970Ma23,
					1967Ha34, 1963Ma17, 1961Ma40, 1960Ma47]
^{152m} Ho*	1.981(13)	6.901(15)	4.667(1)	10.8(17)%*	[1987LiZY, 1987StZU, 1982Ba75, 1982Bo04,
					1981Ga36, 1979To09, 1978AfZZ, 1983Ml01,
					1981Ga36, 1981GaZO, 1980BaYV, 1975ScZG,
					1974Sc19, 1974ToZN, 1974ToZQ, 1973BoXL]
¹⁵⁶ Tm	1.914(15)	6.773(16)	4.345(7)	0.064(10)%	[1982To14, 1981Ga36, 1992Po14, 1991VaZZ
					1989KaYU, 1983Mi01, 1981GaZR, 1980AfZZ,
					1971To10, 1971ToZP, 1971ToZR, 1971ToZX,
					1970ToZS, 1970ToZY]
¹⁶⁰ Lu	1.725(59)	6.145(62)	4.140(59)	$\leq 10^{-4}\%$	[1981Ga36, 1981GaZR]
¹⁶⁴ Ta	1.302(38)	5.029(80)	4.562(63)		
¹⁶⁸ Re	0.991(36)	4.275(42)	5.063(13)	$\approx 0.005\%$	[ <b>1992Me10</b> , 1992MeZW]
¹⁷² Ir	0.371(37)	3.053(34)	5.991(10)	2.0(2)%	[2023Zh03, 2021Ha32, 2014An10, 1992Sc16,
					2017An16, 2004GoZZ]
^{172m} Ir***	0.371(37)-x	3.053(34)-x	5.991(10)+x	9.5(11)%	[2023Zh03, 2021Ha32, 2014An10, 1992Sc16,
					2017An16, 2014Pe02, 2004GoZZ, 1996Pa01,
					1992MeZW, 1984Gr14, 1982De11, 1982DeZA,
					1978Sc26, 1967Si02]
¹⁷⁶ Au [@]	0.101(38)-y	2.313(35)-y	6.433(7)+x	58(5)%	[2021Ha32, 2014An10, 2017An16, 2004GoZZ]
^{176m} Au [@]	0.101(38)-x	2.313(35)-x	6.433(7)+x	29(3)%	2021Ha32, 2014An10, 2017An16, 2013KoZR,
					2004GoZZ, 2002Ro17, 1990KaZI, 1990SEZW,
					1984ScZQ, 1984Gr14, 1975Ca06, 1974CaYE]
¹⁸⁰ Tl	-0.254(75)	1.665(71)	6.706(62)	6(4)%	[2017An16, 2013Le08, 2013KoZR, 2010An13
	``'	. ,	. /	~ /	2003An27, 2003AnZZ, 1998To14, 1993LaZT]
¹⁸⁴ Bi	-1.55(13)#-v	-0.00(12)#-v	8.22(10)#+v	$\approx 100\%^{**}$	[2003An27, 2003AnZZ]
$^{184m}Bi$	-1.55(13)#-x	-0.00(12)#-x	8.22(10)#+x	$\approx 100\%^{**}$	[2003An27, 2003AnZZ]
¹⁸⁸ At	-1.508(40)	-0.184(53)	7.94(13)#	[2025KhXX]	

* Weighted average of 11(2)% [1981Ga36] and 10.5(30)% [1979To09].

** Inferred from half-life.

### Table 3

direct  $\alpha$  emission from ¹⁵²Ho*,  $J^{\pi} = 2^{-}$ ,  $T_{1/2} = 161.8(3)$  s**,  $BR_{\alpha} = 11(3)\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{148}\mathrm{Tb})^{@}$	coincident $\gamma$ -rays	$R_0 (fm)^{@@}$	HF
4.224	4.113	$<\!\!2\%$	<0.2%	3+	0.281	0.110, 0.102, 0.086	1.566(19)	>3.3
4.308	4.195	<2%	<0.2%	3-	0.195	0.110, 0.086	1.566(19)	>11
4.326	4.212	<2%	<0.2%	$2^{+}$	0.178	0.178	1.566(19)	>50
4.395	4.279	$<\!\!2\%$	$<\!0.2\%$	$4^{-}$	0.110	0.110	1.566(19)	>120
4.505(3)	4.386(3)	100%	11(3)%***	$2^{-}$	0.0		1.566(19)	$2.9^{+1.6}_{-1.0}$

* All Values from [1987StZU], except where noted.

** [1982Bo14].

*** From [1977Ha48]. A value of 3(1)% was reported in [1982To14], which would result in a HF =  $11^{+7}_{-4}$  for the 4.386 MeV  $\alpha$  transition.

[2014Ni05].
 [2014Ni05].
 [2014] Interpolated between 1.565(6) fm ¹⁵⁰Dy and 1.556(18) fm ¹⁵⁴Er.

## **Table 4** direct $\alpha$ emission from ^{152m}Ho*, Ex = 160(1) keV, J^{$\pi$} = 9⁺, T_{1/2} = 49.7(3) s**, BR_{$\alpha$} = 10.8(17)%***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{148}\mathrm{Tb})^{@}$	coincident $\gamma$ -rays	$R_0 (fm)^{@@}$	HF
4.258	4.146	$<\!\!2\%$	$<\!0.2\%$	$8^+$	0.406	0.318, 0.238, 0.078	1.566(19)	>1.7
4.336	4.222	$<\!\!2\%$	$<\!0.2\%$	$7^{+}$	0.328	0.238	1.566(19)	>16
4.574(3)	4.454(3)	100%	10.8(17)%***	(9 ⁺ )	0.0901(7)		1.566(19)	$2.1^{+1.0}_{-0.7}$

* All Values from [1987StZU], except where noted.

** Weighted average of 49.5(3) s [1982Ba75], 49.7(4) s [1982Bo04] and 50.0(5) s [1978AfZZ].

*** Weighted average of 11(2)% [1981Ga36] and 10.5(30)% [1979To09].

@ [2014Ni05].

[@] Interpolated between 1.565(6) fm  150 Dy and 1.556(18) fm  154 Er.

#### Table 5

direct  $\alpha$  emission from ¹⁵⁶Tm, J^{$\pi$} = 2⁻, T_{1/2} = 82(3) s*, BR_{$\alpha$} = 0.064(10)%**.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{152}\mathrm{Ho})$	coincident $\gamma$ -rays	R ₀ (fm) [@]	HF	
4.341(10)	4.230(10)	0.064(10)%**	2-	0.0		1.540(54)@	$1.5^{+2.7}$	

* Weighted average of 80(3) s [1982To14] and 86(4) s and [1981Ga36].

** [1981Ga36].

*** [1982To14].

[@] Interpolated between 1.556(18) fm ¹⁵⁴Er and 1.523(51) ¹⁵⁸Yb.

## Table 6

direct $\alpha$ emission from ¹⁶⁸	${}^{8}\text{Re}^{*}, J^{\pi} = (7^{+}), T_{1/2}$	$A_2 = 4.4(1) \text{ s}, BR_{\alpha} = \approx 0.005\%$
----------------------------------------------	---------------------------------------------------	---------------------------------------------------------

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{164}\text{Ta})$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF	
4.951(13)	4.833(13)	$\approx 0.005\%$		0.1118	0.1118	1.611(23) [@]	$\approx 11$	

* All values from [1992Me10].

** Interpolated between 1.660(23) fm  166 W and 1.562(4)  170 Os.

#### Table 7

direct  $\alpha$  emission from ¹⁷²Ir*, J^{$\pi$} = (3⁻, 4⁻), T_{1/2} = 4.1(2) s, BR_{$\alpha$} = 2.0(2)%**.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{168}\mathrm{Re})$	coincident γ-rays	$R_0 (fm)^@$	HF	
5.636(5)	5505(5)	31(8)%	0.36(6)%		0.1360(2) +x	0.1360(2)	1.559(5)@	$13^{+5}_{-4}$
5.648(5)	5.517(5)	13(3)%	0.15(3)%		0.1230(2) + x	0.1230(2)	1.559(5)@	$37^{+18}_{-10}$
5.669(5)	5.537(5)	100(17)%	1.15(2)%		0.1028(3) + x	0.1028(3)	1.559(5)@	$5.9^{+2.0}_{-1.4}$
5.679(5)	5.547(5)	30(7)%	0.34(6)%		0.0894(3) +x	0.0894(3)	1.559(5)@	$23^{+10}_{-6}$

* All values from [2023Zh03], unless otherwise noted.

** [1992Sc16].

*** Interpolated between 1.562(4) ¹⁷⁰Os and 1.5553(31) ¹⁷⁴Pt.

# Table 8

direct  $\alpha$  emission from ^{172m}Ir*, Ex = unk., J^{$\pi$} = (7⁺), T_{1/2} = 2.0(1) s**, BR_{$\alpha$} = 9.5(11)%***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{168}\mathrm{Re})$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF
5.892(7)	5.755(7)	<0.05%	<0.004%		0.224(1)	0.224(1)	1.559(5) ^{@@}	$>7 \times 10^{3}$
6.125(15)	5.818(4) 5.983(15) [@]	100% 8(2)%	8.8(10)% 0.8(2)%	(7 ⁺ )	0.1621(2) 0.0	0.1621(2)	1.559(5) ^{@@}	$7.1_{-1.3}^{+1.5}$ $420_{-13}^{+23}$

* All values from [2023Zh03], unless otherwise noted.

** [1992Sc16].

*** [2014An10].

[@] Only observed in [2021Ha32].

[@] Interpolated between 1.562(4) ¹⁷⁰Os and 1.5553(31) ¹⁷⁴Pt.

Table 9			
direct $\alpha$ emission from	176 Au*, J ^{$\pi$} = (2 ⁻ ,	$(3^{-}), T_{1/2} = 1.046$	(11) s**, $BR_{\alpha} = 58(5)\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{m{\pi}}$	$E_{daughter}($ ¹⁷² Ir)	coincident γ-rays	$R_0 (fm)^{@}$	HF
5.933	5.798	<0.44%	< 0.25%		0.500	0.500	1.5488(41)***	>12
6.192(15)	6.052(15)	3.1(2)%	1.6(2)%		0.2366	0.2366	1.5488(41)***	21(3)
6.281(10)	6.138(10)	6.7(6)%	3.5(4)%		0.1515	0.1515	1.5488(41)***	$21^{+4}_{-2}$
6.300	6.157	<0.9%	0.46(4)%		0.1266	0.1266	1.5488(41)***	>200
6.406(5)	6.260(5)	100%	52(5)%	$(2^{-}, 3^{-})$	0.025		1.5488(41)***	4.4(5)

* All values from [2021Ha32], unless otherwise noted. The relative ordering of the ¹⁷⁶Au isomers in unknown.

** [2004GoZZ].

*** Interpolated between  $1.5553(31)^{174}$ Pt and  $1.5422(27)^{178}$ Hg.

### Table 10

direct  $\alpha$  emission from ^{176m}Au*, Ex = unk., J^{$\pi$} = (7⁺, 8⁺, 9⁺), T_{1/2} = 1.36(2) s**, BR_{$\alpha$} = 29(5)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}($ ^{172m} Ir)	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF
6.221(5)	6.080(5)	55(4)%	9.6(17)%	$(7^+, 8^+, 9^+)$	0.2116+x	0.2116	1.5488(41)***	$5.6^{+1.4}_{-1.0}$
6.256(5)	6.114(5)	100%	17(3)%		0.1752+x	0.1752	1.5488(41)***	$4.3^{+1.1}_{-0.8}$
6.426(10)	6.280(10)	12(2)%	2.0(5)%		Х		1.5488(41)***	$170_{-40}^{+60}$

* All values from [2021Ha32], unless otherwise noted. The relative ordering of the  176 Au isomers in unknown.

** [2004GoZZ]. *** Interpolated between 1.5553(31) ¹⁷⁴Pt and1.5422(27) ¹⁷⁸Hg.

#### Table 11

direct  $\alpha$  emission from ¹⁸⁰Tl*, J^{$\pi$} = (5⁻), T_{1/2} = 1.09(1) s**, BR_{$\alpha$} = 6(4)%**.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	Edaughter( ¹⁷⁶ Au)	coincident $\gamma$ -rays (keV)	R ₀ (fm)***	HF
6.006(8)	5.873(8)	0.25(6)%	0.006(4)%		0.695	695.1(5), 491.2(4), 486.1(3), 361.7(2), 333(1), 209.9(2), 204.8(2)	1.5293(67)	$100_{-40}^{+230}$
6.021(8)	5.887(8)	0.30(6)%	0.0072(50)%		0.678	677.5(7), 570.3(3), 472.5(4), 467.9(4), 209.9(2), 204.8(2)	1.5293(67)	$100^{+220}_{-40}$
6.113(8)	5.977(8)	0.40(6)%	0.0096(66)%		0.596	595.9(5), 391.2(3), 386.5(3), 317.1(2), 279.6(3), 209.9(2), 204.8(2)	1.5293(67)	$160^{+180}_{-40}$
6.131(8)	5.995(8)	0.18(3)%	0.0042(29)%		0.570	570.3(3), 317.1(2), 253(1), 209.9(2), 204.8(2)	1.5293(67)	$500^{+1350}_{-70}$
6.152(8)	6.015(8)	0.13(3)%	0.003(2)%		0.553	553.2(3)	1.5293(67)	$800^{+180}_{-40}$
6.186(9)	6.049(9)	0.08(3)%	0.0018(14)%		0.526	526.1(4)	1.5293(67)	$1.7^{+5.0}_{-0.8} \times 10^3$
6.226(9)	6.088(9)	0.08(3)%	0.0018(14)%		0.473	473.4(4)	1.5293(67)	$3.0^{+8.0}_{-1.0} \times 10^3$
6.307(8)	6.167(8)	0.23(5)%	0.00054(38)%		0.398	397.9(3)	1.5293(67)	$1.9^{+4.5}_{-0.8} \times 10^3$
6.333(7)	6.192(7)	2.26(32)%	0.054(37)%		0.372	204.8(2), 167.6(2)	1.5293(67)	$200^{+50}_{-10}$
6.340(7)	6.199(7)	43.5(50)%	1.0(7)%		0.362	361.7(2), 317.1(2), 209.9(2), 204.8(2), 151.7(2), 112.2(2), 107.1(2)	1.5293(67)	$13^{+28}_{-6}$
6.387(7)	6.245(7)	63(7)%	1.5(10)%		0.317	317.1(2), 209.9(2), 204.8(2), 112.2(2), 107.1(2)	1.5293(67)	$14^{+29}_{-6}$
6.492(7)	6.348(7)	9.1(11)%	0.22(15)%		0.210	209.9(2)	1.5293(67)	$30^{+50}_{-10}$
6.498(7)	6.354(7)	100(9)%	2.4(16)%		0.205	204.8(2)	1.5293(67)	$20^{+50}_{-10}$
6.702(7)	6.553(7)	32(3)%	0.77(0.52)%	$(2^-, 3^-)$	0.0		1.5293(67)	$400_{-200}^{+900}$

* All Values from [2017An16], except where noted.

** [2011El07].

*** Interpolated between 1.5422(27) ¹⁷⁸Hg and 1.5163(61) ¹⁸²Pb.

	<b>I H</b> olin <b>B</b> $\mathbf{I}^*, \mathbf{J}^* = , \mathbf{I}_{1/2}^*$	= $15(2)$ ms, $bR_{\alpha} = \approx$	100%**.		
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}($ ¹⁸⁰ Tl)	coincident γ-rays (keV)
7.28-7.51	7.12-7.35***				
7.354(20)	7.194(20)			0.124	
* All Values ** Inferred *** Comple Table 13	s from [2003An27], excep from half-life. ex structure with contribut	t where noted. The relions from many $\alpha$ -dec	lative ordering of cays.	the ¹⁸⁴ Bi isomers in unknown	1.
direct $\alpha$ emissio	n from ^{184<i>m</i>} Bi*, J ^{$\pi$} = , T _{1/}	$_2 = 6.6(15) \text{ ms}, BR_{\alpha} =$	=≈ 100%**.		
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}($ ¹⁸⁰ Tl)	coincident γ-rays (keV)
7.90-8.02	7.73-7.85***				
7.90-8.02 7.380(15)	7.73-7.85*** 7.220(15)			0.449	
7.90-8.02 7.380(15) 7.610(35)	7.73-7.85*** 7.220(15) 7.445(35)			0.449	
7.90-8.02 7.380(15) 7.610(35) * All Values ** Inferred *** Comple Table 14 direct α emissio	7.73-7.85*** 7.220(15) 7.445(35) s from [2003An27], excep from half-life. ex structure with contribut n from ¹⁸⁸ At*, $T_{1/2} = 190$	t where noted. The relions from many $\alpha$ -dec $\mu^{+350}_{-80}$ $\mu$ s, $BR_p = 100\%$	lative ordering of cays.	0.449 [°] the ¹⁸⁴ Bi isomers in unknowr	ı.
7.90-8.02 7.380(15) 7.610(35) * All Values ** Inferred *** Comple <b>Table 14</b> direct $\alpha$ emissio $E_p(c.m.)$	7.73-7.85*** 7.220(15) 7.445(35) 5 from [2003An27], excep from half-life. ex structure with contribut n from ¹⁸⁸ At*, $T_{1/2} = 190$ $E_p(lab)$	t where noted. The relions from many $\alpha$ -dec $\mu^{+350}_{-80}$ $\mu$ s, $BR_p = 100\%$ $I_p(abs)$	lative ordering of cays. . $J_f^{\pi}$	0.449 The ¹⁸⁴ Bi isomers in unknown $E_{daughter}($ ¹⁸⁷ Po)	ı. coincident γ-rays (keV)

* All Values from [2025KhXX].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +19/2 nuclei.

Last updated 6/2/2025

Observed and predicted $\beta$ -delayed particle emission from the even-Z, $T_z = +19/2$ nuclei	i. Unless otherwise stated, all Q-values are taken from [2021Wa16] or
deduced from values therein. J ^{$\pi$} values for ¹³⁵ Ce, ¹³⁹ Nd, ¹⁴³ Sm, ¹⁴⁷ Gd, ¹⁵⁹ Yb, ¹⁶³ Hf are	taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon \alpha}$	Experimental
135 Co		1/2+	17.8(2) h	2 027(5)	2.055(10)		1.014(10)	[1076Ca10]
139 Nd		$\frac{1}{2}$	17.0(3) II 20.7(5) m	2.027(3) 2.812(28)	-2.933(10) 1 740(28)		1.014(10) 2.202(20)	[1970Ge10] [10671_010]
¹⁴³ Sm		3/2+	29.7(3) m 8.83(1) m	3.444(4)	-0.856(2)		2.202(29)	[1967Ea19] [1968Bl13]
¹⁴⁷ Gd		7/2-	38.06(12) h	2.188(3)	-1.650(3)		5.179(3)	[1969Ch32]
¹⁵¹ Dy		7/2-	17.8(2) m*	2.871(5)	-0.277(7)		6.367(4)	[1978MoZH, 1973Bi06, 1965Ma51, 1964Ma19]
¹⁵⁵ Er		$(7/2^{-})$	5.3(3) m	3.831(18)	0.896(9)		6.989(7)	[1969To06]
¹⁵⁹ Yb		5/2-	1.72(10) m	4.740(30)	2.181(31)		7.781(25)	[1993Al03]
¹⁶³ Hf		$(5/2^{-})$	40.0(6) s	5.520(40)	3.263(30)		8.876(38)	[1982Sc15]
$^{167}W$		$(5/2^{-})$	19.9(5) s	6.260(30)	4.477(34)		10.273(34)	[1989Me02]
¹⁷¹ Os		5/2-	8.3(2) s	6.950(30)	5.705(23)		11.629(33)	[1995Hi02]
¹⁷⁵ Pt		(7/2-)	2.43(4) s	7.686(22)	6.998(21)		13.117(34)	[2014Pe02]
¹⁷⁹ Hg		$(7/2^{-})$	1.05(3) s	8.060(30)	7.776(30)	0.37(6)%**	14.037(31)	[2025Sp01, 1971Ho07, 2002Ko09, 2002Ro17,
102								1971Ha03]
¹⁸³ Pb		$(3/2^{-})$	535(30) ms	9.010(30)	8.708(31)		14.984(31)	[2002Je09]
^{185m} Pb	0.079(6)	$(13/2^+)$	415(20) ms	9.089(30)	8.787(31)		15.063(31)	[2002Je09]
10/Po		$(1/2^{-}, 5/2^{-})$	1.40(25) ms	9.210(30)	10.216(34)		16.986(34)	[2006An11]

* Weighted average of 17.5(5) m [1978MoZH], 16.9(5) m [1973Bi06], 17.7(5) m [1965Ma51] and 18.0(2) m [1964Ma19]. ** [1971Ho17] reports  $I_{\beta p} p/I_{\alpha} = 0.28(4)\%$ . Combining this value with  $BR_{\alpha} = 75(5)\%$  [2012Ve04] results in  $BR_{\beta p} = 0.37(6)\%$ 

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +19/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
135 C		11 (11/10)	0.2(2(10)		
¹³⁵ Ce	6.687(22)	11.641(10)	-0.362(10)		
¹³⁹ Nd	6.177(29)	10.676(28)	0.174(29)		
¹⁴³ Sm	5.665(24)	9.904(4)	0.075(28)		
¹⁴ /Gd	5.528(6)	9.283(1)	1.735(2)		
¹⁵¹ Dy	4.936(8)	8.203(4)	4.180(3)	5.6(4)%	[1974To07, 1982Bo04, 1978MoZH, 1973Bi06, 965Ma51, 1964Ma19,
					11990KaZM, 1989KaYU, 1988KaZK, 1987KaZI, 1985Ne09, 1982De11
					1981HoZM, 1979Ho10, 1978AfZZ, 1975ToZT, 1974ToZN, 1974ToZQ,
					1973BoXL, 1972OkZZ, 1968Go13, 1967Go32, 1960Ma47]
¹⁵⁵ Er	4.859(10)	7.644(7)	4.118(5)	< 0.022(7)%	[1974To07, 1990Po13, 1990KaZM, 1978AfZZ, 1975ToZT, 1974PeZS,
					1970Ma23, 1969To06]
¹⁵⁹ Yb	4.419(31)	6.998(32)	3.951(18)	< 0.0001%***	[1995Hi12]
¹⁶³ Hf	3.727(79)	6.013(30)	4.139(31)		
$^{167}W$	3.284(34)	5.036(34)	4.751(30)	< 0.04(1)%	[1991Me05, 1989Me02]
¹⁷¹ Os	2.682(22)	3.957(24)	5.371(4)	1.8(3)%*	[1995Hi02, 1979Ha10, 2004GoZZ, 1996Pa01, 1978Sc26, 1976HoZD,
					1972To06, 1972ToZC, 1972ToZL, 1972ToZO, 1972ToZW]
¹⁷⁵ Pt	2.212(22)	2.848(24)	6.164(4)	64.5(13)%	[2014Pe02, 1979Ha10, 2004GoZZ, 2002Ko09, 1996Pa01, 1986Ke03,
					1982De11, 1981DeZA, 1981DeZL, 1976HoZD, 1973Ga08, 1971Ha03,
					1970Ha18, 1966Si08]
¹⁷⁹ Hg	1.919(30)	2.140(33)	6.430(4)**	75(6)%	[2025Sp01, 2012Ve04, 2002Ko09, 1979Ho10, 2002Ro17, 1996Pa01,
e					1982HeZM, 1971Ha03, 1971Ho17, 1970Ha18, 1969NaZT, 1968De01]
¹⁸³ Pb	1.542(31)#	1.497(33)#	6.928(7)	obs@	[2002Je09, 1989To01, 2012Ve04, 1987To09, 1986Ke03, 1980Sc09]
^{183m} Pb	1.463(31)#	1.418(33)#	7.007(9)	obs [@]	[2002Je09, 1989To01, 1987To09, 1986Ke03, 1984ScZQ, 1980Sc09]
¹⁸⁷ Po	1.320(37)	0.213(36)	7.979(15)	100%	[2006An11, 2007An19, 2005An17, 2005AnZY]
					-

* Weighted average of 1.9(3)% [1995Hi02] and 1.7(3)% [1979Ha10].

** Deduced from  $\alpha$  energy, 6.351(31) in [2021Wa16].

*** Not observed.

 $\ensuremath{^@}$  Not measured, expected to be 80-90% based on half-life.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi} E_{daughter}(^{147} \text{Gd})$	coincident $\gamma$ -	rays $R_0$ (fm)	HF	
4.184(3)	4.070(3)***	5.6(4)%**	7/2-	0.0		1.5706(33)	1.92(20
* Weigh ** [1974 *** Fror	ted average of 17.5( To07]. n 4.67(3) MeV [198	5) m [1978MoZH] 2Bo04], adjusted t	, 16.9(5) m [1973Bi06 o 4070(3) in [1991Ry(	6], 17.7(5) m [1965M 01].	a51] and 18.0(2) m [19	64Ma19].	
<b>Fable 4</b> lirect α emis	sion from ¹⁵⁵ Er*, J	$\pi = 7/2^-, T_{1/2} = 5.3$	$B(3) \text{ m}^{**}, BR_{\alpha} = <0.0$	22(7)%.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$ $E_c$	_{laughter} ( ¹⁵¹ Dy)	coincident γ-rays	R ₀ (fm)	HF
4.118(5)	4.012(5)	< 0.022(7)%	7/2- 0.0	0		1.546(21)	>2.9
	uss from [1074To0]	7], except where no	ted.				
* All val ** [1969 <b>Table 5</b> direct α emis	To06].	$\pi = (5/2^{-}), T_{1/2} = 1$	9.9(5) s, $BR_{\alpha} = < 0.0$	4(1)%.			
* All val ** [1969 <b>Table 5</b> direct $\alpha$ emis $E_{\alpha}(c.m.)$	sion from ¹⁶⁷ W*, $J$ $E_{\alpha}(\text{lab})$	$\pi = (5/2^{-}), T_{1/2} = 1$ $I_{\alpha}(abs)$	9.9(5) s, $BR_{\alpha} = < 0.0$ $J_f^{\pi} \qquad E_{daa}$	4(1)%. _{ughter} ( ¹⁶³ Hf)	coincident γ-rays	R ₀ (fm)	HF

Calculated using 4.751(30) MeV [2021Wa16] for  $Q_{\alpha}$ .

# Table 6

direct  $\alpha$  emission from ¹⁷¹Os*,  $J^{\pi} = 5/2^{-}$ ,  $T_{1/2} = 8.3(2)$  s,  $BR_{\alpha} = 1.8(3)\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{167}W)$	coincident γ-rays	R ₀ (fm)	HF	
5.290(10) 5.367(7)	5.166(10) 5.241(7)	7.0%*** 100%***	0.12(3)% 1.68(3)%	(7/2 ⁻ ) (5/2 ⁻ )	0.079 0.0	0.079***	1.5721(95) 1.5721(95)	$7.7^{+3.0}_{-2.1}\\1.3^{+4}_{-3}$

* All values from [1995Hi02], except where noted. ** Weighted average of 1.9(3)% [1995Hi02] and 1.7(3)% [1979Ha10].

*** Uncertainties not given in [1995Hi02].

# Table 7

Table /			
direct $\alpha$ emission from	175 Pt*, $J^{\pi} = (7/2^{-1})^{-175}$	), $T_{1/2} = 2.43(4)$ s.	$BR_{\alpha} = 64.5(13)\%$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{171}\mathrm{Os})$	coincident γ-rays	R ₀ (fm)	HF
5.950(4) 5.955(4) 6.087(4) 6.162(4)	5.814(4) 5.819(4) 5.948(4) 6.021(4)	7.3(16)% 1.3(4)% 100(1)% 8.7(15)%	4.0(9)% 0.7(2)% 55.0(5)% 4.8(8)%	(9/2 ⁻ ) (7/2 ⁻ ) (5/2 ⁻ )	0.2112(5) 0.2079(5) 0.0767(3) 0.0	0.2112(5), 0.1341(4), 0.0767(3) 0.2079(5), 0.1308(4), 0.0767(3) 0.0767(3)	1.5574(37) 1.5574(37) 1.5574(37) 1.5574(37)	$\begin{array}{c} 6.6^{+2.1}_{-1.4} \\ 38^{+16}_{-9} \\ 1.71(15) \\ 40^{+9}_{-7} \end{array}$

* All values from [2014Pe02], except where noted.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{175}\mathrm{Pt})$	coincident γ-rays	R ₀ (fm)	HF
6.297(10)	6.156(10)	0.27(10)%	0.20(8)%	(9/2 ⁻ )	0.1315	0.1315	1.5367(27)	117(75)
6.430(9)	6.286(9)	100%	74.8(50)%	(7/2 ⁻ )	0.0		1.5367(27)	1.1(2)

## Table 9

direct  $\alpha$  emission from ¹⁸³Pb*,  $J^{\pi} = (3/2^{-})$ ,  $T_{1/2} = 535(30)$  ms,  $BR_{\alpha} = obs^{**}$ .

direct  $\alpha$  emission from ¹⁷⁹Hg*,  $J^{\pi} = (7/2^{-})$ ,  $T_{1/2} = 1.05(3)$  s,  $BR_{\alpha} = 75(5)\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{179}\mathrm{Hg})$	coincident γ-rays	$R_0$ (fm)	HF
6.717(10) 6.926(7)	6.570(10) 6.775(7)	39(6)% 100(7)%		(3/2 ⁻ ) (7/2 ⁻ )	0.217 0.0	0.217	1.5067(87) 1.5067(87)	$1.7^{+0.5}_{-0.4}_{-0.4}_{3.9^{+0.9}_{-0.8}***}$

* All values from [2002Je01], except where noted.

** Not measured, expected to be 80-90% based on half-life.

*** Value based on a 100% al pha branching ratio for ¹⁸³Pb.

#### Table 10

direct  $\alpha$  emission from ^{183m}Pb*, Ex = 79(6) keV,  $J^{\pi} = (13/2+), T_{1/2} = 415(20)$  ms,  $BR_{\alpha} = \text{obs}^{**}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{179}\mathrm{Hg})$	coincident γ-rays	R ₀ (fm)	HF
6.848(5) 7.013(11)	6.698(5) 6.860(11)	100(6)% 3(1)%		(13/2+) (7/2-)	0.172 0.0	0.0061, 0.111	1.5067(87) 1.5067(87)	${}^{1.12^{+0.24}_{-0.20}}_{140^{+90}_{-50}***}$

* All values from [2002Je01], except where noted.

** Not measured, expected to be 80-90% based on half-life.

*** Value based on a 100% al pha branching ratio for ¹⁸³Pb.

#### Table 11

direct  $\alpha$  emission from ¹⁸⁷Po*,  $J^{\pi} = (1/2^{-}, 5/2^{-}), T_{1/2} = 1.40(25)$  ms,  $BR_{\alpha} = 100\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$E_{daughter}(^{183}\text{Pb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
7.693(15) 7.979	7.528(15) 7.808	$100\% < 2\%^{**}$	$100\% < 2\%^{**}$	(3/2 ⁻ )	0.286(1) 0.0	0.286(1)	1.487(13) 1.487(13)	$0.29^{+0.11\text{@}}_{-0.09}$ >100

* All values from [2006An11].

** A single event at this energy was observed.

*** Inferred from half-life.

[@] The very low value for HF may indicate that the decay of ¹⁸⁷Po has other unobserved transitions.

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$  = +19/2 nuclei.

last updated 6/4/25

Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z = +19/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{$\pi$} values for ¹³³La, ¹³⁷Pr, ¹⁴¹Pm, ¹⁴⁵Eu, ¹⁵³Ho are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	0 ₆	$O_{\varepsilon n}$	$O_{\varepsilon \alpha}$	BR _{BE}	Experimental
		-	1/2	CC .	$z_{ep}$	200	pr	1
¹³³ La		$5/2^{+}$	4.0 h	2.059(28)	-5.631(28)	0.777(28)		[1973Re05]
¹³⁷ Pr		$5/2^{+}$	1.28(3) h	2.717(8)	-4.453(54)	1.927(8)		[1973Bu18]
¹⁴¹ Pm		$5/2^{+}$	20.90(5) m	3.669(14)	-3.126(15)	2.971(14)		[1967Bl27]
¹⁴⁵ Eu		$5/2^{+}$	5.93(4) d	2.660(2.7)	-3.864(4)	3.775(4)		[1980Ho33]
¹⁴⁹ Tb		$1/2^{+}$	4.13(5) h*	3.639(4)	-2.480(11)	6.738(4)		[1960To10, 1968St09]
^{149m} Tb	0.03578(8)	$11/2^{-}$	4.16(4) m	3.675(4)	-2.516(11)	6.774(4)		[2022Si28, 1973Bi06]
¹⁵³ Ho		11/2-	2.02(3) m	4.131(6)	-1.584(40)	7.690(6)		[1993Al03]
^{153m} Ho	0.0687(3)	$1/2^{+}$	9.3(5) m	4.200(6)	-1.515(40)	7.759(6)		[2020Ni06, 1967Ha34]
¹⁵⁷ Tm		$1/2^{+}$	3.6(3) m	4.700(40)	-0.460(48)	8.009(28)		[1976La03]
¹⁶¹ Lu		$1/2^{+}$	78(2) s	5.270(30)	0.450(43)	8.426(39)		[1983Ge08]
¹⁶⁵ Ta		$(9/2^{-})$	31.0(15) s	5.790(30)	1.506(31)	9.561(20)		[1982Li17]
¹⁶⁹ Re		(9/2-)	8.1(3) s	6.509(19)	2.696(30)	10.801(30)		[1992Me10, 1992MeZW]
^{169m} Re	0.187(17)	$(1/2^+, 3/2^+)$	16.3(8) s	6.696(25)	2.883(34)	10.988(34)		[2021Ha32, 1992Me10,
					. ,			1992MeZW]
¹⁷³ Ir		$(1/2^+)$	8.3(3) s**	7.170(18)	4.009(37)	12.224(19)		[2004GoZZ, 1992Bo21,
								1992Sc16
173mIr	0.213(6)	$(11/2^{-})$	2.150(47) s***	7.386(19)	4.222(37)	12.437(20)		[2021Ha32, 2004GoZZ,
								1992Sc16]
¹⁷⁷ Au		$(1/2^+)$	1.501(20) s	7.825(18)	5.047(13)	13.468(18)		[2025Sp01, 2021Ha32,
								2009An14, 2004GoZZ,
								2001Ko14]
^{177m} Au	0.1819(4)	$(11/2^{-})$	1.186(12) s [@]	8.843(18)	6.056(13)	13.650(18)		[2025Sp01, 2021Ha32, 2001Ko14]
¹⁸¹ Tl		$(1/2^+)$	2.9(1) s	7.862(18)	5.538(10)	14.147(18)		[2018Cu04]
181m Tl ^e	0.8359(4)	(9/2 ⁻ )	1.40(3) ms	7.862(18)	5.538(10)	14.983(18)		[2009An14]
¹⁸⁵ Bi		$(1/2^+)$	$2.8^{+23}_{-10} \mu s$	9.310(80)#	7.359(82)#	16.001(82)#		[2021Do08]
			-					

* Weighted average of 4.10(5) h [1960To10] and 4.15(5) h [1968St09].

** Weighted average of 9.8(14) s [1992Sc16], 8.1(3) s [1992Bo21] and 10(1) [2004GoZZ].

*** Weighted average of 2.20(5) s [1992Sc16] and 2.105(47) s [2004GoZZ].

[@] Weighted average of 1.193(13) s [2021Ha32], and 1.180(12) s [2001Ko14].

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +19/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$BR_p$	$S_{2p}$	Qα	BRα	Experimental
¹³³ La	4.348(28)		12.017(28)	-0.420(28)		
¹³⁷ Pr	3.982(8)		11.136(12)	-0.132(29)		
¹⁴¹ Pm	3.555(14)		10.272(14)	0.254(16)		
¹⁴⁵ Eu	3.315(3)		9.609(4)	0.106(14)		
¹⁴⁹ Tb	2.508(3)	_	8.522(4)	4.078(2)	17.6(14)%*	[1978Ja14, 1974To07, 1968Ch30, 1968St09, 1967Go32, 1960To10, 1996Pa01, 1981KoZL, 1979Ho10, 1978AfZZ, 1974PeZS, 1974ToZN, 1974ToZO, 1974ToZQ, 1873Bi06, 1973BoXW, 1972OkZZ, 1968Wi21, 1967Ch28, 1968Ch32, 1965Gr28, 1964Da20, 1961Ma39, 1961St15, 1960To1011
^{149m} Tb	2.472(3)		8.486(4)	4.114(2)	0.022(3)%**	[ <b>1974T007, 1973Bi06, 1964Ma14</b> , 1973BoXW, 1974ToZN, 1974ToZO, 1974ToZQ, 1968Go13, 1967Go32, 1963Ma17, 1960Ma47]
¹⁵³ Ho	2.183(7)		7.966(6)	4.052(4)	0.039(14)%***	[ <b>1974ToZN</b> , 1978AfZZ, 1974ToZQ, 1974Sc19, 1971ToO1 1964Ma10 1961Ma40 1960Ma47]
^{153m} Ho	2.114(7)		7.897(6)	4.121(4)	0.14(4)% [@]	[ <b>1974ToZN</b> , 1974Sc19, 1974PeZS, 1974ToZQ, 1971ToZX, 1970ToZS, 1970ToZY, 1968Go13, 1967Ha34 1963Ma17, 1961Ma40]
¹⁵⁷ Tm	1.787(37)		7.247(33)	3.878(28)		
¹⁶¹ Lu	1.688(28)		6.570(40)	3.722(40)		
¹⁶⁵ Ta	1.318(20)		5.634(31)	4.290(31)		
¹⁶⁹ Re	0.805(16)		4.636(30)	5.014(13)	obs	[1992Me10, 1992MeZW]
^{169m} Re	0.618(23)		4.449(34)	5.101(21)	obs	[ <b>1992Me10, 1992MeZW</b> , 1984Sc06, 1982De11, 1981DeZA, 1981DeZL, 1978Ca11]
¹⁷³ Ir	0.314(15)		3.596(30)	5.716(9)	4(2)%	[2021Ha32, 2004GoZZ, 1992Bo21, 1992Sc16 2009An14, 1992McZW]
^{173m} Ir	0.101(16)		3.383(30)	5.929(11)	11(1)% ^{@@}	[ <b>2021Ha32, 2004GoZZ, 1996Pa01, 1992Sc16</b> <b>1982De11</b> , 2009An14, 1992MeZW, 1986Ke03, 1967Si02]
¹⁷⁷ Au	-0.099(14)		2.729(16)	6.298(4)	54(5)% ^{@@@@}	[2025Sp01, 2021Ha32, 2009An14, 2004GoZZ, 2001Ko14, 2000KoZN, 1996Pa01, 1991Se01, 1990KaZI, 1984Gr14, 1975Ca06, 1973Ga08, 1968Si011
^{177m} Au	-0.099(14)		2.729(16)	6.298(4)	56(8)%	[ <b>2025Sp01, 2021Ha32, 2001Ko14</b> , 2009An14, 2004GoZZ, 2000KoZN, 1996Pa01, 1991Se01, 1990KaZI, 1984Gr14, 1975Ca06, 1973Ga08, 1968Si01]
¹⁸¹ Tl	-0.999(14)		1.552(15)	6.322(4)	8.6(6)%	[2018Cu04, 2009An14, 1998To14, 1993BoZK 1992BoZO, 1992BlZW,1984ScZQ]
181m Tl	-0.163(14)		2.388(15)	7.158(4)	0.40(6)%	[ <b>2009An14</b> , 1998To14, 1984ScZQ]
¹⁸⁵ Bi	$-1.592(5)^b$	91(2)% ^a	0.226(82)#	8.207(15) ^b	$9(2)\%^{c}$	[ <b>2021Do08, 2004An07</b> , 2001Po05, 2000PoZY, 1996Da06, 1995DaZX]

* Weighted average of 15.8(14)% [1978Ja14] and 22.6(23)% [1968Ch30].

** Weighted average of 0.020(4)% [1973Bi06] and 0.0225(25)% [1964Ma14].

*** Weighted average of 0.034(17)% and 0.051(25)% [1974ToZN].

[@] Weighted average of 0.12(5)% and 0.18(8)% [1974ToZN].

[@] Weighted average of 7(2)% [1996Pa01], 12(1)% [1992Sc16] and 14(3)% [2004GoZZ].

^{@@@} Weighted average of 40(6)% [2009An14] and 64(5)%5 [2021Ha32].

^a Weighted average of 92(2)% [2021D008], and 90(2)% [2004An07].

^b Deduced from  $\alpha$  and p energies;  $S_p = -1.527(81)$ #, and  $Q_\alpha = 8.138(81)$ # in [2021Wa16]. Combining the p energy and the mass excess of ¹⁸⁴Pb gives -2.171(14) MeV for the mass excess of ¹⁸⁵Bi. The  $\alpha$  energy and mass excess of ¹⁸¹Tl gives -2.167(17) MeV, resulting in a weighted average of -2.169(11) MeV; -2.240(80)# in [2021Wa16].

^c Weighted average of 8(2)% [2021Do08], and 10(2)% [2004An07].

direct $\alpha$ emis	ssion from ¹⁴⁹ Tb, $J^{\pi}$	$= 1/2^+, T_{1/2} = 4.13$	$(5) h^*, BR_{\alpha} = 17$	.6(14)%**.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{m{\pi}}$	$E_{daughter}(^{145}\mathrm{Eu})$	coincident γ-rays	$R_0$ (fm)	HF	7
3.745(5) 4.076(5)	3.644(5)*** 3.967(5)***	0.03(1)% 100% [@]	0.0068(23)% [@] 17.6(14)%**	7/2+ 5/2+	0.330 0.0	0.330	1.5656( 1.5656(	18)     13       18)     5.9	$0^{+70}_{-30}$ 9(7)
* Weigh ** Weig *** [196 @ [1968	nted average of 4.10( whted average of 15.8 67Go32]. 3Ch30].	5) h [1960To10] and 8(14)% [1978Ja14] a	4.15(5) h [19688 nd 22.6(23)% [19	St09]. 968Ch30].					
Table 4 direct $\alpha$ emis	ssion from ^{149m} Tb, H	Ex = 35.75(8)  keV,	$\pi^{\pi} = 11/2^{-}, T_{1/2} =$	= 4.16(4) m**, <i>Bl</i>	$R_{\alpha} = 0.022(3)\%^{***}$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{145}$	Eu) coincid	ent $\gamma$ -rays R ₀ (	(fm)	HF	
4.109(7)	3.999(7) [@]	0.22(3)%***	5/2+	0.0		1.56	656(18)	$127^{+26}_{-21}$	
* [2022] ** [1972 *** Wei @ [1974 Table 5	Si28]. 3Bi06]. ighted average of 0.0 FT007].	)20(4)% [1973Bi06]	and 0.0225(25)%	6 [1964Ma14].					
direct $\alpha$ emis	ssion from ¹⁵⁵ Ho, J [#]	$r = 11/2^{-}, T_{1/2} = 2.0$	$D_{2}(3) \text{ m}^{*}, BR_{\alpha} = 0$	0.039(14)%**.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{12}$	^{19m} Tb) coin	cident γ-rays R	R ₀ (fm)	HF	
4.070(5)	3.910(5)***	0.039(14)%**	11/2-	0.036		1	.565(11)	$1.5\substack{+0.9 \\ -0.5}$	
* [1993] ** Weig *** [197 Table 6	A103]. hted average of 0.03 74ToZN].	34(17)% and 0.051(2	5)% [1974ToZN]	].					
direct $\alpha$ emis	ssion from ^{153m} Ho, 1	Ex = 68.7(3)  keV*, J	$\pi = 1/2^+, T_{1/2} =$	9.3(5) m**, $BR_{\alpha}$	= 0.14(4)%***.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{149}$	Tb) coinci	dent $\gamma$ -rays R ₀	(fm)	HF	
4.119(5)	4.011(5)@	0.14(4)%***	1/2+	0.0		1.5	565(11)	$4.1^{+2.2}_{-1.3}$	
* [2020] ** [1967 *** Wei @ [1974	Ni06]. 7Ha34]. ighted average of 0.1 IToZN].	2(5)% and 0.18(8)%	5 [1974ToZN].						
Table 7 direct $\alpha$ emis	ssion from ¹⁶⁹ Re*, J	$\pi = (9/2^{-}), T_{1/2} = 8$	$.1(3)$ s, $BR_{\alpha}$ = ob	98.					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J^{\pi}_{c}$	Edauahtar ( ¹⁶⁵ Ta	) coincide	ent γ-rays Ro	(fm)	HF	
4.814(12) 4.989(12)	4.700(12) 4.871(12)	~ ~ /	J	0.175 0.0?		1.5 1.5	571(21) 571(21)		

* All values taken from [1992Me10].

direct $\alpha$ emis	sion from ^{169m} Re*,	Ex = 187(7)  keV	$J^{\pi} = (1/2^+, 3/2^+),$	$T_{1/2} = 16.3($	(8) s, $BR_{\alpha} = obs$ .			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{m{\pi}}$	E _{daughter} (	( ¹⁴⁹ Tb)	coincident γ-rays	R ₀ (fm)	HF
5.184(10)	5.061(10)			х			1.571(21)	
* All val	ues taken from [199	02Me10].						
Table 9 direct $\alpha$ emis	sion from ¹⁷³ Ir, $J^{\pi}$ =	= (3/2 ⁺ , 5/2 ⁺ ), T	$1/2 = 8.3(3) \text{ s}^*, BR_0$	$\alpha = 4(2)\%^{**}.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\boldsymbol{\pi}}$	Edau	_{ghter} ( ¹⁶⁹ Re)	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.546(4)	5.418(4)***	4(2)%**	(1/2 ⁺ , 3/2 ⁺ )	0.18	7(7)		1.5691(81)	$1.3^{+1.4}_{-0.5}$
* Weight ** [2004 *** [202	ed average of 9.8(1 GoZZ]. 1Ha32].	4) s [1992Sc16],	8.1(3) s [1992Bo2]	1] and 10(1) [	2004GoZZ].			
direct $\alpha$ emis	sion from ^{173m} Ir*, I	Ex = 213(16)  keV	$J^{\pi} = (11/2^{-}), T_{1/2}$	$_2 = 2.150(47)$	$s^{**}, BR_{\alpha} = 11($	1)%***.		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{169}$	$\gamma^{9}$ Re) coincident $\gamma^{-1}$	-rays R ₀ (fm)	HF
5.809(5) 5.953(15)	5.675(5) 5.815(15)	100% 6(1)%**	10(1)% 0.7(1) %	(11/2 ⁻ ) (9/2 ⁻ )	0.1362(2) 0.0		1.5691(81) 1.5691(81)	) $2.0(5)$ ) $120^{+41}_{-31}$

* All values taken from [2021Ha32], except where noted.

** Weighted average of 2.20(5) s [1992Sc16] and 2.105(47) s [2004GoZZ].

*** Weighted average of 7(2)% [1996Pa01], 12(1)% [1992Sc16] and 14(3)% [2004GoZZ].

### Table 11

direct  $\alpha$  emission from ¹⁷⁷Au*, J^{$\pi$} = (1/2⁺), T_{1/2} = 1.501(20) s, BR_{$\alpha$} = 64(5)%**.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{173}\mathrm{Ir})$	coincident $\gamma$ -rays (keV)	$R_0$ (fm)	HF
6.137(9)	5.998(9)	<0.38%	<0.24%	$(3/2^+)$	0.1561	21.6, 134.5, 156.1	1.5503(36)	>88
6.301(9)	6.156(9)	100%	64(5)%**	$(1/2^+)$	0.0		1.5503(36)	1.8(5)

* All values from [2025Sp01], except where noted.

** [2021Ha32].

### Table 12

direct  $\alpha$  emission from ^{177m}Au*, Ex. = 181.9(4) keV, J^{$\pi$} = (11/2⁻), T_{1/2} = 1.186(12) s**, BR_{$\alpha$} = 56(8)%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{173}\mathrm{Ir})$	coincident γ-rays(keV)	R ₀ (fm)	HF
6.069(12)	5.932(12)	1.2(5)%	0.67(28)%	(9/2 ⁻ )	0.424(13)	215.7***	1.5503(36)	$18^{+15}_{-6}$
6.267(5)	6.125(5)	100%	55(8)%	(11/2 ⁻ )	0.213(16)		1.5503(36)	$1.5^{+0.4}_{-0.3}$

* All values from [2021Ha32], except where noted.

** Weighted average of 1.193(13) s [2021Ha32], and 1.180(12) s [2001Ko14].

*** [2025Sp01].

#### Table 13

direct $\alpha$ emiss	arect $\alpha$ emission from ¹⁸¹ Tl*, J ^{$\pi$} = (1/2 ⁺ ), T _{1/2} = 2.9(1) s, BR _{$\alpha$} = 8.6(6)%.												
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{177}\mathrm{Au})$	coincident $\gamma$ -rays	R ₀ (fm)	HF						
6.323(5)	6.183(5)**	8.6(6)%	$(1/2^+)$	0.0		1.5209(44)	3.3(4)						

* All values from [2018Cu04], except where noted.

** Weighted average of 6.183(7) MeV [2018Cu04], 6.181(7) MeV [2009An14], and 6.186(10) MeV [1998To14].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{177}\mathrm{Au})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
6.727(7)	6.578(7)	96.0(7)%	0.38(6)%	(5/2+)	0.431(16)	0.2415	1.5209(44)	$1.3^{+0.4}_{-0.3}$
6.972(15)	6.818(15)	1.4(7)%	0.006(3)%	$(11/2^{-})$	0.189(16)		1.5209(44)	$600_{-30}^{+70}$
7.131(15)	6.9748(15)	2.6(7)%	0.010(3)%	(9/2 ⁻ )	0.031(16)		1.5209(44)	$1.1^{+0.6}_{-0.4} \times 10^3$
* All va	lues from [2009Ar	114], except when	re noted.					
Table 15 direct p emis	sion from ¹⁸⁵ Bi, J	$^{\pi} = (1/2^+),  \mathrm{T}_{1/2} =$	$= 2.8^{+23}_{-10} \mu s^*, BR$	$_{p} = 91(2)\%^{**}$				
$E_p(\text{c.m.})$	$E_p(\text{lab})$	$I_p$	(abs)	${ m J}_f^\pi$	$E_{daughter}(^{184}\mathrm{Pb})$	coincident γ-rays		
1.592(5)	1.583(5)**	** 91	(2)%**	$0^+$	0.0			
* [2021] ** Weig *** [200	Do08]. hted average of 92 04An07].	2(2)% [2021Do08	3], and 90(2)% [2	004An07].				
Table 16	105		. 22					
direct $\alpha$ emis	ssion from ¹⁸⁵ Bi, J	$\pi = (1/2^+), T_{1/2}$	$=2.8^{+23}_{-10}\ \mu s^*, BK$	$a = 9(2)\%^{**}$ .				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(ab)$	s) $J_f^{\pi}$	$E_{dd}$	aughter ( ¹⁸¹ Tl)	coincident γ-rays	R ₀ (fm)	HF

direct  $\alpha$  emission from ^{181m}Tl*, Ex. = 836.9(4) keV, J^{$\pi$} = (9/2⁻), T_{1/2} = 1.40(3) ms, BR_{$\alpha$} = 0.40(6)%.

* [2021Do08].

8.207(15)

Table 14

** Weighted average of 8(2)% [2021Do08], and 10(2)% [2004An07].

9(2)%**

 $(1/2^+)$ 

*** [2004An07].

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0.0

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +10 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +10$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon \alpha}$	Experimental
148 C 4	$0^+$	72 1(10) -**	0.029(10)	4 202(1)		2 722(2)	100000400 0000E-10 1001E-0( 000004V71
1 SGu	U	72.1(10) y*	0.028(10)	-4.292(1)		2.722(5)	[2023CI125, 2003FU10, 1981F100, 2023CI1AZ]
¹⁵² Dy	$0^+$	2.37(2) h	0.600(40)	-3.218(5)		3.755(11)	[1965Ma14]
¹⁵⁶ Er	$0^+$	19.5(10) m	1.330(50)	-2.345(26)		4.081(47)	[1975Al26]
¹⁶⁰ Yb	$0^+$	4.8(2) m	2.140(30)	-0.891(7)		4.950(39)	[1969NeZW]
¹⁶⁴ Hf	$0^+$	111(8) s	2.820(30)	0.187(22)		6.058(36)	[1989Hi04]
¹⁶⁸ W	$0^+$	51(2) s**	3.500(30)	1.286(31)		7.325(31)	[1992HeZV, 1991Me05, 1990Me12]
172Os	$0^+$	19.2(9) s	4.320(40)	2.553(31)		8.725(31)	[1995Hi02]
¹⁷⁶ Pt	$0^+$	6.33(15) s	4.948(15)	3.882(17)		10.208(38)	[1973Ga08]
¹⁸⁰ Hg	$0^+$	2.56(2) s	5.375(14)	4.729(15)		11.206(15)	[1993Wa03]
¹⁸⁴ Pb	$0^+$	480(25) ms	5.832(16)	5.464(15)		12.149(14)	[1999To11]
¹⁸⁸ Po	$0^+$	270(30) $\mu s$	6.650(23)	7.154(21)		13.914(22)	[2003Va16]

* Weighted average of 86.9(39) y [2023Ch23], 70.9(10) y [2003Fu10], and 74.6(30) y [1981Pr06].

** Weighted average of 47(3) s [1992HeZV], 49(5) s [1991Me05] and 53(2) s [1990Me12].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +10$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	BR _α	Experimental
¹⁴⁸ Gd	6.014(2)	9.851(3)	3.271(1)	100%	[ <b>1973Go29</b> , 2023Ch23, 2023ChXZ 2003Fu10, 2002FuZW, 2001FuZY, 1981Pr06, 1973MiZU,
¹⁵² Dy	5.783(6)	8.932(7)	3.727(4)	0.100(7)%*	1966Fr11, 1962Si14, 1957SuXX, 1953Ra02] [ <b>1974To07, 1967Go32, 1965Ma14, 1962Si14</b> 1975ToZT, 1974PeZS, 1974ToZN, 1974ToZQ,
¹⁵⁶ Er	5.461(30)	8.396(26)	3.541(10)**	7(2)×10 ⁻⁶ %***	[2002KaZR, 1996ByZY, 1995KaZS, 2002KaZO
		0.000 0(200)		.(_)	1992KaZP, 1989KaYU, 1978BiZF]
¹⁶⁰ Yb	4.882(28)	7.437(26)	3.624(25)		· · · ·
¹⁶⁴ Hf	4.316(32)	6.575(22)	3.920(17)		
¹⁶⁸ W	3.831(31)	5.612(31)	4.501(11)	$<4.1(6)\times10^{-3}\%$	[ <b>1991Me05</b> , 1992HeZV]
¹⁷² Os	3.282(31)	4.531(18)	5.224(7)	1.2(2)%@	[2004GoZZ, 1996Pa01, 1995Hi02, 1971Bo06]
¹⁷⁶ Pt	2.828(18)	3.516(16)	5.885(2)	38(3)%@@	[1996Pa01, 1982De11, 1979Ha10, 1974Ho26,
					1973Ga08, 1982Bo04, 1966Si08]
¹⁸⁰ Hg	2.551(17)	2.831(16)	6.258(2)	48(2)%	[1999To11, 1993Wa03, 2010An13, 1996Pa01,
					1993WaZO, 1987La23, 1986Si19, 1982HeZM.
					1979Ha10, 1977Hu05, 1974Ho26, 1970Ha18.
					1969NaZT, 1969NaZU, 1968De01]
¹⁸⁴ Pb	1.753(16)	2.053(16)	6.774(3)	80(15)%	[2004An07, 1999To11. 2001Po05, 1998Co27,
					1998ToZW, 1987To09, 1982HeZM, 1980Du02,
100_					1980Sc09]
¹⁰⁰ Po	1.450(22)	0.441(23)	8.082(15)	100%	[2003Va16, 1999An52, 2002VaZZ, 2000AnZZ]

* Weighted average of 0.94(9)% and 1.08(11)% [1974To07].

** From  $\alpha$  energy, 3.481(25) MeV in [2021Wa16]. *** Weighted average of 1.2(3)×10⁻⁵% [1996ByZY], and 5(2)×10⁻⁶% [1995KaZS].

 $^{@}$  Weighted average of 1.1(2)% [1995Hi02] and 1.4(3)% [2004GoZZ].

[@] [@] Weighted average of 42(4)% [1996Pa01] and 438(3)% [1979Ha10].

^{@@@} Deduced from short half-life.

### Table 3

direct $\alpha$ emission from	148 Gd, J $^{\pi}$ = 0	$0^+, T_{1/2} =$	= 72.1(10) y*,	$BR_{\alpha} = 100\%^{**}$
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{144}\mathrm{Sm})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
3.271198(24)	3.182787(24)***	100%**	$0^+$	0.0		1.5695(23)	0.961(13)

* Weighted average of 86.9(39) y [2023Ch23], 70.9(10) y [2003Fu10], and 74.6(30) y [1981Pr06].

** Only decay channel open.

*** 3.182787(24) MeV in [1973Go29], adjusted to 3.182680(24) MeV in [1991Fy01].

direct $\alpha$ emis	sion from ¹⁵² Dy, J ^{$\pi$}	$= 0^+, T_{1/2} = 2.37(2)$ h	$h^*, BR_{\alpha} = 0.$	100(7)%**.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{148}\mathrm{Gd})$	) coincident γ-rays	$R_0$ (fm)	HF	
3.726(4)	3.628(4)***	1.0(7)%**	$0^+$	0.0		1.5796(54)	0.98(7)	
* [1965] ** Weig *** Wei [1991Ry01])	Ma14]. hted average of 0.94( ghted average of 3.62	(9)% and 1.08(11)% [ 27(8) MeV [1965Ma14	1974To07]. 4] (adjusted	to 3.630(8) MeV i	n [1991Ry01]), and 3.630(	5) MeV [1965Ma14] (	adjusted to 3.628	3(5) MeV in
direct $\alpha$ emis	sion from ¹⁵⁶ Er, $J^{\pi}$ =	$= 0^+, T_{1/2} = 19.5(10)$	$m^*, BR_{\alpha} = 7$	$7(2) \times 10^{-6}\%^{**}.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{15}$	² Dy) coincident $\gamma$ -r	rays R ₀ (fm)	HF	
3.541(10)	3.450(10)***	7(2)×10 ⁻⁶ %**	$0^+$	0.0		1.531(25)	$1.2\substack{+0.7\\-0.4}$	
* [1975 <i>A</i> ** Weig *** [200 <b>Table 6</b> direct α emis	Al26]. hted average of 1.2(3 )2KaZR]. ssion from ¹⁶⁸ W*, J ^π	B) $e^{-5}\%$ [1996ByZY], = 0 ⁺ , T _{1/2} = 51(2) s*	and $5(2)e^{-6\alpha}$	% [1995KaZS]. 1(6)×10 ^{−3} %.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{164}$	Hf) coincident $\gamma$ -ra	ays $R_0$ (fm)	HF	
4.506(12)	4.399(12)	$<4.1(6) \times 10^{-3}\%$	0+	0.0		1.580(35)	>0.86	
* All val ** Weig <b>Table 7</b> direct α emis	ues from [1991Me03 hted average of 47(3 ssion from 172 Os, J ^{$\pi$}	5], except where noted s [1992HeZV], 49(5) = $0^+$ , $T_{1/2} = 19.2(9)$ s	.) s [1991Me0 *, $BR_{\alpha} = 1.2$	05] and 53(2) s [19 2(2)%**.	990Me12].			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{168}W)$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
5.227(5)	5.106(5)***	1.2(2)%	$0^{+}$	0.0		1.583(13)	$1.14_{-0.21}^{+0.29}$	
* [1995] ** Weig *** Wei <b>Table 8</b> direct α emis	Hi02]. hted average of 1.1(2 ghted average of 5.1( ssion from 176 Pt. J ^{$\pi$} =	2)% [1995Hi02] and 1. (0)(5) MeV [2004GoZ] $= 0^+$ , T ₁ (2 = 6.33(15))	A(3)% [2004] Z], 5.106(10 s* $BR_{\alpha} = 39$	4GoZZ]. ) MeV [1996Pa01 9(3)%**.	], 5.100(7) MeV [1995Hi0	2] and 5.105(10) MeV	7 [1971Bo06].	
		., -1/2	,u 0)	<u></u>	172			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{1/2}\mathrm{Os})$ C	coincident γ-rays	R ₀ (fm)	HF
5.662(10) 5.888(3)	5.534(10)*** 5.754(3) [@] @	0.26(13)% [@] 100%	0.10(5)% 39(3)%*	$2^+ * 0^+$	0.2277(10) ( 0.0 -	0.2277(10)	1.5597(42) 1.5571(45)	$\begin{array}{r} 40^{+40}_{-20} \\ 1.05(9) \end{array}$

* [1973Ga08]. ** Weighted average of 42(4)% [1996Pa01] and 438(3)% [1979Ha10].

*** Weighted average of 5.537(10) MeV [1979Ha10] (adjusted to 5.536(10) MeV in [1991Ry01]) and 5.528(15) MeV [1974Ho26].
 [@] [1979Ha10].
 [@] Weighted average of 5.753(3) MeV [1982De11] and 5.757(5) MeV [1974Ho26] (adjusted to 5.756(5) MeV in [1991Ry01]).

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{m{\pi}}$	$E_{daughter}(^{176})$	Pt)*** coinciden	t γ-rays***	R ₀ (fm)	HF
5.818(5) 6.259(5) 6.259(5)	5.689(5) 6.120(5) 6.120(5)	$\approx 0.01\%$ $\approx 0.05\%$ 100%	$\approx 0.005\%$ $\approx 0.024\%$ $48(2)\%^{**}$	${0^+ \atop 2^+ \atop 0^+}$	0.443(1) 0.2640(3) 0.0	0.443(1), 0.2640(3)	0.2640(3), 0.179(1)	1.5324(24) 1.5324(24) 1.5324(24)	≈130 ≈160 0.99(4)
* All va ** [199 *** [20	alues from [1993 19To11]. 106Ba16].	Wa03], excep	t where noted						
Table 10 direct $\alpha$ em	ission from ¹⁸⁴ Pt	$b^*, J^{\pi} = 0^+, T$	$S_{1/2} = 480(25)$	) ms**, <i>I</i>	$3R_{\alpha} = 80(15)\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs$	$s) J_j^{i}$	<b>C</b>	$E_{daughter}(^{180}\mathrm{H}$	g) coinciden	t $\gamma$ -rays R ₀ (fm)	HF	
6.773(6)	6.626(6)	80(15	)% 0	+	0.0		1.504(11	$0.89^{+0}_{-0}$	0.26 0.18
* All va ** [199	alues from [2004 99To11].	An07], excep	t where noted						
Table 11 direct $\alpha$ emi	ission from ¹⁸⁸ Po	$b^*, J^{\pi} = 0^+, T$	$T_{1/2} = 270(30)$	μs, BR	_α = 100%.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\mathbf{r})$	el) Ia	(abs)	${ m J}_f^\pi$	$E_{daughter}(^{180}\mathrm{Pb})$	coincident γ-rays	R ₀ (fm)	HF
7.513(26)	7.353(26)* 7.911(13) [@]	* 25(5	5)% 20 % 8	)(4)%	$(0^+)$ $0^+$	0.570(30)		1.4874(76)	$0.08^{+0.04}_{-0.03}$

direct  $\alpha$  emission from ¹⁸⁰Hg*, J^{$\pi$} = 0⁺, T_{1/2} = 2.56(2) s, BR_{$\alpha$} = 48(2)%**.

* All values from [2003Va16], except where noted.

** Weighted average of 7.355(35) MeV [2003Va16] and 7.350(40) MeV [1999An52].

*** The unphysically low value is as yet unexplained.

[@] Weighted average of 7.910(15) MeV [2003Va16] and 7.915(25) MeV [1999An52].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +10 nuclei.

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +10$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduce	ed
from values therein. $J^{\pi}$ values for ¹³⁴ La. ¹³⁸ Pr. ¹⁴² Pm. ¹⁴⁶ Eu. ¹⁵⁰ Tb. ¹⁵⁴ Ho. ¹⁵⁸ Tm. ¹⁶² Lu. ¹⁶⁶ Ta. ¹⁷⁰ Re are taken from ENSDF.	

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	$\mathrm{BR}_{\varepsilon F}$	Experimental
10.1								
¹³⁴ La		$1^{+}$	6.67(2) m	3.731(20)	-4.437(20)	2.237(20)		[1968Bi02]
¹³⁸ Pr		$1^{+}$	1.44(8) m	4.437(10)	-3.277(10)	3.396(10)		[1971Ju01]
¹⁴² Pm		$1^{+}$	40.5(5) m	4.809(24)	-2.416(24)	3.999(24)		[1970Ar17]
¹⁴⁶ Eu		$4^{-}$	4.52(4) d*	3.879(6)	-3.139(6)	6.408(6)		[2025Gu07, 1970Ch09, 1964Ta11]
¹⁵⁰ Tb		$(2^{-})$	3.48(16) h	4.658(8)	-1.953(8)	7.466(8)		[1973Vy01]
¹⁵⁴ Ho		2-	11.75(20 m	5.755(10)	-0.615(9)	8.700(10)		[1993Al03]
^{154m} Ho	0.239(28)**	$8^{+}$	2.80(13) m	5.994(30)	-0.376(29)	8.939(30)		[1993Al03]
¹⁵⁸ Tm		$2^{-}$	3.94(6) m	6.600(30)	0.841(34)	9.266(26)		[1993Al03]
¹⁶² Lu		1-	1.37(2) m	6.990(80)	1.778(80)	10.047(79)		[1983Ge08]
¹⁶⁶ Ta		$(2)^+$	34.4(5) s	7.760(40)	3.055(39)	11.298(32)		[1982Li17]
¹⁷⁰ Re		$(5^+)$	9.2(2) s	8.387(17)	4.097(30)	12.530(30)		[1992Me10]
¹⁷⁴ Ir		$(3^{+})$	7.8(6) s	9.209(15)	5.479(30)	14.080(17)		[1992Bo21]
174m Ir	0.129(17)	$(7^{+})$	5.0(2) s***	9.338(23)	5.608(34)	14.209(24)		[2020Cu04, 1992Bo21, 1992Si16]
¹⁷⁸ Au		$(2^+, 3^-)$	3.4(5) s	9.694(14)	6.455(22)	15.267(14)		[2020Cu04]
^{178m} Au	0.189(14)	$(7^+, 8^-)$	2.7(5) s	9.883(20)	6.644(26)	15.456(20)		[2020Cu04]
¹⁸² Tl [@]		low spin	1.9(1) s	10.250(15)	7.255(23)	16.245(16)		[2016Va01]
¹⁸⁶ Bi@@		(3 ⁺ )	14.8(8) ms	11.535(20)	9.323(27)	18.006(20)	0.022(13)%@@@@	[2013La02, 2003An27]
^{186m} Bi ^{@@}	х	$(10^{+})$	9.8(4) ms	11.535(20)+x	9.323(27)+x	18.006(20)+x	0.022(13)%@@@@	[2013La02, 2003An27]
190At@		low spin	$0.56^{+2.69}_{-0.16}$ ms	$11.756(24)^a$	$9.969(29)^{a}$	$17.237(29)^a$	. /	[2023AnXX, 2023Ko10]
^{190m} At	х	high spin	$1.2^{+1.3}_{-0.4}$ ms ^b	$11.756(24)+x^a$	9.969(29)+x ^{<i>a</i>}	$17.237(29)+x^a$		[2023AnXX, 2023Ko10]

* Weighted average of 4.21(5) d [2025Gu07], 4.65(4) d [1970Ch09] and 4.59(4) d [1964Ta11].

** Based on  $\alpha$  energies and the energy of the isomeric state in ¹⁵⁰Tb.

*** Weighted average of 5.0(4) s [1992Bo21], 4.9(3) s, 5.5(6) s [1992Si16].

[@] May not be the ground state.

What not be the ground state. ^(a) ^(a) ^(a) ^(a) ^(b) ^(b) ^(b) ^(c) ^(b) ^(c) ^(b) ^(c) ^(b) ^(c) taken from [2021Wa16]. ^b Weighted average of  $2.67^{+3.65}_{-0.98}$ ms [2023AnXX] and  $1.0^{+1.4}_{-0.4}$ ms [2023Ko10].

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +10$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
1341 0	4.054(20)	12 644(20)	0.744(22)		
138 D.	4.934(20)	12.044(20) 11.660(54)	-0.744(22)		
142 D	4.499(10)	11.009(34)	-0.333(22)		
146 F	4.239(24)	11.033(24)	-0.438(20)		
150m	3./55(6)	10.279(6)	1.599(24)		
150'Tb	3.268(8)	9.386(12)	3.587(5)		
¹⁵⁴ Ho	2.785(9)	8.500(41)	4.041(4)	0.028(9)%	[ <b>1974Sc19</b> , 1982To14, 1981ZuZU, 1981ZuZY, 1978AfZZ, 1974PeZS, 1974ToZQ, 1971To01, 1971ToZR, 1970ToZS, 1970ToZY, 1968Go13, 1967Ha34]
^{154m} Ho	2.546(29)	8.261(50)	4.280(28)	< 0.01%	[1974Sc19, 1971To01, 1968Go13]
¹⁵⁸ Tm	2.579(37)	7.743(46)	3.511(27)		
¹⁶² Lu	2.286(77)	7.109(82)	3.447(79)		
¹⁶⁶ Ta	1.751(40)	6.033(40)	4.309(80)		
¹⁷⁰ Re	1.275(19)	5.088(30)	4.769(30)		
¹⁷⁴ Ir	0.637(19)	3.797(37)	5.693(16)	$\approx 0.4\%$	[1992Sc16]
174m Ir	0.508(25)	3.668(41)	5.822(23)	2.5(3)%	[ <b>1992Si16</b> , 1992MeZW, 1986Ke03, 1967Si02]
¹⁷⁸ Au	0.222(18)	2.999(13)	6.058(5)	16(1)%	[2020Cu04, 2021Gi08, 1996Pa01, 1986Ke03,
					1984Gr14, 1968Si01, 1965Si07]
^{178m} Au	0.033(23)	2.810(19)	6.247(15)	18(1)%	[2020Cu04, 2021Gi08]
¹⁸² Tl*	-0.045(19)	2.280(13)	6.551(6)	>0.49%	[2016Va01, 1993BoZK, 1992BIZW, 1991BoZZ,
					1986Ke03]
¹⁸⁶ Bi**	-1.107(23)	0.840(20)	7.757(12)	$\approx 100\%$	[2003An27, 2003AnZZ, 1997Ba21]
¹⁸⁶ Bi**	-1.107(23)-x	0.840(20)-x	7.757(12)+x	$\approx 100\%$	[2003An27, 2003AnZZ, 1997Ba21, 1984ScZQ]
¹⁹⁰ At*	-1.326(30)	$0.190(23)^{@}$	7.913(10)***	100%	[2023AnXX, 2023Ko10]
^{190m} At*	-1.326(30)-x [@]	0.190(23)-x [@]	7.913(10)+x***	100%	[2023AnXX, 2023Ko10]

* May not be the ground state.

** The ordering of these states is unknown. *** From  $\alpha$  energy to ¹⁸⁶Bi.

^a Deduced from mass excess of 7.193(20) for ¹⁹⁰At (deduced from the  $\alpha$  energy and the mass of the daughter ¹⁸⁶Bi), and the mass excess for the daughter taken from [2021Wa16].

#### Table 3

direct  $\alpha$  emission from ¹⁵⁴Ho*, J^{$\pi$} = 2⁻, T_{1/2} = 11.75(20 m**, BR_{$\alpha$} = 0.028(9)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{m{\pi}}$	$E_{daughter}(^{150}\mathrm{Tb})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
4.046(5)	3.941(5)***	0.028(9)%	(2-)	0.0		1.560(26) [@]	$9^{+7}_{-4}$

* All values from [1974Sc19], except where noted.

** [1993Al03].

*** 3.937 MeV in [1974Sc19], adjusted to 3.941 meV in [1991Ry01].

[@] Interpolated between 1.5796(54) fm  152 Dy and 1.541(26) fm  156 Er.

## Table 4

direct  $\alpha$  emission from ^{154m}Ho*, Ex = 239(28) keV, J^{$\pi$} = 8⁺, T_{1/2} = 2.80(13) m**, BR_{$\alpha$} = <0.01%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{150}\mathrm{Tb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
3.824(5)	3.725(5)***	<0.01%	0.461(27)@		1.560(26)@@	>0.18	

* All values from [1974Sc19], except where noted.

** [1993Al03].

*** 3.721 MeV in [1974Sc19], adjusted to 3725 meV in [1991Ry01].

@ [2013Ba31].

@@ Interpolated between 1.5796(54) fm ¹⁵²Dy and 1.541(26) fm ¹⁵⁶Er.

direct $\alpha$ emission from ¹⁷⁴ Ir*, J ^{$\pi$} = (3 ⁺ ), T _{1/2} = 7.8(6) s**, BR _{$\alpha$} = $\approx$ 0.4%.									
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{170}\mathrm{Re})$	coincident γ-rays	$R_0 (fm)^@$	HF		
5.399(10)	5.275(10)	≈0.4%	(3+)	0.289***	0.224, 0.193, 0.031	1.571(14)***	$\approx 2.7^{@@}$		

* All values from [1992Sc16], except where noted.

** [1992Bo21].

*** Reported as decaying to a 224.7(3) keV state, which then cascades to the ground state in [1992Sc16]. However this would imply an isomer energy of 193(12) keV in contrast to the measured value of 129(17) keV [2020Cu04]. It is suggested that the  $\alpha$ -decay is to a state 224.7-keV above an isomer in ¹⁷⁰Re with an energy of 64(20) keV [2020Cu04].

[@] Interpolated between 1.583(13) fm ¹⁷²Os and 1.5597(42) fm ¹⁷⁶Pt. [@] Calculated assuming the isomer decays to the 370-keV state in ¹⁵⁰Tb, (which then  $\gamma$ -cascades to the ground state), giving a Q_{\alpha} = 5.688(23) MeV.

#### Table 6

direct  $\alpha$  emission from ^{174m}Ir*, Ex = 193(12) keV, J^{$\pi$} = (7⁺), T_{1/2} = 5.0(2) s **, BR_{$\alpha$} = 2.5(3)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{170}\mathrm{Re})^{***}$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF
5.441(10) 5.607(6)	5.316(10) 5.478(6) ^{@@}	100% ≈13%	2.2(3)% ≈0.3%	(7/2+)	0.3701(6)? 0.2103(2)?	0.210, 0.190, 0.159, 0.020 0.210, 0.190, 0.020	1.571(14) [@] 1.571(14) [@]	$0.52^{+0.21}_{-0.16}\\21^{+9}_{-7}$

* All values from [1992Sc16], except where noted.

** Weighted average of 5.0(4) s [1992Bo21], 4.9(3) s, 5.5(6) s [1992Si16].

*** [2018Ba41].

[@] Interpolated between 1.583(13) fm ¹⁷²Os and 1.5597(42) fm ¹⁷⁶Pt.

@@ [1967Si02].

#### Table 7

direct  $\alpha$  emission from ¹⁷⁸Au*, J^{$\pi$} = (2⁺, 3⁻), T_{1/2} = 3.4(5) s, BR_{$\alpha$} = 16(1)%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{174}\mathrm{Ir})$	coincident $\gamma$ -rays	$R_0 (fm)^{**}$	HF
5 882(10)	5.750(10)	1.05(2)%	0.15(1)%		0.1748(5)	0.1748(5)	1 5460(48)**	41(8)
5.945(10)	5.811(10)	2.01(3)%	0.28(2)%		0.157(3)	0.157(3)	1.5460(48)**	39(8)
5.974(10)	5.840(10)	12.6(1)%	1.7(1)%		0.0900(3)	0.0900(3), 0.0828(3)	1.5460(48)**	8.0(15)
6.058(5)	5.922(5)	100%	13.8(9)%	(3 ⁺ )	0.0		1.5460(48)**	2.4(5)

* All values from [2020Cu04].

** Interpolated between 1.5597(42) fm ¹⁷⁶Pt and 1.5324(24) fm ¹⁸⁰Hg.

### Table 8

direct  $\alpha$  emission from ^{178m}Au*, Ex = 189(14) keV, J^{$\pi$} = (7⁺, 8⁻), T_{1/2} = 2.7(5) s, BR_{$\alpha$} = 18(1)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{174}\mathrm{Ir})$	coincident γ-rays	R ₀ (fm)**	HF
5.648(7)	5.521(7)	1.16(3)%	0.18(1)%		0.601(17)	0.472(1)	1.5460(48)**	$0.54^{+0.17}_{-0.15}$
5.699(7)	5.571(7)	0.97(2)%	0.15(1)%		0.550(17)	0.421.4(10)	1.5460(48)**	$1.13^{+0.35}_{-0.32}$
5.973(10)	5.839(10)	6.87(7)%	1.07(6)%		0.277(17)	0.1392(3), 0.0912(3), 0.0568(3)	1.5460(48)**	2.8(8)
6.061(7)	5.925(7)	100%	15.5(9)%		0.186(17)	0.0568(3)	1.5460(48)**	$0.48^{+0.14}_{-0.13}$
6.114(10)	5.977(10)	6.83(14)%	1.06(6)%	(7+)	0.129(17)		1.5460(48)**	$12^{+4}_{-3}$

* All values from [2020Cu04].

** Interpolated between 1.5597(42) fm ¹⁷⁶Pt and 1.5324(24) fm ¹⁸⁰Hg.

direct $\alpha$ emission from	¹⁸² Tl*, $J^{\pi}$ = low soin,	$T_{1/2} = 1.9(1) s,$	$BR_{\alpha} = >0.49\%.$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pmb{\pi}}$	E _{daughter} ( ¹⁷⁸ Au)	coincident γ-rays	R ₀ (fm)**	HF
6.096(5)	5.962(5)	21(3)%	>0.042%		0.446	0.4461(14), 0.2658(2), 0.2322(3), 0.2067(1), 0.1692(3), 0.1129(1)	1.518(12)	<27
6.182(6)	6.046(6)	16(3)%	>0.032%		0.362	0.3615(1), 0.3126(1), 0.2967(3), 0.2478(7), 0.2318(2), 0.1975(8), 0.1827(3), 0.1693(2), 0.1534(2), 0.1317(4), 0.1129(1), 0.1020(5)	1.518(12)	<80
6.304(6)	6.165(6)	62(10)%	>0.12%		0.247	0.2472(5), 0.2322(1), 0.1975(2), 0.1823(2), 0.1692(1), 0.1329(4), 0.1187(3), 0.1129(2)	1.518(12)	<62
6.503(6)	6.360(6)	100%	>0.20%		0.046		1.518(12)	<230
6.550(10)	6.406(10	45(7)%	>0.09%	$(2^+, 3^-)$	0.0		1.518(12)	<1600

* All values from [2016Va01].

** Interpolated between 1.5324(24) fm  180 Hg and 1.504(11)  184 Pb.

#### Table 10

direct  $\alpha$  emission from ¹⁸⁶Bi*, J^{$\pi$} = (3⁺), T_{1/2} = 14.8(8) s, *BR*_{$\alpha$} = $\approx$ 100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{182}\mathrm{Tl})$	coincident γ-rays
7.225-7.389	7.070-7.230**					0.087, 0.098, 0.133, 0.215, 0.238, 0.276, 0.281, 0.371, 0.380, 0.444, 0.520
7.236(15)	7.080(15)	28(14)%			0.520	0.520
7.276(15)	71.20(15)***					0.133
7.309 (15)	7.152(15)	100%			0.444	0.444
7.385(15)	7.226 (15)***					0.238

* All values from [2003An27].

** Unresolved multiplet.

*** May belong to the other isomer.

#### Table 11

direct  $\alpha$  emission from ^{186m}Bi*, J^{$\pi$} = (10⁻), T_{1/2} = 9.8(4) s, *BR*_{$\alpha$} = $\approx$ 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{182}\mathrm{Tl})$	coincident γ-rays
7.423(5) 7.531(10)	7.263(5) 7.369(10)**	100% <2%	pprox 98% $< 2%$		0.1085 0.0	0.1085(5)

* All values from [2003An27].

** Tentative assignment.

### Table 12

direct $\alpha$ emissi	lirect $\alpha$ emission from ¹⁹⁰ At*, J ^{$\pi$} = low spin,T _{1/2} = 0.56 ^{+2.69} _{-0.16} ms, BR _{$\alpha$} = 100%.										
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	E _{daughter} ( ¹⁸⁶ Bi)	coincident $\gamma$ -rays						
7.913(10)	7.746(10)	100%	(3 ⁺ )	0.0		1.551(15)	$1.0^{+5.0}_{-0.4}$				

* All values taken from [2023AnXX]. In that paper, the authors present two scenarios. In the first, two  $\alpha$  transitions 7.746(10) MeV (25%) and 7.739(10) MeV de-excite the same state, indicating that the (10⁻)^{186m}Bi isomer has an energy of 7 keV. This however, results in large HF for the two transitions of 15 and 5 respectively. The 2nd scenario is reflected here, combined with data from [2023Ko10], resulting in mostly unhindered transitions from two isomers in ¹⁹⁰At.

direct  $\alpha$  emission from ^{190m}At, J^{$\pi$} = high spin, T_{1/2} = 1.2^{+1.3}_{-0.4} ms^{*}, BR_{$\alpha$} = 100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{oldsymbol{\pi}}$	$E_{daughter}(^{186}\mathrm{Bi})$	coincident $\gamma$ -rays		
7.907(9)	7.741(9)**	100%	(10 ⁻ )	х		1.551(15)	$2.1^{+2.4}_{-0.9}$

* Weighted average of  $2.67^{+3.65}_{-0.98}$ ms [2023AnXX] and  $1.0^{+1.4}_{-0.4}$ ms [2023Ko10].

** Weighted average of 7.739(10) MeV [2023AnXX] and 7.750(20) MeV [2023Ko10].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +21/2 nuclei.

Last updated 3/28/23

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +21/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values for are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta\alpha}$	Experimental
¹⁴¹ Nd ¹⁴⁵ Sm		3/2+ 7/2 ⁻	2.54(5) h 340(3) d	1.823(3) 0.616(3)	-3.406(3) -4.192(1)		0.524(4) 2.938(2)		[1961Ra06] [1959Br65]
¹⁴⁹ Gd ¹⁵³ Dy ¹⁵⁷ Er		7/2 ⁻ 7/2 ⁻ 3/2 ⁻	9.25(10) d 6.29(10) h 18.65(10) m	1.314(4) 2.170(2) 3.420(30)	-3.080(3) -1.725(4) -0.173(27)		3.715(4) 4.873(6) 5.475(27)		[1968Ch30] [1970Ch09] [1984GrZL]
¹⁶¹ Yb ¹⁶⁵ Hf ¹⁶⁹ W ¹⁷³ Os ¹⁷⁷ Pt		3/2 ⁻ (5/2 ⁻ ) (5/2 ⁻ ) (5/2 ⁻ ) 5/2 ⁻	4.2(2) m 75(3) s 78(6) s* 22.4(9) s 9 8(4) s	4.060(30) 4.810(40) 5.370(30) 6.120(30) 6.677(25)	0.941(29) 2.088(32) 3.154(32) 4.370(32) 5.472(19)		6.574(28) 7.838(40) 9.099(31) 10.427(32) 11.759(32)		[1974Ad10] [1981LiZM] [1990Me12, 1992HeZV] [1995Hi02] [1993Me13]
¹⁸¹ Hg ¹⁸⁵ Pb ¹⁸⁵ mPb ¹⁸⁹ Po ¹⁹³ Rn	X	$ \frac{1/2^{-}}{(3/2^{-})} \\ (13/2^{+}) \\ (5/2^{-}) $	3.6(1) s 4.3(2) s 6.3(4) s 3.5(5) ms 1.15(27) ms	$\begin{array}{c} 7.210(25) \\ 8.217(26) \\ 8.217(26) \\ 8.640(30) \\ 9.110(30) \end{array}$	6.480(18) 7.515(19) 7.515(19)+x 9.100(24) 9.820(27)	0.014(4)%	12.961(25) 13.905(26) 13.905(26)+x 15.911(30) 16.683(33)	9(3)×10 ⁻⁶ %	[1976/h010, 1975Ho02, 1971Ho07, 1970HoZZ] [2002An15] [2002An15] [2005Va04] [2006An36, 2006AnZT]

* Weighted average of 76(6) s [1990Me12] and 80(6) s [1992HeZV].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +21/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Sp	S _{2<i>p</i>}	Qα	BR _α	Experimental
¹⁴¹ Nd	6.794(7)	11.812(4)	-0.698(3)		
¹⁴⁵ Sm	6.524(3)	11.227(1)	1.115(3)		
¹⁴⁹ Gd	6.119(10)	10.439(3)	3.099(3)	4.3(12)×10 ⁻⁴ %	[1967Go32, 1966Wi12, 1965Si06, 1965Ma48]
¹⁵³ Dy	5.715(40)	9.532(5)	3.557(5)*	0.0113(17)%	[ <b>1974T007, 1967G032</b> , 1978AfZZ, 1974PeZS, 1974ToZN, 1974ToZQ, 1965Ma51, 1964Ma19, 1960Ma47, 1960To05, 1958To27]
¹⁵⁷ Er	5.164(47)	8.836(28)	3.305(27)		
¹⁶¹ Yb	4.822(36)	7.851(16)	3.154(31)		
¹⁶⁵ Hf	4.282(40)	6.920(32)	3.774(32)		
¹⁶⁹ W	3.813(32)	6.028(32)	4.293(32)		
¹⁷³ Os	3.160(39)	4.930(32)	5.055(6)	$0.020^{+0.010}_{-0.004}\%$	[1995Hi02, 1971Bo06, 1973Be67, 1971BoZK]
¹⁷⁷ Pt	2.777(17)	3.843(19)	5.643(3)	5.7(5)%	[1979Ha10, 2004GoZZ, 1992MeZW, 1992Bo04, 1982HeZM, 1973BoXL, 1970Ha18, 1966Si08]
¹⁸¹ Hg	2.324(16)	2.971(17)	6.284(4)	26.3(41)%**	[ <b>1979Ha10</b> , 1996Pa01, 1992BoZO, 1990SaZU, 1986Ke03, 1984ScZQ, 1982HeZM, 1970Ha18, 1969NaZT, 1969NaZU]
¹⁸⁵ Pb	1.947(19)	2.314(18)	6.695(5)	42(25)%***	[2005Va04, 2002An15, 1984ScZQ, 1982HeZM, 1980Sc09, 1975Ca06, 1974CaYE]
^{185m} Pb	1.947(19)-x	2.314(18)-x	6.695(5) + x	50(25)%	[2002Va15, 2005Va04, 1975Ca06, 1974CaYE
¹⁸⁹ Po	1.516(25)	1.013(23)	7.694(15)	$\approx 100\%^{@}$	[2005Va04, 2000AnZZ, 1999An52]
¹⁹³ Rn	1.172(38)	0.466(26)	8.040(12)	100% [@]	[ <b>2006An36</b> , 2006AnZT]

* From α energy, 3.559(4) in [2021Wa16].

** Sum of  $\alpha$  intensities from [1979Ha10].

*** Weighted average of 50(25)% [2002AN15] and 34(25)% [2005Va04].

[@] Based on short Half-life.

#### Table 3

direct $\alpha$ emissi	rect $\alpha$ emission from ¹⁴⁹ Gd, J ^{$\pi$} = 7/2 ⁻ , T _{1/2} = 9.25(10) d*, BR _{$\alpha$} = 4.3(12)×10 ⁻⁴ %**.								
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{145}\mathrm{Sm})$	coincident $\gamma$ -rays	R ₀ (fm)	HF		
3.099(5)	3.016(5)***	4.3(12)×10 ⁻⁴ %**	7/2-	0.0		1.5722(55)	$2.5^{+1.1}_{-0.7}$		

* [1968Ch30].

** Weighted average of  $4.0(12) \times 10^{-4}$ % [1966Wi12] and  $4.6(15) \times 10^{-4}$ % [19665Si06].

*** 3.018(5) MeV in [1967Go32] (adjusted to 3.016(5) MeV in 1999Ry01).

direct $\alpha$ emission from ¹⁵³ Dy, J ^{$\pi$} = 7/2 ⁻ , T	$_{1/2} = 6.29(10) \text{ h}^*, BR_{\alpha} = 0.0113(17)\%^{**}.$
-------------------------------------------------------------------------------------------------------	-------------------------------------------------------------------

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$		$I_{\alpha}(abs)$		$J_f^{\pi}$	$E_{daughter}(^{149})$	Gd) coincident $\gamma$ -r	ays $R_0$ (fm	) HF
3.394(5)	3.305(5)***	* 0.09(7)	%**	2.12e ⁻⁶ %	1	5/2-	0.165	0.165	1.560(2	21) $50^{+190}_{-30}$
3.557(5)	3.464(5)***	* 100%*	*	0.01133(1	7)%**	0.0	7/2-		1.560(2	$21)    0.9^{+0.5}_{-0.3}$
* [1970 ** [197 *** [19	)Ch09]. 74To07]. 967Go32].									
<b>Table 5</b> direct $\alpha$ emi	ission from ¹⁷³ C	Ds, $J^{\pi} = (5/2^{-}),$	$T_{1/2} = 22.4$	4(9) s*, <i>BR</i>	$R_{\alpha} = 0.020^{+10}_{-4}$	⁰ %**.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(ab)$	os)	J	$\frac{\pi}{f}$	Edaughte	r( ¹⁶⁹ W)	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.055(7)	4.938(7)*	0.01	33(17)%**	• (	5/2-)	0.0			1.562(24)	$7^{+9}_{-4}$
* [1995 ** [197	5Hi02]. 71Bo06].									
<b>Table 6</b> direct $\alpha$ emi	ission from ¹⁷⁷ F	$Pt^*, J^{\pi} = (5/2^-)$	$, T_{1/2} = 9.8$	(4) s**, <i>Bl</i>	$R_{\alpha} = 5.7(5)\%$					
			,							
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(z)$	abs)	$\mathbf{J}_f^{\boldsymbol{\pi}}$	Edaugh	$ter(^{173}Os)$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.561(10)	5.435(10)	13(2)%	0.65	5(5)%	$(7/2^{-})$	0.091	5(1)***	0.0916***	1.563(37)	$3.9^{+1.2}_{-0.9}$
5.655(6)	5.527(6)	100(8)%	5.00	(4)%	(5/2 ⁻ )	0.0			1.563(37)	$1.41_{-0.24}^{+0.29}$
* All va ** [199 *** [19	alues from [1979 93Me13]. 991Ka05].	9Ho10], except	where note	d.						
direct $\alpha$ em	ission from ¹⁸¹ H	$Ig^*, J^{\pi} = 1/2^-,$	$T_{1/2} = 3.6($	1) s, $BR_{\alpha}$	=26.3(41)%.					
			·							
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	Edaughter	$(^{173}Os)$	coincident $\gamma$ -	rays	$R_0$ (fm)	HF
6.050(10)	5.916(10)	5.2(24)%	1.2(5)%	(5/2-)	0.2398(	4)	0.0809, 0.092	4, 0.1474, 0.1587, 0.239	8 1.5250(33)	$64^{+28}_{-17}$
6.072(10)	5.938(10)	7.0(21)%	1.6(4)%	$(3/2^{-})$	0.2142(	5)	0.2142		1.5250(33)	$27^{+10}_{-7}$
6.142(5)	6.006(5)	100(17)%	23(4)%	$(1/2^{-})$	0.1474(-	4)	0.1474		1.5250(33)	$0.87^{+0.32}_{-0.21}$
6.208(10)	6.071(10)	1.7(4)%	0.39(7)%		0.0810(4	4)	0.0810		1.5250(33)	$23^{+11}_{-6}$
6.287(10)	6.148(10)	0.57(16)%	0.13(3)%	(5/2-)	0.0				1.5250(33)	$70^{+00}_{-20}$

 $\ast$  All values from [1979Ho10], except where noted.

** Sum of  $\alpha$  intensities from [1979Ha10].

#### Table 8

direct  $\alpha$  emission from ¹⁸⁵Pb*,  $J^{\pi} = (3/2^{-})$ ,  $T_{1/2} = 6.3(4)$  s,  $BR_{\alpha} = 42(25)\%^{**}$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{173}\mathrm{Os})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.427(5)	6.288 (5)	100(4)%	24(14)%	(3/2 ⁻ )	0.269	0.269, 0.205	1.495(11)	$1.7^{+2.8}_{-0.8}$
6.629(5) 6.693	6.486 (5) 6.548	79(5)% < $0.6\%$	18(11)% <1.4%	(3/2 ⁻ ) 1/2 ⁻	0.064 0.0		1.495(11) 1.495(11)	$13^{+22}_{-6}$ >700

* All values from [2002An15], except where noted. ** Weighted average of 50(250% [2002AN15] and 34(25)% [2005Va04].

$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{173}\mathrm{Os})$	coincident γ-rays	R ₀ (fm)	HF
6.550(5)	6.408 (5)	50(25)%	(13/2+)	x		1.495(11)	$1.7^{+1.9}_{-0.7}$

direct  $\alpha$  emission from ^{185m}Pb*, Ex = unk, J^{$\pi$} = (13/2⁺), T_{1/2} = 4.3(2) s, BR_{$\alpha$} =50(25)%.

* All values from [2002An15].

#### Table 10

direct  $\alpha$  emission from ¹⁸⁹Po*, J^{$\pi$} = (7/2⁻), T_{1/2} = 3.5(5) ms, BR_{$\alpha$} =100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{173}\mathrm{Os})$	coincident γ-rays	R ₀ (fm)	HF
7.416(15) 7.467(20)	7.259(15) 7.309(20)	100(21)% 15(7)%	80(12)% 12(5)%	(5/2 ⁻ )	0.280 0.226	0.280 0.226	1.4991(51) 1.4991(51)	$0.18^{+0.07}_{-0.05}$ ** $1.8^{+1.8}_{-0.7}$
7.695(20)	7.53(20)	10(8)%	8(6)%	(3/2 ⁻ )	0.0		1.4991(51)	$14_{-7}^{-0.7}$

* All values from [2005Va04].

** The reason for this unphysically low value is unknown.

#### Table 11

direct  $\alpha$  emission from ¹⁹³Rn*, J^{$\pi$} = , T_{1/2} = 1.15(27) ms, *BR*_{$\alpha$} =100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{173}\mathrm{Os})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.848(15) 8.042(20)	7.685(15) 7.875(20)	100(27)% 35(19)%	74(20)% 26(12)%	(5/2 ⁻ )	0.194 0.0	0.194	1.561(16) 1.561(16)	${}^{1.0^{+0.8}_{-0.5}}_{10^{+14}_{-6}}$

* All values from [20006An14].

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Table 1			
Observed and predicted $\beta$ -delayed	particle emission from the odd- $Z$	$T_z = +21/2$ values for	are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	O _F	$O_{\mathcal{E}n}$	$O_{\mathcal{F}\mathcal{A}}$	Experimental
			1/2	a	<b>2</b> 0 <i>p</i>	200	1
¹³⁹ Pr		5/2+	4.41(4) h	2.129(3)	-5.604(4)	0.597(4)	[1968Li08]
¹⁴³ Pm		5/2+	265(10) d	1.042(3)	-6.463(3)	1.572(4)	[1963Pa21]
¹⁴⁷ Eu		5/2+	24.1(6) d	1.721(2)	-5.379(5)	4.033(3)	[1971Av09]
¹⁵¹ Tb		$1/2^{+}$	17.609(14) h	2.565(4)	-4.120(7)	5.218(4)	[1984Gr15]
¹⁵⁵ Ho		$5/2^{+}$	48(2) m	3.116(17)	-3.172(49)	5.724(18)	[1972To07]
¹⁵⁹ Tm		5/2+	9.15(17) m	3.991(28)	-1.672(39)	6.161(30)	[1982By03]
¹⁶³ Lu		$1/2^{+}$	3.97(13) m	4.500(30)	-0.603(38)	7.345(28)	[1983Ge08]
¹⁶⁷ Ta		$(3/2^+)$	80(4) s	5.120(40)	0.381(41)	8.518(32)	[1992HeZV]
¹⁷¹ Re		$(9/2^{-})$	15.2(4) s	5.840(40)	1.598(40)	9.793(40)	[1987Ru05]
¹⁷⁵ Ir		$(1/2^+)$	8(1) s	6.711(17)	2.990(31)	11.267(31)	[2004GoZZ]
175mIr	0.169(7)*	(9/2-)	4.9(4) s	6.880(18)	3.159(32)	11.436(32)	[2004GoZZ]
¹⁷⁹ Au		1/2+	7.3(3) s	7.280(14)	3.977(22)	12.692(17)	[2021Ha32]
¹⁸³ Tl		$(5/2^{-})$	6.9(7) s	7.217(12)	4.428(21)	13.256(12)	[1992BoZO]
^{183m} Tl	0.6287(3)	$(9/2^{-})$	53.3(3) ms	7.846(12)	5.077(21)	13.885(12)	[2022Ve01, 2011Ve01]
¹⁸⁷ Bi		$(1/2^+)$	38(2) ms**	8.604(11)	6.211(23)	14.996(12)	[2006An11, 1999Ba45]
^{187m} Bi	0.112(11)	$(9/2^{-})$	370(20) µs	8.716(16)	6.211(25)	14.996(16)	[2006An11]
¹⁹¹ At		$(1/2^+)$	$1.7^{+1.1}_{-0.5}$ ms	8.933(18)	7.171(26)	16.426(17)	[2003Ke08]
^{191m} At	0.050(30)	(7/2 ⁻ )	$2.1^{+0.3}_{-0.3}$ ms	8.983(35)	7.221(40)	16.476(34)	[2003Ke08]

* Excitation calculated as 169(7) keV, based on an unhindered  $\alpha$ -decay of the ¹⁷⁵Ir isomer to the ground state of ¹⁷¹Re, and the  $\alpha$ -energy of the ¹⁷⁵Ir ground state to an unhindered to the 189.8 keV in ¹⁷¹Re.

** Weighted average of 40(2) ms [2006An11] and 32(3) ms [1999Ba45].

# Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +21/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	Experimental
139 <b>D</b> r	4 552(4)	12 266(4)	0.610(10)		
143 Dm	4.332(4)	12.200(4) 11.524(2)	-0.010(10)		
147 E.	4.500(5)	11.324(3) 10.855(2)	-0.337(3)	0.0022(())	[10(7C-22 10(2C:14 10(4T-04 10(0T-05
Eu	3.837(4)	10.855(3)	2.991(3)	0.0022(6)%	[ <b>1907G032, 19025114</b> , 19041004, 19001005, 1953Ra02]
¹⁵¹ Tb	3.148(7)	9.760(5)	3.496(4)	0.0095(15)%	[1974To07, 1967Go32, 1975ToZT, 1970ToZV,
					1969To04, 1967Ko09, 1967Ch32, 1967Ch28,
					1966Ch22, 1964Ma19, 1960Ma47, 1960To05,
					1953Ra02]
¹⁵⁵ Ho	2.935(19)	9.304(18)	3.159(18)		
¹⁵⁹ Tm	2.556(38)	8.315(36)	3.044(33)		
¹⁶³ Lu	2.259(32)	7.471(40)	3.354(40)		
¹⁶⁷ Ta	1.781(40)	6.487(39)	4.015(40)		
¹⁷¹ Re	1.248(31)	5.538(40)	4.676(40)		
¹⁷⁵ Ir	0.688(16)	4.419(31)	5.710(5)	0.85(22)%	[2004GoZZ, 1986Ke03, 1967Si02, 1992Sc16]
175mIr	0.518(17)	4.250(32)	5.879(9)*	$pprox 70\%^{**}$	[2004GoZZ]
¹⁷⁹ Au	0.280(15)	3.519(23)	5.981(5)	22.0(9)%	[2021Ha32, 1986Ke03, 2004Ra28, 1996Pa01,
	. ,				1980Da09, 1968De01, 1968Si01, 1965Si07]
¹⁸³ Tl	0.299(14)	3.294(22)	5.976(9)		
^{183m} Tl	-0.330(14)	2.665(22)	6.605(9)	1.45(42)%	[2022Ve01, 2011Ve01, 2006An11, 2004Ra28,
					1987To09, 1984ScZQ, 1980Sc09]
¹⁸⁷ Bi	-1.009(15)	1.203(23)	7.779(4)	≈100%***	[2006An11, 1999Ba45, 2003Ke08, 1998DaZR,
		× /			1984ScZQ]
^{187m} Bi	-1.121(19)	1.091(25)	7.891(12)	≈100%***	[2006An11, 1999Ba45, 2003Ke08, 1998DaZR.
					1984ScZQ]
¹⁹¹ At	-1.138(21)	0.649(26)	7.822(14)	100%@	[ <b>2003Ke08</b> , 2005Ke10, 2005Su03]
^{191m} At	-1.188(40)	0.599(40)	7.872(33)	$100\%^{@}$	[ <b>2003Ke08</b> , 2005Ke10, 2005Su03]
					L THE

* Deduced from  $\alpha$  energies, 5.431(31) MeV in [2021Wa16]. ** Assuming an unhindered (HF =1.0) to the ground state of ¹⁷¹Re.

*** Based on half-life.

Table 3 direct $\alpha$ emis	sion from ¹⁴⁷ Eu, J [#]	$T = 5/2^+, T_{1/2} = 24$	$1(6) d^*, BR_{\alpha} = 0$	0.0022(6)%**.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{143}\mathrm{Pm})$	coincident γ-	rays R ₀ (fm)	HF	
2.987(5)	2.906(5)***	0.0022(6)%**	5/2+	0.0	5/2+		1.5813(49)	$0.63\substack{+0.27\\-0.17}$
* [19714 ** [1962 *** 2.90	Au09]. 2Si14]. 8(5) MeV [1967Gc	932], adjusted to 2.9	906(5) MeV in [1	991Ry01].				
Table 4 direct $\alpha$ emis	ssion from ¹⁵¹ Tb, J [#]	$T = 1/2^+, T_{1/2} = 17$	$1.609(14) h^*, BR_{\alpha}$	= 0.0095(15)%**.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{147}\mathrm{Eu})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
3.268(5) 3.500(5)	3.181(5)*** 3.407(5) [@]	0.1%*** 100%***	9.5(15)×10 ⁻⁶ % 90.0095(15)%**	** 7/2 ⁺ 5/2 ⁺	0.2292 0.0	0.2292	1.5772(70) 1.5772(70)	$81 \\ 6.3^{+1.8}_{-1.4}$
** [1974 *** 3.18 @ 3.4090 Table 5 direct α emis	iTo07]. 3(5) MeV [1967Go (5) MeV [1967Go3 sion from ¹⁷⁵ Ir, J ^π	b32], adjusted to 3. 2], adjusted to 3.40 = $(1/2^+)$ , $T_{1/2} = 8(1/2^+)$	181(5) MeV in [1 7(5) MeV in [199 1) s*, $BR_{\alpha} = 0.85$	991Ry01]. 91Ry01]. 5(22)%**.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{j}^{r}$	E Edaughte	$rr(^{171}\text{Re})$ c	oincident γ-rays	R ₀ (fm)	HF
* [20040 ** [1986 *** Wei @ [2018 Table 6 direct α emis	GoZZ]. GoZZ]. ghted average of 5 Ba33]. ssion from ^{175m} Ir, E	0.83(22) 395(5) [2004GoZZ x = 169(7) keV*, J	] and 5.393(5) Me $\pi = (9/2^{-}), T_{1/2} =$	$= 4.9(4) \text{ s}^{**}, BR_{\alpha} =$	<u>;</u> ≈ 70%***.	.1699(3)	1.330(19)	<u></u>
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{m \pi}$	$E_{da}$	ughter( ¹⁷¹ ERe)	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.879(5)	5.745(5)**	0.85(22)%	** (9/2-	.) 0.0		1.550(19)	$\approx 1.0$	
* Excita state to an un ** [2004 *** Asso @ [2018 Table 7 direct α amic	tion calculated as 1 hindered to the 189 GoZZ]. uming an unhindere Ba33].	69(7) keV, based o .8 keV in ¹⁷¹ Re. ed (HF =1.0) to the $I^{\pi} = 1/2^{+}$ . Te $x = 7$	n an unhindered of ground state of $17$	$\alpha$ -decay of the ¹⁷⁵ I ^{'1} Re.	r isomer to the grour	nd state of ¹⁷¹ Re, and th	he $\alpha$ -energy of the	¹⁷⁵ Ir ground

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{175}\mathrm{Ir})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.72810 5.835(15) 5.849(10) 5.982(4)	5.600(10) 5.705(15) 5.718(10) 5.848(4)	0.36(1)% <0.16(7)% <0.98(31)% 100	$\begin{array}{l} 0.078(4)\% \\ < 0.036(16)\% \\ < 0.22(7)\% \\ 22.0(9)\% \end{array}$	(1/2+)	0.2603(7) 0.1460(7) 0.1319(4) 0.0	0.0261, 0.2342 0.0261, 0.1199 0.0261, 0.1053, 0.1319	1.5516(28) 1.5516(28) 1.5516(28) 1.5516(28)	$38(4) \\ > 270^{+23}_{-9} \\ > 51^{+28}_{-15} \\ 1.85(17)$

* All values from [2021Ha32], except where noted. ** [1986Ke03].

Table 8	
direct $\alpha$ emission from ^{183m} Tl*, Ex = 628.7(3) keV, J ^{$\pi$} = (9/2 ⁻ ), T _{1/2} = 53.3(3) ms, BR _{$\alpha$} = 1.45(42)%.	

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{179}\mathrm{Au})$	coincident γ-rays	R ₀ (fm)	HF
6.193(15) 6.475(9)	6.058(15) 6.333(9)	1.6(3)% 100(2)%	0.024(8)% 1.45(42)%	$(9/2^{-})$ $(9/2^{-})$	0.407(17) 0.127(17)	0.0271, 0.0624, 0.0895, 0.2798 0.0271, 0.0624, 0.0895	1.5108(76) 1.5108(76)	$6^{+4}_{-2}$ $1.3^{+0.7}_{-0.4}$
6.602(15)	6.458(15)	1.13 (31)%	0.016(7)%	$(1/2^+)$	0.0		1.5108(76)	$350^{+250}_{-120}$

* All values from [2022Ve01], except where noted.

#### Table 9

direct $\alpha$ emission from ¹⁸⁷ Bi*, J ^{$\pi$} = (1/2 ⁺ ), T _{1/2} = 38(2) ms**, BR _{$\alpha$} = $\approx$ 100%
------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{183}\text{Tl})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.156(5)	7.000(5)	100(5)%	88(4)%	(9/2 ⁻ )	0.625(7)		1.4864(88)	$0.43\substack{+0.10\\-0.08}$
7.506(15)	7.342(15)	3.4(8)%	3.0(7)%	$(3/2^+)$	0.273(1)	0.273	1.4864(88)	$170^{+70}_{-50}$
7.782(5)	7.612 (5)	10.2(7)%	9.0(5)%	$(1/2^+)$	0.0		1.4864(88)	$390^{+80}_{-70}$

* All values from [2006An11], except where noted.

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** Weighted average of 40(2) ms [2006An11] and 32(3) ms [1999Ba45].

#### Table 10

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_{\mathcal{L}}^{\pi}$	$E_{daughter}(^{183}\text{Tl})$	coincident <i>γ</i> -rays	$R_0$ (fm)	HF
7.894(10)	7.721(10)	100%	(1/2 ⁺ )	0.0		1.4864(88)	$0.72^{+0.16}_{-0.13}$
* All value	es from [2006An11],	except where note	ed.				
Table 11							

Fired $\alpha$ emission from ¹⁹¹ At*, J ^{$\pi$} = (1/2 ⁺ ), T _{1/2} = 1.7 ⁺¹¹ ₋₅ ms, BR _{$\alpha$} = 100%.										
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{187}\mathrm{Bi})$	coincident γ-rays	R ₀ (fm)	HF			
7.714(11)	7.552(11)	100%	(1/2 ⁺ )	0.112(20)		1.522(12)	0.41(29)			

* All values from [2003Ke08].

#### Table 12

direct $\alpha$ emis	direct $\alpha$ emission from ^{191m} At*, Ex = 50(30) keV, J ^{$\pi$} = (7/2 ⁻ ), T _{1/2} = 2.1 ⁺⁴ ₋₃ ms, BR _{$\alpha$} = 100%.										
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	<i>E</i> _{daughter} ( ¹⁸⁷ Bi)	coincident $\gamma$ -rays	$R_0$ (fm)	HF			
7.817(15)	7.653(15)	100(2)%	98(2)%	(7/2-)	0.063(10)	0.063(10)	1.522(12)	$1.1\substack{+0.4 \\ -0.3}$			
7.880(15)	7.715(15)	2(2)%	2(2)%	$(9/2^{-})$	0.0		1.522(12)	1200(1100)			

* All values from [2003Ke08].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +11 nuclei.

Last updated 4/4/23

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +11$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
146		7				
¹⁴⁰ Sm	$0^{+}$	6.8(7)×10' y	stable			[2012Ki16]
¹⁵⁰ Gd	$0^{+}$	1.78(8)×10 ⁶ y	stable			[1966Fr11]
¹⁵⁴ Dy	$0^{+}$	$3.0(15) \times 10^6$ y	stable			[1985HoZM]
¹⁵⁸ Er	$0^+$	2.24(10) h	0.880(40)	-3.168(26)	2.428(52)	[1982Vy06]
¹⁶² Yb	$0^+$	18.87(19) m	1.660(30)	-1.909(17)	3.941(31)	[1972Ch23]
¹⁶⁶ Hf	$0^{+}$	6.77(30) m	2.160(40)	-0.853(39)	5.194(38)	[1974De09]
$^{170}W$	$0^{+}$	2.42(4) m	2.850(30)	0.137(31)	6.305(33)	[1990Me12]
¹⁷⁴ Os	$0^{+}$	44(4) s*	3.678(30)	1.443(30)	7.717(30)	[1972Be89, 1971Bo06]
¹⁷⁸ Pt	$0^{+}$	20.8(5) s**	4.257(21)	2.670(18)	9.251(30)	[2000Ko16, 1982Bo14, 1980Sc09,
						[1968De01, 1966Si08]
¹⁸² Hg	$0^+$	10.83(6) s	4.727(21)	3.516(17)	10.253(21)	[1993Wa03, 1993WaZO]
¹⁸⁶ Pb	$0^{+}$	4.79(5) s	5.202(23)	4.214(18)	11.198(22)	[1980Sc09]
¹⁹⁰ Po	$0^+$	2.45(5) ms	6.033(25)	5.992(19)	12.895(25)	[2001An07, 2000An14]
¹⁹⁴ Rn	$0^+$	780(160)µs	6.441(29)	6.761(22)	13.896(27)	[2006An36]

* Weighted average of 44(4) s [1972Be89] and 42(6) s [1971Bo06].

** Weighted average of 20(2) s [2000Ko16, 21(1) s [1982Bo14], 19(2) s [1980Sc09], 21.2(8) s [1968De01] and 21.3(15) s [1966Si08].

 Table 2

 Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +11$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
¹⁴⁶ Sm	7.018(4)	11.826(3)	2.529(3)	100%*	[ <b>1987Me08</b> , 2012Ki16, 1990Pe06, 1967Gu14, 1966Fr11, 1964Nu02,
¹⁵⁰ Gd	6.612(7)	11.006(6)	2.807(6)	100%*	[ <b>1961</b> Ma03, 1960Ka23, 1960Ma47, 1953Du21, 1952L020] [ <b>1962Si14</b> , 1967Go32, 1966Fr11, 1965Og01, 1962Do13, 1960To05, 1953Ra02]
¹⁵⁴ Dy	6.369(8)	10.265(7)	2.945(5)	100%*	[ <b>1967Go32</b> , 1985HoZN, 1971Go08, 1965Ma51, 1962Ry03, 1961Ma18, 1960Ma47, 1958To27]
¹⁵⁸ Er	5.760(34)	9.352(25)	2.665(26)		
¹⁶² Yb	5.211(32)	8.335(29)	3.058(29)		
¹⁶⁶ Hf	4.706(39)	7.425(32)	3.537(32)		
$^{170}W$	4.289(31)	6.508(31)	4.143(31)		
¹⁷⁴ Os	3.730(30)	5.476(30)	4.871(10)	$0.020^{+0.010}_{-0.004}\%$	[ <b>1971Bo06</b> , 1971BoZK]
¹⁷⁸ Pt	3.239(22)	4.444(15)	5.573(2)	7.5(3)%	[2000Ko16, 1980Sc09, 1992MeZW, 1982HeZM, 1979Ha10, 1973BoXL,
					1970Ha18, 1968De01, 1966Si08]
¹⁸² Hg	2.995(22)	3.725(14)	5.996(5)	15.2(8)%	[1979Ha10, 1980Sc09, 1993Wa03, 1993WaZO, 1982HeZM, 1970Ha18,
					1969Ha03, 1968De11]
¹⁸⁶ Pb	2.212(23)	2.914(15)	6.471(5)	38(9)%	[1994Wa23, 1999An22, 2000Va34, 1998DaZQ, 1997An09, 1997Ba25,
					1984To09, 1980Sc09, 1974JoZU, 1974Le02, 1972Ga27]
¹⁹⁰ Po	1.787(25)	1.330(17)	7.693(7)	100%***	[2001An07, 2000An14, 2000AnZZ, 1999An22, 1997An09, 1998DaZQ,
					1997Ba25, 1996Ba35, 1988QuZZ]
¹⁹⁴ Rn	1.497(27)	0.787(20)	7.862(10)	100%***	[ <b>2006An36</b> , 2007An19, 2006AnZT]

* Only decay mode energetically possible.

** [1958To27] also report a 3.350(50) MeV  $\alpha$  attributed to an isomeric state of ¹⁵⁴Dy. A later study [1971Go08] with far more statistics did not observe this. *** based on short half-life.

# Table 3

direct  $\alpha$  emission from ¹⁴⁶Sm, J^{$\pi$} = 0⁺, T_{1/2}=6.8(7)×10⁷ y*, BR_{$\alpha$} =100%**.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{142}\text{Nd})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
2.524(4)	2.455(4)***	100%	0+	0.0		1.5930(74)	1.0

* [2012Ki16].

** Only decay mode energetically possible.

*** [1987Me08].

direct $\alpha$ emission from ¹⁵⁰ Gd, J ^{$\pi$} =0 ⁺	$T_{1/2}=1.78(8)\times 10^6 \text{ y*}, BR_{\alpha}=100\%^{**}.$
------------------------------------------------------------------------------------------------	------------------------------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{142}\text{Nd})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
2.805(10)	2.730(10)***	100%	$0^+$	0.0		1.5748(86)	1.0
* [1966Fr ** Only d *** [1962	11]. lecay mode energet 2Si14].	tically possible.					
<b>Fable 5</b> direct $\alpha$ emiss	ion from ¹⁵⁴ Dy, J ^{$\pi$}	$= 0^+, T_{1/2} = 3.0(15)$	5)×10 ⁶ y*, <i>BK</i>	$P_{\alpha} = 100\%^{**}.$			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{142}\mathrm{Nd})$	coincident γ-rays	R ₀ (fm)	HF
2.947(5)	2.870(5)***	100%	$0^+$	0.0	_	1.541(36)	1.0
* [1985H ** Only d *** 2.872	oZM]. lecay mode energet 2(5) MeV in [19670	tically possible. Go32], adjusted to	2.870(5) MeV	/ in [1999Ry01].			
* [1985H ** Only d *** 2.872 <b>Table 6</b> direct $\alpha$ emiss $E_{\alpha}$ (c.m.)	oZM]. lecay mode energet 2(5) MeV in [19670 ion from ¹⁷⁴ Os*, J $E_{\alpha}(lab)$	tically possible. Go32], adjusted to $\pi = 0^+, T_{1/2} = 44(4)$ $I_{\alpha}(abs)$	2.870(5) MeV ) $s^{**}, BR_{\alpha} = 0$ $J_{e}^{\pi}$	7 in [1999Ry01]. .020 ⁺¹⁰ %. <i>E</i> _{daughter} ( ¹⁷⁰ W)	coincident γ-rays	R ₀ (fm)	HF
* [1985H ** Only d *** 2.872 <b>Table 6</b> direct $\alpha$ emisss <u>$E_{\alpha}$(c.m.)</u> 4.872(10)	oZM]. lecay mode energet b(5) MeV in [19670 ion from ¹⁷⁴ Os*, J $E_{\alpha}(lab)$ 4.760(10)	tically possible. Go32], adjusted to $\frac{\pi = 0^+, T_{1/2} = 44(4)}{I_{\alpha}(abs)}$	2.870(5) MeV $\frac{0.5^{**}, BR_{\alpha} = 0}{J_f^{\pi}}$ $0^+$	7 in [1999Ry01]. $020^{+10}_{-4}$ %. $E_{daughter}(^{170}W)$ 0.0	coincident γ-rays	R ₀ (fm) 1.540(34)	HF 1.0
* [1985H ** Only d *** 2.872 <b>Table 6</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 4.872(10) * All valu *** Weig <b>Table 7</b> direct $\alpha$ emiss	oZM]. lecay mode energet (5) MeV in [19670 ion from ¹⁷⁴ Os*, J $E_{\alpha}$ (lab) 4.760(10) les from [1971Bo00 hted average of 440 ion from ¹⁷⁸ Pt*, J [#]	tically possible. Go32], adjusted to $\pi = 0^+, T_{1/2} = 44(4)$ $I_{\alpha}(abs)$ 100% 6], except where n (4) s [1972Be89] a $F = 0^+, T_{1/2} = 20.8(3)$	2.870(5) MeV ) s**, $BR_{\alpha} = 0$ $J_{f}^{\pi}$ 0 ⁺ oted. and 42(6) s [19] 5) s**, $BR_{\alpha} = 0$	7 in [1999Ry01]. .020 ⁺¹⁰ %. <u>Edaughter</u> ( ¹⁷⁰ W) 0.0 071Bo06]. 7.5(3)%.	coincident γ-rays	R ₀ (fm) 1.540(34)	НF 1.0
* [1985H ** Only d *** 2.872 <b>Fable 6</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 4.872(10) * All valu *** Weig <b>Fable 7</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$	oZM]. lecay mode energet (5) MeV in [19670 ion from ¹⁷⁴ Os*, J $E_{\alpha}$ (lab) 4.760(10) tes from [1971Bo00 hted average of 440 ion from ¹⁷⁸ Pt*, J ^π $E_{\alpha}$ (lab)	tically possible. Go32], adjusted to $\pi = 0^+, T_{1/2} = 44(4)$ $I_{\alpha}(abs)$ 100% 6], except where n (4) s [1972Be89] a $x = 0^+, T_{1/2} = 20.8(3)$ $I_{\alpha}(rel)$ $I_{\alpha}$	2.870(5) MeV ) s**, $BR_{\alpha} = 0$ $J_{f}^{\pi}$ 0 ⁺ oted. ind 42(6) s [19 5) s**, $BR_{\alpha} = 0$ (abs)	7 in [1999Ry01]. $0.020^{+10}_{-4}\%.$ $E_{daughter}(^{170}W)$ 0.0 0.0 0.110006]. 7.5(3)%. $J_f^{\pi}$ $E_{daughter}(^{174}G)$	coincident γ-rays —– Ds) coincident γ-rays	R ₀ (fm) 1.540(34) R ₀ (fm)	НF 1.0 НF

# Table 8

direct  $\alpha$  emission from ¹⁸²Hg, J^{$\pi$} = 0⁺, T_{1/2}=10.83(6) s*, *BR*_{$\alpha$} =15.2(8)%**.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{178}\text{Pt})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.578(10) 5.828(5) 5.999(5)	5.455(10) [@] 5.700(5) [@] 5.867(5) [@]	0.09(3)% 0.58(16)% 100(22)%	0.014(3)% 0.09(2)% 15(3)%	$0^+ 2^+ 0^+$	0.4210(6) 0.1703(1) 0.0	0.1703(1), 0.2506, 0.421 0.1703(1)	1.5176(41) 1.5176(41) 1.5176(41)	$13^{+7}_{-4} \\ 28^{+15}_{-7} \\ 1.0$

* [1993Wa03].

** [1990 wa05].
*** [1980Sc09].
*** From α intensity ratios in [1979Ha10].
@ [1979Ha10].

direct $\alpha$ emission from	¹⁸⁶ Pb*, $J^{\pi} = 0^+, T_{1/2} = 4.79(5)$ s**	$BR_{\alpha} = 38(9)\%^{***}.$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{182}\mathrm{Hg}$	) coincident $\gamma$	-rays R ₀ (fm)	) HF
6.146(13) 6.470(6)	6.014(13) 6.331(6)	${<}0.20\%$ ${<}100\%$	<0.076(18)% <38(9)%	$(0^+) \\ 0^+$	0.328 0.0		1.486(1 1.486(1	$\begin{array}{c} 0) & >25 \\ 0) & 1.0 \end{array}$
* All valu ** [1980] *** [1999	ues from [1994Wa Sc09]. 9An22].	a23], except where	e noted.					
<b>Table 10</b> direct $\alpha$ emiss	tion from ¹⁹⁰ Po*,	$J^{\pi} = 0^+, T_{1/2} = 2.4$	$45(5) \text{ ms}, BR_{\alpha} = 10$	0%.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$ E	E _{daughter} ( ¹⁸⁶ Pb)	coincident γ-rays	R ₀ (fm)	HF
7.044(20)	6.896(20)	0.3(1%)	0.3(1)%	0+ 0	).650		1.5114(26)	$2.5^{+1.3}_{-0.7}$
7.163(20)	7.012(20)	3.4(4)%	3.3(4)%	0+ 0	0.532		1.5114(26)	$0.58_{-0.07}^{-0.09}$
7.695(10)	7.533(10)	100.0(4)%	96.4(4)%	0+ 0	0.0		1.5114(26)	1.0
* All valu	ies from [2001Ar	n07, 2000An14].						
Table 11 direct $\alpha$ emiss	tion from ¹⁹⁴ Rn*,	, $J^{\pi} = 0^+, T_{1/2} = 78$	$0(160)\mu$ s, $BR_{\alpha}$ =1	00%.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{18}$	⁶ Pb) coinci	ident γ-rays	R ₀ (fm)	HF
7.862(10)	7.700(10)	100%	$0^+$	0.0			1.590(11)	1.0

* All values from [2006An36].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ =+11 nuclei.

Last updated 4/4/23

Observed and predicted $\beta$ -delayed particl	le emission fron	n the odd-Z, $T_z = +$	-11 nuclei	. Unless otherwise stated, all Q	-values are taken from [	2021Wa16] or deduced
from values therein. $J^{\pi}$ values for ¹⁴⁴ Pm,	¹⁴⁸ Eu, ¹⁵² Tb, ¹	¹⁵⁶ Ho, ¹⁶⁰ Tm, ¹⁶⁴ L	Lu, ¹⁶⁸ Ta,	¹⁷² Re are taken from ENSDF.		

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Q _ε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta F}$	Experimental
144 <b>D</b> m		5-	262(14) d*	0.550(2)	5 627(2)	1 222(2)		[1062Da21 1064Du12
¹⁴⁸ Eu		5-	55.6(2) d	3.039(10)	-3.037(2) -4.544(10)	4.233(3) 5.026(10)		[1903F a21, 1904Bu13 [1980Ho33]
¹⁵² Tb		$2^{-}$	17.5(1) h	3.990(40)	-3.353(40)	6.194(40)		[1967Gr12]
¹⁵⁶ Ho		4-	55(1) m	4.990(40)	-1.577(40)	6.744(38)		[1966La11]
¹⁶⁰ Tm		1-	9.4(4) m*	5.760(40)	-0.260(33)	7.803(33)		[1970De13, 1975St12]
¹⁶⁴ Lu		1-	3.15(3) m**	6.370(30)	0.797(28)	8.997(37)		[1984Ad09, 1983Ge08, 1977Hu02]
¹⁶⁸ Ta		$(2^{-}, 3^{+})$	2.0(1) m	6.970(40)	1.843(47)	10.193(32)		[1989Hi04]
¹⁷² Re		$(5^+)$	15(3) s	7.530(50)	2.864(45)	11.369(45)		[1977Be66]
¹⁷⁶ Ir		5+	8(1) s	8.249(14)	4.117(29)	12.790(29)		[1967Si02]
¹⁸⁰ Au		$(1^{+})$	8.1(3) s	8.804(11)	5.167(11)	14.081(12)		[1977Hu05]
¹⁸⁴ Tl***	У	(2 ⁻ )	9.5(2) s	9.461(14)+y	6.019(14)+y	15.122(14)+y		[2016Va01]
^{184m1} Tl***	х	$(7^{+})$	11(1) s	9.461(14)+x	6.019(14)+x	15.122(14)+x		[2016Va01, 1976CoZH]
184m2 Tl	x + 0.506	(10 ⁻ )	47.1(7) ms	9.967(14)+x	6.525(14)+x	15.628(14)+x		[2015Va10]
¹⁸⁸ Bi		$(3^{+})$	60(3) ms	10.616(15)	7.961(14)	16.725(15)	0.46(9)%	[2020An12, 2003An26, 2013La02, 1993LaZT]
^{188m} Bi	х	(10 ⁻ )	265(10) ms	10.616(15)+x	7.961(14)+x	16.725(15)+x	$\approx 0.11\%$	[2020An12, 2003An26, 2013La02, 1993LaZT]
¹⁹² At	У		11.5(6) ms	10.992(30)	8.876(29)	18.312(30)	0.42(9)%@	[2006An04, 2013An03]
^{192m} At	х	$(9^{-}, 10^{-})$	88(6) ms	10.992(30)+x	8.876(29)+x	18.312(30)+x	$0.42(9)\%^{@}$	[2006An04, 2013An03]

* Weighted average of 377(16) d [1963Pa21] and 349(16) d [1964Bu13].

* Weighted average of 9.2(4) m [1970De13] and 9.5(4) m [1975St12].

** Weighted average of 3.12(3) m [1984Ad09], 3.15(8) m [1983Ge08] and 3.17(3) m [1977Hu02].

*** The ordering of the isomers is uncertain.

[@] [2013An03] state that the measured BR_{$\beta F$} is likely from the 88-ms isomer.

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +11$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
¹⁴⁴ Pm	4 703(3)	12 208(3)	0.845(7)		
¹⁴⁸ Eu	4 320(10)	11.200(3) 11.421(11)	2.694(10)	$94(28) \times 10^{-7}\%$	[ <b>1964To04</b> ]
¹⁵² Th	3 817(40)	10.503(41)	3.155(41)	). <del>4</del> (20)×10 %	
¹⁵⁶ Ho	3 671(40)	9 960(60)	2 754(55)		
¹⁶⁰ Tm	3.029(33)	8.692(42)	2.812(50)		
¹⁶⁴ Lu	2.637(32)	7.743(38)	3.234(43)		
¹⁶⁸ Ta	2.215(40)	6.951(41)	3.824(40)		
¹⁷² Re	1.770(45)	6.007(45)	4.402(45)		
¹⁷⁶ Ir	1.066(14)	4.787(29)	5.260(36)	2.4(4)%*	[1967Si02, 1990Bo19, 1986Ke03]
¹⁸⁰ Au	0.646(9)	3.949(19)	5.831(7)	0.58(10)%	[2020Ha24] 2020Cu02,1993Wa03,
					1986Ke03]
¹⁸⁴ Tl	0.368(12)-y	3.157(21)-y	6.317(9)+y	1.22(30)%	[2016Va01, 1978CoYS, 1977ToZS,
					1976Co24, 1976To06, 1976WoZJ]
184m1 Tl	0.368(12)-x	3.157(21)-x	6.317(9)+x	0.047(6)%	[2016Va01, 1976CoZH, 1978CoYS]
^{184m2} Tl	-0.138(12)+x	2.651(21)-x	6.823(9)+x	0.089(19)%	[2016Va01, 2015Va10]
¹⁸⁸ Bi	-0.503(12)	1.890(24)	7.264(5)	≈100%**	[2003An26, 2006An04, 2003AnZZ,
					1997Wa05, 1993An19, 1984ScZQ]
^{188m} Bi	-0.503(12)-x	1.890(24)-x	7.264(5)+x	$\approx 100\% **$	[2003An26, 2006An04, 2003AnZZ,
					1997Wa05, 1993An19, 1984ScZQ]
¹⁹² At	-0.706(29)	1.056(35)	7.696(26)	$\approx 100\% **$	[ <b>2006An04</b> , 2005AnZY]
^{192m} At	-0.706(29)-x	1.056(35)-x	7.696(26)+x	$\approx 100\% **$	[ <b>2006An04</b> , 2005AnZY]

* Weighted average of 3.1(6)% [1990Bo19], and 2.1(4)% [1986Ke03].

** Based on short half-life.

	direct $\alpha$ emission from ¹⁴⁸ Eu*, J ^{$\pi$} = 5 ⁻ , T ₁	$_{/2} = 55.6(2) \text{ d}^{**}, BR_{\alpha} = 9.4(28) \times 10^{-7}\%.$
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	<i>E</i> _{daughter} ( ¹⁴⁴ Pm)	coincident $\gamma$ -rays	R ₀ (fm)***	⊧ HF	
2.703(30)	2.630(30)	9.4(28)×10 ⁻⁷ 9	% 5-	0.0		1.584(11)	$4^{+5}_{-3}$	
* All val ** [1980 *** Inter <b>Table 4</b> direct <i>α</i> emis	* All values from [1964To04], except where noted. ** [1980Ho33]. *** Interpolated between 1.5930(74) fm ¹⁴⁶ Sm and 1.5748(86) ¹⁵⁰ Gd. Fable 4 literet $\alpha$ emission from ¹⁷⁶ Ir* $I^{\pi} = 5^+$ . The $= 8(1)$ s. <i>BR</i> = $= 2.4(4)$ %**							
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{172}\mathrm{Re})$	coincident γ-rays	R ₀ (fm)***	HF	
5.237(10)	5.118(10)	2.4(4)%***	(5 ⁺ )	0.0		1.556(34)	$0.06^{+0.06@}_{-0.03}$	

* All values from [1967Si02], except where noted.

** Weighted average of 3.1(6)% [1990Bo19], and 2.1(4)% [1986Ke03]. *** Interpolated between 1.540(34) fm ¹⁷⁴Os and 1.5708(31) ¹⁷⁸Pt.

[@] The reason for this un-physically low HF value is unknown. A likely possibility is the observed peak at 5.118 MeV is an unresolved multiplet consisting of multiple  $\alpha$  transitions and conversion electron summing.

# Table 5

direct  $\alpha$  emission from ¹⁸⁰Au*, J^{$\pi$} = (1⁺), T_{1/2} = 8.1(3) s**, BR_{$\alpha$} =0.58(10)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{176}\mathrm{Ir})$	coincident γ-rays	R ₀ (fm)	HF
5.476(20) 5.548(20)	5.354(20) 5.425(20)	0.51(26)% 2 3(8)%	0.0012(6)% 0.005(2)%		0.338(20) 0.2648(9)	0.0365.0.0415.0.1778.0.2188	1.5442(51)	$180^{+230}_{-80}$ 90^{+60}
5.610(10)	5.485(10)	100(10)%	0.23(5)%	(1 ⁺ )	0.2052(9)	0.0365, 0.0415, 0.1089, 0.1180, 0.1599, 0.1957, 0.2052	1.5442(51)	$4.0^{+14}_{-10}$
5.637(15)	5.512(15)	8.5(18)%	0.019(4)%		0.1766(9)	0.0365, 0.0415, 0.0891, 0.1033	1.5442(51)	$64^{+27}_{-18}$
5.725(8)	5.598(8)	60.5(87)%	0.14(3)%		0.0875(8)	0.0365, 0.0415,	1.5442(51)	$23^{+8}_{-6}$
5.767(7)	5.639(7)	85(12)%	0.19(4)%		0.0460(7)	0.0365	1.5442(51)	$25^{+8}_{-6}$
$\approx 5.804$	$\approx$ 5.675	<1.3%	< 0.0029%		0.0095(7)		1.5442(51)	>2400
$\approx 5.815$	$\approx$ 5.686	<1.3%	< 0.0029%	$5^{+}$	0.0		1.5442(51)	>2700

* All values from [2020Ha24], except where noted.

** [1977Hu05].

*** Interpolated between 1.5708(31) ¹⁷⁸Pt and 1.5176(41) fm ¹⁸²Hg.

# Table 6

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direct \alpha emission from <sup>184</sup>Tl*, J<sup>\pi</sup> = (2<sup>-</sup>), T<sub>1/2</sub> = 9.5(2) s, BR<sub>\alpha</sub> =1.22(30)%.
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{180}\mathrm{Au})$	coincident γ-rays
5 876(12)	5 748(12)	<0.4%	<0.0024%		$x \pm 0.426$	0.4260(5)
5.935(12)	5.810(12)	<0.4 <i>%</i> 6.0(4)%	0.037(9)%		x + 0.365	0.3651(2), 0.3151(2), 0.2728(3), 0.1984(9)
6.097(13)	5.964(13)				x + 0.224	0.2243(3)
6.121(12)	5.988(12)	100%	0.61(15)%		x + 0.201	0.2013(3), 0.1842(1), 0.1785(1), 0.1263(1)
6.298(10)	6.161(10)	93(1)%	0.57(14)%		x + 0.017	

* All values from [2016Va01].

# Table 7

direct $\alpha$ emission	on from ^{184m1} Tl*	34m1 Tl*, J ^{$\pi$} = (7 ⁺ ), T _{1/2} = 11(1) s**, <i>BR</i> _{$\alpha$} =0.047(6)%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{180}\mathrm{Au})$	coincident γ-rays
5.785(5)	5.659(5)	0.047(6)%		z + 0.183	0.3633(6), 0.2618(3), 0.2577(3), 0.1757(3)

* All values from [2016Va01], except where noted.

** [1976CoZH].

direct $\alpha$ emission from 184m2	$Tl^*, J^{\pi} = (10^-), T_{1/2}$	$_{1/2} = 47.1(7) \text{ ms}^{**}, BR_{\alpha} = 0.089(19)\%.$
------------------------------------------	-----------------------------------	----------------------------------------------------------------

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{180}\mathrm{Au})$	coincident $\gamma$ -rays
6.268(19)	6.132(19)	0.089(19)%		z + 0.206	0.2059(2), 0.1626(1), 0.1079(2), 0.1013(6)

* All values from [2016Va01], except where noted.

** [2015Va10].

#### Table 9

direct  $\alpha$  emission from ¹⁸⁸Bi*, J^{$\pi$} = (3⁺), T_{1/2} = 60(3) ms, *BR*_{$\alpha$} =~100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{184}\text{Tl})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF
7.039(10) 7.144(5) 7.260(5)	6.889(10) 6.992(5) 7.106(5)	0.34(1)% 100% 2.1(2)%	$\approx 98\%$ $\approx 2.0\%$	$\approx 0.33$ (3 ⁺ ) (2 ⁺ )	y + 0.216 y + 0.1775 y	0.099, 0.1175 0.1175 1.4985(10)	1.4985(10) 1.4985(10) $\approx 89$	≈100 0.46(3)

* All values from [2003An26].

** Interpolated between 1.486(10) ¹⁸⁶Pb and 1.5114(26) fm ¹⁹⁰Po. Note this value is likely too low as Pb is a closed proton shell.

Table 1
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direct $\alpha$ emission from ^{188m}	Bi*, $J^{\pi} = (10^{-}), T_{1/2}$	$= 265(10) \text{ ms}, BR_{\alpha} = \approx 100\%.$
-----------------------------------------------	------------------------------------	------------------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{184}\mathrm{Tl})$	coincident γ-rays	R ₀ (fm)**	HF
6.961(5) 7.147(15) 7.389(10) 7.461(5)	6.813(5) 6.995(15) 7.232(10) 7.302(5)	100% 1.5(5)% 4.5(1)% 3.6(1)%	$\approx 91\%$ $\approx 1.4\%$ $\approx 4.1\%$ $\approx 3.3\%$	(10 ⁻ ) (6 ⁺ ) (7 ⁺ )	0.500 x + 0.320 x + 0.0705 x	0.0705, 0.249, 0.320 0.0705	1.4985(10) 1.4985(10) 1.4985(10) 1.4985(10)	$\begin{array}{l} \approx 0.8 \\ \approx 230 \\ \approx 510 \\ \approx 1050 \end{array}$

* All values from [2003An26], except where noted.
 ** Interpolated between 1.486(10) ¹⁸⁶Pb and 1.5114(26) fm ¹⁹⁰Po. Note this value is likely too low as Pb is a closed proton shell.

#### Table 11

direct  $\alpha$  emission from ¹⁹²At*, J^{$\pi$} = , T_{1/2} = 11.5(6) ms, BR_{$\alpha$} = $\approx$ 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	E _{daughter} ( ¹⁸⁸ Bi)	coincident γ-rays	R ₀ (fm)**	HF
7.520(15)	7.363(15)	21(4)%	12(2)%		0.172(29)		1.551(12)	$11^{+6}_{-4}$
7.593(15)	7.435(15)	100(7)%	56(4)%		0.101(25)	0.036	1.551(12)	$4.0^{+1.7}_{-1.3}$
7.629(15)	7.470(15)	55(7)%	31(3)%		0.065(25)		1.551(12)	$19^{+4}_{-3}$
7.670-7.721	7.510-7.560	$\leq 1.8(9)\%$	1.0(5)%	(3 ⁺ )	0.0			-

* All values from [2006An04].

** Interpolated between 1.5114(26) fm ¹⁹⁰Po and 1.590(11) ¹⁹⁴Pb and Note this value is likely too low as Pb is a closed proton shell.

# Table 12

direct  $\alpha$  emission from ^{192m}At*, J^{$\pi$} = (9⁻, 10⁻), T_{1/2} = 88(6) ms, BR_{$\alpha$} = $\approx$ 100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	Edaughter( ¹⁸⁸ Bi)	coincident γ-rays	R ₀ (fm)**	HF
7.348(15)	7.195(15)	4.9(4)%	4.0(7)%		x +0.188	0.188	1.551(12)	$70^{+40}_{-20}$
7.378(15)	7.224(15)	100(4)%	82(3)%	(9 ⁻ , 10 ⁻ )	x + 0.165	0.165	1.551(12)	$4.2^{+1.9}_{-1.5}$
7.542(15)	7.385(15)	17.1(7)%	14(2)%	(10 ⁻ )	х		1.551(12)	$80_{-30}^{-1.5}$
7.670-7.721	7.510-7.560	$\leq 1.8(9)\%$	1.0(5)%	(3 ⁺ )	0.0			50

* All values from [2006An04].

** Interpolated between 1.5114(26) fm ¹⁹⁰Po and 1.590(11) ¹⁹⁴Pb and Note this value is likely too low as Pb is a closed proton shell.

*** unresolved multiplet.

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$  = +23/2 nuclei.

Last updated 4/24/23

Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +23/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{$\pi$} values for ¹⁴³Nd, ¹⁴⁷Sm, ¹⁵¹Gd, ¹⁵⁵Dy, ¹⁵⁹Er, ¹⁶³Yb, ¹⁶⁷Hf, ¹⁷¹W, ¹⁷⁵Os are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	$Q_{\varepsilon}$	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon \alpha}$	Experimental
			1/2		$\sim c_P$	PP	200	
¹⁴³ Nd		$7/2^{-}$	stable	stable				
¹⁴⁷ Sm		$7/2^{-}$	$1.068(9) \times 10^{11} \text{ y}^*$	stable				[2010Su30, 2009Ko15]
¹⁵¹ Gd		$7/2^{-}$	123.9(10) d	0.464(3)	-4.427(3)		2.428(3)	[1984Gr15]
¹⁵⁵ Dy		3/2-	9.59(10) h	2.095(2)	-2.739(10)		3.072(10)	[1970Ch09]
¹⁵⁹ Er		3/2-	36(1) m	2.769(2)	-1.443(4)		4.264(10)	[1966La11]
¹⁶³ Yb		3/2-	10.96(35) m	3.435(16)	-0.249(15)		5.611(15)	[1972Ch23]
¹⁶⁷ Hf		$(5/2^{-})$	2.05(5) m	4.060(50)	0.837(29)		6.836(28)	[1973Me09]
$^{171}W$		$(5/2^{-})$	2.38(4) m	4.630(40)	1.879(40)		8.015(47)	[1990Me12]
¹⁷⁵ Os		$(5/2^{-})$	1.4(1) m	5.180(30)	2.833(30)		9.190(30)	[1972Be89]
¹⁷⁹ Pt		$1/2^{-}$	21.2(4) s	5.814(13)	3.987(16)		10.595(29)	[1993Me13, 1993MeZW]
¹⁸³ Hg		1/2-	8.9(2) s	6.387(12)	5.075(15)	$2.7(6) \times 10^{-4}\%$	11.852(12)	[2022Hu09, 1971Ho07,
								1970HaZL, 1970HoZZ]
¹⁸⁷ Pb		$(3/2^{-})$	15.2(3) s	7.458(10)	6.263(13)		12.780(11)	[1981Mi12]
^{187m} Pb	0.020(17)**	$(13/2^+)$	17.9(2) s	7.478(20)	6.283(21)		12.800(20)	[2022Hu09, 1981Mi12]
¹⁹¹ Po		$(3/2^{-})$	22(2) ms	8.171(10)	8.059(14)		14.951(11)	[2002An16]
^{191m} Po	0.063(24)***	$(13/2^+)$	93(3) ms	8.234(26)	8.122(28)		15.014(26)	[2002An16]
¹⁹⁵ Rn		$(3/2^{-})$	$6^{+3}_{-2}$ ms	8.520(50)	8.766(53)		15.865(52)	[2001Ke06, 2001Uu01]
195mRn	$0.082(26)^{@}$	$(13/2^+)$	$5^{+\bar{3}}_{-2}$ ms	8.602(56)	8.848(59)		15.947(59)	[2001Ke06, 2001Uu01]
			-					

* Weighted average of  $1.065(10) \times 10^{11}$  y [2010Su30] and  $1.070(9) \times 10^{11}$  y [2009Ko15]. ** Deduced from  $\alpha$  and  $\gamma$  energies [2022Hu09, 1981Mi12] of the two isomers *** Deduced from  $\alpha$  energies [2002An16] and excitation energy of ^{187m}Pb. See table 8 for more detail.

[@] Deduced from  $\alpha$  energies [2001Ke06] and excitation energy of ^{191m}Po.

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +23/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
¹⁴³ Nd ¹⁴⁷ Sm	7.505(1) 7.101(4)	13.149(1) 12.412(1)	0.531(2) 2.3113(5)	100%*	[ <b>1970Gu14, 1966Ma05, 1962Si14, 1961Ma05, 1960Ka27</b> , 2017Wi01, 2010Su30, 2009Ko15, 2003Ki26, 2001Be81, 1992Ma26, 1987Al28, 1965Va16, 1964Do01, 1961Gr37, 1961Wr02, 1960Ka23, 1959Vo28, 1954Be69, 1954Le55, 1949Pi01, 1946Cu01, 1934Li03, 1934MaAA, 1933HeAA]
¹⁵¹ Gd	6.686(7)	11.631(3)	2.652(3)	$8^{+8}_{-4}{ imes}10^{-7}\%$	[1965Si06]
¹⁵⁵ Dy	6.288(46)	10.851(10)	2.608(10)		
¹⁵⁹ Er	5.663(27)	9.714(6)	2.170(10)		
¹⁶³ Yb	5.105(30)	8.671(17)	2.842(16)		
¹⁶⁷ Hf	4.736(41)	7.750(39)	3.401(32)		
$^{171}W$	4.237(40)	6.947(40)	3.957(40)		
175Os	3.721(30)	5.956(30)	4.556(30)		
¹⁷⁹ Pt	3.303(20)	4.890(17)	5.307(7)**	0.24(4)%***	[2021Ha32, 1980Sc09, 1970Ha18, 1982Bo14, 1979Ha10,
¹⁸³ Hg	2.790(20)	4.001(15)	6.039(4)	23.7(7)%	1973BoXL, 1970Ho18, 1970HaZT, 1966Si08] [ <b>2022Hu09, 1979Ha10</b> , 1992BoZO, 1984Ma41, 1980Sc09 1969NaZT, 1969NaZU, 1968De01]
¹⁸⁷ Pb	2.393(21)	3.381(15)	6.393(6)	7(2)%	[1999An36, 1981Mi12, 1981MiZY, 1999An10, 1999An36
^{187m} Pb	2.373(27)	3.361(23)	6.413(18)	12(2)%	1974JoZU, 1974Le02, 1972Ga27] [ <b>2022Hu09, 1999An36, 1981Mi12</b> , 1981MiZY, 1999An10, 1999An36
¹⁹¹ Po	1.762(22)	1.803(16)	7.493(5)	$\approx 100\%$ [@]	[2002An19, 2001Ke06, 2001Uu01, 1999An10, 1999An36,
^{191m} Po ¹⁹⁵ Rn ^{195m} Rn	1.699(33) 1.522(57) 1.440(63)	1.740(29) 1.202(54) 1.120(60)	7.556(25) 7.694(11) ^{@@} 7.776(28)	$\approx 100\%^{@}$ $100\%^{@}$ $100\%^{@}$	1998DaZQ, 1997Ba25, 1993Qu03, 1988QuZZ] [ <b>2002An19</b> , 2001Ke06, 2001Uu01, 1999An10, 1999An36] [ <b>2001Ke06, 2001Uu01</b> ] [ <b>2001Ke06, 2001Uu01</b> ]

* Only decay channel energetically possible.

** Deduced from  $\alpha$  energies, 5.412(9) MeV in [2021Wa16].

*** Weighted average of 0.21(4)% [1980Sc09] and 0.27(4)% [1970Ha18].

[@] Based on the short half-life.

[@] [@] Deduced from  $\alpha$  energies, 7.694(51) MeV in [2021Wa16].

			<u> </u>						
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	, $I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	Edaughter	( ¹⁴³ Nd) coinc	ident γ-rays	R ₀ (fm)	HF	
2.298(3)	2.235(3)**	100%	7/2-	0.0			1.5895(	97) 1.42	$2^{+0.32}_{-0.26}$
* Weigł ** Take MeV), and 2	nted average of 1 en from [1999Ry 2.231(10) MeV [1	$.065(10) \times 10^{11}$ (01], based on we (1962Si14] (adjust	y [2010Su30] an eighted average ed to 2.230(10)	d 1.070(9) 2.233(5) M MeV).	× 10 ¹¹ y [2009Ko15] [eV [1970Gu14] (adju	usted to 2.238(5	) MeV), 2.2	31(5) [1966Ma	05] (adjusted to 2.2
<b>able 4</b> irect $\alpha$ emi	ssion from ¹⁵¹ Ge	$d^*, J^{\pi} = 7/2^-, T_{1_2}$	$y_2 = 123.9(10) d,$	$BR_{\alpha} = 8^{+8}_{-4}$	$\times 10^{-7}$ %.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughte}$	$r_r(^{147}\mathrm{Sm})$ coin	cident γ-rays	R ₀ (fn	n) H	F
2.670(30)	2.600(30)	$0.8^{+0.8}_{-0.4}\%$	7/2-	0.0			1.574	5(66) 0.	$7^{+0.9}_{-04}$
* All va	llues from [1965	Si06].							
<b>Table 5</b> lirect $\alpha$ emi	ssion from ¹⁷⁹ Pt	*, $J^{\pi} = 1/2^{-}, T_{1/2}$	$_2 = 21.2(4) \text{ s**}, E$	$BR_{\alpha} = 0.24(4$	4)%***.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pmb{\pi}}$	$E_{daughter}(^{175}\mathrm{Os})^{@}$	coincident	γ-rays [@]	R ₀ (fm)	HF
5.233(15) 5.307(7)	5.116(15) 5.188(7)	27.6(16)% 100.0(15)%	0.052(9)% 0.188(31)%	(5/2 ⁻ )	0.1756(2) 0.0	0.073, 0.10	02, 0.176	1.5588(47) 1.5588(47)	$0.80\substack{+0.22\\-0.16}\\1.8\substack{+0.5\\-0.4}$
* All va ** [199 *** We [@] [2004	lues from [2021] 93Me13, 1993M ighted average of 4Ba89].	Ha32], except wh [eZW]. f 0.21(4)% [1980	ere noted. Sc09] and 0.27(4	4)% [1970H	Ia18].				
Table 6 lirect $\alpha$ emi	ssion from ¹⁸³ Hg	$g^*, J^{\pi} = 1./2^-, T_1$	$_{/2} = 8.9(2) \text{ s}, BR_c$	α =23.7(7)%	6.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{179}\mathrm{Pt})^{@}$	coincident	γ-rays [@]	$R_0$ (fm)	HF
5.797(10)	5.670(10)**	$\approx 0.28\%$	≈0.06%	7/2-	0.241(1)	0.1528		1.5148(61)	$\approx 24$
5.950(10)	5.820(10)**	4.1(11)%	0.87(23)%	$5/2^{-}$	0.0874(10)	0.087		1.5148(61)	$8.1^{+3.5}_{-2.1}$
5.965(10)	5.835(10)**	5.8(22)%	1.24(47)%	3/2-	0.0714(10)	0.071		1.5148(61)	$7^{+5}_{-2}$
.037(5)	5.905(5)**	100(26)%	21.5(58)%	1/2-	0.0			1.5148(61)	$0.78^{+0.32}_{-0.20}$
* All va ** [197 *** Rel @ [2009	llues from [2022] 9Ha10]. ative ratios taken 9Ba02].	Hu09], except wh 1 from [1979Ha10	ere noted. )].						

# Table 7

direct  $\alpha$  emission from ¹⁸⁷Pb*,  $J^{\pi} = (3/2^{-}), T_{1/2} = 15.2(3)$  s,  $BR_{\alpha} = 7(2)\%^{**}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{183}\mathrm{Hg})$	coincident γ-rays	R ₀ (fm)	HF
6.124(10)	5.993(10)	67(7)%	4.7(14)%	(3/2-)	0.275	0.067, 0.208, 0.275	1.4873(66)	$1.8^{+0.9}_{-0.5}$
6.329(10)	6.194(10)	100(7)%	7.0(21)%	3/2-	0.067	0.067	1.4873(66)	$9^{+4}_{-2}$

* All values from [1981Mi12], except where noted. ** [1999An36].

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{183}\mathrm{Hg})^{@}$	coincident γ-rays [@]	R ₀ (fm)	HF	
6.213(4)	6.080(4)	12(2)%	(13/2-)	0.204(14)		1.4873(66)	$1.2^{+0.3}_{-0.2}$	

direct  $\alpha$  emission from ^{187m}Pb*, Ex = 20(17) keV**, J^{$\pi$} = (13/2⁺), T_{1/2} =17.9(2) s, BR_{$\alpha$} =12(2)%***.

* All values from [2022Hu09], except where noted.

** Deduced from  $\alpha$  and  $\gamma$  energies [2022Hu09, 1981Mi12] of the two isomers

*** [1999An36].

Table	9
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direct  $\alpha$  emission from ¹⁹¹Po*,  $J^{\pi} = T_{1/2} = 22(2)$  ms,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$J_f^{\pi}, I_{\alpha}(abs)$	$E_{daughter}(^{187}\mathrm{Pb})$	coincident γ-rays	R ₀ (fm)	HF	
7.115(10) 7.491(5)	6.966(10) 7.334(5)**	8.7(25)% 100(3)%	8.0(23)% 92(3)%**	(3/2 ⁻ ) (13/2 ⁺ )	0.375(1) 0.0	0.375(1)	1.5126(20) 1.5126(20)	$1.6^{+0.9}_{-0.5}$ 2.4(3)

* All values from [2002An16], except where noted.

** [2002An16] list two  $\alpha$  transitions with nearly identical energies (7.334(5) and 7.336(15) MeV), with the former feeding the ground state and the latter as a crossover between the (3/2⁻) ¹⁹¹Po ground state feeding a state at 2(15) keV in the (13/2⁺) ¹⁸⁷Pb ground state. A more recent work [2022Hu09] establishes the (13/2⁺) ¹⁸⁷Pb state as an isomer. The 7.336(15) is taken from a background subtracted  $\alpha_1 - \alpha_2$  coincidence spectrum (Fig. 5 in [2002An16]) with a 6.070 MeV  $\alpha$  from the decay of ^{187m}Pb. Note that there may be a small peak at  $\approx$  6.97 MeV in this spectrum. The observed peak at 7.336 MeV may be due to random correlations of the large 7.334 MeV peak (see Fig 1 [2002An16]). This evaluation treats them as one peak at 7.334(5) MeV and an intensity equal to the sum.

# Table 10

direct  $\alpha$  emission from ^{191m}Po*, Ex = 63(24)** keV, J^{$\pi$} = ,T_{1/2} =93(3) ms, BR_{$\alpha$} = $\approx$ 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{187}\mathrm{Pb})$	coincident γ-rays	R ₀ (fm)	HF
6.935(15)	6.790(15)***	1.1(6)%	0.5(3)%7		0.657(24)	0.594(1)	1.5126(20)	$30^{+40}_{-10}$
6.961(15)	6.815(15)	21(4)%	10(2)%	$(9/2^+)$	0.636(28)	. ,	1.5126(20)	$1.6^{+0.8}_{-0.5}$
7.035(5)	6.888(5)	80(17)%	38(8)%	$(13/2^+)$	0.557(24)	0.494(2)	1.5126(20)	$0.8_{-0.3}^{+0.4}$
7.057(15)	6.909(15)	8.2(23)%	3.9(11)%	$(9/2^+)$	0.535(24)	0.472(1)	1.5126(20)	$9^{+5}_{-3}$
7.534(15)	7.376(15)	100.0(5)%	47.6(15)%	$(13/2^+)$	0.063(24)		1.5126(20)	$27^{+8}_{-7}$

* All values from [2002An16], except where noted.

** Deduced from  $\alpha$  energies [2002An16] and excitation energy of ^{187m}Pb. See table 8 for more detail.

*** Labeled as tentative [2002An16].

# Table 11

direct  $\alpha$  emission from ¹⁹⁵Rn*, J^{$\pi$} = *3/2⁻), T_{1/2} =6⁺³₋₂ ms, BR_{$\alpha$} =100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{191}\text{Po})$	coincident γ-rays	R ₀ (fm)	HF
7.694(11)	7.536(11)	100%	(3/2 ⁻ )	0.0		1.588(13)	$3.2^{+1.5}_{-1.4}$

* All values from [2001Ke06, 2001Uu01].

#### Table 12

direct  $\alpha$  emission from ^{195m}Rn*, Ex. = 82(26) keV**, J^{$\pi$} = (13/2⁺), T_{1/2} = 5⁺³₋₂ ms, BR_{$\alpha$} =100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{191}\mathrm{Po})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.713(11)	7.555(11)	100%	(13/2 ⁺ )	0.063(24)		1.588(13)	$3.6^{+1.8}_{-1.6}$

* All values from [2001Ke06, 2001Uu01], except where noted.

** Deduced from  $\alpha$  energies [2001Ke06] and excitation energy of ^{191m}Po.

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +23/2$ nuclei.	Unless otherwise stated, all Q-values are taken from [2021Wa16] or
deduced from values therein. $J^{\pi}$ values for ¹⁴⁵ Pm are taken from ENSDF	

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
145-		L					
¹⁴⁵ Pm		5/2+	17.7(4) y	0.165(3)	-7.806(3)	1.739(3)	[1959Br65]
¹⁴⁹ Eu		5/2+	93.1(4) d	0.695(4)	-6.864(7)	2.566(4)	[1970Ch09]
¹⁵³ Tb		$5/2^{+}$	56.2(2) h	1.569(4)	-5.714(4)	3.397(4)	[1970Ch09]
¹⁵⁷ Ho		7/2+	12.6(2) m	2.592(24)	-4.031(24)	3.625(23)	[ <b>1972To05</b> ]
¹⁶¹ Tm		7/2+	30.2(8) m	3.303(29)	-2.805(32)	5.101(28)	[1993Al02]
¹⁶⁵ Lu		$1/2^{+}$	10.74(10) m	3.850(40)	-1.822(36)	6.334(28)	[1982Ra19]
¹⁶⁹ Ta		$(5/2^+)$	5.0(5) m	4.430(40)	-0.507(47)	7.580(39)	[1969Ar22]
¹⁷³ Re		$(5/2^{-})$	1.98(26) m	5.170(40)	0.487(40)	8.738(40)	[1986Sz05]
¹⁷⁷ Ir		5/2-	26(2) s*	5.909(25)	1.726(34)	10.255(34)	[1990Bo19, 1967Si02]
¹⁸¹ Au		$(3/2^{-})$	14.5(4) s	6.510(24)	2.817(29)	11.660(25)	[1995Bi01]
¹⁸⁵ Tl		$(1/2^+)$	19.5(5) s	6.426(25)	3.272(30)	12.199(25)	[1991BoZV]
^{185m} Tl	0.4548(15)	$(9/2^{-})$	1.7(2) s	6.881(25)	3.727(30)	12.654(25)	[1980ToZZ, 1976To06, 1977Si03]
¹⁸⁹ Bi		$(9/2^{-})$	688(3) ms	7.779(25)	4.983(36)	13.694(25)	[2007DoZW]
^{189m} Bi	0.182(8)	$(1/2^+)$	5.0(1) ms	7.961(26)	5.165(37)	13.876(26)	[2007DoZW]
¹⁹³ At		$(1/2^+)$	$28^{+5}_{-4}$ ms	8.258(26)	6.178(37)	15.352(26)	[2003Ke08]
^{193m1} At	0.010(5)**	$(7/2^{-})$	21(5) ms	8.268(26)	6.188(37)	15.362(26)	[2003Ke08]
^{193m2} At	0.044(7)**	$(13/2^+)$	$27^{+4}_{-3}$ ms	8.302(27)	6.222(38)	15.396(27)	[2003Ke08]
¹⁹⁷ Fr		$(7/2^{-})$	$0.6^{+3.0}_{-0.3}$ ms	8.740(60)	6.878(64)	16.154(58)	[2013Ka16]

* Weighted average of 30(2) s [1990Bo19] and 26(2) s [1967Si02].

** Deduced from  $\alpha$  energies.

# Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +23/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
¹⁴⁵ Pm	4.808(3)	12.777(3)	2.322(3)	2.8(6)×10 ⁻⁷ %	[1962Nu01]
¹⁴⁹ Eu	4.394(4)	11.977(4)	2.401(5)		
¹⁵³ Tb	3.895(4)	11.238(4)	2.703(5)		
¹⁵⁷ Ho	3.592(23)	10.160(25)	2.056(24)		
¹⁶¹ Tm	3.124(37)	9.147(28)	2.509(36)		
¹⁶⁵ Lu	2.719(31)	8.292(27)	3.032(39)		
¹⁶⁹ Ta	2.219(40)	7.342(47)	3.727(39)		
¹⁷³ Re	1.746(40)	6.412(40)	4.312(40)		
¹⁷⁷ Ir	1.205(23)	5.337(34)	5.082(34)	0.06(1)%	[1990Bo19, 1967Si02, 1986Ke03]
¹⁸¹ Au	0.730(22)	4.367(22)	5.751(3)	2.7(5)%	[1995Bi01, 1993BiZY, 1992BiZZ, 1990SaZU,
					1984BrZR, 1984ScZQ, 1979Ha10, 1970Ha18,
					1968De01, 1968Si01, 1965Si07]
¹⁸⁵ Tl	0.702(23)	4.144(23)	5.688(5)		
^{185m} Tl	0.247(23)	43.689(23)	6.143(5)	obs	[1980ToZZ, 1976To06, 1992BIZW, 1991BoZV,
					1980Sc09, 1977ToZS, 1976BoYC]
¹⁸⁹ Bi	-0.457(23)	2.198(22)	7.268(3)	obs	[1997Wa05, 2007DoZW, 2001An11, 2000Sc46,
					1998Kr23, 1997An09, 1995Ba75, 1995BaZP,
					1993An19, 1985Co06, 1984ScZQ, 1978Va21,
					1974Le02, 1973Ga08, 1973LiYK]
^{189m} Bi	-0.639(24)	2.016(23)	7.450(9)	83(5)%	[1997Wa05, 2007DoZW, 1983Ke08, 2001An11,
					2000Sc46, 1998Kr23, 1997An09, 1995Ba75,
					1995BaZP, 1993An19, 1985Co06, 1984ScZQ]
¹⁹³ At	-0.710(24)	1.406(23)	7.572(7)	$\approx 100\%$ *	[2003Ke08]
^{193m1} At	-0.720(24)	1.396(23)	7.582(9)	$\approx 100\%*$	[ <b>2003Ke08</b> , 1995Le15]
^{193m2} At	-0.754(25)	1.362(24)	7.616(10)	24(10)%	[2003Ke08]
¹⁹⁷ Fr	-0.990(58)	0.854(57)	7.888(15)**	100%*	[2013Ka16]

* Based on short half-life.

** Deduced from  $\alpha$  energy, 7.896(53) in [2021Wa16].
direct $\alpha$ emission from	1 ⁴⁵ Pm*, J ^π	$= 5/2^+, T_{1/2}$	$_2 = 17.7(4) \text{ y}^{**}$	*, $BR_{\alpha} = 2.8(6) \times 10^{-7}$	%.
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{141}\mathbf{H})$	Pr) coincident	rays R ₀ (fm)	HF	
2.304(40)	2.240(40)	100%	5/2+	0.0		1.5958(78)	$1.3\substack{+0.5 \\ -0.3}$	
* All valu ** [1959] Table 4	ues from [1962Nut Br65].	01], except whe	re noted.					
direct $\alpha$ emiss	sion from ¹⁷⁷ Ir, J ^{$\pi$}	$= 5/2^{-}, T_{1/2} = 2$	$26(2)$ s*, $BR_{\alpha}$	=0.06(1)%**.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	E _{daughter} ( ¹⁸¹ Au)	coincident γ-rays	$R_0$ (fm)	HF
5.126(10)	5.011(10)	100%	(5/2-)	0.0				

* Weighted average of 30(2) s [1990Bo19] and 26(2) s [1967Si02]. *** [1990Bo19]. *** [1067Si02].

## Table 5

direct  $\alpha$  emission from ¹⁸¹Au*, J^{$\pi$} = (3/2⁻), T_{1/2} =14.5(4) s, BR_{$\alpha$} =2.7(5)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{177}\mathrm{Ir})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
5.010/10	-	0.0 (1) 01	<b>a</b> ((1 <b>a</b> ) - 1 <b>a</b> - 3 <b>c</b>		0.425		1.5000(50)	21+21
5.313(10)	5.196(10)	0.2 (1)%	$2.4(13) \times 10^{-5}\%$		0.435		1.5322(52)	$21^{+21}_{-8}$
5.360(10)	5.242(10)	$\approx 0.1\%$	$\approx 1.2 \times 10^{-3}\%$		0.390		1.5322(52)	$\approx 80$
5.421(5)	5.301(5)	0.6(1)%	$7.1(18) \times 10^{-3}\%$		0.332		1.5322(52)	$24^{+9}_{-6}$
5.485(5)	5.364(5)	9(1)%	0.11(2)%		0.2659	0.0856, 0.1802, 0.2659	1.5322(52)	$3.3_{-0.7}^{+1.1}$
5.529(5)	5.407(5)	6(1)%	0.071(18)%	7/2-	0.2231	0.052, 0.054, 0.0624, 0.0751,	1.5322(52)	$8.0^{+3.0}_{-1.9}$
						0.0856, 0.0968, 0.1178, 0.1480, 0 1778, 0 2231		
5.603(5)	5.479(5)	100(1)%	1.2(2)%	3/2-	0.1480	0.052, 0.0624, 0.0.0856, 0.0968, 0.148	1.5322(52)	$1.1\substack{+0.3 \\ -0.2}$
5.670(5)	5.545(5)	7(1)%	0.083(19)%	$1/2^{-}$	0.0856	0.0856	1.5322(52)	$30^{+10}_{-7}$
5.707(5)	5.581(5)	7(1)%	0.083(19)%		0.0453		1.5322(52)	$45^{+16}_{-11}$
5.753(5)	5.626(5)	98(1)%	1.2(2)%	5/2+	0.0	—	1.5322(52)	$5.2^{+1.5}_{-1.1}$

* All values from [1995Br01].

## Table 6

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direct \alpha emission from <sup>185m</sup>Tl*, Ex = 454.8(15) keV**, J<sup>\pi</sup> = (9/2<sup>-</sup>), T<sub>1/2</sub> =14.5(4) s, BR<sub>\alpha</sub> =obs.
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{177}\mathrm{Ir})$	coincident γ-rays	$R_0$ (fm)	HF	
6.108(5)	5.976(5)	100(6)%							
6.143(5)	6.010(5)	19(6)%							

* All values from [1976To09, 1980ToZZ], except where noted. ** [1977Si03].

Table 7			
direct $\alpha$ emission from	189 Bi*, J ^{$\pi$} = (9/2 ⁻ ).	$T_{1/2} = 688(5)s^{**},$	$BR_{\alpha} = obs^{***}$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{185}\mathrm{Tl})^{@}$	coincident γ-rays [@]	R ₀ (fm)	HF
6.692(15)	6.55(15)	1.3(9)%	1.2(9)%	(11/2 ⁻ )	0.576(8)	1.5000(29)	1.5000(29)	$19^{+57}_{-8}$
6.816(5)	6.672(5)	100(2)%	95(2)%	(9/2-)	0.4548(15)	0.169, 0.286	1.5000(29)	0.67(6)
6.981(7)	6.833(7)	1.4(6)%	1.3(6)%	$(3/2^+)$	0.286(1)	0.286	1.5000(29)	$200^{+170}_{-60}$
7.268(6)	7.114(6)	3.3(6)%	3.1(7)%	$(1/2^+)$	0.0		1.5000(29)	$760_{-160}^{+240}$

* All values from [1997Wa05], except where noted. ** [2007DoZW].

*** Assumed to be 100% in [1997Wa05]. This value is used in this table for  $I_{\alpha}$ (abs) and HF. @ [2005Wu07].

Table	8
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direct (	α emission fro	m ^{189m} Bi*,	Ex = 1	182(8) k	eV, $J^{\pi}$	$=(1/2^+)$	, T _{1/}	$r_2 = 5.0(1) \text{ms}^*$	*, $BR_{\alpha}$	=obs***	
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{185}\mathrm{Tl})$	coincident γ-rays	R ₀ (fm)	HF
7.268(7) 7.450(6)	7.114(7) 7.292(6)	14(6)% 100(3)%	10(3)% 73(5)%	(1/2 ⁺ )	0.182(7) 0.0		1.5000(29) 1.5000(29)	$\begin{array}{c} 1.7^{+0.7}_{-0.4} \\ 0.90(9) \end{array}$

* All values from [1997Wa05], except where noted. ** [2007DoZW].

## Table 9

direct $\alpha$ emission from	193 At*, J $^{\pi}$ =	$(1/2^+), T_{1/2}$	$=28^{+5}_{-4}$ n	ns, $BR_{\alpha} =$	100%
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{189}\mathrm{Bi})$	coincident γ-rays	R ₀ (fm)	HF	
7.388(5)	7.235(5)	100%	(1/2 ⁺ )		0.182(8)		1.5519(62)	1.29(31)

* All values from [2003Ke08].

#### Table 10

## direct $\alpha$ emission from ^{193*m*1}At*, Ex = 10(5) keV, J^{$\pi$} = (7/2⁻), T_{1/2} =21(5) ms, *BR*_{$\alpha$} =100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	Edaughter( ¹⁸⁹ Bi)	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.480(5)	7.325(5)	2(2)%	2(2)%	(7/2 ⁻ )	0.0946(5)		1.5519(62)	≈100
7.580(5)	7.423(5)	100%	98(2)%	(9/2 ⁻ )	0.0		1.5519(62)	4.1(11)

* All values from [2003Ke08].

## Table 11

direct $\alpha$ emission from ^{193m2} At*, Ex = 44(7) keV, J	$\pi = (13/2^+), T_{1/2}$	$=27^{+4}_{-3}$ ms, $BR_{\alpha}$	=24(10)%
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{189}\mathrm{Bi})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF	
7.256(5)	7.106(5)	24(10)%	(13/2 ⁺ )	0.357.6(5)	0.357.6(5)		$2.0^{+1.9}_{-0.8}$	
* All values from [2003Ke08].								
Table 12 direct $\alpha$ emission	sion from ¹⁹⁷ Fr*	$J^{\pi} = (7/2^{-}), T_{1}$	$_{/2} = 0.6^{+30}_{-3}$ ms,	$BR_{\alpha} = 100\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{193}\mathrm{At})$	coincident γ-rays	R ₀ (fm)	HF	
7.888(15)	7.728(15)	100%	(7/2-)	0.010(5)		1.603(20)	0.53(27)	

* All values from [2013Ka16].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +12 nuclei.

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α

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +12$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
144	~ I					
¹⁴⁴ Nd	$0^+$	$2.4(2) \times 10^{13} \text{ y}^*$	-2.332(3)			[1961Ma05, 1987Al28, 1965Is01]
¹⁴⁸ Sm	$0^{+}$	$6.4^{+1.2}_{-1.3} \times 10^{15} \text{ y}$	stable			[2016Ca43]
¹⁵² Gd	$0^+$	$1.08(8) \times 10^{14} \text{ y}$	stable			[1961Ma05]
¹⁵⁶ Dy	$0^+$	$\geq 3.8 \times 10^{16} \text{ y}$	stable			[2011Be18]
¹⁶⁰ Er	$0^+$	28.58(9) h	0.318(29)	-4.186(24)	1.602(25)	[1970Ka23]
¹⁶⁴ Yb	$0^+$	75.8(17) m	0.897(29)	-3.134(16)	2.945(21)	[1972Ch23]
¹⁶⁸ Hf	$0^+$	25.92(20) m	1.710(50)	-2.060(28)	4.123(37)	[1970Ch17]
$^{172}W$	$0^+$	6.6(9) m	2.230(40)	-0.955(40)	5.551(47)	[1990Me12]
¹⁷⁶ Os	$0^+$	3.6(5) m	2.930(30)	0.213(30)	6.774(30)	[1970Ar15]
¹⁸⁰ Pt	$0^+$	58(3) s**	3.548(24)	1.301(18)	8.208(30)	[1993Me13, 2020Cu02]
¹⁸⁴ Hg	$0^+$	30.6(3) s	3.974(24)	2.139(17)	9.208(24)	[1972Fi12]
¹⁸⁸ Pb	$0^+$	25.5(1) s	4.530(30)	3.019(16)	10.083(24)	[1993Wa03]
¹⁹² Po	$0^+$	32.5(10) ms***	5.470(30)	4.936(13)	11.845(32)	[1996Bi17, 2003Va16]
¹⁹⁶ Rn	$0^+$	$4.4^{+1.3}_{-0.9}$ ms	5.890(30)	5.803(15)	13.085(33)	[2001Ke06]

* Weighted average of  $2.4(3) \times 10^{15}$  y [1961Ma05],  $2.65(37) \times 10^{15}$  y [1987Al28] and  $2.1(4) \times 10^{15}$  y [1965Is01]. ** Weighted average of 60(3) s [1993Me13] and 56(3) s [2020Cu02].

*** Weighted average of 33.2(14) ms [1996Bi17] and 31.8(15) ms [2003Va16].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +12$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
¹⁴⁴ Nd	7.969(1)	13,793(2)	1.901(1)	100%	[ <b>1965]s01</b> , 1961Br43, 1987A128, 1961Ma05.
110	(1)(1)	101170(2)	11/01(1)	10070	1956Po16, 1954Wa051
¹⁴⁸ Sm	7.583(0)	12.988(1)	1.987(1)	100%*	[ <b>2016Ca43</b> , 1970Gu14, 1968Ko06, 1961Ma05, 1960Ka23]
¹⁵² Gd	7.343(1)	12.234(1)	2.204(1)	100%*	[ <b>1961Ma05</b> , 1966Ka23, 1959Ri34, 1956Po16]
¹⁵⁶ Dy	6.568(10)	11.401(18)	1.7530(3)		
¹⁶⁰ Er	6.024(24)	10.235(24)	2.040(24)		
¹⁶⁴ Yb	5.573(16)	9.256(15)	2.627(29)		
¹⁶⁸ Hf	5.123(47)	8.345(29)	3.227(32)		
$^{172}W$	4.666(40)	7.421(40)	3.838(40)		
176Os	4.132(30)	6.482(30)	4.541(30)		
¹⁸⁰ Pt	3.637(14)	5.464(17)	5.276(5)	0.52(5)%	[2020Cu02, 1993Me12, 1968De01, 1966Si08]
¹⁸⁴ Hg	3.442(13)	4.754(16)	5.660(4)	1.26(20)%	[1994Wa23, 1970Ha18, 1990Sc09, 1976To06,
-					1976WoZJ, 1972Fi12, 1970FiZZ, 1970HoZT,
					1969NaZT, 1969NaZU]
¹⁸⁸ Pb	2.655(13)	3.850(15)	6.109(3)	8.5(5)%**	[1993Wa03, 1999An22, 2003Va16, 1994Wa13,
					1993WaZI, 1992Wa14, 1984To09, 1981To02,
					1980ElZY, 1980Sc09, 1977De32, 1974JoZU,
					1974Le02, 1973Ho01, 1973LiYK, 1972Ga27]
¹⁹² Po	2.116(13)	2.228(16)	7.320(3)	$\approx 100\%$	[2003Va16, 1998Al27, 2005Uu03, 2004An23,
					2003Wa05, 2002VaZZ, 2001Hu21, 2001Ju09,
					2001Ke06, 2001Uu01, 1999An22, 1999Pa20,
					1997Pu01, 1993Wa04, 1982LeZN, 1981Le23,
					1981LeZU, 1977De32, 1977DeXF]
¹⁹⁶ Rn	1.844(17)	1.598(19)	7.617(9)	100%***	[2001Ke06, 2001Uu01, 1997Pu01, 1996PuZZ,
					1995Mo14, 1995NoZW]

* Only decay mode energetically possible.

** Weighted average of 9.3(8)% [1999An22] and 8.0(6)% [2003Va16].

*** Based on short half-life.

direct $\alpha$ emis	ssion from ¹⁴⁴ Nd, J	$\pi = 0^+, T_{1/2} = 2$	$.4(2) \times 10^{15} \text{ y}^*$	$BR_{\alpha} = 100\%.$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{140}\mathrm{Ce}$	e) coinciden	t γ-rays	R ₀ (fm)	HF	
1.882(20)	1.830(20)**	100%**	$0^+$	0.0			1.5986(8	0.41	(3)***
* Weigh ** [1965 *** The	tted average of 2.4( 5Is01]. reason for this low	3)×10 ¹⁵ y [1961 v value is unclear.	Ma05], 2.65(3	87)×10 ¹⁵ y [1987	$7A128$ ] and $2.1(4) \times$	10 ¹⁵ y [196	5Is01].		
<b>Fable 4</b> lirect α emis	ssion from ¹⁴⁸ Sm*,	$J^{\pi} = 0^+, T_{1/2} = 0^+$	$5.4^{+1.2}_{-1.3} \times 10^{15}$	y, $BR_{\alpha} = 100\%^{**}$	k.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{144}N$	Id) coincide	ent γ-rays	R ₀ (fr	n) HF	7
1.9873(5)	1.9376(5)	100%**	$0^+$	0.0			1.586	(12) 1.0	02(1)
* All va ** Only	lues from [2016Ca decay mode energ	43]. etically possible.							
Table 5 direct $\alpha$ emis	ssion from ¹⁵² Gd*,	$J^{\pi} = 0^+, T_{1/2} = 1$	.08(8)×10 ¹⁴ y	y, $BR_{\alpha} = 100\%^{**}$	۰.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{148}\mathrm{St}$	n) coincide	nt γ-rays	R ₀ (fm	) HI	F
2.198(30)	2.140(30)	100%**	$0^+$	0.0			1.5741	(45) 0.8	81(7)
* All va ** Only	lues from [1961Ma decay mode energ	.05]. etically possible.							
<b>Table 6</b> direct $\alpha$ emised	ssion from ¹⁸⁰ Pt*, .	$\mathbf{J}^{\pi} = 0^+,  \mathbf{T}_{1/2} = 58$	$B(3)$ s**, $BR_{\alpha}$	= 0.52(5)%.					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^{\pi}$	$E_{daughter}(^{176}\mathrm{Os}$	) coinciden	t γ-rays	R ₀ (fm)	HF	
5.277(5)	5.160(5)	0.52(5)%	$0^+$	0.0			1.5468(	52) 1.02	1(11)
* All va ** Weig	lues from [2020Cu thted average of 60	05], except where (3) s [1993Me13]	e noted.   and 56(3) s [2	2020Cu02].					
<b>Table 7</b> direct α emis	ssion from ¹⁸⁴ Hg, J	$\pi = 0^+, T_{1/2} = 30$	$0.6(3)  s^*, BR_{\alpha}$	= 1.26(20)%**.					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{180}\mathrm{Pt})$	coincide	nt γ-rays	$R_0$ (fm)	HF
5.167(15) 5.500(15) 5.658(15)	5.055(15)*** 5.380(15)** 5.535(15)**	0.17(1)% [@] 0.40(8)% 100%	0.0021(6)9 0.005(1)% 1.25(20)%	$\% 0^+ 0^+ 2^+ 0^+$	0.478 0.153 0.0	0.153 0.153		1.5120(81) 1.5120(81) 1.5120(81)	$2.4(2)^{***} \\ 44^{+16}_{-9} \\ 0.88^{+0.16}_{-0.12}$

* [1972Fi12].
*** [1970Ha18].
**** [1994Wa23].
@ [1994Wa23] reports a HF of 2.4(2) for this transition which corresponds to a branching ratio of 0.17(1)% relative to the 5.525-MeV transition.

direct $\alpha$ emission from	$1^{188}$ Pb*, $J^{\pi} = 0^+$	$T_{1/2} = 25.5(1) \text{ s},$	$BR_{\alpha} = 8.5(5)\%^{**}$ .
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{184}\mathrm{Hg})$	coincident γ-rays	R ₀ (fm)	HF	
5.736(10)	5.614(10)	0.10(1)%***	8.5(13)×10 ⁻³ %	$0^+$	0.375	0.375	1.4885(12)	21(3)***	
5.755(10)	5.633(10)	0.07(1)%***	$4.8(11) \times 10^{-3}\%$	$2^{+}$	0.367	0.367	1.4885(12)	34(7)***	
6.110(10)	5.980(10)	100%	9.3(8)%	$0^{+}$	0.0		1.4885(12)	1.00(8)	

* All values taken from [1993Wa03], except where noted.

** Weighted average of 9.3(8)% [1999An22] and 8.0(6)% [2003Va16].

*** The relative branching ratios are derived from the HF given by [1993Wa03].

#### Table 9

direct $\alpha$ emission from ¹⁹² Po, $J^{\pi} = 0^+$ , $T_{1/2} = 32.5(10)$ ms*,	$BR_{\alpha} = \approx 100\%$
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{@}$	$I_{\alpha}(\text{rel})^{**}$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{188}\text{Pb})$	coincident γ-rays	R ₀ (fm)	HF
≈6.594 6.741(7) 7.319(4)	≈6.457** 6.601(7)*** 7.167(4)**	≤0.005% 1.4(1)% 100.0(2)%	$\leq 0.005\%$ 1.4(1)% 98.6(2)%	$0^+ \ 0^+ \ 0^+$	0.725 0.578 0.0		1.51737(13) 1.51737(13) 1.51737(13)	≥ 51 0.66(7) 0.997(13)

* Weighted average of 33.2(14) ms [1996Bi17] and 31.8(15) ms [2003Va16].

** [2003Va16].

*** Weighted average of 6.611(7) MeV [1998Al27] and 6.591(7) [2003Va16].

[@] In addition, [1998Al27] report a transition with  $E_{\alpha} = 6.416(13)$  MeV. However, this was not observed in [2003Va16] and may have been the 6.420(20) MeV transition from the fine structure in the  $\alpha$ -decay of ¹⁹³Po [2002Va13].

#### Table 10

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direct \alpha emission from <sup>196</sup>Rn*, J<sup>\pi</sup> = 0<sup>+</sup>, T<sub>1/2</sub>= 4.4<sup>+1.3</sup><sub>-0.9</sub> ms, BR<sub>\alpha</sub> = 100%.
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{192}\text{Po})$	coincident γ-rays	R ₀ (fm)	HF
7.616(9)	7.461(9)	100%	0+	0.0		1.585(15)	1.00(30)

* All values from [2001Ke06].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +1/2 nuclei.

Last updated 5/8/23

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +12$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{$\pi$} values for ¹⁴²Pr, ¹⁴⁶Pm, ¹⁵⁰Eu, ¹⁵⁴Tb, ¹⁵⁸Ho, ¹⁶²Tm, ¹⁶⁶Lu, ¹⁷⁰Ta, ¹⁷⁴Re, ¹⁷⁸Ir and ¹⁸²Au are taken from ENSDF.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta F}$	Experimental
¹⁴² Pr		$2^{-}$	19.12(4) h*	2.164(1)	-8.145(4)	2.051(2)		[1966Ot03, 1968La17]
¹⁴⁶ Pm		3-	5.53(5) v	1.542(3)	-7.117(8)	2.654(5)		[ <b>1967Bu12</b> ]
¹⁵⁰ Eu		5-	36.9(9) y	0.972(4)	-6.017(6)	3.709(6)		[1993Th04]
¹⁵⁴ Tb		0	21.4(5) h	0.240(50)	-4.078(45)	4.470(45)		[1973La20]
¹⁵⁸ Ho		5+	11.5(5) m	4.220(27)	-2.713(27)	5.094(27)		[1962Sc10]
¹⁶² Tm		1-	21.77(26) m	4.857(26)	-1.570(26)	6.505(26)		[1971Ch30]
¹⁶⁶ Lu		6-	2.65(10) m	5.570(30)	-0.380(30)	7.888(30)		[1974De09]
¹⁷⁰ Ta		$(3^{+})$	6.76(6( m	6.120(40)	0.656(28)	9.031(29)		[1976Le04]
¹⁷⁴ Re			2.40(15) m	6.550(40)	1.434(40)	10.156(40)		[1977Ha24]
¹⁷⁸ Ir			12(2) s	7.290(23)	2.726(34)	11.548(34)		[1973HaVR]
¹⁸² Au		$(2^+)$	15.6(4) s	7.864(23)	3.870(19)	12.815(23)		[1992Ro21]
¹⁸⁶ Tl		$(2^{-})$	$3.4^{+0.5}_{-0.4}$ s	8.656(24)	4.686(21)	13.861(25)		[2020St11]
^{186m} Tl	0.077(56)	$(7^{+})$	27.5(10) s	8.733(61)	4.763(60)	13.938(61)		[1977Co21]
¹⁹⁰ Bi		(3+)	6.3(1) s	9.821(24)	6.731(23)	15.518(24)	$2.5(5) \times 10^{-5}$	[2009An11, 1988Hu03]
^{190m} Bi	0.191(65)	(10 ⁻ )	6.2(1) s	10.012(69)	6.922(69)	15.709(69)	$4.1^{+0.8}_{-1.5} \times 10^{-5}$	[2009An11, 1988Hu03]
¹⁹⁴ At		$(2^{-})$	253(10) ms	10.288(27)	7.879(25)	17.275(27)	0.059(4)%***	[2014Gh09, 2009An11, 2013An03]
^{194m} At	0.056(21)**	$(9^{-}, 10^{-})$	310(8) ms	10.344(34)	7.935(33)	17.331(34)	0.059(4)%***	[2014Gh09, 2009An11, 2013An03]
¹⁹⁸ Fr		$(2^{-})$	15(3) ms	10.810(30)	8.644(32)	18.157(34)		[2013Ka16, 2013Uu01]
^{198m1} Fr	х	$(6^+, 7^+)$	$16^{+13}_{-5}$ ms	10.810(30)+x	8.644(32)+x	18.157(34)+x		[2013Uu01]
^{198m2} Fr	У	h.s.	1.1(7) ms	10.810(30)+y	8.644(32)+y	18.157(34)+y		[2013Ka16]

* Weighted average of 19.14(5) h [1966Ot03] and 19.09(7) h [1968La17].

** Deduced from  $\alpha$ -decay energies [2009An11].

*** value is acombination of the two isomers [2014Gh09].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +12$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BR _α	Experimental
140					
¹⁴² Pr	5.644(1)	14.052(2)	0.302(2)		
¹⁴⁶ Pm	5.311(4)	13.282(5)	1.907(4)		
¹⁵⁰ Eu	4.945(6)	12.504(8)	2.237(7)		
¹⁵⁴ Tb	4.563(45)	11.846(45)	2.211(46)		
¹⁵⁸ Ho	4.052(27)	10.674(27)	1.544(53)		
¹⁶² Tm	3.565(27)	9.673(30)	2.285(38)		
¹⁶⁶ Lu	3.015(40)	8.690(39)	3.032(40)		
¹⁷⁰ Ta	2.710(40)	7.643(47)	3.458(41)		
¹⁷⁴ Re	2.235(40)	6.921(40)	4.040(40)		
¹⁷⁸ Ir	1.587(24)	5.769(34)	4.994(34)		
¹⁸² Au	1.211(23)	4.904(29)	5.525(4)	0.13(5)%	[1995Bi01, 1993BiZY, 1992BiZZ, 1979Ha10,
					1970Ha18]
¹⁸⁶ Tl	0.988(25)	4.142(30)	5.996(26)	obs	[2020St11]
¹⁸⁶ Tl	0.911(62)	4.065(64)	6.073(63)	0.006(2)%	[1977Co21, 1976Ij01, 1977IjZZ, 1976ToZR,
					1976To06]
¹⁹⁰ Bi	0.041(25)	2.837(37)	6.862(3)	$90^{+10}_{-30}\%$	[2003An26, 1991Va04, 2013Ny01, 2009An11,
				50	2003AnZZ, 1997An09, 1993An19, 1988Hu03,
					1985HuZY]
^{190m} Bi	-0.150(70)	2.646(375)	7.053(65)	70(9)%	[2003An26, 1991Va04, 2013Ny01, 2009An11,
					2003AnZZ, 1997An09, 1993An19, 1988Hu03,
					1985HuZY, 1974Le02, 1972Ga27]
¹⁹⁴ At	-0.320(28)	1.760(38)	7.454(11)	$\approx 100\%^*$	[2009An11, 2013Ka16, 2013Ny01, 2013Uu01,
					1995Le15, 1984YaZY]
^{194m} At	-0.376(35)	1.648(43)	7.510(24)	$\approx 100\%^*$	[2009An11, 2013Ka16, 2013Ny01, 2013Uu01]
¹⁹⁸ Fr	-0.778(35)	1.087(43)	7.770(15)**	100%*	[2013Ka16, 2013Uu01]
¹⁹⁸ Fr	-0.778(35)-x	1.087(43)-x	7.770(15)+x	100%*	[2013Uu01]
¹⁹⁸ Fr	-0.778(35)-y	1.087(43)-y	7.770(15)+y	100%*	[2013Ka16]

* based on short half-life.

** Deduced from  $\alpha$  energy, 7.869(20) in [2021Wa16].

# **Table 3** direct $\alpha$ emission from ¹⁸²Au*, J^{$\pi$} = (2⁺), T_{1/2}= 15.6(4) s**, BR_{$\alpha$} = 0.13(5)%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{178}\mathrm{Ir})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
5.402(5) 5.472(5) 5.524(5)	5.283(5) 5.352(5) 5.403(5)	10(1)% 100(1)% 29(1)%	0.009(4)% 0.094(36)% 0.027(10)%	(2+)	0.123 0.0544 0.0	0.0544	1.529(10) 1.529(10) 1.529(10)	$15^{+11}_{-5} \\ 3.3^{+2.3}_{-1.2} \\ 21^{+15}_{-7}$

* All values from [1995Bi01], except where noted.

** [1992Ro21].

*** Interpolated between 1.5468(62) fm ¹⁸⁰Pt and 1.5120(81) ¹⁸⁴Hg.

#### Table 4

direct  $\alpha$  emission from ¹⁸⁶Tl*, J^{$\pi$} = (2⁻), T_{1/2}= 3.4^{+0.5}_{-0.4} s, BR_{$\alpha$} = obs.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{182}\mathrm{Au})$	coincident γ-rays	R ₀ (fm)***	HF
(5.647)	(5.526)	4.4%		0.2731	0.0253, 0.1041, 0.1294, 0.1437, 0.2731	1.5002(82)	
(5.651) 5.647(51)	(5.529) 5.670(51)	5.3% 100%		0.2702	0.0253, 0.1041, 0.1294, 0.1408	1.5002(82) 1.5002(82)	

* All values from [2020St11].

** [2020St11] report one  $\alpha$  transition feeding a level at 129 keV in ¹⁸²Au. However, they report  $\gamma$ 's in coincidence with an  $\alpha$  multiplet from 4.550 to 6.500 MeV that arise from 273.1 and 270.2-keV levels in ¹⁸²Au. The intensities recorded here are based on the intensities of the coincident  $\gamma$ -rays.

direct $\alpha$	emission	from	^{186m} Tl,	Ex =	77(56)	keV, J ²	$\tau = (7)$	'+), T	$1/2 = 2^{2}$	7.5(10)	s*, 1	$BR_{\alpha} =$	= 0.006	(2)%**	۴.
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{182}\mathrm{Au})$	coincident γ-rays	R ₀ (fm)***	HF
5.765(10)	5.641(10)**	0.006(2)%**	$2^{+}$	0.0		1.5002(82)	$160^{+90}_{-50}$

* [1977Co21].

** [1976Ij01

*** Interpolated between 1.5120(81) fm ¹⁸⁴Hg and 1.4885(12) fm ¹⁸⁸Pb.

#### Table 6

direct  $\alpha$  emission from ¹⁹⁰Bi*, J^{$\pi$} = (3⁺), T_{1/2}= 6.3(1) s, BR_{$\alpha$} = 90⁺¹⁰₋₃₀%**.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	$E_{daughter}(^{186}\text{Tl})$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF
6.359(10)	6.225(10)	0.06(1)%	$0.054^{+0.011}_{-0.020}\%$		0.507	0.213, 0.294	1.5029(12)	$120^{+70}_{-9}$
6.550(10)	6.412(10)	0.10(2)%	$0.09^{+0.02}_{-0.03}\%$		0.314	0.314	1.5029(12)	$720_{-70}^{+380}$
6.569(5)	6.431(5)	100%	$90^{+10}_{-30}\%$	(3 ⁺ )	0.294	0.079, 0.105, 0.111	1.5029(12)	$0.90_{-0.09}^{+0.40}$
6.647(5)	6.507(5)**	0.24(8)%**	$0.22^{+0.08}_{-0.10}\%$	$(2^{-})$	0.226	0.105, 0.111	1.5029(12)	$700^{+300}_{-110}$
6.753(10)	6.611(10)	2.2(3)%	$1.98_{-0.71}^{+0.35}\%$	$(4^{+})$	0.105	0.105	1.5029(12)	$200^{+100}_{-19}$
6.860(10)	6.716(10)	1.5(2)%	$1.35_{-0.48}^{+0.23}\%$	(2 ⁻ )	0.0		1.5029(12)	$710_{-60}^{+390}$

* All values from[2003An26], except where noted.

** [1991Va04].

*** [2022Ba26].

[@] Interpolated between 1.4885(12) fm  188 Pb and 1.51737(13) fm  192 Po.

Table 7					
direct $\alpha$ emission from	^{190m} Bi*, J ^{$\pi$}	$=(10^{-}), T$	$\Gamma_{1/2} = 6.2(1)$ s	$BR_{\alpha} = 7$	0(9)%**.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	$E_{daughter}(^{186}\text{Tl})$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF
6 520(10)	6 202(10)	0.24(4)0	0.16(2)0		0.441	0.441	1 5020(12)	220+100
0.529(10)	0.392(10)	0.24(4)%	0.10(5)%		0.441	0.441	1.3029(12)	550-60
6.595(5)	6.456(5)	100%	67(9)%		0.374	0.374	1.5029(12)	$1.43^{+0.25}_{-0.19}$
6.611(10)	6.472(10)	0.41(7)%	0.28(6)%		0.356	0.895, 0.267, 0.385	1.5029(12)	$410^{+130}_{-80}$
6.687(10)	6.546(10)	0.046(8)%	0.031(7)%		0.281	0.281	1.5029(12)	$7.0^{+2.2}_{-1.4} \times 10^3$
6.711(10)	6.570(10)	0.039(8)%	0.026(6)%		0.255	0.255	1.5029(12)	$1.0^{+0.4}_{-0.2} \times 10^4$
6.879(10)	6.734(10)	1.5(2)%	1.01(19)%		0.0895	0.0895	1.5029(12)	$1.07_{-0.18}^{+0.27} \times 10^3$
6.966(10)	6.819(10)	2.0(3)%	1.34(27)%		0.0		1.5029(12)	$1.7^{+0.5}_{-0.3} \times 10^3$

* All values from[2003An26], except where noted.

** [1991Va04].

*** [2022Ba26].

[@] Interpolated between 1.4885(12) fm  188 Pb and 1.51737(13) fm  192 Po.

## Table 8

direct  $\alpha$  emission from ¹⁹⁴At*, J^{$\pi$} = (2⁻), T_{1/2}= 253(10) ms, BR_{$\alpha$} =  $\approx 100\%$ **.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{190}\mathrm{Bi})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
7.295(15)	7.145(15)	11(4)%	9(3)%		0.168(15)	0.0465, 0.076	1.551(15)	$7^{+5}_{-3} \times 10^3_{-3+4}$
7.341(15) 7.419(15) 7.464(15)	7.190(15) 7.266(15) 7.31(15)	100(5)% 8(4)% >1.26%	83(3)% 7(3)% >1.0(5)%	(3 ⁺ )	0.121(15) 0.045(15) 0.0	0.076	1.551(15) 1.551(15) 1.551(15)	$10^{+3}_{-3}$ $220^{+200}_{-100}$ $>2.1 \times 10^{3}$

* All values from [2009An11].

** Based on short half-life.

*** Interpolated between 1.51737(13) fm  $^{192}\mathrm{Po}$  and 1.585(15) fm  $^{196}\mathrm{Rn}.$ 

#### Table 9

direct  $\alpha$  emission from ^{194m}At*, Ex. = 56(21) keV, J^{$\pi$} = (9⁻, 10⁻), T_{1/2}= 310(8) ms, BR_{$\alpha$} =  $\approx$  100%**.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	<i>E</i> _{daughter} ( ¹⁹⁰ Bi)	coincident γ-rays	R ₀ (fm)***	HF
7.053(15)	6.908(15)	1.3(4)%	1.0(3)%		0.465	0.274	1.551(15)	$110^{+70}$
7.234(15)	7.085(15)	17(3)%	13(2)%		0.288	0.097	1.551(15)	$34^{+14}_{-11}$
7.285(15)	7.135(15)	10(3)%	8(2)%		0.231	0.40	1.551(15)	$90^{+50}_{-30}$
7.329(15)	7.178(15)	100(9)%	78(5)%	$(10^{-})$	0.191		1.551(15)	$12_{-4}^{+5}$

* All values from [2009An11].

** Based on short half-life.

*** Interpolated between 1.51737(13) fm  $^{192}\mathrm{Po}$  and 1.585(15) fm  $^{196}\mathrm{Rn}.$ 

## Table 10

direct  $\alpha$  emission from ¹⁹⁸Fr*, J^{$\pi$} = (2⁻), T_{1/2}= 15(3) ms, BR_{$\alpha$} =  $\approx 100\%$ **.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{194}\mathrm{At})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.770(15)	7.613(15)***	100%	(2 ⁻ )	0.0			

* [2013Ka16].

** Based on short half-life.

*** From [2013Uu01]. [2013ka16] report an  $\alpha$  transition of  $\approx$  7.710 MeV and an unresolved multiplet from 7.470 and 7.920 MeV.

#### Table 11

direct $\alpha$ emiss	ion from ^{198m1} Fr	*, Ex. = x, $J^{\pi}$ =	$(6^+, 7^+), T_{1/2} =$	$16^{+13}_{-5}$ ms, $BR_{\alpha} = 1009$	%**.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{m \pi}$	$E_{daughter}(^{194}\mathrm{At})$	coincident γ-rays	$R_0$ (fm)	HF	
7.842(15)	7.684(15)	100%	(6 ⁺ , 7 ⁺ )	x'				

* All values from [2013Uu01].

** Based on short half-life.

### Table 12

direct $\alpha$ emission from	198m2 Fr*, Ex. = y,	$J^{\pi}$ = high spin, $T_{1/2}$ =	$= 1.1(7) \text{ ms}, BR_{\alpha} = 100\%^{**}.$
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{194}\mathrm{At})$	coincident γ-rays	R ₀ (fm)	HF
7.736-8.094	7.580-7.930***	100%		у'			

* All values from [2013Ka16].

** Based on short half-life.

*** Unresolved multiplet.

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Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +25/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
			-/-		*		
¹⁴⁵ Nd		$7/2^{-}$	$>10^{17}  ext{ y}$	stable			[1966Ka23]
¹⁴⁹ Sm		$7/2^{-}$	$>2 \times 10^{15} \text{ y}$	stable			[1970Gu14]
¹⁵³ Gd		3/2-	239.472(69) d	0.485(1)	-5.409(0)	0.757(2)	[1992Un01]
¹⁵⁷ Dy		3/2-	8.2(1) h	1.339(5)	-4.178(5)	1.518(5)	[1953Ha81]
¹⁶¹ Er		3/2-	3.24(4) h	1.995(9)	-2.818(9)	3.138(9)	[1972Wo08]
¹⁶⁵ Yb		5/2-	9.8(5) m*	2.635(27)	-1.642(27)	4.476(27)	[1968Ta05, 1967Pa04]
¹⁶⁹ Hf		5/2-	3.26(5) m	3.366(28)	-0.426(28)	5.788(28)	[1970Ch17]
¹⁷³ W		5/2-	7.6(1) m	3.670(40)	0.386(37)	6.930(28)	[1991KuZN]
¹⁷⁷ Os		$1/2^{-}$	3.1(2) m	4.310(30)	1.396(32)	8.015(32)	[1972Be89]
¹⁸¹ Pt		$1/2^{-}$	51(5) s	5.082(15)	2.686(21)	9.463(31)	[1966Si08]
¹⁸⁵ Hg		1/2-	49.1(10) s	5.674(14)	3.860(20)	10.854(15)	[2013Sa43]
^{185m} Hg	0.1037(5)**	$13/2^{+}$	21.6(15) s	5.778(14)	3.964(20)	10.958(15)	[2013Sa43, 1982Bo27]
¹⁸⁹ Pb		$(3/2^{-})$	39(8) s	6.772(16)	5.065(16)	11.589(14)	[2013Sa43, 2009Sa09]
^{189m} Pb	0.040(4)**	$(13/2^+)$	50(3) s	6.812(16)	5.105(16)	11.629(14)	[2013Sa43, 2009Sa09]
¹⁹³ Po		(3/2-)	420(40) ms	7.559(16)	6.938(16)	13.866(17)	[2013Sa43]
^{193m} Po	0.095(6)	$(13/2^+)$	240(10) ms	7.654(17)	7.033(17)	13.961(18)	[2013Sa43]
¹⁹⁷ Rn		$(3/2^{-})$	$53^{+7}_{-5}$ ms	7.866(18)	7.690(17)	14.970(18)	[2013Sa43, 2008An05]
^{197m} Rn	0.194(10)	$(13/2^+)$	$25^{+3}_{2}$ ms	8.060(21)	7.884(20)	15.164(21)	[2013Sa43, 2008An05]
²⁰¹ Ra		$(3/2^{-})$	$8^{+40}$ ms	8.348(22)	8.648(21)	15.867(22)	[2014Ka23]
^{201m} Ra	0.260(30)	$(13/2^+)$	$1.6^{+7.7}_{-0.7}$ ms	8.608(37)	8.908(37)	16.127(37)	[2014Ka23, 2005Uu02]

* Weighted average of 9.0(5) m [1968Ta05] and 10.5(5) m [1967Pa04]. ** [2013Sa43].

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +25/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
1.45					
¹⁴⁵ Nd	7.970(2)	14.404(2)	1.574(1)		
¹⁴⁹ Sm	7.559(6)	13.567(1)	1.871(1)		
¹⁵³ Gd	7.283(1)	12.884(1)	1.828(1)		
¹⁵⁷ Dy	6.623(6)	11.932(5)	1.033(5)		
¹⁶¹ Er	6.108(17)	10.612(9)	1.798(10)		
¹⁶⁵ Yb	5.675(36)	9.706(27)	2.481(28)		
¹⁶⁹ Hf	4.933(47)	8.705(28)	3.154(39)		
$^{173}W$	4.686(40)	7.874(40)	3.565(40)		
¹⁷⁷ Os	4.183(32)	6.902(32)	4.346(32)		
¹⁸¹ Pt	3.693(26)	5.939(21)	5.150(5)	0.074(10)%	[ <b>1995Bi01</b> , 1993BiZY, 1993Me13, 1992MeZW, 1966Si08
¹⁸⁵ Hg	3.154(26)	4.988(20)	5.773(4)	≈6.04%	[ <b>2013Sa43</b> , 1979Ha10, 1977Ij01, 1976GrZC, 1976GrZL, 1970Ha18, 1970Ma24, 1969Ha03, 1969NaZT, 1969NaZU, 1968De01, 1963Ka17, 1953Ba021
^{185m} Hg	3.050(26)	4.884(20)	5.877(4)	≈0.030%	[ <b>2013Sa43</b> , 1979Ha10, 1976GrZC, 1976GrZL, 1970Ha18]
¹⁸⁹ Pb	2.797(33)	4.303(19)	5.915(4)	$\leq 0.4\%$	[2013Sa43]
^{189m} Pb	2.757(33)	4.263(19)	5.955(4)	$\approx 0.4\%$	[ <b>2013Sa43, 1974Ho26</b> , 1993An19, 1974JoZU, 1974Le02, 1973LiYK, 1972Ga27]
¹⁹³ Po	2.080(33)	2.612(16)	7.094(4)	$\approx 100\%^*$	[ <b>2013Sa43, 2002Va13</b> , 1997Fo06, 1995Mo14, 1993Wa04, 1982LeZW, 1981Le23, 1977De32, 1977DeXF]
^{193m} Po	1.985(33)	2.517(17)	7.189(6)	$\approx 100\%^*$	[ <b>2013Sa43, 2002Va13</b> , 1997Fo06, 1995Mo14, 1993Wa04, 1982LeZW, 1981Le23, 1977De32, 1977DeXF, 1967Si09, 1965Si22]
¹⁹⁷ Rn	1.865(34)	1.951(17)	7.411(7)	$\approx 100\%*$	[ <b>2013Sa43, 2008An05</b> , 1996En01, 1996MoZV, 1995LeZY, 1995Mo14, 1995NoZW]
^{197m} Rn	1.865(34)	1.951(17)	7.411(7)	$\approx 100\% *$	[ <b>2013Sa43, 2008An05</b> , 2005Uu02, 1997Pu01, 1996En01, 1995LeZY, 1995NoZW]
²⁰¹ Ra	1.486(37)	1.081(22)	8.002(12)	100%	[2014Ka23]
201m Ra	1.746(48)	1.341(37)	8.362(32)	100%	[2014Ka23, 2005Uu02]

* Based on short half-life.

## Table 3

direct  $\alpha$  emission from ¹⁸¹Pt*,  $J_i^{\pi} = 1/2^-$ ,  $T_{1/2} = 51(5) s^{**}$ ,  $BR_{\alpha} = 0.074(10)\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{177}\mathrm{Os})$	coincident γ-rays	R ₀ (fm)	HF
5.062(20) 5.150(5)	4.95(20) 5.036(5)	4% 100%	0.0028(4)% 0.071(10)%	1/2-	0.88(21) 0.0	_	1.5504(65) 1.5504(65)	14 1.6(5)

* All values from [1995Bi01], except where noted.

** [1966Si08].

## Table 4

direct  $\alpha$  emission from ¹⁸⁵Hg*,  $J_i^{\pi} = 1/2^-$ ,  $T_{1/2} = 49.1(10)$  s,  $BR_{\alpha} = \approx 6.04\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{181}\mathrm{Pt})$	coincident γ-rays	R ₀ (fm)	HF
5.692(5) 5.778(5)	5.569(5) 5.653(5)	4 % 100%	$\approx 0.24\%$ $\approx 5.8\%$	5/2 ⁻ 1/2 ⁻	0.094 0.0	0.079, 0.094	1.506(13)	11 1.1

* All values from [2013Sa43].

Table 5		
direct $\alpha$ emission from	^{185m} Hg*, Ex = 103.7(5) keV, $J_i^{\pi} = 13/2^{-1}$	$T_{1/2}$ = 21.6(15) s, <i>BR</i> _α = ≈0.030%

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{181}\mathrm{Pt})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.491(8) 5.528(10)	5.372(8) 5.408(10)	100% 25%	$\approx 0.024\%$ $\approx 0.006\%$	$(13/2^+)$ $(11/2^+)$	0.381 0.343	0.0228, 0.405, 0.094, 0.105, 0.119, 0.159 0.056, 0.727, 0.079, 0.094, 0.1206, 0.1607	1.506(13) 1.506(13)	$\approx 7 \approx 40$
5.550	5.430	<25%	< 0.006%	$(11/2^+)$	0.320	0.0228, 0.405, 0.044, 0.094, 0.119, 0.159	1.506(13)	>51

* All values from [2013Sa43], except where noted.

## Table 6

direct $\alpha$ emission from	1 ¹⁸⁹ Pb*, J	$\frac{\pi}{i} = (3/2^{-}),$	$T_{1/2} = 39(8) s^*$	*, $BR_{\alpha} = \le 0.4\%$
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{185}\mathrm{Hg})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.740(6)	5.619(6)	11%	$\leq 0.04\%$	(3/2-)	0.1739	0.026, 0.148, 0.174	1.4904(44)	$\geq 1.6$
5.889(5)	5.764(5)	100%	$\leq 0.36\%$		0.026	0.026	1.4904(44)	$\geq 4.3$

* All values from [2013Sa43], except where noted.

** [2009Sa09].

#### Table 7

Table /					
direct $\alpha$ emission from	189m Pb*, Ex =	$= 40(4) \text{ keV}, J_i^{\pi} =$	$=, T_{1/2} = 50(3)$	$s^{**}, BR_{\alpha} = \approx 0.4\%$	6.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{185}\mathrm{Hg})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.851(5)	5.727(5)	≈0.4%	(13/2 ⁺ )	0.1037	0.0124, 0.0260, 0.0653	1.4904(44)	≈3.3

* All values from [2013Sa43], except where noted. ** [2009Sa09].

## Table 8

direct  $\alpha$  emission from ¹⁹³Po*,  $J_i^{\pi} = (3/2^-)$ ,  $T_{1/2} = 420(40)$  ms,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{189}\mathrm{Pb})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
6.556(20) 7.095(4)	6.420(20)** 6.948(4)	0.7(3)% 100.0(25)%	0.7(3)%*** 99.3(25)%***	(3/2 ⁻ ) (3/2 ⁻ )	0.539(20) 0.0	0.539	1.5125(26) 1.5125(26)	$3.5^{+3.3}_{-1.4} \\ 2.37(27)$

* All values from [2013Sa43], except where noted.

** [2013Sa43, 2002Va13].

*** [2003Va13].

### Table 9

direct  $\alpha$  emission from ^{193m}Po*, Ex = 95(6) keV,  $J_i^{\pi} = (13/2^+)$ ,  $T_{1/2} = 240(10)$  ms,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{189}\mathrm{Pb})$	coincident γ-rays	R ₀ (fm)	HF		
6.510(15) 7.152(4)	6.375(15)** 7.004(4)	0.8(3)% 100.0(35)%	0.8(3)%*** 99.2(35)%***	(13/2 ⁺ ) (13/2 ⁺ )	0.677(15) 0.040(4)	0.637	1.5125(26) 1.5125(26)	$2.0^{+1.4}_{-0.7}$ 3.20(28)		
* All values from [2013Sa43], except where noted.										

** [2013Sa43, 2002Va13].

*** [2003Va13].

## Table 10

direct  $\alpha$  emission from ¹⁹⁷Rn*,  $J_i^{\pi} = (3/2^-)$ ,  $T_{1/2} = 53^{+7}_{-5}$  ms**,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{193}\text{Po})$	coincident γ-rays	R ₀ (fm)	HF
7.410(7)	7.260(7)	100%	(3/2 ⁻ )	0.0	_	1.5653(89)	$1.8^{+0.5}_{-0.4}$

* All values from [2013Sa43], except where noted.

** [2008An05].

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$		$J_f^{\pi} E_{daughter}(^{193}\text{Po})$	coincident γ-rays	R ₀ (fm)	HF		
7.509(8)	7.357(8)	100%	(13/2 ⁺ )	0.095(6)		1.5653(89)	$3.8^{+1.0}_{-0.9}$		
* All val ** [2008	ues from [2013S An05].	a43], except wh	nere noted.						
Table 12direct $\alpha$ emission	sion from ²⁰¹ Ra	*, $J_i^{\pi} = (3/2^-), T_i^{\pi}$	$\Gamma_{1/2} = 8^{+40}_{-4} \text{ ms}$	$, BR_{\alpha} = \approx 100\%.$					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	<i>E</i> _{daughter} ( ¹⁹⁷ Rn)	coincident γ-rays	R ₀ (fm)	HF		
8.001(12)	7.842(12)	100%	(3/2-)	0.0		1.590(18)	$7^{+33}_{-3}$		
* All val	ues from [2014]	Ka23].							
<b>Table 13</b> direct $\alpha$ emission from 201m Ra*, Ex = 260(30) keV, $J_i^{\pi} = (13/2^+)$ , $T_{1/2} = 1.6^{+7.7}_{-0.7}$ ms, $BR_{\alpha} = 100\%$ .									
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	Edaughter( ¹⁹⁷ Rn)	coincident γ-rays	R ₀ (fm)	HF		
8.066(20)	7.905(20)	100%	(13/2 ⁺ )	0.194(10)		1.590(18)	$2.1^{+10.0}_{-1.3}$		

direct  $\alpha$  emission from ^{197m}Rn*, Ex = 194(10) keV,  $J_i^{\pi} = (13/2^+)$ ,  $T_{1/2} = 25^{+3}_{-2}$  ms**,  $BR_{\alpha} = \approx 100\%$ .

* All values from [2005Uu02].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +25/2 nuclei.

Last updated 2/6/2024

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +25/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Q _ε	$Q_{\varepsilon p}$	Qεα	Experimental
¹⁴³ Pr		7/2+	13.56(2) d*	-1.462(3)			[1971Ba28, 1957Pe09, 1965Is01]
¹⁴⁷ Pm		7/2+	2.62346(27) y	0.105(2)	-9.657(34)	0.139(3)	[1999Po32]
¹⁵¹ Eu		5/2+	$4.6(12) \times 10^{18} \text{ y}^{**}$	stable			[2014Ca03]
¹⁵⁵ Tb		3/2+	5.32(6) d	0.820(10)	-6.801(10)	0.901(10)	[1970Ch09]
¹⁵⁹ Ho		7/2-	33.05(11) m	1.838(3)	-5.148(3)	2.316(3)	[1982Vy02]
¹⁶³ Tm		$1/2^{+}$	1.810(5) h	2.439(3)	-3.977(6)	4.014(6)	[1982Vy02]
¹⁶⁷ Lu		7/2+	51.5(10) m	3.060(40)	-2.929(39)	5.216(38)	[1976Me06]
¹⁷¹ Ta		$(5/2^+)$	23.3(3) m	3.710(40)	-1.703(33)	6.445(28)	[1972Ch45]
¹⁷⁵ Re		$(5/2^{-})$	5.89(5) m	4.340(40)	-0.837(40)	7.718(40)	[1984Sz07]
¹⁷⁹ Ir		(5/2-)	79(1) s	4.938(18)	0.283(30)	9.126(30)	[1992Bo19]
¹⁸³ Au		(5/2-)	44.6(19) s	5.582(17)	1.571(23)	10.404(18)	[1995Bi01]
¹⁸⁷ Tl		$(1/2^+)$	$\approx 45 \text{ s}$	5.674(15)	1.981(22)	10.904(16)	[1981Mi12]
^{187m} Tl	0.333(8)***	(9/2-)	15.60(12) s	6.007(17)	2.314(23)	11.237(18)	[1981Mi12]
¹⁹¹ Bi		(9/2-)	12.1(4) s@	7.052(10)	3.838(10)	12.454(15)	[2013Ny01, 2003Ke04]
^{191m} Bi	0.234(8)	$(1/2^+)$	116(5) ms@@	7.052(10)	3.838(10)	12.454(15)	[2013Ny01, 2003Ke04, 1999An36]
¹⁹⁵ At		$(1/2^+)$	309(20) ms ^{@@@}	7.646(11)	5.264(11)	14.396(12)	[2013Ny01, 2003Ke04]
^{195m} At	0.033(8)***	$(7/2^{-})$	$144(3) \text{ ms}^a$	7.679(14)	5.297(14)	14.429(14)	[2013Ny01, 2003Ke04]
¹⁹⁹ Fr		$(1/2^+)$	$5^{+7}_{-2}$ ms	8.331(16)	6.191(15)	15.463(15)	[2013Uu01]
^{199m1} Fr	0.057(26)***	$(7/2^{-})$	$7^{+3}_{-2}$ ms	8.388(16)	6.191(15)	15.463(15)	[2013Uu01]
^{199m2} Fr	$\leq 0.300^{***}$	$(13/2^+)$	$1.6^{+1.6}_{-0.6}$ ms	≥8.631(31)	≥6.548(30)	≥15.811(30)	[2013Uu01]
²⁰³ Ac			$56^{+269}_{-25}$ µs	8.977(23) ^b	$7.187(22)^{b}$	$16.722(22)^{b}$	[2024WaXX]

* weighted average of 13.57(2) d [1971Ba28], 13.59(4) d [1957Pe09] and 13.55(2) d [1965Is01]. ** Reported as 4.62 (95 stat.) (68 syst.)  $\times 10^{18}$  y [2014Ca03].

*** Deduced from  $\alpha$  energies.

[@] Weighted average of 11.7(4) s [2013Ny01] and 12.4(4) s [2003Ke04]. [@] Weighted average of 114(6) ms [2013Ny01],  $121^{+8}_{-7}$  ms [2003Ke04] and 115(10) ms [1999An36].

^{@@@@} Weighted average of 290(20) ms [2013Ny01] and 328(20) ms [2003Ke04].

^a Weighted average of 143(3) ms [2013Ny01] and 147(5) ms [2003Ke04].

^b Deduced from  $\alpha$  energy and mass of daughter [2021Wa16].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +25/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
142-					
¹⁴⁵ Pr	5.824(2)	14.716(4)	1.729(2)		
¹⁴ /Pm	5.405(1)	13.994(7)	1.601(1)		
¹⁵¹ Eu	4.891(1)	13.167(2)	1.964(1)	100%*	[ <b>2014Ca03</b> , 2012Pa16]
¹⁵⁵ Tb	4.833(10)	12.461(10)	0.978(10)		
¹⁵⁹ Ho	4.211(4)	11.144(3)	1.496(10)		
¹⁶³ Tm	3.683(5)	10.110(6)	2.176(6)		
¹⁶⁷ Lu	3.222(38)	9.174(37)	2.777(38)		
¹⁷¹ Ta	2.755(40)	8.216(28)	3.381(47)		
¹⁷⁵ Re	2.350(40)	7.470(40)	4.007(40)		
¹⁷⁹ Ir	1.826(17)	6.390(30)	4.782(30)		
¹⁸³ Au	1.312(16)	5.306(11)	5.465(3)	0.8(2)%	[1995Bi01, 1992BiZZ, 1984BrZR, 1982Bo04,
					1982BoZL, 1970Ha18, 1970Ma24, 1968De01,
					1968Si01, 1965Si07]
¹⁸⁷ Tl	1.195(14)	5.164(8)	5.322(7)		
^{187m} Tl	0.862(16)	4.831(11)	5.655(11)	0.15(5)%	[1991Wa21, 1980Sc09, 1976To06, 1976BoYC]
¹⁹¹ Bi	0.112(15)	3.201(11)	6.780(3)	51(10)%	[2013Ny01, 2003Ke04, 1999An36, 2000Sc46
					1999Ta20, 1999TaZS, 1998Kr23, 1993An19,
					1991Wa21, 1985Co06, 1982LeZN, 1978Va21,
					1974Le02, 1972Ga27]
^{191m} Bi	-0.122(16)	2.967(13)	7.014(7)	68(5)%	[2013Ny01, 2003Ke04, 1999An36, 2024WaXX,
					1993An19, 1991Wa21, 1985Co06, 1982LeZN,
					1978Va21, 1974Le02, 1972Ga27]
¹⁹⁵ At	-0.245(16)	2.164(12)	7.344(6)	$\approx 100\%$	[2013Ny01, 2003Ke04, 2024WaXX, 1999Ta20,
					1999TaZS, 1996PuZZ, 1995Le15, 1995NoZW,
					1984YaZY]
^{195m} At	-0.278(18)	2.131(14)	7.377(10)	88(4)%	[2013Ny01, 2003Ke04, 1999Ta20, 1999TaZS,
		( )			

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +25/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

					1996PuZZ, 1995Le15, 1995NoZW, 1984YaZY]
¹⁹⁹ Fr	-0.713(19)	1.451(16)	7.817(10)	100%	[ <b>2013Uu01</b> , 2024WaXX]
^{199m1} Fr	-0.770(32)	1.394(31)	7.874(28)	100%	[2013Uu01, 2013Ka16, 1999Ta20, 1999TaZS, 2024WaXX]
^{199m2} Fr	<-1.013(19)	<1.151(16)	>8.117(10)	100%	[2013Uu01]
²⁰³ Ac	-1.214(26)***	0.589(23)***	8.382(16)**	100%	[2024WaXX]

* Only decay available.

** Deduced from  $\alpha$  energy.

*** Deduced from  $\alpha$  energy and mass of daughter [2021Wa16].

## Table 3

|--|

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{147}\mathrm{Pm})$	coincident γ-rays	R ₀ (fm)	HF
1.9489(86)	1.8973(86)	100%	7/2-	0.0	_	1.583(16)	$18^{+11}_{-9}$

* All values from [2014Ca13].

### Table 4

direct  $\alpha$  emission from ¹⁸³Au*, J^{$\pi$} = (5/2⁻), T_{1/2}= 44.6(19) s, BR_{$\alpha$} = 0.8(2)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{179}\mathrm{Ir})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.075(10)	4.964(10)	0.2(1)%	0.0016(9)%		0.394		1.5330(75)	$6^{+8}_{-3}$
5.198(10)	5.084(10)	0.4(1)%	0.0032(11)%		0.271		1.5330(75)	$13^{+9}_{-4}$
5.275(5)	5.160(5)	0.6(1)%	0.0048(14)%		0.1932	0.0925, 0.0997, 0.1932	1.5330(75)	$23^{+12}_{-7}$
5.469(5)	5.349(5)	100(1)%	0.8(2)%	(5/2 ⁻ )	0.0		1.5330(75)	$1.3_{-0.4}^{+0.6}$

* All values from [1995Bi01].

#### Table 5

direct  $\alpha$  emission from ^{187m}Tl, Ex = 333(8) keV*, J^{$\pi$} = (9/2⁻), T_{1/2} = 15.60(12) s**, BR_{$\alpha$} = 0.15(5)%***.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{183}\mathrm{Au})$	coincident γ-rays	R ₀ (fm)	HF
5.648(10)	5.528(10) [@]	0.15(5)%***	(9/2 ⁻ )	0.0124(4) ^{@@}		1.494(10)	$0.9\substack{+0.6 \\ -0.4}$
* Deduced ** [1981M *** [1991V [@] [1980Sc ^{@@} [2016E	from α energies o i12]. Wa21]. 09]. Ba19].	of ¹⁹¹ Bi decay.					

## Table 6

direct  $\alpha$  emission from ¹⁹¹Bi, J^{$\pi$} = (9/2⁻), T_{1/2} = 12.1(4) s*, BR_{$\alpha$} = 51(10)%**.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{187}\mathrm{Tl})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.450(4) 6.723(15) 6.783(7)	6.315(4)*** 6.582(15) [@] 6.641(7)***	100% [@] 0.78% [@] 3% [@]	49(10)% 0.40% 1.5(3)%	(9/2 ⁻ ) (3/2 ⁺ ) (1/2 ⁺ )	0.333(8) 0.300 0.0	1.5030(34) 0.300	$1.1^{+0.4}_{-0.3}$ 1.5030(34) 1.5030(34)	200 670

* Weighted average of 11.7(4) s [2013Ny01] and 12.4(4) s [2003Ke04].

** [2003Ke04].

*** [2013Ny01].

@ [1999An36].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{187}\text{Tl})$	coincident 7	Y-rays 1	$R_0$ (fm)	HF
6.723(15) 7.022(4)	6.582(15) 6.875(4) [@]	$0.24\%^{@@}$ $100\%^{@@}$	0.163(12)% 68(5)%	(3/2 ⁺ ) (1/2 ⁺ )	0.300 0.0	0.300		1.5030(34) 71.5030(34)	36 1.03(12)
* Deduc ** Weig *** [20 [@] [2013 [@] [199	ted from $\alpha$ energi hted average of 1 03Ke04]. Ny01]. 09An36].	ies. 14(6) ms [2013]	Ny01], 121 ⁺⁸ ms	[2003Ke04] ar	nd 115(10) ms [1999.	An36].			
Table 8 direct $\alpha$ emi	ssion from ¹⁹⁵ At,	$J^{\pi} = (1/2^+), T_{1/2}$	$r_2 = 309(20) \text{ ms}^*$	$BR_{\alpha} = \approx 1009$	%.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^{{m \pi}}$	$E_{daughter}($	¹⁹¹ Bi) coincid	ent γ-rays	R ₀ (fm)	HF	
7.100(3)	6.954(3)**	$\approx 100\%$	(1/2 ⁺ ),	0.234(8)			1.5482(9	5) $1.6^{+0.4}_{-0.2}$	4 3
* Weigh ** Weig	ated average of 29 shted average of 6	00(20) ms [2013] 5.956(4) MeV [20	Ny01] and 328(20 013Ny01] and 6.9	0) ms [2003Ket 953(3) MeV [2	04]. 003Ke04]				
Table 9 direct $\alpha$ emi	ssion from ^{195m} A	t, Ex = 33(8) ke	$V, J^{\pi} = (7/2^{-}), T_{1}$	$_{/2} = 144(3)$ ms	$S^*, BR_{\alpha} = 88(4)\%^{**}.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	<i>E</i> _{daughter} ( ¹⁹¹ Bi)	coincident	γ-rays	R ₀ (fm)	HF
									. 12
7.223(3) 7.373(4) * Weigh ** [201	7.075(3)*** 7.222(4) [@] atted average of 14 3Nv011.	100% 4.7(5)% 43(3) ms [2013N	84(4)% 4.0((5)% y01] and 147(5)	(9/2 ⁻ ) ms [2003Ke04]	0.1486 0.0 ].	0.1486		1.5482(95) 1.5482(95)	$49^{+13}_{-11} \\ 7.2^{+1.6}_{-1.4}$
7.223(3) 7.373(4) * Weigh ** [201 *** Wei @ Weig Table 10 direct α emi	7.075(3)*** 7.222(4) [@] atted average of 14 3Ny01]. ighted average of 7. ssion from ¹⁹⁹ Fr*	$100\% \\ 4.7(5)\% \\ 3(3) \text{ ms } [2013N \\ 7.076(5) \text{ MeV } [2013] \\ .222(4) \text{ MeV } [2013] \\ .5, J^{\pi} = (1/2^{+}), T_{1}$	84(4)% 4.0((5)% y01] and 147(5) 2013Ny01] and 7 2013Ny01] and 7.2 $y_{1/2} = 5^{+7}_{-2}$ ms, <i>BR</i>	$(9/2^{-})$ ms [2003Ke04] 2.075(4) MeV [20 221(4) MeV [20 $\alpha = 100\%$ .	0.1486 0.0 ]. 2003Ke04] 003Ke04]	0.1486		1.5482(95) 1.5482(95)	$49^{+13}_{-11} \\ 7.2^{+1.6}_{-1.4}$
7.223(3) 7.373(4) * Weigt ** [201 *** Wei @ Weig <b>Table 10</b> direct $\alpha$ emi $E_{\alpha}$ (c.m.)	7.075(3)*** 7.222(4) [@] atted average of 14 3Ny01]. ighted average of 7. ssion from ¹⁹⁹ Fr* $E_{\alpha}(\text{lab})$	$100\% \\ 4.7(5)\% \\ 3(3) \text{ ms } [2013N \\ 7.076(5) \text{ MeV } [2013] \\ .222(4) \text{ MeV } [2013] \\ .303 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\ .304 \\$	84(4)% 4.0((5)% y01] and 147(5) f 2013Ny01] and 7 2013Ny01] and 7.2 $J_{1/2}^{\pi} = 5^{+7}_{-2}$ ms, <i>BR</i>	$(9/2^{-})$ ms [2003Ke04] 2.075(4) MeV [ 221(4) MeV [20] $\alpha = 100\%.$ $E_{daughter}(^{-1})$	0.1486 0.0 ]. 2003Ke04] 003Ke04] ⁹⁵ At) coincid	0.1486 —- ent γ-rays	R ₀ (fm)	1.5482(95) 1.5482(95) HF	$49^{+13}_{-11} \\ 7.2^{+1.6}_{-1.4}$
7.223(3) 7.373(4) * Weigh ** [201. *** Weig @ Weig Table 10 direct $\alpha$ emi $E_{\alpha}(c.m.)$ 7.801(20)	7.075(3)*** 7.222(4) [@] atted average of 14 3Ny01]. ighted average of 7. ssion from ¹⁹⁹ Fr* $E_{\alpha}(\text{lab})$ 7.644(20)	$\frac{100\%}{4.7(5)\%}$ $\frac{4.7(5)\%}{3(3) \text{ ms } [2013N]}$ $\frac{7.076(5) \text{ MeV } [200]}{(222)(4) \text{ MeV } [200]}$ $\frac{1}{2}, J^{\pi} = (1/2^{+}), T_{1}$ $\frac{I_{\alpha}(\text{abs})}{100\%}$	84(4)% 4.0((5)% y01] and 147(5) f 2013Ny01] and 7 2013Ny01] and 7.2 $J_{f}^{\pi}$ (1/2 ⁺ )	$(9/2^{-})$ ms [2003Ke04] 2.075(4) MeV [ 221(4) MeV [20] $\alpha = 100\%.$ $E_{daughter}(^{-1})$ 0.0	0.1486 0.0 ]. 2003Ke04] 003Ke04] 9 ⁵ At) coincid	0.1486  ent γ-rays	R ₀ (fm) 1.576(11	1.5482(95) 1.5482(95) HF ) 1.7 ^{+2.4} _{-0.8}	$49^{+13}_{-11} \\ 7.2^{+1.6}_{-1.4}$
7.223(3) 7.373(4) * Weigh *** [201. *** Weig @ Weig <b>Table 10</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$ 7.801(20) * All va	7.075(3)*** 7.222(4) [@] atted average of 14 3Ny01]. ighted average of 7. ssion from ¹⁹⁹ Fr* $E_{\alpha}(1ab)$ 7.644(20) lues from [2013U	$100\% \\ 4.7(5)\% \\ 3(3) \text{ ms } [2013N \\ 7.076(5) \text{ MeV } [2013] \\ .222(4) \text{ MeV } [2013] \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ .3333 \\ $	84(4)% 4.0((5)% y01] and 147(5) = 2013Ny01] and 7 2013Ny01] and 7.2 $J_{1/2}^{-2} = 5^{+7}_{-2}$ ms, <i>BR</i> $J_{f}^{\pi}$ (1/2 ⁺ )	$(9/2^{-})$ ms [2003Ke04] 2.075(4) MeV [ 221(4) MeV [20] $\alpha = 100\%.$ $E_{daughter}(^{-1})$ 0.0	0.1486 0.0 ]. 2003Ke04] 003Ke04] 9 ⁵ At) coincid 	0.1486  ent γ-rays	R ₀ (fm) 1.576(11	HF 1.5482(95) 1.5482(95) HF 1.7 ^{+2.4} _{-0.8}	$49^{+13}_{-11} \\ 7.2^{+1.6}_{-1.4}$
7.223(3) 7.373(4) * Weigh ** [201 *** Weige @ Weigi <b>Table 10</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$ 7.801(20) * All va <b>Table 11</b> direct $\alpha$ emi	7.075(3)*** 7.222(4) [@] atted average of 14 3Ny01]. ighted average of 7. ission from ¹⁹⁹ Fr* $E_{\alpha}(lab)$ 7.644(20) lues from [2013U ssion from ^{199m1} F	$100\% \\ 4.7(5)\% \\ 3(3) \text{ ms } [2013N \\ 7.076(5) \text{ MeV } [2000] \\ 2.22(4) \text{ MeV } [2000] \\ 3.00\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% $	84(4)% 4.0((5)% y01] and 147(5) = 2013Ny01] and 7.2 13Ny01] and 7.2 $J_{1/2} = 5^{+7}_{-2}$ ms, <i>BR</i> J ^{$\pi$} (1/2 ⁺ ) keV, J ^{$\pi$} = (7/2 ⁻ ),	(9/2 ⁻ ) ms [2003Ke04] (.075(4) MeV [ (.21(4) MeV [20] $\alpha = 100\%.$ $E_{daughter}(1)$ 0.0 $T_{1/2} = 7^{+3}_{-2} ms$	0.1486 0.0 ]. 2003Ke04] $\frac{95}{\text{At}}$ coincid	0.1486  ent γ-rays	R ₀ (fm) 1.576(11	1.5482(95) 1.5482(95) HF ) 1.7 ^{+2.4} _{-0.8}	49 ⁺¹³ ₋₁₁ 7.2 ^{+1.6} 7.2 ^{-1.4}
7.223(3) 7.373(4) * Weigt ** [201] *** Weig @ Weig <b>Table 10</b> direct $\alpha$ emi <i>E</i> _{$\alpha$} (c.m.) 7.801(20) * All va <b>Table 11</b> direct $\alpha$ emi <i>E</i> _{$\alpha$} (c.m.)	7.075(3)*** 7.222(4) [@] atted average of 14 3Ny01]. ighted average of 7. ssion from ¹⁹⁹ Fr* <u>E_{\alpha}(lab)</u> 7.644(20) lues from [2013U ssion from ^{199m1} F <u>E_{\alpha}(lab)</u>	$100\% \\ 4.7(5)\% \\ 4.7(5)\% \\ 3(3) \text{ ms } [2013N \\ 7.076(5) \text{ MeV } [2000] \\ 222(4) \text{ MeV } [2000] \\ 3.00\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100$	84(4)% 4.0((5)% y01] and 147(5) f 2013Ny01] and 7 2013Ny01] and 7.2 $J_{f}^{\pi}$ (1/2 ⁺ ) keV, $J^{\pi} = (7/2^{-}),$ $J_{f}^{\pi}$	(9/2 ⁻ ) ms [2003Ke04] 2.075(4) MeV [ 221(4) MeV [20] $\alpha = 100\%.$ $E_{daughter}(^{-1})$ 0.0 $T_{1/2} = 7^{+3}_{-2}$ ms $E_{daughter}(^{-195}_{-2})$	0.1486 0.0 ]. 2003Ke04] 2003Ke04 2003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04 3003Ke04	0.1486  ent γ-rays  t γ-rays	R ₀ (fm) 1.576(11 R ₀ (fm)	1.5482(95) 1.5482(95) HF ) 1.7 ^{+2.4} 1.7 ^{+2.4} HF	$49^{+13}_{-11} \\ 7.2^{+1.6}_{-1.4}$
7.223(3) 7.373(4) * Weigt ** [2011 *** Weige @ Weige <b>Table 10</b> direct $\alpha$ emining E_{\alpha}(c.m.) 7.801(20) * All van <b>Table 11</b> direct $\alpha$ emining E_{\alpha}(c.m.) 7.825(15)	$7.075(3)^{***}$ $7.222(4)^{@}$ atted average of 14 3Ny01]. ighted average of f ssion from ¹⁹⁹ Fr* <u>E_{\alpha}(lab)</u> 7.644(20) lues from [2013U <u>ssion from ^{199m1}F</u> <u>E_{\alpha}(lab)}</u> 7.668(15)	$100\% \\ 4.7(5)\% \\ 4.7(5)\% \\ 3(3) \text{ ms } [2013N \\ 7.076(5) \text{ MeV } [200 \\ 222(4) \text{ MeV } [200 \\ 3, J^{\pi} = (1/2^{+}), T_{1} \\ \hline I_{\alpha}(abs) \\ 100\% \\ 100\% \\ 5T, Ex. = 57(26) 1 \\ \hline I_{\alpha}(abs) \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% \\ 100\% 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\\ 100\% \\ 100\% \\ 100\% \\ 100\%$	84(4)% 4.0((5)% y01] and 147(5) = 2013Ny01] and 7.2 1/2 = $5^{+7}_{-2}$ ms, <i>BR</i> $J_f^{\pi}$ (1/2 ⁺ ) keV, $J^{\pi} = (7/2^{-})$ , $J_f^{\pi}$	(9/2 ⁻ ) ms [2003Ke04] 2.075(4) MeV [ 221(4) MeV [20] $\alpha = 100\%.$ $E_{daughter}(^{-1})$ 0.0 $T_{1/2} = 7^{+3}_{-2}$ ms $E_{daughter}(^{-195}_{-2})$ 0.033(8)	0.1486 0.0 ]. 2003Ke04] 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 2003Ke04 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7.2 ^{+1.6} 7.2 ^{-1.4}
7.223(3) 7.373(4) * Weigt ** [201 *** Weig @ Weig <b>Table 10</b> direct $\alpha$ emi $E_{\alpha}$ (c.m.) 7.801(20) * All va <b>Table 11</b> direct $\alpha$ emi $E_{\alpha}$ (c.m.) 7.825(15) * All va	$7.075(3)^{***}$ $7.222(4)^{@}$ atted average of 14 3Ny01]. ighted average of 14 3Ny01]. ighted average of 7. ssion from ¹⁹⁹ Fr* <u>E_{\alpha}(lab)</u> 7.644(20) lues from [2013U <u>ssion from ^{199m1}F</u> <u>E_{\alpha}(lab)</u> 7.668(15) lues from [2013U	$100\% \\ 4.7(5)\% \\ 4.7(5)\% \\ 3(3) \text{ ms } [2013N \\ 7.076(5) \text{ MeV } [2000 \\ 222(4) \text{ MeV } [2000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\ 3000 \\$	84(4)% 4.0((5)% y01] and 147(5) = 2013Ny01] and 7.2 1/2 = $5^{+7}_{-2}$ ms, <i>BR</i> $J_f^{\pi}$ (1/2 ⁺ ) keV, $J^{\pi} = (7/2^{-})$ , $J_f^{\pi}$	(9/2 ⁻ ) ms [2003Ke04] 2.075(4) MeV [ 221(4) MeV [20] $\alpha = 100\%.$ <u>$E_{daughter}(1)$</u> 0.0 <u>$T_{1/2} = 7^{+3}_{-2}$ ms <u>$E_{daughter}(195)$</u> 0.033(8)</u>	0.1486 0.0 ]. 2003Ke04] $\frac{95}{\text{At}}$ coincid $\frac{95}{\text{At}}$ coinciden 5, $BR_{\alpha} = 100\%$ .	0.1486  ent γ-rays  t γ-rays	R ₀ (fm) 1.576(11 R ₀ (fm) 1.576(11)	$\frac{\text{HF}}{1.5482(95)}$	49 ⁺¹³ ₋₁₁ 7.2 ^{+1.6} 7.2 ^{-1.4}
7.223(3) 7.373(4) * Weigh ** [201] *** Wei @ Weigi <b>Table 10</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$ 7.801(20) * All va <b>Table 11</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$ 7.825(15) * All va <b>Table 12</b> direct $\alpha$ emi	7.075(3)*** 7.222(4) [@] atted average of 14 3Ny01]. ighted average of 7. ssion from ¹⁹⁹ Fr* <u>E_{\alpha}(lab) 7.644(20) lues from [2013U ssion from ^{199m1}F <u>E_{\alpha}(lab)</u> 7.668(15) lues from [2013U ssion from ^{199m2}F</u>	$100\% \\ 4.7(5)\% \\ 4.7(5)\% \\ 3(3) \text{ ms } [2013N \\ 7.076(5) \text{ MeV } [2000 \\ (222(4) \text{ MeV } [2000 \\ (222(4) \text{ MeV } [2000 \\ (222(4) \text{ MeV } [2000 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 \\ (2200 $	84(4)% 4.0((5)% y01] and 147(5) = 2013Ny01] and 7.2 1/2 = $5^{+7}_{-2}$ ms, <i>BR</i> $J_f^{\pi}$ (1/2 ⁺ ) keV, $J^{\pi} = (7/2^{-}),$ $J_f^{\pi}$ seV, $J^{\pi} = (13/2^{+})$	(9/2 ⁻ ) ms [2003Ke04] (0.075(4)  MeV  [2003Ke04] (2.21(4)  MeV  [2003Ke04] (2.21	0.1486 0.0 ]. 2003Ke04] 95 At) coincid 95 At) coincid 6 ms, $BR_{\alpha} = 100\%$ .	0.1486  ent γ-rays t γ-rays	R ₀ (fm) 1.576(11 R ₀ (fm) 1.576(11)	$\frac{\text{HF}}{1.5482(95)}$	49 ⁺¹³ ₋₁₁ 7.2 ^{+1.6} 7.2 ^{-1.4}
7.223(3) 7.373(4) * Weigh ** [201] *** Wei @ Weigi <b>Table 10</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$ 7.801(20) * All va <b>Table 11</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$ 7.825(15) * All va <b>Table 12</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$	$7.075(3)^{***}$ $7.222(4)^{@}$ atted average of 14 3Ny01]. ighted average of 7. ighted average of 14 ighted average of 16 ighted average of 100 ighted average of 100 ighted average of 100	$100\% \\ 4.7(5)\% \\ 4.7(5)\% \\ 3(3) \text{ ms } [2013N \\ 7.076(5) \text{ MeV } [200 \\ 222(4) \text{ MeV } [200 \\ 3.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1.37 \\ 1$	84(4)% 4.0((5)% y01] and 147(5) = 2013Ny01] and 7.2 1/2 = $5^{+7}_{-2}$ ms, <i>BR</i> J ^{$\pi$} (1/2 ⁺ ) keV, J ^{$\pi$} = (7/2 ⁻ ), J ^{$\pi$} $J_{f}$ keV, J ^{$\pi$} = (13/2 ⁺ ) J ^{$\pi$}	(9/2 ⁻ ) ms [2003Ke04] 2.075(4) MeV [ 221(4) MeV [20] $\alpha = 100\%.$ <u>Edaughter(1</u> 0.0 <u>T_{1/2} = 7⁺³₋₂ ms <u>Edaughter(1957</u> 0.033(8) <u>C_1/2</u> = 1.6^{+1.1} <u>Edaughter(1957</u>)</u>	0.1486 0.0 ]. 2003Ke04] $\frac{95}{\text{At}}$ coincid $\frac{95}{\text{At}}$ coincid $\frac{95}{\text{At}}$ coinciden $\frac{6}{6}$ ms, $BR_{\alpha} = 100\%$ . $\frac{195}{\text{At}}$ coinci	0.1486  ent γ-rays t γ-rays	R ₀ (fm) 1.576(11 R ₀ (fm) 1.576(11)	1.5482(95) 1.5482(95) HF 1.7 ^{+2.4} 1.7 ^{+2.4} 1.7 ^{+2.4} 1.7 ^{+2.4} 1.7 ^{+2.4} 1.7 ^{+2.4} 1.7 ^{+2.4} 1.7 ^{+2.4} 1.7 ^{+2.4} 1.5 ⁴⁸² 1.5 ⁴⁸²	49 ⁺¹³ ₋₁₁ 7.2 ^{+1.6} 7.2 ^{-1.4}

## **Table 13** direct $\alpha$ emission from ²⁰³Ac*, T_{1/2} = 56⁺²⁶⁹₋₂₅ $\mu$ s, BR $_{\alpha}$ = 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}($ ¹⁹⁹ Fr)	coincident $\gamma$ -rays	R ₀ (fm)	HF
8.382(16)	8.217(16)	100%					

* All values from [2024WaXX].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +13 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +13$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\epsilon p}$	$Q_{\epsilon \alpha}$	Experimental
¹⁴² Ce	$0^+$	stable	-4.509(6)			
¹⁴⁶ Nd	$0^{+}$	stable	-4.256(30)			
¹⁵⁰ Sm	$0^+$	stable	-3.454(20)			
¹⁵⁴ Gd	$0^+$	stable	-1.968(2)			
¹⁵⁸ Dy	$0^+$	stable	-0.963(3)			
162Er	$0^{+}$	stable	-0.294(3)			
¹⁶⁶ Yb	$0^+$	56.7(1) h	0.293(14)	-4.361(7)	2.022(8)	[1970Ka13]
¹⁷⁰ Hf	$\tilde{0}^+$	15.82(15) h	1.050(30)	-3.167(28)	3.208(30)	[1970Ch17]
$^{174}W$	$0^{+}$	33.9(5) m*	1.510(40)	-2.104(40)	4.654(33)	[1990Me12, 1985Sz03, 1964Sa22]
¹⁷⁸ Os	$0^+$	5.0(4) m	2.110(30)	-1.131(31)	5.772(31)	[1972Be89]
¹⁸² Pt	$0^{+}$	2.2(1) m	2.883(25)	0.093(29)	7.060(31)	[1972Fi12]
¹⁸⁶ Hg	$0^+$	1.41(8) m**	3.176(24)	0.860(28)	8.088(24)	[1970Ha18, 1969Ha03]
¹⁹⁰ Pb	$0^{+}$	71(1) s	3.950(14)	1.921(34)	8.873(24)	[1996Ri12]
¹⁹⁴ Po	$0^{+}$	392(4) ms	5.018(14)	3 936(17)	10.937(15)	[1993Wa04]
¹⁹⁸ Rn	$\tilde{0}^+$	65(2) ms***	5.019(14)	4.874(17)	12.368(14)	[1999Ta03, 1995Bi17]
²⁰² Ra	$\tilde{0}^+$	$3.8^{+1.3}_{-0.8}$ ms	5.973(16)	5.893(18)	13.359(16)	[2014Ka23]

* Weighted average of 35.3(5) m [1990Me12], 33.2(9) m [1985Sz03] and 29(1) m [1964Sa22].

*** Weighted average of 1.42(10) m [1970Ha18], and 1.38(13) m [1969Ha03]. *** Weighted average of  $66^{+3}_{-2}$  ms [1999Ta03] and 63(2) ms [1995Bi17].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +13$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
142 C	8 802(5)	15.042(0)	1 204(2)		
146NL1	8.892(5)	15.845(8)	1.304(2)		
140 Nd	8.589(7)	15.072(3)	1.182(2)		
¹⁵⁰ Sm	8.276(2)	14.221(2)	1.450(1)		
¹⁵⁴ Gd	7.628(1)	13.521(1)	0.920(1)		
¹⁵⁸ Dy	6.932(2)	12.450(2)	0.874(2)		
¹⁶² Er	6.427(2)	11.240(1)	1.648(2)		
¹⁶⁶ Yb	5.953(7)	10.229(7)	2.316(7)		
¹⁷⁰ Hf	5.460(28)	9.252(28)	2.915(29)		
$^{174}W$	5.120(40)	8.403(37)	3.602(40)		
¹⁷⁸ Os	4.564(31)	7.481(31)	4.258(31)		
¹⁸² Pt	3.994(14)	6.390(20)	4.951(5)	0.038(2)%	[1995Bi01, 1966Si08, 1963Gr08]
¹⁸⁶ Hg	3.970(12)	5.785(19)	5.204(10)	0.016(5)%	[1970Ha18, 1996Ri12, 1993ToZY, 1969Ha03,
C					1969NaZT, 1969NaZU]
¹⁹⁰ Pb	3.089(15)	4,796(14)	5.698(5)	0.24(7)%*	[1996Ri12, 1992Wa14, 1984To09, 1974Ho26,
					1996Bi17, 1992WaZV, 1989De18, 1981El03,
					1977De32, 1974Ho26, 1974JoZU, 1973LiYK
					1972Ga27]
¹⁹⁴ Po	2.409(15)	3.031(14.)	6.987(3)	93(7)%	[1994Wa13, 1993Wa04, 1985Va03, 2014Ka23,
	,()			20(1)/-	2005Uu02, 1993WaZO, 1989De18, 1982LeZN.
					1981Le23 1977De32 1967Si09 1967Tr04
					1967Tr061
¹⁹⁸ Rn	2.164(16)	2.340(14)	7.349(4)	≈100%**	[ <b>1995Bi17</b> 2014Ka23 1999Ta03 1996En02
		(1)			1995BiZY, 1993Wa02, 1984Ca321
²⁰² Ra	1.803(18)	1.503(16)	7.880(7)	100%*	[2014Ka23, 2005Uu02, 1996Le09]
				10070	[,,,,,,,,

* Weighted average of 0.37(12)% [1992Wa14], 0.22(7)% [1984To09] and 0.21(7)% [1974Ho26].

** Based on short half-life.

		, , , , , , , , , , , , , , , , , , ,	$-2.2(1)$ III , $DR_{\alpha}$ -	- 0.030(2)70.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{178}\mathrm{Os})$	coincident γ-ra	ays $R_0$ (fm)	HF	
4.952(5)	4.843(5)	0.038(2)%	$0^+$	0.0		1.5539(68)	1.0	
* All va ** [197	alues from [1995 [2Fi12].	Bi01], except who	ere noted.					
<b>Table 4</b> direct $\alpha$ emi	ission from ¹⁸⁶ H	$g^*, J_i^{\pi} = 0^+, T_{1/2}$	$= 1.41(8) \text{ m}^{**}, BR_{c}$	$\alpha = 0.016(5)\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	$E_{daughter}(^{182}\mathrm{Pt})$	) coincident γ-1	rays $R_0$ (fm)	HF	
5.208(15)	5.094(15)	0.038(2)	% 0+	0.0		1.500(17)	1.0	
** Weig	ghted average of	35.3(5) m [1990]	Me12], 33.2(9) m [1	985Sz03] and 29(	1) m [1964Sa22].			
** Weig <b>Table 5</b> direct $\alpha$ emi	ghted average of ission from ¹⁹⁰ Pt	5.3(5)  m [1990] $5^*, J_i^{\pi} = 0^+, T_{1/2}$	Ae12], 33.2(9) m [1 = 71(1) s, $BR_{\alpha}$ =0.2	985Sz03] and 29( 4(7)%.	1) m [1964Sa22].			
** Weig <b>Table 5</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$	ghted average of the second s	$J_{\alpha}^{\pi}(rel)$ (rel)	Me12], 33.2(9) m [1 = 71(1) s, $BR_{\alpha} = 0.2$ $I_{\alpha}(abs)$	985Sz03] and 29( 4(7)%. $J_{f}^{\pi} = E_{dau}$	1) m [1964Sa22]. _{ghter} ( ¹⁸⁶ Hg)*** co	oincident γ-rays***	R ₀ (fm)	HF
** Weig <b>Table 5</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$ 5.169(12)	ghted average of ission from ¹⁹⁰ Pt $E_{\alpha}(\text{lab})$ 5.060(12)	$\frac{11}{35.3(5) \text{ m } [1990]}{\frac{1}{35.3(5) \text{ m } [1990]}{I_{\alpha}(\text{rel})}}$	$\frac{I}{A}(abs) = \frac{I}{A}(abs) + \frac{I}$	985Sz03] and 29( 4(7)%. $J_{f}^{\pi} E_{dau}$ 0 ⁺ 0.52	1) m [1964Sa22]. ghter( ¹⁸⁶ Hg)*** co 25(7)	oincident γ-rays***	R ₀ (fm) 1.4923(55)	HF 23 ⁺²⁶ -9
** Weiş <b>Table 5</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$ 5.169(12) 5.297(5) 5.697(5)	ghted average of $E_{\alpha}(lab)$ 5.060(12) 5.185(5) 5.577(5)	$J_{\alpha}^{\pi}(rel) = 0^{+}, T_{1/2}$ $I_{\alpha}(rel)$ $0.014(6)\%$ $0.084(15)\%$ $100\%$	$\frac{I_{\alpha}(\text{abs})}{3.3(17) \times 10^{-5}\%}$ $\frac{I_{\alpha}(\text{abs})}{0.24(7)\%}$	9855z03] and 29( 4(7)%. $J_f^{\pi} E_{dau}$ 0 ⁺ 0.52 2 ⁺ 0.40 0 ⁺ 0.0	1) m [1964Sa22]. ghter( ¹⁸⁶ Hg)*** co 25(7) 53 0 -	oincident γ-rays*** .4053	R ₀ (fm) 1.4923(55) 1.4923(55) 1.4923(55)	$\frac{\rm HF}{\begin{array}{c}23^{+26}_{-9}\\18^{+10}\\1.0\end{array}}$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{190}\text{Pb})^{***}$	coincident γ-rays***	R ₀ (fm)	HF
6.321(7) 6.988(3)	6.191(7)** 6.844 (3) [@]	0.24% 100.00%	0.22%*** 93%***	${0^+ \atop 0^+}$	0.677(7) 0.0		1.724(13) 1.724(13)	1.06 1.0

* [1993Wa04].

* [1995 wa04]. ** [1985 Va03]. *** [1994 Wa13]. [@] Values from [1991 Ry01], based on weighted average of 6.847(10) MeV [1967 Si09], 6.845(7) MeV (adjusted to 6.847(7) MeV) [1967 Tr06], 6.840(5) MeV [1977 De32] and 6.846(5) MeV [1985 Va03].

## Table 7

Table /	
direct $\alpha$ emission from ¹⁹⁸ Rn, $J_i^{\pi} = 0^+$ , $T_{1/2} = 65(2)$ ms**, $BR_{\alpha} = \approx 100\%$ *.	
	2

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{194}\text{Po})^{***}$	coincident γ-rays***	R ₀ (fm)	HF
7.035(8)	6.893(8)	0.07(2)%	0.07(2)%	$2^{+}$	0.3193(1)***	0.319	1.7622(23)	$110^{+50}_{-30}$
7.354(5)	7.205(5)	100%	99.93(2)%	$0^+$	0.0		1.7622(23)	1.0

* All values from [1995Bi17], except where noted. ** Weighted average of  $66^{+3}_{-2}$  ms [1999Ta03] and 63(2) ms [1995Bi17]. *** [2021Ch50].
**Table 8** direct  $\alpha$  emission from ²⁰²Ra*,  $J_i^{\pi} = 0^+$ ,  $T_{1/2} = 3.8^{+1.3}_{-0.8}$  ms,  $BR_{\alpha} = 100\%$ 

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	<i>E</i> _{daughter} ( ¹⁹⁸ Rn)	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.878(7)	7.722(7)	100%	0+	0.0		1.794(23)	1.0

* All values from [2014Ka23]

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +13 nuclei.

Last updated 4/4/23

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +13$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta F}$	Experimental
			/		*		F	
¹⁴⁴ Pr*		$0^{-}$	17.27(4) m	-0.319(4)				[1957Pe09]
¹⁴⁸ Pm*		$1^{-}$	5.370(15) d	0.542(6)	-8.711(17)	1.141(6)		[1970Ca09]
¹⁵² Eu**		3-	13.506(8) d	1.874(1)	-6.791(5)	2.095(2)		[2010Sc08]
¹⁵⁶ Tb		3-	5.35(10) d	2.444(4)	-5.562(4)	2.247(4)		[1959He44]
¹⁶⁰ Ho		$5^{+}$	25.6(3) m	3.290(15)	-4.139(15)	3.728(15)		[1965St08]
¹⁶⁴ Tm		$1^{+}$	1.9(1) m***	4.034(25)	-2.820(25)	5.339(25)		[1965Ba40, 1963Ra15, 1960Wi17]
¹⁶⁸ Lu		6-	5.5(1) m	4.510(40)	-1.819(38)	6.445(38)		[1972Ch44]
¹⁷² Ta		$(3^{+})$	36.7(4) m	5.070(40)	-0.790(28)	7.825(28)		[1972Ch45]
¹⁷⁶ Re		$(3^+)$	5.2(4) m	5.580(40)	0.057(40)	8.914(37)		[1977Ha24]
¹⁸⁰ Ir		$(3^+)$	1.5(1) m	6.379(27)	1.318(33)	10.239(35)		[1972Ak03]
¹⁸⁴ Au		5+	21(1) s	7.014(27)	2.594(33)	11.613(27)		[1977Za03]
^{184m} Au	0.06846(4)	2+	46.4(10) s@	7.082(27)	2.662(33)	11.681(27)		[1977Za03, 1992Ro21, 1995Bi01]
¹⁸⁸ Tl		$(2^{-})$	71(2) s	7.860(30)	3.403(37)	12.571(33)		[1984Co17]
¹⁹² Bi		$(3^{+})$	34.6(7) s	9.020(30)	5.459(31)	14.239(31)		[1991Va04]
^{192m} Bi	0.140(30)	$(10^{-})$	39.7(4) s ^{@@}	9.160(42)	5.599(43)	14.379(43)		[1988Hu03, 1991Va04, 2017Au03]
¹⁹⁶ At		(3+)	371(5) ms	9.560(30)	6.823(31)	16.214(31)	9(1)×10 ⁻³ %	[2016Tr07]
²⁰⁰ Fr		(3+)	48(4) ms@@@@	10.130(30)	7.668(31)	17.177(31)	> 1.4%	[2014Ka23, 2005De01]
²⁰⁴ Ac		(3+)	$75^{+23}_{-15}$ ms	10.600(34) ^a	8.496(34) ^a	18.237(34) ^a		[2022Hu12]

* 100%  $\beta^-$  emitter.

** 72%  $\beta^+$ , 23%  $\beta^-$  emitter.

*** Weighted average of 2.0(1) m [1965Ba40], 1.8(1) m [1963Ra15] and 2.04(10) m [1960Wi17].

[@] Weighted average of 48(1) s [1977Za03], 45(1) s [1992Ro21] and 45.8(18) s [1995Bi01].

^{@@} Weighted average of 39.6(4) s [1988Hu03], 40.6(9) s [1991Va04].

^{@@@} Weighted average of 46(4) ms [2014Ka23] and 49(4) ms [2005De01].

 a  Deduced from  $^{204}Ac~\alpha$  energy [2022Hu12] and values from [2021Wa16].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +13$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
144 p	( 100 (0)	15,205(7)	1.127(2)		
149 Pr	6.433(3)	15.305(7)	1.13/(3)		
¹⁴⁰ Pm	6.008(6)	14.770(35)	1.460(6)		
¹⁵² Eu	5.601(1)	13.869(20)	1.552(6)		
¹⁵⁶ Tb	5.310(4)	12.931(4)	0.373(4)		
¹⁶⁰ Ho	4.504(15)	11.489(15)	1.284(15)		
¹⁶⁴ Tm	4.031(25)	10.446(25)	2.049(29)		
¹⁶⁸ Lu	3.772(38)	9.764(40)	2.411(45)		
¹⁷² Ta	3.188(40)	8.602(33)	3.318(47)		
¹⁷⁶ Re	2.719(40)	7.900(40)	3.842(40)		
¹⁸⁰ Ir	2.246(27)	6.902(35)	4.660(35)		
¹⁸⁴ Au	1.834(26)	5.845(31)	5.193(5)*		
^{184m} Au	1.766(26)	5.777(31)	5.305(5)	0.013(3)%	[1995Bi01, 1995BiZZ, 1993BiZY, 1992BiZZ,
					1970Ha18, 1970HaZT]
¹⁸⁸ Tl	1.507(33)	5.199(37)	5.557(37)		
¹⁹² Bi	0.532(31)	3.746(31)	6.377(4)	12(5)%	[1991Va04, 2016Tr07, 2013Ny01, 1988Hu03,
					1985HuZY, 1974Le02, 1972Ga27, 1970Ta14]
^{192m} Bi	0.393(43)	3.606(43)	6.517(30)	10(3)%	[1991Va04, 1988Hu03, 2016Tr07]
¹⁹⁶ At	0.085(31)	2.468(31)	7.196(3)	97.5(3)%	[2016Tr07, 2022Hu12, 2019Gh11, 2014Ka23,
					2013Ny01, 2005De01, 2004DeZV, 1997Pu01,
					1996En01, 1995Mo14, 1967Tr04, 1967Tr06]
²⁰⁰ Fr	-0.404(31)	1.736(31)	7.622(4)	>97.5%	[2014Ka23, 2022Hu12, 2013Uu01, 2005De01,
					2004DeZV, 1996En01, 1996MoZV, 1995LeZY,
					1995Mo14, 1995NoZW]
$204 \Delta c$	-0.771(35)***	1 019(34)***	8 107(15)***	~100%**	[2022Hu12]

* Deduced from  $\alpha$  energy, 5.234(5) in [2021Wa16].

** Based on short half-life.

*** Deduced from  204 Ac  $\alpha$  energy [2022Hu12] and values from [2021Wa16].

## Table 3 direct $\alpha$ emission from ^{184m}Au*, $J_i^{\pi} = 2^+$ , Ex = 68.46(4) keV**, $T_{1/2} = 46.4(10)$ s***, $BR_{\alpha} = 0.013(3)\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{180}\mathrm{Ir})$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF
5.051(5)	4 980(5)	23(1)%	$14(3) \times 10^{-3}\%$		0.212	0 0897 0 1304 0 1717 0 1838 0 1979 0 2124	1 527(18)	4 7+2.7
5.096(5)	5.024(5)	22(1)%	$1.3(3) \times 10^{-3}\%$		0.167	0.0502, 0.1426	1.527(18)	$9^{+5}_{-3}$
5.137(15)	5.065(15)	14(1)%	$9(2) \times 10^{-4}\%$		0.114	0.1135	1.527(18)	$26^{+16}_{-10}$
5.182(5)	5.109(5)	100(1)%	$6.1(14) \times 10^{-3}\%$		0.0804	0.0553, 0.0804	1.527(18)	$5.5^{+3.1}_{-2.1}$
5.261(5)	5.187(5)	55(1)%	$3.3(8) \times 10^{-3}\%$	(3+)	0.0		1.527(18)	$27^{+15}_{-19}$

* All values from [1995Bi01], except where noted.

** [2005Sa40].

*** Weighted average of 48(1) s [1977Za03], 45(1) s [1992Ro21] and 45.8(18) s [1995Bi01].

[@] Interpolated between 1.5539(68) fm ¹⁸²Pt and 1.500(17) ¹⁸⁶Hg.

### Table 4

direct $\alpha$ emission from	$^{192}\text{Bi*}, J_i^{\pi} = (3^+),$	$T_{1/2} = 34.6(7) s$ ,	$BR_{\alpha} = 12(5)\%$
-------------------------------	----------------------------------------	-------------------------	-------------------------

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{188}\mathrm{Tl})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF
6.189(5) 6.378(5)	6.060(5) 6.245(5)	100% 3.1(6)%	11.6(5)% 0.36(17)%	(3 ⁺ ) (2 ⁻ )	0.1846 0.0	0.1846	1.608(14) 1.608(14)	${}^{11^{+9}_{-5}}_{2.1^{+20}_{-9}\times10^3}$

* All values from [1991Va04], except where noted.

** Interpolated between 1.4923(55) fm ¹⁹⁰Pb and 1.724(13) ¹⁹⁴Po.

### Table 5

# direct $\alpha$ emission from ^{192m}Bi*, $J_i^{\pi} = (10^-)$ , Ex = 140(30) keV**, $T_{1/2} = 39.7(4)$ s***, $BR_{\alpha} = 120(3)\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{188}\text{Tl})$	coincident γ-rays	$R_0 (fm)^@$	HF
6.181(5)	6.052(5)	100%	9.(3)%	10-	0.337(30)	0.0336, 0.1031, 0.2688	1.608(14)	$15^{+9}_{-5}$
6.210(10)	6.081(10)	7.2(7)%	0.65(21)%	9-	0.304(30)	0.1031, 0.2688	1.608(14)	$280^{+160}_{-100}$
6.386(5)	6.253(5)	0.6(2)%	0.05(2)%	$6^{+}$	0.138(30)	0.1031	1.608(14)	$1.8^{+1.9}_{-0.7} \times 10^4$
6.483(5)	6.348(5)	2.5(2)%	0.23(7)%	$7^{+}$	0.035(30)		1.608(14)	$1.0^{+0.6}_{-0.4}  imes 10^4$

* All values from [1991Va04], except where noted.

** [2017Au03].

*** Weighted average of 39.6(4) s [1988Hu03], 40.6(9) s [1991Va04].

^(a) Interpolated between 1.4923(55) fm ¹⁹⁰Pb and 1.724(13) fm ¹⁹⁴Po.

#### Table 6

Table 0	
direct $\alpha$ emission from ¹⁹⁶ At*, $J_i^{\pi} = (3^+)$ , $T_{1/2} = 371(5)$ ms, $BR_{\alpha} = 97.5(3)\%$ .	

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{192}\mathrm{Bi})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF
6.782(8)	6 644(8)	0.14(3)%	0.14(3)%		0.409(8)	0 200, 0 221	1.743(13)	$5.5^{+2.3} \times 10^{3}$
6.887(5)	6.746(5)	1.84(6)%	1.79(6)%		0.316	0.116, 0.200, 0.316	1.743(13)	$940^{+270}_{-5210}$
6.997(6)	6.854(6)	0.27(3)%	0.26(3)%		0.200	0.200	1.743(13)	$1.7^{+0.5}_{-0.4} \times 10^{4}$
7.200(5)	7.053(5)	100.0(1)%	97.5(3)%	(3+)	0.0		1.743(13)	$220_{-50}^{+60}$

* All values from [2016Tr07].

7.470(5)

** Interpolated between 1.724(13) fm  194 Po and 1.7622(23) fm  198 Rn.

#### Table 7

7.622(5)

direct $\alpha$ emis	irect $\alpha$ emission from ²⁰⁰ Fr*, $J_{\pi}^{\pi} = (3^+)$ , $T_{1/2} = 48(4)$ ms**, $BR_{\alpha} = \approx 100\%$ .									
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{196}\mathrm{At})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF			

0.0

* All values from [2014Ka23], except where noted.

** Weighted average of 46(4) ms [2014Ka23] and 49(4) ms [2005De01]. *** Interpolated between 1.7622(23) fm ¹⁹⁸Rn and 1.794(23) fm ²⁰²Ra.

 $(3^+)$ 

 $\approx 100\%$ 

 $250^{+140}_{-90}$ 

1.778(23)

**Table 8** direct  $\alpha$  emission from ²⁰⁴Ac*, T_{1/2} = 75⁺²³₋₁₅ ms,  $BR_{\alpha} = >97.5\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$E_{daughter}(^{200}\mathrm{Fr})$	coincident γ-rays	$R_0$ (fm)	HF
8107(15)	7.948(15)	$\approx 100\%$	0.0			

* All values from [2014Ka23].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +27/2 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +27/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. J^{$\pi$} values for ¹⁴³Ce, ¹⁴⁷Nd, ¹⁵¹Sm, ¹⁵⁵Gd, ¹⁵⁹Dy, ¹⁶³Er, ¹⁶⁷Yb, ¹⁷¹Hf, ¹⁷⁵W, ¹⁷⁹Os ¹⁸³Pt and ¹⁸⁷Hg are taken from ENSDF

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$Q_{\mathcal{E}\alpha}$	Experimental
¹⁴³ Ce*		3/2-	33 ()39(6) h	-3 435(8)			[19894618]
¹⁴⁷ Nd*		5/2-	11 03(3) d	-2.703(16)			[2019Br01]
¹⁵¹ Sm*		5/2-	90(6) v**	-1.190(4)			[1968Re04, 1965Fl02]
¹⁵⁵ Gd		3/2-	stable	stable			[]
¹⁵⁹ Dy		3/2-	144.4(2) d	0.365(1)	-5.766(1)	0.226(2)	[1959Ke28]
¹⁶³ Er		5/2-	75.1(4) m	1.211(5)	-4.275(5)	1.940(5)	[1963Pe16]
¹⁶⁷ Yb		5/2-	17.5(2) m***	1.953(4)	-2.955(4)	3.363(4)	[1964Wa04, 1960Wi15]
¹⁷¹ Hf		7/2+	12.1(4) h	2.397(29)	-1.956(29)	4.687(29)	[1970Ch17]
¹⁷⁵ W		$(1/2^{-})$	35.2(6) m	2.780(40)	-1.077(28)	5.771(28)	[1984Sz07]
¹⁷⁹ Os		$1/2^{-}$	6.3(3) m	3.564(29)	0.098(22)	6.964(32)	[1976Be62]
¹⁸³ Pt		1/2-	6.5(10) m	4.429(28)	1.547(26)	8.386(28)	[1963Gr08]
¹⁸⁷ Hg		3/2-	2.2(3) m	4.910(26)	2.457(25)	9.659(28)	[1970Ha18]
¹⁹¹ Pb		$(3/2^{-})$	1.3(3) m	5.992(10)	3.790(17)	10.313(23)	[1974Le02]
¹⁹⁵ Po		$(3/2^{-})$	4.64(9) s	6.909(8)	5.802(18)	12.741(10)	[1993Wa04]
^{195m} Po	0.150(10)	$(13/2^+)$	1.92(2) s	7.059(13)	5.952(21)	12.891(14)	[2017Al34, 1993Wa04
¹⁹⁹ Rn		$(3/2^{-})$	620(25) ms@	7.264(9)	6.624(19)	14.041(9)	[1984Ca32, 1999Ti03]
199mRn	0.223(12)	$(13/2^+)$	316(16) ms@@	7.487(15)	6.847(22)	14.264(15)	[1984Ca32, 1999Ti03]
²⁰³ Ra		$(3/2^{-})$	$31^{+17}_{-9}$ ms	7.725(12)	7.587(20)	15.000(11)	[2005Uu02]
203mRa	0.249(13)	$(13/2^+)$	$24_{-4}^{+6}$ ms	7.975(18)	7.837(24)	15.250(17)	[2005Uu02]
²⁰⁷ Th			$9.7^{+46.6}_{-4.4}$ ms	8.164(65)@@@	8.459(31)@@@	16.013(26)@@@	[2022Ya15]

* 100%  $\beta^-$  emitter.

*** Weighted average of 93(8) y [1968Re04] and 87(9) y [1965Fl02]. *** Weighted average of 17.7(2) m [1960Wi15] and 17.3(2) m [1964Wa04].

^(a) Weighted average of 620(25) ms [1984Ca32] and 570(30) ms [1999Ti03].
^(a) Weighted average of 325(25) ms [1984Ca32] and 310(20) ms [1999Ti03].
^(a) Deduced from our mass excess (19314(25) keV) for ²⁰⁷Th and daughter mass excesses from [2021Wa16].

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +27/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	BRα	Experimental
143 <b>C</b> e	8 871(6)	16 452(6)	0.883(2)		
147 N.d	8.762(24)	15.452(0)	1.025(2)		
151 Cm	8.702(34)	13.038(34)	1.033(2)		
155 G 1	8.208(20)	14.779(2)	1.145(1)		
155 Gd	7.621(1)	14.088(1)	0.081(1)		
¹³⁹ Dy	6.985(1)	12.921(1)	0.478(1)		
¹⁰³ Er	6.416(6)	11.690(5)	1.575(5)		
¹⁶⁷ Yb	5.992(12)	10.646(4)	2.153(6)		
$^{171}{ m Hf}$	5.414(33)	9.634(29)	2.734(29)		
$^{175}W$	5.181(40)	8.799(40)	3.374(40)		
¹⁷⁹ Os	4.656(32)	7.896(32)	4.188(32)		
¹⁸³ Pt	4.010(25)	6.801(29)	4.822(9)	9.6(5)×10 ⁻³ %	[1995Bi01, 1993BiZY, 1966Si08, 1963Gr08]
¹⁸⁷ Hg	3.693(25)	6.008(20)	5.145(20)*	$>3.7 \times 10^{-3}\%$	[1970Ha18, 1969NaZT, 1969NaZU]
¹⁹¹ Pb	3.214(10)	5.243(32)	5.402(14)	0.051(5)%	[2010Co13, 1974Ho26, 1974Le02, 1974JoZU]
¹⁹⁵ Po	2.383(8)	3.465(12)	6.750(3)	94(4)%	[2010Co13, 2017Al34, 2005Uu01, 2002Va13,
					1993Wa04, 1982LeZN, 1967Si09, 1967Tr04,
					1967Tr06]
^{195m} Po	2.233(13)	3.315(16)	6.900(10)	93(7)%	[2010Co13, 2017Al34, 1993Wa04, 2005Uu01,
					2002Va13, 1982LeZN, 1967Si09, 1967Tr04,
					1967Tr06]
¹⁹⁹ Rn	2.140(9)	2.745(12)	7.132(4)	$\approx 100\%^{**}$	[2005Uu02, 2014Ka23, 1999Ta03, 1993Wa04,
					1984Ca32, 1982Hi14, 1982HiZR, 1981En02,
					1980Di071
^{199m} Rn	1.917(15)	2,522(17)	7.355(13)	$\approx 100\%^{**}$	[2005Uu02, 2014Ka23, 1999Ta03, 1993Wa04
		()			1984Ca32 1982Hi14 1982HiZR 1980Di071
²⁰³ <b>R</b> a	1 789(11)	1 869(14)	7 736(6)	~ 100%**	[2014K ₉ 23, 2005Up02, 1996Le02]
203mRa	1 539(17)	1.8619(14)	7.986(19)	$\approx 100\%$	$[2014K_{9}23, 2005U_{0}02, 1996L_{0}2]$
207 Th	1.555(17) $1.455(74)^{@}$	1.0017(14) $1.068(34)^{@}$	8 328(21)***	$\sim 100\%$	[20171Xu20, 2000 0 002, 19901202]
111	1.755(74)	1.000(34)	0.520(21)	$\sim 100 / 0^{-1}$	[20221013]

* Deduced from  $\alpha$  energy, 5.230(14) in [2021Wa16].

** Not measured, based on short half-life.

*** Deduced from  $\alpha$  energy, assuming it feeds the ground state of ²⁰³Ra, giving a mass excess for ²⁰⁷Th of 19314(25) keV. ^(a) Deduced from our mass excess (19314(25) keV) for ²⁰⁷Th and daughter mass excesses from [2021Wa16].

### Table 3

direct  $\alpha$  emission from ¹⁸³Pt*,  $J_i^{\pi} = 1/2^-$ ,  $T_{1/2} = 6.5(10)$  m**,  $BR_{\alpha} = 9.6(5) \times 10^{-3} \%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{179}\mathrm{Os})$	coincident γ-rays	R ₀ (fm)	HF
4.819(10)	4.714(10)	9.6(5)×10 ⁻³ %	1/2-	0.0		1.548(17)	$1.5\substack{+0.7\\-0.5}$

* All values from [1995Bi01], except where noted.

** [1963Gr08].

### Table 4

direct  $\alpha$  emission from ¹⁸⁷Hg*,  $J_i^{\pi} = 3/2^-$ ,  $T_{1/2} = 2.2(3)$  m,  $BR_{\alpha} = >3.7 \times 10^{-3} \%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{183}\text{Pt})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.976(20) 5.145(20)	4.870(20) 5.035(20)	32(5)% 100%	$>1.2 \times 10^{-3}\%$ >2.5 \times 10^{-3}\%	1/2-	0.169(28) 0.0		1.490(16) 1.490(16)	<1.3 <3.5

* All values from [1970Ha18].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	Edaughter	( ¹⁸⁷ Hg) coir	ncident $\gamma$ -rays	R ₀ (fm	) HI	7
5.403(20)	5.290(20)	0.051(5)%**	3/2-	0.0			1.4964	(71) 1.4	$1^{+1.4}_{-0.7}$
* All va ** [201	llues from [1974 0Co13].	Le02], except where	e noted.						
<b>able 6</b> irect $\alpha$ emi	ssion from ¹⁹⁵ Pe	$b^*, J_i^{\pi} = (3/2^-), T_{1/2}$	$_2 = 4.64(9) \text{ s}^{**}$	$BR_{\alpha} = 94(4)^{\alpha}$	%.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{191}\text{Pb})$	coincident $\gamma$ -1	rays	R ₀ (fm)	HF
5.110(10) 5.153(5) 5.533(10) 5.744(5)	5.985(10) 6.027 5(5) 6.399(10) 6.606(5)	0.036(3)% 0.34(3)% 0.054(12)% 100.00(2)%	0.034(3)% 0.32(3)% 0.051(12)% 94(4)%	(3/2 ⁻ ) (3/2 ⁻ ) (5/2 ⁻ ) (3/2 ⁻ )	0.642 0.5972 0.20148 0.0	0.2148, 0.427 0.2148, 0.383 0.2148	, 0.5972	1.5120(34) 1.5120(34) 1.5120(34) 1.5120(34)	$\begin{array}{c} 11.5(14) \\ 1.91(24) \\ 450^{+150}_{-100} \\ 1.64(16) \end{array}$
* All va ** [199	dues from [2010 3Wa04].	Co13], except wher	e noted.						
Fable 7		-* E 150(10)1	keV $I^{\pi} = (13/2)$	$(t^{+}), T_{1/2} = 1.9$	$2(2) s^{***}, BR_{\alpha} = 93$	3(7)%***.			
direct $\alpha$ emi	ssion from ^{195m}	$P0^*$ , EX. = 150(10)	$kev, j_i = (15/2)$	), -1/2		( )			
direct $\alpha$ emineration $\Xi_{\alpha}(c.m.)$	Example 1955 Example 1957 Exam	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi}$	$E_{daughter}(^{191}\mathrm{Pb})$	coincident γ	-rays	R ₀ (fm)	HF
$\frac{1}{2} \frac{1}{\alpha} (\text{c.m.})$	$E_{\alpha}(\text{lab})$ 6.047(5) 6.699(5)	$I_{\alpha}$ (rel) 0.17(1)% 100.00(1)%	$\frac{I_{\alpha}(\text{abs})}{0.16(2)\%}$ 93(7)%		$E_{daughter}(^{191}Pb)$ 0.725(12) 0.55(12)	coincident γ 0.6697	-rays	R ₀ (fm) 1.5120(34) 1.5120(34)	HF 1.99(24) 1.54(17)
$\frac{\text{lirect } \alpha \text{ emi}}{E_{\alpha}(\text{c.m.})}$ 5.174(5) 5.839(5) * All va ** [201 *** [19]	$\frac{E_{\alpha}(\text{lab})}{6.047(5)}$ 6.699(5) alues from [2010 7A[34]. 93Wa04].	$I_{\alpha}$ (rel) 0.17(1)% 100.00(1)% Co13], except wher	$I_{\alpha}(abs)$ 0.16(2)% 93(7)% e noted.		$E_{daughter}(^{191}Pb)$ 0.725(12) 0.55(12)	coincident γ 0.6697	-rays	R ₀ (fm) 1.5120(34) 1.5120(34)	HF 1.99(24) 1.54(17)
direct α emi $E_{\alpha}(c.m.)$ 5.174(5) 5.839(5) * All v _i ** [20] *** [19 <b>Fable 8</b> direct α emi	$\frac{E_{\alpha}(\text{lab})}{6.047(5)}$ 6.699(5) illues from [2010 7A134]. 93Wa04]. ssion from ¹⁹⁹ R	$I_{\alpha}$ (rel) $I_{\alpha}$ (rel) 0.17(1)% 100.00(1)% Co13], except wher $n^*, J_i^{\pi} = (3/2^-), T_{1/2}$	$I_{\alpha}(abs)$ 0.16(2)% 93(7)% e noted. 2 = 620(25) ms	$J_{f}^{\pi}$ $(13/2^{+})$ $(13/2^{+})$ $(13/2^{+})$	<i>E_{daughter}</i> ( ¹⁹¹ Pb) 0.725(12) 0.55(12)	coincident γ 0.6697	-rays	R ₀ (fm) 1.5120(34) 1.5120(34)	HF 1.99(24) 1.54(17)
direct $\alpha$ emi $E_{\alpha}(c.m.)$ 5.174(5) 5.839(5) * All va ** [20] *** [19 <b>Fable 8</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$	$\frac{E_{\alpha}(\text{lab})}{6.047(5)}$ 6.699(5) dues from [2010 7Al34]. 93Wa04]. ssion from ¹⁹⁹ R $E_{\alpha}(\text{lab})$	$I_{\alpha}$ (rel) $I_{\alpha}$ (rel) 0.17(1)% 100.00(1)% Co13], except wher $n^*, J_i^{\pi} = (3/2^-), T_{1/2}$ $I_{\alpha}(abs)$	$I_{\alpha}(abs)$ 0.16(2)% 93(7)% re noted. 2 = 620(25) ms J_{f}^{\pi}	$J_{f}^{\pi}$ $(13/2^{+})$ $(13/2^{+})$ $(13/2^{+})$ $S^{**}, BR_{\alpha} = \approx$ $E_{daughter}(^{1})$	<i>E_{daughter}</i> ( ¹⁹¹ Pb) 0.725(12) 0.55(12) 100%***.	coincident γ 0.6697 ident γ-rays	-rays R ₀ (fm)	R ₀ (fm) 1.5120(34) 1.5120(34) HF	HF 1.99(24) 1.54(17)
direct α emi $E_{\alpha}(c.m.)$ 5.174(5) 5.839(5) * All va ** [201 *** [19] <b>Fable 8</b> direct α emi $E_{\alpha}(c.m.)$ 7.132(6)	$\frac{E_{\alpha}(\text{lab})}{6.047(5)}$ 6.047(5) 6.699(5) Hues from [2010 7A134]. 93Wa04]. <u>ssion from ¹⁹⁹R</u> <u>E_{\alpha}(\text{lab})</u> 6.989(6)	$\frac{I_{\alpha}(\text{rel})}{0.17(1)\%}$ $\frac{I_{\alpha}(\text{rel})}{100.00(1)\%}$ Co13], except wher $\frac{n^{*}, J_{i}^{\pi} = (3/2^{-}), T_{1/2}}{I_{\alpha}(\text{abs})}$ $\approx 100\%$	$I_{\alpha}(abs)$ 0.16(2)% 93(7)% re noted. $\frac{J_{f}^{\pi}}{(3/2^{-})}$	$J_{f}^{\pi}$ $(13/2^{+})$ $(13/2^{+})$ $(13/2^{+})$ $S^{**}, BR_{\alpha} = \approx \frac{1}{E_{daughter}}$	Edaughter(191 Pb)         0.725(12)         0.55(12)         100%***.         95 Po)       coinc	coincident γ 0.6697 ident γ-rays	-rays R ₀ (fm) 1.5330(e	$R_0$ (fm) 1.5120(34) 1.5120(34) HF 60) ≈1	HF 1.99(24) 1.54(17)
$\frac{\text{direct } \alpha \text{ emi}}{E_{\alpha}(\text{c.m.})}$ 5.174(5) 5.839(5) * All va ** [20] *** [19 <b>Fable 8</b> direct $\alpha$ emi $E_{\alpha}(\text{c.m.})$ 7.132(6) * All va ** Weig *** No	$\frac{E_{\alpha}(\text{lab})}{6.047(5)}$ $\frac{E_{\alpha}(\text{lab})}{6.699(5)}$ $\frac{E_{\alpha}(1)}{1000}$ $\frac{199}{1000}$ $\frac{E_{\alpha}(1)}{1000}$ $\frac{199}{1000}$ $\frac{E_{\alpha}(1)}{1000}$ $\frac{199}{1000}$ $\frac{E_{\alpha}(1)}{1000}$ $\frac{1000}{1000}$	$\frac{I_{\alpha}(\text{rel})}{I_{\alpha}(\text{rel})}$ 0.17(1)% 100.00(1)% Co13], except wher $\frac{n^{*}, J_{i}^{\pi} = (3/2^{-}), T_{1/i}}{I_{\alpha}(\text{abs})}$ $\approx 100\%$ Uu02], except wher 620(25) ms [1984Cd on short half-life.	$I_{\alpha}(abs)$ 0.16(2)% 93(7)% e noted. $J_{f}^{\pi}$ (3/2 ⁻ ) re noted. Ca32] and 570(3)	$J_{f}^{\pi}$ $(13/2^{+})$ $(13/2^{+})$ $(13/2^{+})$ $S^{**}, BR_{\alpha} = \approx$ $E_{daughter}(^{1}$ $0.0$ $30) \text{ ms [1999T]}$	E _{daughter} ( ¹⁹¹ Pb)         0.725(12)         0.55(12)         100%***. ⁹⁵ Po)       coinc         i03].	coincident γ 0.6697 ident γ-rays	R ₀ (fm)	$R_0$ (fm) 1.5120(34) 1.5120(34) HF 60) ≈1	HF 1.99(24) 1.54(17)
direct α emi $E_{\alpha}(c.m.)$ 5.174(5)         5.839(5)         * All va         ** [20]         *** [19 <b>Table 8</b> direct α emi $E_{\alpha}(c.m.)$ 7.132(6)         * All va         *** No <b>Table 9</b> direct α emi	$\frac{E_{\alpha}(\text{lab})}{E_{\alpha}(\text{lab})}$ $\frac{E_{\alpha}(\text{lab})}{6.047(5)}$ $\frac{6.047(5)}{6.699(5)}$ $\frac{1}{2010}$ $\frac{1}{7A134]}$ $\frac{1}{93Wa04]}$ $\frac{1}{33Wa04]}$ $\frac{1}{6}$	$\frac{I_{\alpha}(\text{rel})}{I_{\alpha}(\text{rel})}$ $\frac{I_{\alpha}(\text{rel})}{0.17(1)\%}$ $100.00(1)\%$ $\text{Co13], except wher}$ $\frac{n^{*}, J_{i}^{\pi} = (3/2^{-}), T_{1/i}}{I_{\alpha}(\text{abs})}$ $\approx 100\%$ $Uu02], except wher 620(25) ms [1984Cd on short half-life. Rn^{*}, Ex. = 223(12)$	$I_{\alpha}(abs)$ 0.16(2)% 93(7)% e noted. $\frac{J_{f}^{\pi}}{(3/2^{-})}$ re noted. Ca32] and 570(3) keV, $J_{i}^{\pi} = (13/2^{-})$	$J_{f}^{\pi}$ (13/2 ⁺ ) (13/2 ⁺ ) (13/2 ⁺ ) (13/2 ⁺ ) 5***, BR _{\alpha} = \approx E _{daughter} ( ¹ 0.0 30) ms [1999T 2 ⁺ ), T _{1/2} = 310	$E_{daughter}(^{191} Pb)$ 0.725(12) 0.55(12) 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***.	coincident γ 0.6697 ident γ-rays ≈ 100%***.	R ₀ (fm)	$R_0$ (fm) 1.5120(34) 1.5120(34) HF 60) ≈1	HF 1.99(24) 1.54(17)
$\frac{\text{direct } \alpha \text{ emi}}{E_{\alpha}(\text{c.m.})}$ 5.174(5) 5.174(5) 5.839(5) * All va ** [201 *** [19 <b>Table 8</b> direct $\alpha$ emi E_{\alpha}(c.m.) 7.132(6) * All va ** Weig *** No <b>Table 9</b> direct $\alpha$ emi E_{\alpha}(c.m.)	$\frac{E_{\alpha}(\text{lab})}{E_{\alpha}(\text{lab})}$ $\frac{E_{\alpha}(\text{lab})}{6.047(5)}$ $\frac{6.047(5)}{6.699(5)}$ $\frac{1}{2}$	$\frac{I_{\alpha}(\text{rel})}{I_{\alpha}(\text{rel})}$ 0.17(1)% 100.00(1)% Co13], except wher $\frac{n^*, J_i^{\pi} = (3/2^-), T_{1/}}{I_{\alpha}(\text{abs})}$ $\approx 100\%$ Uu02], except wher 620(25) ms [1984Cd on short half-life. Rn*, Ex. = 223(12) $I_{\alpha}(\text{abs})$	$I_{\alpha}(abs)$ 0.16(2)% 93(7)% e noted. $J_{f}^{\pi}$ (3/2 ⁻ ) re noted. Ca32] and 570(3) keV, $J_{i}^{\pi} = (13/2)$	$J_{f}^{\pi}$ (13/2 ⁺ ) (13/2 ⁺ ) (13/2 ⁺ ) (13/2 ⁺ ) S**, BR _{\alpha} = \approx 2 <u>E_{daughter}(1</u> 0.0 30) ms [1999T 2 ⁺ ), T _{1/2} = 316 <u>E_{daughter}(1</u> )	$E_{daughter}(^{191} Pb)$ 0.725(12) 0.55(12) 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%***. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**. 100%**.	coincident $\gamma$ 0.6697 ident $\gamma$ -rays $\approx 100\%$ ***.	-rays R ₀ (fm) 1.5330( R ₀ (fm)	$R_0$ (fm) 1.5120(34) 1.5120(34) HI 60) ≈1 → HI	HF 1.99(24) 1.54(17)

* All values from [2005Uu02], except where noted.
** Weighted average of 325(25) ms [1984Ca32] and 310(20) ms [1999Ti03].
*** Not measured, based on short half-life.

#### Table 10 direct $\alpha$ emission from ²⁰³Ra, $J_i^{\pi} = (3/2^-)$ , $T_{1/2} = 31^{+17}_{-9}$ ms*, $BR_{\alpha} = \approx 100\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{199}\mathrm{Rn})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
7.736(8)	7.584(8)**	pprox 100%	(3/2-)	0.0		1.549(15)	1.9(12)
* [2005] ** Weig *** Not	Uu02]. hted average of 7.5 measured, based or	75(10) MeV [20] n short half-life.	4Ka23] and 7.	589(8) MeV [2005Uu02	].		
Table 11 direct $\alpha$ emission	ssion from ^{203m} Ra, 1	Ex. = 250(13) ke	V, $J_i^{\pi} = (13/2^+)^{\pi}$	), $T_{1/2} = 24^{+6}_{-4} \text{ ms}^*$ , $BR_a$	$= \approx 100\%$ ***.		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	E _{daughter} ( ¹⁹⁹ Rn)	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.763(6)	7.610(6)**	pprox 100%	(13/2 ⁺ )	0.223(12)		1.5330(60)	1.8(8)
* [2005] ** Weig *** Not	Uu02]. hted average of 7.5' measured, based or	75(10) MeV [20] 1 short half-life.	4Ka23] and 7.	589(8) MeV [2005Uu02	].		
Table 12 direct $\alpha$ emis	ssion from ²⁰⁷ Th*. 7	$\Gamma_{1/2} = 9.7^{+46.6}$ m	is, $BR_{\alpha} = \approx 10$	00%**.			
	,	-1/2		202-			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{203}\mathrm{Ra})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
8.328(21)	8.167(21)	$\approx 100\%$		0.0***			
* All val ** Not r	lues from [2022Ya1	5]. short half-life					

*** Transition assumed to feed the ground state.

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**Fig. 1**: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +27/2 nuclei.

Last updated 7/19/2023

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +27/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon_P}$	$Q_{\varepsilon \alpha}$	Experimental
			-/ -		Å		
¹⁴¹ La*		$7/2^{+}$	3.92(3) h	-3.197(7)			[1981Ge04]
¹⁴⁵ Pr*		$7/2^{+}$	5.984(10) h	-2.560(30)			[1980Ge11]
¹⁴⁹ Pm*		$7/2^{+}$	53.09(9) h	-1.689(3)			[1960Bu06]
¹⁵³ Eu		$5/2^{+}$	stable	stable			
¹⁵⁷ Tb		$3/2^{+}$	99(10) y	0.060	-7.970(3)	-0.629(1)	[1983Be42]
¹⁶¹ Ho		7/2-	2.48(5) h	0.859(2)	-6.649(2)	1.203(2)	[1965Ab04]
¹⁶⁵ Tm		$1/2^{+}$	30.06(5) h	1.591(2)	-5.238(2)	2.701(2)	[1970Ka23]
¹⁶⁹ Lu		7/2+	34.06(5) h	2.293(3)	-4.059(3)	4.014(3)	[1970Ka23]
¹⁷³ Ta		5/2-	3.65(5) h	3.020(40)	-2.949(28)	5.554(28)	[1963Sa14]
¹⁷⁷ Re		5/2-	14(1) m	3.430(40)	-2.193(42)	6.718(40)	[1970Go20]
¹⁸¹ Ir		5/2-	4.90(15) m	4.087(26)	-0.915(22)	7.814(28)	[1978La04]
¹⁸⁵ Au		5/2-	4.2(1) m	4.830(26)	0.464(28)	9.267(25)	[1995Bi01]
¹⁸⁹ Tl		$(1/2^+)$	2.3(2) m	5.010(30)	0.466(9)	9.647(27)	[1976Ha25]
¹⁹³ Bi		$(9/2^{-})$	67(3) s**	6.345(13)	2.699(33)	11.317(32)	[1985Co06, 1972Ga27]
^{193m} Bi	0.307(7)	$(1/2^+)$	3.4(2) s***	6.652(15)	3.006(34)	11.624(33)	[1985Co06, 1972Ga27]
¹⁹⁷ At		(9/2-)	388(6) ms	7.038(13)	4.365(26)	13.449(13)	[1999Sm07]
^{197m} At	0.048(10)	$(1/2^+)$	2.0(2) s	7.086(16)	4.413(28)	13.497(16)	[1999Sm07]
²⁰¹ Fr		$(9/2^{-})$	63(3) ms@	7.696(14)	5.287(26)	14.557(13)	[2014Ka23, 2005De01, 2005Uu02]
^{201m} Fr	0.130(14)	$(1/2^+)$	$10^{+12}_{-3}$ ms ^{@@}	7.826(20)	5.417(30)	14.687(19)	[2014Ka23, 2005Uu02]
²⁰⁵ Ac		(9/2-)	$20^{+97}_{-9}$ ms	8.300(60)	6.210(64)	15.789(60)	[2014Zh03]

* 100%  $\beta^-$  emitter.

** Weighted average of 67(3) s [1985Co06] and 62.2(36) s [1972Ga27].

*** Weighted average of 3.2(2) s [1905C006] and 3.48(18) s [1972Ga27]. [@] Weighted average of 64(3) ms [2014Ka23], 67(3) ms [2005De01] and 53(4) ms [2005Uu02]. [@] Weighted average of  $8^{+12}_{-3}$  ms [2014Ka23], and  $19^{+19}_{-6}$  ms [2005Uu02].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +27/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
¹⁴¹ La	6.951(9)	16.807(5)	1.191(4)		
¹⁴⁵ Pr	6.483(7)	16.032(10)	0.879(8)		
¹⁴⁹ Pm	5.945(2)	15.198(16)	1.137(7)		
¹⁵³ Eu	5.893(1)	14.559(5)	0.272(2)		
¹⁵⁷ Tb	5.517(0)	13.523(1)	0.179(1)		
¹⁶¹ Ho	4.813(2)	12.242(2)	1.143(2)		
¹⁶⁵ Tm	4.276(1)	11.130(2)	1.841(3)		
¹⁶⁹ Lu	3.792(3)	10.117(3)	2.423(3)		
¹⁷³ Ta	3.283(37)	9.146(28)	3.261(28)		
¹⁷⁷ Re	2.917(40)	8.438(40)	3.702(40)		
¹⁸¹ Ir	2.396(17)	7.457(25)	4.381(28)		
¹⁸⁵ Au	1.815(15)	6.234(25)	5.180(5)	0.26(6)%	[1995Bi01, 1993BiZY, 1991Bi04, 1970Ha18, 1968De01,
					1968Si01, 1965Si07]
¹⁸⁹ Tl	1.707(11)	6.165(24)	4.817(9)		
¹⁹³ Bi	0.622(9)	4.180(11)	6.307(5)	2.2(5)%	[2005De01, 1985Co06, 1972Ga27, 2004DeZV, 1993An19,
					1990AnZR, 1989AnZF, 1984Co13, 1982LeZN, 1978Va21,
					1974Le02, 1970Ta14, 1967Tr06]
^{193m} Bi	0.315(11)	3.873(13)	6.614(9)	75(25)%	[1993An19, 1985Co06, 1972Ga27, 2005De01, 2004DeZV
					1984Co13, 1982LeZN, 1978Va21, 1974Le02, 1970Ta14,
					1967Tr06]
¹⁹⁷ At	0.175(10)	2.908(10)	7.104(3)	$\approx 100\%*$	[2014Ka23, 2005De01, 2005Uu02, 1999Sm07, 1996En01,
					2015We13, 2004DeZV, 1986Co12, 1985HuZY, 1967Tr04,
					1967Tr06]
^{197m} At	0.127(14)	2.860(14)	7.152(10)	$\approx 100\%*$	[2014Ka23, 2005De01, 1999Sm07, 2004DeZV, 1986Co12,
					1985HuZY]
²⁰¹ Fr	-0.300(11)	2.166(11)	7.519(4)	$\approx 100\%*$	[2014Ka23, 2005De01, 2005Uu02, 1996En01, 2004DeZV,]
					1980Ew03, 1979Ca16]
201m Fr	-0.430(17)	2.036(18)	7.649(14)	100%*	[2014Ka23, 2005Uu02]
²⁰⁵ Ac	-0.757(60)	1.348(60)	8.093(59)	$\approx 100\%*$	[2014Zh03]

* Based on short half-life.

direct $\alpha$ em	ission from ¹⁸⁵ A	Au*, $J_i^{\pi} = 5/2^-$	, $T_{1/2} = 4.2(1) \text{ m}$ , E	$BR_{\alpha} = 0.26(6)\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{181}\mathrm{Ir})$	coincident γ-rays**	* $R_0$ (fm)	HF
4.680(10) 4.933(10) 5.181(5)	4.579(10) 4.826(10) 5.069 5(5)	0.03(1)% 0.15(1)% 100(1)%	$7.8(32) \times 10^{-5} \%$ 3.9(9)×10 ⁻⁴ % 0.26(6)%	(3/2 ⁻ , 5//2 ⁻ ) (5/2 ⁻ )	0.501 0.243 0.0	0.112, 0.131, 0.243	1.521(22) 1.521(22) 1.521(22)	$\begin{array}{c} 3.0^{+2.8}_{-1.4} \\ 20^{+14}_{-9} \\ 0.7^{+4}_{-3} \end{array}$
* All va ** [200	alues from 1005 )5Wu07 ].	Bi01], except	where noted.					
<b>Table 4</b> direct $\alpha$ emi	ission from ¹⁹³ E	Bi, $J_i^{\pi} = (9/2^-)$	, $T_{1/2} = 67(3) s^*$ , B	$R_{\alpha} = 2.2(5)\%^{**}.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$ i	$E_{daughter}(^{189}\mathrm{Tl})$	coincident γ-rays	R ₀ (fm)	HF
6.024(5) 6.305(5)	5.899(5)*** 6.174(5)***	100% 4.4(5)%	$\begin{array}{c} 0.021(5)\%\\ 9.3(2){\times}10^{-4}\%\end{array}$	$(9/2^{-})$ ( $(1/2^{+})$ (	0.281(7) 0.0		1.5059(63) 1.5059(63)	$2.9^{+1.1}_{-0.8}$ $1000^{+500}_{-300}$
* Weig ** [200 *** [19	hted average of 05De01]. 085Co06].	67(3) s [19850	Co06] and 62.2(36)	s [1972Ga27].				
Table 5 direct $\alpha$ emi	ission from ^{193m}	Bi, Ex = 307(	7) keV, $J_i^{\pi} = (1/2^+)$ ,	$T_{1/2} = 3.4(2) s^*,$	$BR_{\alpha} = 75(25)\%^{**}.$			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}$ (abs	) $J_f^{\pi}$	$E_{daughter}(^{18}$	⁹ Tl) coinciden	tt $\gamma$ -rays $R_0$ (fm)	HF	
6.612(5)	6.475(5)***	* 75(25)	%** (1/2 ⁺ )	0.0		1.5059(	63) $1.0^{+0}_{-0}$	0.6 0.3
* Weig ** [199 *** [19	hted average of 93An19]. 985Co06].	3.2(2) s [1985	Co06] and 3.48(18)	s [1972Ga27].				
Table 6 direct $\alpha$ emi	ission from ¹⁹⁷ A	At, $J_i^{\pi} = (9/2^-)$	, $T_{1/2} = 388(6) \text{ ms}^*$	$BR_{\alpha} = \approx 100\%.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	E _{daughter} ( ¹⁹³ Bi	i) coincident γ	r-rays R ₀ (fm)	HF	
7.105(3)	6.961(3)**	$\approx 1009$	% (9/2 ⁻ )	0.0		1.5291(28)	) 1.53(10	))
* [1999 ** Weig	9Sm07]. ghted average of	6.963(5) MeV	7 [2014Ka23], 6.963	8(4) MeV [2005De	e01], 6.959(6) MeV [	2005Uu02], 6.960(5) [1	1999Sm07] and	6.956(5) MeV [1996En01].
<b>Table 7</b> direct $\alpha$ em	ission from ^{197m}	At*, Ex = 48(	10) keV, $J_i^{\pi} = (1/2^+)$	), $T_{1/2} = 2.0(2) s$ ,	$BR_{\alpha} = \approx 100\%.$			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	E _{daughter} ( ¹⁹³ Bi	i) coincident γ	r-rays R ₀ (fm)	HF	
6.846(5)	6.707(5)**	$\approx 1009$	% (1/2 ⁺ )	0.307(7)		1.5291(28)	) 0.93(12	
* All va	alues from [1999	9Sm07].						
Table 8 direct $\alpha$ emi	ission from ²⁰¹ F	Fr, $J_i^{\pi} = (9/2^-)$ .	$T_{1/2} = 63(3) \text{ ms}^*, H$	$BR_{\alpha} = \approx 100\%.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	) $J_f^{\pi}$	$E_{daughter}(^{197}A)$	At) coincident	$\gamma$ -rays R ₀ (fm)	HF	
7.519(5)	7.369(5)**	$\approx 100^{\circ}$	% (9/2 ⁻ )	0.0		1.547(12	$1.7^{+0.5}_{-0.4}$	

* Weighted average of 64(3) ms [2014Ka23], 67(3) ms [2005De01] and 53(4) ms [2005Uu02]. ** Weighted average of 7.369(5) MeV [2014Ka23], 7.379(7) MeV [2005De01], 7.369(8) MeV [2005Uu02], and 7.361(7) MeV [1996En01].

7.601(8) 7.450(8)** 100% (1/2 ⁺ ) 0.048(10) 1.547(12) $0.5^{+0.5}_{-0.2}$	$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{197}\mathrm{At})$	coincident γ-rays	R ₀ (fm)	HF
	7.601(8)	7.450(8)**	100%	(1/2+)	0.048(10)		1.547(12)	$0.5\substack{+0.5 \\ -0.2}$

direct  $\alpha$  emission from ^{201m}Fr, Ex = 130(14) keV,  $J_i^{\pi} = (1/2^+)$ ,  $T_{1/2} = 10^{+12}_{-3}$  ms*,  $BR_{\alpha} = 100\%$ .

* Weighted average of  $8^{+12}_{-3}$  ms [2014Ka23], and  $19^{+19}_{-6}$  ms [2005Uu02].

** Weighted average of 7.445(8) MeV [2014Ka23], and 7.454(8) MeV [2005Uu02].

#### Table 10

direct  $\alpha$  emission from ²⁰⁵Ac*,  $J_i^{\pi} = (9/2^-)$ ,  $T_{1/2} = 20^{+97}_{-9}$  ms,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{201}\mathrm{Fr})$	coincident γ-rays	R ₀ (fm)	HF
8.093(30)	7.935(30)	$\approx 100\%$	(9/2-)	0.0	_	1.541(17)	6 ⁺⁶ ₋₃

* All values from [2014Zh03].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +14 nuclei.

last updated 8/1/2023

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +14$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	Q _ε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
160 0	0+	. 11				
Dy	0	stable				
¹⁶⁴ Er	$0^+$	stable				
¹⁶⁸ Yb	$0^+$	stable				
¹⁷² Hf	$0^+$	1.86(3) y	0.334(25)	-4.384(24)	2.485(24)	[1971Ch57]
$^{176}W$	$0^+$	2.3(1) h	0.720(40)	-3.449(28)	3.670(28)	[1963Va20]
¹⁸⁰ Os	$0^{+}$	21.7(6) m	1.481(27)	-2.350(21)	4.584(35)	[1966Ho16]
¹⁸⁴ Pt	$0^+$	17.3(2) m	2.280(30)	-0.958(52)	6.080(26)	[1972Fi12]
¹⁸⁸ Hg	$0^+$	3.25(15) m	2.173(7)	-0.802(25)	6.988(29)	[1972Fi12]
¹⁹² Pb	$0^+$	3.5(1) m	3.320(30)	0.751(23)	7.395(6)	[ <b>1979To06</b> ]
¹⁹⁶ Po	$0^+$	5.8(2) s	4.540(25)	2.980(7)	9.979(32)	[1985Va03]
²⁰⁰ Rn	$0^+$	1.06(2) s	4.987(25)	3.949(8)	11.584(25)	[1984Ca32]
²⁰⁴ Ra	$0^+$	$58^{+10}_{-7}$ ms*	5.454(26)	4.956(11)	12.624(26)	[2005Uu02, 1996Le09]
²⁰⁸ Th	$0^+$	$1.7^{+1.7}_{-0.6}$ ms	5.930(70)	5.885(66)	13.656(40)	[2010He25]

* Weighted average of  $54^{+19}_{-11}$  ms [2005Uu02] and  $59^{+12}_{-9}$  ms [1996Le09].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +14$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
160 Da	7 420(1)	12 560(1)	0.428(1)		
164 D	7.429(1)	13.300(1)	0.436(1)		
Er	6.854(0)	12.339	1.305(0)		
¹⁶⁸ Yb	6.326(1)	11.234	1.938(1)		
¹⁷² Hf	5.863(24)	10.216(24)	2.753(24)		
$^{176}W$	5.522(40)	9.375(28)	3.336(37)		
¹⁸⁰ Os	5.061(29)	8.527(22)	3.860(32)		
¹⁸⁴ Pt	4.419(29)	7.301(26)	4.599(8)	$1.7(7) \times 10^{-3}\%$	[1995Bi01, 1993BiZY, 1966Si08, 1963Gr08]
¹⁸⁸ Hg	4.459(24)	6.912(23)	4.709(15)	$\approx$ 3.7 $\times$ 10 ⁻⁵ %	[ <b>1979Ha10</b> , 1993ToZY]
¹⁹² Pb	3.558(9)	5.759(17)	5.222(5)	$6.0(5) \times 10^{-3}\%$ *	[1992Wa14, 1979To06, 1992WaZV, 1984To09, 1974Ho16,
					1974Le02]
¹⁹⁶ Po	2.732(8)	3.839(18)	6.658(2)	94(5)%	[1996Ta18, 1993Wa04, 1985Va03, 2016Tr07, 1993WaZO,
					1992WaZV, 1967Si09, 1967Tr06, 1965Si22]
²⁰⁰ Rn	2.466(8)	3.105(18)	7.043(2)	$86^{+14}_{-4}\%$	[1995Bi17, 1993Wa04, 1984Ca32, 2015We15, 2005Uu02
				-4	1995BiZY, 1992WaZV, 1971Ho01]
²⁰⁴ Ra	2.104(11)	2.242(20)	7.637(7)	$\approx 100\%^{**}$	[2005Uu02, 1996Le09, 1995Le04, 1995Le15, 1995LeZY]
²⁰⁸ Th	1.747(65)	1.456(37)	8.202(31)	100%	[2010He25]

* Weighted average of  $6.2(6) \times 10^{-3}\%$  [1992Wa14] and  $5.7(10) \times 10^{-3}\%$  [1979To06].

** Based on short half-life.

# Table 3

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{180}\mathrm{Os})$	coincident γ-rays	R ₀ (fm)	HF
4.602(10)	4.502(10)	$1.7(7) \times 10^{-3}\%$	$0^+$	0.0		1.542(27)	$1.0^{+0.7}_{-0.3}$
* All val ** [1972 <b>Table 4</b> direct α emis	ues from [1995Bi( Fi12]. sion from ¹⁸⁸ Hg*,	01], except where noted $J_i^{\pi} = 0^+, T_{1/2} = 3.25(1)$	5) m**, <i>Bk</i>	$R_{\alpha} = \approx 3.7 \times 10^{-5} \%.$			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{184}\text{Pt})$	coincident γ-rays	R ₀ (fm)	HF
	4 610(20)	$1.7(7) \times 10^{-3}$ of	$0^+$	0.0		1 480(15)	1.01

** [1972Fi12].

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direct $\alpha$ emis	sion from ¹⁹² Pb*.	$J_i^{\pi} = 0^+, T_{1/2} = 3.5($	1) m, $BR_{\alpha}$	= 6.0(5)×10 ⁻	³ %**.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	Edaughte	$r(^{188}H_{2})$	g) coincident	γ-rays	$R_0$ (fm)	HF	
5.221(5)	5.112(5)	$6.0(5) \times 10^{-3}\%^{**}$	$0^+$	0.0				1.5126(28)	0.98(9)	
* All val ** Weigl	ues from [1979To nted average of 6.	06], except where no $2(6) \times 10^{-3}\%$ [1992W	ted. /a14] and :	5.7(10)×10 ⁻³	% [197	9To06].				
Table 6 direct $\alpha$ emis	sion from ¹⁹⁶ Po, .	$\mathbf{J}_i^{\pi} = 0^+,  \mathbf{T}_{1/2} = 5.8(2$	) s*, $BR_{\alpha}$ :	= 94(5)%**.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}($	¹⁹² Pb)	coincident γ-	rays	R ₀ (fm)	HF	
6.654(1)	6.518(1)***	94(5)%**	$0^+$	0.0				1.5005(86)	1.00(6)	
<b>Table 7</b> direct $\alpha$ emis	sion from ²⁰⁰ Rn,	$\mathbf{J}_i^{\pi} = 0^+,  \mathbf{T}_{1/2} = 1.060$	(2) s*, <i>BR</i> ₀	$\alpha = 86^{+14}_{-4}\%^{**}.$						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$I_{\alpha}(abs)$	J	$\frac{\pi}{f}$	$E_{daughter}($ ¹⁹⁶ Po)	coincide	ent γ-rays	R ₀ (fm)	HF
6.485(6) 6.586(4) 7.0433(25)	6.355(6) 6.454(4) 6.9024(25)	$\begin{array}{c} 6(2) \times 10^{-3}\% \\ 8.1(7) \times 10^{-3}\% \\ 100\% \end{array}$	$\begin{array}{c} 5.2^{+10}_{-5} \\ 7.0^{+14}_{-9} \\ 86^{+14}_{-4} \end{array} \\ \end{array}$	$<10^{-3}\%$ 0 $<10^{-3}\%$ 2 $_{0}$ 0	)+ 2+ )+	0.558(7) $0.4631(1)^{@}$ 0.0	0.4631(	1)@	1.5205(93) 1.5205(93) 1.5205(93)	$140^{+90}_{-40} \\ 242^{+60}_{-24} \\ 1.3^{+4}_{-1}$
* [1984C ** [1993 *** [199 [@] [2007]	Ca32]. Wa04]. 6Tr18]. Hu13].									
<b>Table 8</b> direct $\alpha$ emis	sion from ²⁰⁴ Ra,	$\mathbf{J}_i^{\pi} = 0^+,  \mathbf{T}_{1/2} = 58^{+10}_{-7}$	⁰ ms*, <i>BR</i>	$\alpha = \approx 100\%.$						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{20}$	⁰ Rn)	coincident γ-ra	iys	R ₀ (fm)	HF	
7.636(6)	7.486(6)**	$\approx 100\%$	$0^+$	0.0				1.525(14)	1.07(19)	
* Weight ** Weigl	ted average of 54 nted average of 7.	⁺¹⁹ ms [2005Uu02] a 486(8) MeV [2005Uu	nd 59 ⁺¹² r 102], 7.484	ns [1996Le09] 4(10) MeV [19	96Le09	9], and 7.488(12) Me	V [1995Le	:04].		
<b>Table 9</b> direct $\alpha$ emis	sion from ²⁰⁸ Th*	, $\mathbf{J}_i^{\pi} = 0^+$ , $\mathbf{T}_{1/2} = 1.7^+$	$^{+1.7}_{-0.6}$ ms, BI	$R_{\alpha} = 100\%.$						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}$ ( ²⁰⁴ )	Ra)	coincident γ-ray	/8	R ₀ (fm)	HF	
8.202(30)	8.044(30)	100%	0+	0.0				1.555(18)	$0.66^{+0.66}_{-0.24}$	
* All val	ues from [2010He	25].								

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$  = +14 nuclei.

Last updated 6/2/2025

Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +14$ nuclei. J ^{$\pi$} values for ¹⁶² Ho, ¹⁴⁶⁶ Tm, ¹⁷⁰ Lu, ¹⁷⁴ Ta, ¹⁷⁸ Re, ¹⁸² Ir, and ¹⁹⁰ Tl are ta	aken
from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.	

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Q _ε	$Q_{\varepsilon n}$	$Q_{\varepsilon \alpha}$	$BR_{\epsilon F}$	Experimental
			1/2		~	~~~		*
¹⁶² Ho		$1^{+}$	15.0(10) h	0.294(3)	-5.868(3)	2.224(3)		[1965St08]
¹⁶⁶ Tm		$2^{+}$	7.70(4) h*	3.038(12)	-4.277(12)	3.870(12)		1960Wi12, 1960Gr15]
¹⁷⁰ Lu		$0^+$	2.03(3) d**	3.458(17)	-3.321(17)	5.193(17)		[1970Ka23, 1960Wi14]
¹⁷⁴ Ta		3+	1.06(4) h	4.104(28)	-2.149(28)	6.598(28)		[1985Sz03]
¹⁷⁸ Re		3+	13.2(2) m	4.750(30)	-1.228(28)	7.766(28)		[1970Go20]
¹⁸² Ir		3+	15(1) m	5.560(30)	0.177(24)	8.930(26)		[1972Ak03]
¹⁸⁶ Au		3-	10.7(5) m	6.150(30)	1.332(35)	10.469(30)		[1970Jo02]
¹⁹⁰ Tl		$2^{-}$	2.6(3) m	7.004(17)	1.927(21)	11.073(23)		[1976Bi09]
¹⁹⁴ Bi		$(3^{+})$	95(3) s	8.185(18)	4.165(9)	12.923(17)		[1991Va04]
^{194m} Bi	0.161(8)	(10 ⁻ )	114(4) s	8.346(20)	4.326(12)	13.084(19)		[2019Gi11, 1991Va04]
¹⁹⁸ At		(3 ⁺ )	4.47(5) s	8.765(18)	5.689(10)	15.074(18)		[2019Gi11]
^{198m} At	0.265(3)	$(10^{-})$	1.25(5) s***	9.028(18)	5.954(10)	15.339(18)		[2019Gi11, 2014Ka23]
²⁰² Fr		(3 ⁺ )	372(10) ms	9.376(19)	6.602(10)	16.150(18)	obs	[2014Ka23, 2014Gh09]
^{202m} Fr	0.253(8)	$(10^{-})$	286(13) ms	9.629(21)	6.855(13)	16.403(20)	obs	[2014Ka23, 2014Gh09]
²⁰⁶ Ac		$(3^{+})$	$22^{+9}_{5}$ ms	9.920(70)	7.506(66)	17.334(67)		[1998Es02]
^{206m} Ac	0.198(30)	$(10^{-})$	$33^{+22}_{-0}$ ms	10.118(76)	7.704(72)	17.532(73)		[1998Es02]
²¹⁰ Pa		. /	$6.0^{+1.5}_{-1.1}$ ms	10.470(91)	8.221(62)	23.209(23)		[2025ZhXX]

* Weighted average of 7.69(5) h [1960Wi12] and 7.74(8) h [1960Gr15]. ** Weighted average of 2.02 d [1970Ka23] and 2.05(5) h [1960Wi14]. *** Weighted average of 1.28(10) s [2019Gh11] and 1.24(6) s [2014Ka23].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +14$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	S _{2p}	Qα	$BR_{\alpha}$	Experimental
¹⁶² Ho	5 274(3)	12 782(3)	1.005(3)		
¹⁶⁶ Tm	4.654(12)	11.484(12)	1.729(12)		
¹⁷⁰ Lu	4.220(17)	10.572(17)	2.155(20)		
¹⁷⁴ Ta	3.618(40)	9.583(28)	3.141(33)		
¹⁷⁸ Re	3.241(40)	8.866(42)	3.662(40)		
¹⁸² Ir	2.791(33)	7.792(30)	4.177(35)		
¹⁸⁶ Au	2.316(33)	6.682(35)	4.912(14)	$8(2) \times 10^{-4}\%$	[1990Ak04, 1995Bi01, 1993BiZY, 1992BiZZ]
¹⁹⁰ Tl	2.029(32)	6.573(8)	4.924(22)		
¹⁹⁴ Bi	1.083(12)	4.729(32)	5.918(5)	0.46(25)%	[1991Va04, 1988Hu03, 1985HuZY]
^{194m} Bi	0.922(14)	4.568(33)	6.079(9)	0.20(7)%	[1991Va04, 1988Hu03, 1985HuZY, 1974Le02, 1970Ta14]
¹⁹⁸ At	0.605(11)	3.278(25)	6.889(2)	>94%	[2019Gi11, 2014Ka23, 1995BiZZ, 2015We13, 2005Uu02,
					2005Uu03, 1999Ta03, 1998Bo14, 1992Hu04, 1980Ew03,
					1967Tr04, 1967Tr06
^{198m} At	0.340(11)	3.013(25)	7.154(4)	>86%	[2019Gi11, 2014Ka23, 1995BiZZ, 2005Uu02, 2005Uu03,
					1999Ta03, 1998Bo14, 1996En01, 1992Hu04, 1980Ew03,
					1967Tr04, 1967Tr06
²⁰² Fr	0.080(12)	2.489(25)	7.385(4)	97.6(2)%*	[2019Gh11, 2014Ka23, 2014Ly01, 2005Uu02, 1996En01,
					1995BiZZ, 1992Hu04, 1980Ew03, 1976HaYQ, 1976HoZD]
202m Fr	-0.173(14)	2.236(26)	7.638(9)	97.6(2)%*	[2019Gh11, 2014Ka23, 2014Ly01, 1996En01, 1995BiZZ,
200					1992Hu04]
²⁰⁶ Ac	-0.392(69)	1.700(70)	7.958(65)	$\approx 100\%^{**}$	[ <b>2014Zh03, 1998Es02</b> , 1998LuZV]
^{206m} Ac	-0.590(75)	1.502(76)	8.156(71)	$\approx 100\%^{**}$	[1998Es02]
²¹⁰ Pa	-0.66(10)#	0.988(62)	8.445(15)	100%	[2025ZhXX]

* [2019Gh11] estimate a  $\beta$ -branching ratio for a combination of the ground state and isomer of 2.4(2)%.

** Based on short half-life.

Tuble 5			
direct $\alpha$ emission from	186 Au*, $J_i^{\pi} = 3^-, T_1$	$_{/2} = 10.7(5) \text{ m}^{**},$	$BR_{\alpha} = 8(2) \times 10^{-4} \%.$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}($ ¹⁸² Ir)	coincident $\gamma$ -rays	R ₀ (fm)***	HF
4.755(15)	4.653(15)	8(2)×10 ⁻⁴ %	0+	0.0		1.519(23)***	$2.2^{+1.7}_{-1.1}$

* All values from [1990Ak04], except where noted.

** [1970Jo02].

*** Interpolated between 1.542(27) fm (¹⁸⁴Pt) and 1.480(15) fm (¹⁸⁸Hg).

### Table 4

direct $\alpha$ emission from	194Bi*, J	$\int_{\pi}^{\pi} = (3^+),$	$T_{1/2} = 95(3)$	b) s, $BR_{\alpha} =$	0.46(25)%
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}($ ¹⁹⁰ Tl $)$	coincident γ-rays	R ₀ (fm)**	HF
5.764(5)	5.645(5)	100%	4.6(25)×10 ⁻³ %	(3+)	0.1513	0.1513	1.5066(90)	$1.4^{+1.8}_{-0.6}$
5.921(5)	5.799(5)	0.59(7)%	$2.7(15) \times 10^{-3}\%$	$(2^{-})$	0.0		1.5066(90)	$1200^{+1600}_{-500}$

* All values from [1991Va04], except where noted.

** Interpolated between 1.5126(28) fm (¹⁹²Pb) and 1.5005(86) fm (¹⁹⁶Po).

#### Table 5

direct  $\alpha$  emission from ^{194m}Bi*, Ex. = 161(8) keV,  $J_i^{\pi} = (10^-)$ ,  $T_{1/2} = 114(4)$  s,  $BR_{\alpha} = 0.20(7)\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}($ ¹⁹⁰ Tl)	coincident γ-rays	R ₀ (fm)	HF
5.447(5)	5.335(5)	0.16(3)%	2.9(12)×10 ⁻⁶ %	$(11^{-})$	0.572	0.069, 0.2724	1.5066(90)	$60^{+50}_{-20}$
5.717(5)	5.599(5)	100%	$1.8(6) \times 10^{-3}\%$	(10 ⁻ )	0.300	0.069	1.5066(90)	$2.3^{+1.5}_{-0.8}$
5.779(5)	5.660(5)	2.2(2)%	$4.0(15) \times 10^{-5}\%$	(9-)	0.236		1.5066(90)	$210_{-70}^{+140}$
5.903(5)	5.781(5)	3.0(2)%	$5.5(20) \times 10^{-5}\%$	$(6^+, 7^+)$	0.1122	0.1122	1.5066(90)	$600^{+400}_{-200}$
6.016(5)	5.892(5)	3.9(2)%	$7.1(25) \times 10^{-5}\%$	7+	0.0		1.5066(90)	$1.4_{-0.5}^{+0.9} \times 10^{+3}$

* All values from [1991Va04], except where noted. ** Interpolated between 1.5126(28) fm ( 192 Pb) and 1.5005(86) fm ( 196 Po).

#### Table 6

direct  $\alpha$  emission from ¹⁹⁸At*,  $J_i^{\pi} = (3^+)$ ,  $T_{1/2} = 4.47(5)$  s,  $BR_{\alpha} = >94\%$ **.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	Edaughter( ¹⁹⁴ Bi)	coincident $\gamma$ -rays	$R_0 \left( fm \right)^@$	HF
6.404(8)	6.275(8)	0.08(1)%	>0.075%		0.486	0.103, 0.218, 0.267, 0.382, 0.486	1.511(13)	<36
6.489(8)	6.358(8)	0.11(1)%	>0.10%		0.400	0.181, 0.218, 0.400	1.511(13)	<59
6.492(9)	6.361(9)	0.008(2)%	>0.0075%		0.382	0.382	1.511(13)	<1000
6.670(8)	6.535(8)	0.020(3)%	>0.019%		0.218	0.218	1.511(13)	<1700
6.886(5)	6.747(5)***	100 %	>94%	(3 ⁺ )	0.0		1.511(13)	<2.2

* All values from [2019Gh11], except where noted.

** [1995BiZZ].

*** [2014Ka23].

[@] Interpolated between 1.5005(86) fm ( 196 Po) and 1.5205(93) fm ( 200 Rn).

#### Table 7 direct $\alpha$ emission from ^{198m}At*, Ex.=265(3) keVJ_i^{$\pi$} = (10⁻), T_{1/2} = 1.25(5) s**, BR_{$\alpha$} = >86%***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	Edaughter( ¹⁹⁴ Bi)	coincident γ-rays	$R_0 \ (fm)^{@@}$	HF
6.452(12) 6.469(8) 6.892(8) 6.990(5)	6.322(12) 6.338(8) 6.753(8) 6.849(5) [@]	0.005(3)% 0.09-0.13% 0.05-0.34% 100%	>0.0043% >0.08-0.11% >0.04-0.29% >86%	(10 ⁻ )	0.699(8) 0.686(8) 0.266(8) 0.161(8)	0.538 0.525 0.105	1.511(13) 1.511(13) 1.511(13) 1.511(13)	<340 <15-20 < 230-1700 <1.5

* All values from [2019Gh11], except where noted.

** Weighted average of 1.28(10) s [2019Gh11] and 1.24(6) s [2014Ka23].

*** [1995BiZZ].

@ [2014Ka23].

@@ Interpolated between 1.5005(86) fm (¹⁹⁶Po) and 1.5205(93) fm (²⁰⁰Rn).

#### Table 8

direct  $\alpha$  emission from ²⁰²Fr*,  $J_i^{\pi} = (3^+)$ ,  $T_{1/2} = 372(10)$  ms**,  $BR_{\alpha} = 97.6(2)\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{198}\mathrm{At})$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF
7.229(8) 7.249(8) 7.384(5)	7.086(8) 7.105(8) 7.238(5)**	0.03-0.11% 0.09(2)% 100%	0.03-0.11% 0.09(2)% 97.6(2)%	(3+)	0.154 0.130 0.0	0.154 0.130	1.523(17) 1.523(17) 1.523(17)	$\begin{array}{c} 620\text{-}2300\\ 900_{300}^{+500}\\ 2.4_{-0.7}^{+1.0}\end{array}$

* All values from [2019Gh11], except where noted.

** [2014Ka23].

*** [2019Gh11] estimate a  $\beta$ -branching ratio for a combination of the ground state and isomer of 2.4(2)%. ^(a) Interpolated between 1.5205(93) fm (²⁰⁰Rn) and 1.525(14) fm (²⁰⁴Ra).

# Table 9 direct $\alpha$ emission from ^{202m}Fr*, Ex. = 253(8) keV, $J_i^{\pi} = (10^-)$ , $T_{1/2} = 286(13)$ ms**, $BR_{\alpha} = 97.6(2)\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{198}\text{At})$	coincident $\gamma$ -rays	$R_0 \left( fm \right)^@$	HF
6.860(8)	6.724(8)	0.06(1)%	0.06(1)%	(8-)	0.792(3)	0.130, 0.151, 0.511(3), 0.527	1.523(17)	$34^{+18}_{-12}$
7.253(8)	7.109(8)	0.28-0.53%	0.27-0.52%	(8-, 9-)	0.391(3)	0.126	1.523(17)	110-220
7.311(8)	7.166(8)	0.06(1)%	0.06(1)%		0.334(7)	0.053(7), 0.130, 0.151	1.523(17)	$1.5^{+0.8}_{-0.6} \times 10^3$
7.363(8)	7.217(8)	0.23(5)%	0.22(5)%	(6 ⁻ )	0.281	0.130, 0.151	1.523(17)	$600_{-300}^{+400}$
7.372(5)	7.226(5)**	100%	97.6(2)%	(10 ⁻ )	0.265(3)		1.523(17)	$1.6^{+0.7}_{-0.5}$
7.530(26)	7.381(26)	0.014(6)%	0.014(6)%	(5 ⁺ )	0.130	0.130	1.523(17)	$3.2^{+3.0}_{-1.4} \times 10^3$
7.635(32)	7.484(32)	< 0.008	< 0.008	(3 ⁺ )	0.0		1.523(17)	$>1.5 \times 10^{5}$

* All values from [2019Gh11], except where noted.

** [2014Ka23].

*** [2019Gh11] estimate a  $\beta$ -branching ratio for a combination of the ground state and isomer of 2.4(2)%.

[@] Interpolated between 1.5205(93) fm (²⁰⁰Rn) and 1.525(14) fm (²⁰⁴Ra).

#### Table 10

direct $\alpha$ emis	direct $\alpha$ emission from ²⁰⁶ Ac*, $J_i^{\pi} = (3^+)$ , $T_{1/2} = 22^{+9}_{-5}$ ms, $BR_{\alpha} = \approx 100\%$ .										
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{202}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF				
7.958(21)	7.804(21)**	100%	(3+)	0.0		1.540(23)	$2.6^{+2.0}_{-1.5}$				

* All values from [1998Es02], except where noted.

** Weighted average of 7.817(30) MeV [2014Zh03] and 7.790(30) MeV [1998Es02].

*** Interpolated between 1.555(18) fm ( 208 Th) and 1.525(14) fm ( 204 Ra).

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{202}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF		
7.903(20)	7.750(20)	100%	(10 ⁻ )	0.253(8)		1.540(23)	$2.6^{+2.4}_{-2.0}$		
* All val ** Interp <b>Table 12</b> direct α emis	* All values from [1998Es02]. ** Interpolated between 1.555(18) fm ( ²⁰⁸ Th) and 1.525(14) fm ( ²⁰⁴ Ra). <b>Fable 12</b> firset $\alpha$ emission from ²¹⁰ Pa* T ₁ , $\alpha = 6.0^{+1.5}$ ms. $BR_{\alpha} = 100\%$								
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{202}\mathrm{Fr})$	coincident γ-rays	R ₀ (fm)***	HF		
8.445(15)	8.284(15)	100%		0.0?	_				

direct  $\alpha$  emission from ^{206m}Ac*, Ex. = 198(30) keV,  $J_i^{\pi} = (10^-)$ ,  $T_{1/2} = 33^{+22}_{-9}$  ms,  $BR_{\alpha} = \approx 100\%$ .

* All values from [2025ZhXX].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +29/2 nuclei.

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Observed and predicted $\beta$ -delayed particle emission from the even-Z, $T_z = +29/2$ nuclei. J ^{$\pi$} values for ¹⁶¹ Dy, ¹⁴ Er, ¹⁶⁹ Yb, ¹⁷³ hf, ¹⁷⁷ W, ¹⁸¹ Os, and ¹⁸⁵ Pt are tak	<i>cen</i>
from ENSDF. Unless otherwise stated, all O-values are taken from [2021Wa16] or deduced from values therein.	

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Q _ε	$Q_{\varepsilon n}$	$Q_{\mathcal{E}\alpha}$	Experimental
			1/2		~r	~~~	*
¹⁶¹ Dy		5/2+	stable				
¹⁶⁵ Er		5/2-	10.36(4) h*	0.377(1)	-5.843(1)	0.516(2)	[1963Zy01, 1963Ry01, 1963Ra15]
¹⁶⁹ Yb		7/2+	32.1047(93) d	0.899(0.8)	-4.675(0)	2.098(1)	[2002Un02]
¹⁷³ Hf		$1/2^{-}$	23.6(1) h	1.469(28)	-3.445(28)	3.438(28)	[1951Wi08]
177 W		$1/2^{-}$	133(3) m**	2.013(28)	-2.414(28)	4.754(28)	[1963Sa14, 1950Wi67]
¹⁸¹ Os		1/2-	105(3) m	2.967(28)	-1.203(25)	5.740(26)	[1966Ho16]
¹⁸⁵ Pt		9/2+	70.9(24) m	3.650(40)	0.275(26)	7.404(29)	[1970FiZZ]
¹⁸⁹ Hg		3/2-	7.9(2) m***	3.960(40)	0.906(32)	8.284(42)	[1975Be17, 1970ErZX, 1950Wi67]
¹⁹³ Pb		$(3/2^{-})$	. /	5.248(12)	2.493(19)	8.928(23)	
¹⁹⁷ Po		(3/2-)	53(1) s	6.294(13)	4.666(13)	11.659(12)	[1993Wa04]
^{197m} Po	0.199(11)	$(13/2^+)$	25.8(1) s	6.493(17)	4.865(17)	11.858(16)	[2017Al34, 1993Wa04]
²⁰¹ Rn		(3/2-)	7.0(4) s	6.682(13)	5.545(13)	13.155(13)	[1971Ho01]
^{201m} Rn	0.248(12)	13/2(+)	3.8(4) s	6.930(18)	5.793(18)	13.403(18)	[2017Al34, 1971Ho01]
²⁰⁵ Ra		$(3/2^{-})$	$210^{+41}_{-26} \text{ ms}^{@}$	7.114(24)	6.485(24)	14.168(24)	[1996Le09, 1995Le15]
^{205m} Ra	0.278(31)	$13/2^{(+)}$	$182^{+\frac{58}{24}}$ ms ^{@@}	7.392(39)	6.763(39)	14.446(39)	[2017Al34, 1996Le09, 1995Le15]
²⁰⁹ Th	x	$(3/2^{-})$	-24	7.55(12)#	7.38(10)#	15.28(10)#	
^{209m} Th	х	(13/2+)	$2.5^{+1.7}_{-0.7}$ ms	7.55(12)#+x	7.38(10)#+x	15.28(10)#+x	[2010He25]

* Weighted average of 10.39(7) h [1963Zy01], 10.34(5) h [1963Ry01] and 10.4(1) h [1963Ra15].

** Weighted average of 10.5(7) m [19052;01], 10.54(9) m [1905K901] and 10.4(1) m [1905K415]. ** Weighted average of 135(3) m [1905Be17], 7.7(2) m [1970ErZX] and 130(3) m [1950Wi67]. [@] Weighted average of 210⁺⁶⁰₋₄₀ ms [1996Le09] and 210⁺⁵⁵₋₃₅ ms [1995Le15]. [@] Weighted average of 170⁺⁶⁰₋₄₀ ms [1996Le09] and 190⁺⁵⁰₋₃₀ ms [1995Le15].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +29/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
1(1					
¹⁶¹ Dy	7.508(1)	14.072(1)	0.343(1)		
¹⁶⁵ Er	6.830(1)	12.718(1)	1.109(1)		
¹⁶⁹ Yb	6.352(2)	11.664(1)	1.721(1)		
¹⁷³ Hf	5.965(28)	10.683(28)	2.539(28)		
$^{177}W$	5.625(42)	9.798(28)	3.285(40)		
¹⁸¹ Os	5.002(33)	8.833(29)	3.727(38)		
¹⁸⁵ Pt	4.366(38)	7.602(56)	4.437(10)		
¹⁸⁹ Hg	4.544(32)	7.519(40)	4.637(41)	${<}3 imes10^{-7}\%$	[1963Ka17]
¹⁹³ Pb	3.646(33)	6.215(25)	4.972(33)		
¹⁹⁷ Po	2.673(26)	4.233(11)	6.411(3)	71(3)%*	[1996Ta18, 1993Wa04, 1981Sc01, 1987Wo04, 1971Ho01,
					1970HoZT, 1967Le21, 1967Si09, 1965Br17, 1965Si22]
^{197m} Po	2.474(28)	4.034(16)	6.610(11)	56(2)%**	[2002Va13, 1996Ta18, 1993Wa04, 1981Sc01, 1987Wo04,
					1973BoXL, 1971Ho01, 1970HoZT, 1967Le21, 1967Si09,
					1965Br17, 1965Si22]
²⁰¹ Rn	2.408(26)	3.447(11)	6.861(2)	pprox 80~%	[1996Ta18, 1993Wa04, 1971Ho01, 1987He10, 1967Va17
					1965Nu04]
201mRn	2.160(29)	3.199(16)	7.109(12)	pprox 90~%	[1996Ta18, 1993Wa04, 1971Ho01, 1987He10, 1967Va17
					1965Nu04]
²⁰⁵ Ra	2.092(34)	2.590(24)	7.486(20)	$\approx 100\%^{***}$	[1996Le09, 1995Le04, 1995Le15, 1987He10]
^{205m} Ra	1.814(46)	2.312(39)	7.764(37)	$\approx 100\%^{***}$	[1996Le09, 1995Le15]
²⁰⁹ Th	1.66(12)	1.70(12)	8.17(11)		
^{209m} Th	1.66(12)-x	1.70(12)-x	8.17(11)+x	100%	[2010He25, 1996Ik01, 1996IkZY]

* Weighted average of 76(3)% [1993Wa04] and 44(7)% [1981Sc01].

** Weighted average of 55(2)% [1993Wa04] and 84(9)% [1981Sc01].

*** Based on short half-life.
$\frac{\text{direct } \alpha \text{ emi}}{\alpha \text{ emi}}$	ssion from ¹⁹⁷ Po, $J_i^7$	$T = (3^{-}), T_{1/2} = 5$	$3(1) s^*, BR_{\alpha} =$	= 71(3)%**.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{193}\mathrm{Pb}$	) coincident	t γ-rays	$R_0 (fm)^@$	HF	
6.411(2)	6.281(2)***	71(3)%**	(3 ⁻ )	0.0			1.5044(24	4) 1.19(8	)
* [1993 ** Weig *** [19	Wa04]. ghted average of 76( 96Ta18].	3)% [1993Wa04]	and 44(7)% [1	1981Sc01].					
Table 4 direct $\alpha$ emi	ssion from ^{197m} Po, 1	Ex. = 199(11) keV	$V^*, \mathbf{J}_i^{\pi} = (13/2^+)$	⁺ ), $T_{1/2} = 25.8(1)$ s	$***, BR_{\alpha} = 56(2)\%$	***.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{193}\text{Pb})$	coinciden	t γ-rays	$R_0 (fm)^@$	HF
5.739(25) 6.512(1)	5.622(25) ^{@@} 6.380(1) [@]	≥0.05(3)% 100%	≥0.03(2)% 56(2)%	(13/2 ⁺ ) (13/2 ⁺ )	0.757(1) 0.0	0.757(1)		1.5044(24) 1.5044(24)	$1.9^{+2.9}_{-0.7}$ $1.86(12)$
* [2017 ** [199 *** We [@] [1996 [@] @ [20	A134]. 3Wa04]. ighted average of 55 5Ta18]. 02Va13].	5(2)% [1993Wa04	] and 84(9)% [	[1981Sc01].					
<b>Table 5</b> direct $\alpha$ emi	ssion from 201 Rn, J ² ₁	$\pi = (3^{-}), T_{1/2} = 7$	$T.0(4)$ s*, $BR_{\alpha}$	$= \approx 80 \%^*.$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{197}\text{Po})$	coincident	γ-rays	$R_0 (fm)^@$	HF	
6.861(2)	6.724(2)**	$\approx 80~\%^*$	(3-)	0.0			1.5156(71	1) ≈ 1.6	
* [1971 ** Weig	Ho01]. ghted average of 6.7	25(2) MeV [1996	Ta18] and 6.72	237(25) MeV [1993	3Wa04].				
<b>Table 6</b> direct $\alpha$ emi	ssion from ^{201m} Rn,	$Ex. = 248(12) \text{ ke}^{3}$	$V^*, J_i^{\pi} = 13/2^{(-1)}$	⁺⁾ , $T_{1/2} = 3.8(4) s^*$	**, $BR_{\alpha} = \approx 90 \%$ *	*.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{197})$	Po) coincide	ent γ-rays	$R_0$ (fm)	@ HF	
6.910(2)	6.733(2)***	$pprox 90~\%^{**}$	13/2 ⁽⁺⁾	0.199(11)			1.5156(7	71) ≈ 1.1	.6
* [2017 ** [197 *** We	A134]. 1Ho01]. ighted average of 6.	773(2) MeV [199	6Ta18] and 6.7	7721(25) MeV [199	93Wa04].				
Table 7 direct α emi	ssion from ²⁰⁵ Ra, $J_i^2$	$\tau = (3^-), T_{1/2} = 2$	$10^{+41}_{-26}$ ms*, <i>BF</i>	$R_{\alpha} = \approx 100 \%.$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	<i>E</i> _{daughter} ( ²⁰¹ Rn)	coincident	γ-rays	R ₀ (fm) [@]	HF	
7.498(8)	7.352(8)**	pprox 100~%	(3 ⁻ )	0.0			1.5269(91)	) $1.5^{+0.5}_{-0.3}$	

* Weighted average of  $210^{+60}_{-40}$  ms [1996Le09] and  $210^{+55}_{-35}$  ms [1995Le15]. ** Weighted average of 7.340(20) MeV [1996Le09], 7.350(25) MeV [1995Le15], and 7.340(20) MeV [1995Le04]. In addition [1987He10] report one peak from  205 Ra at 7.360(20) MeV which may an unresolved combination of the two isomers.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^{\pi}$	$E_{daughter}(^{201}\mathrm{Rn})$	coincident $\gamma$ -rays	$R_0 \; (fm)^@$	HF
7.519(16)	7.372(16)**	$\approx 100~\%$	13/2 ⁽⁺⁾	0.248(12)		1.5269(91)	$1.5_{-0.4}^{+0.5}$
* Weight ** Weigl	ted average of $210^{+60}_{-44}$ and average of 7.370	) ms [1996Le09 (20) MeV [1996	] and 210 ⁺⁵⁵ m 6Le09], and 7.3	s [1995Le15]. 75(25) MeV [1995Le15	].		
<b>Table 9</b> direct $\alpha$ emis	sion from ^{209m} Th*, E	Ex. = unk, $J_i^{\pi} = ($	$(13/2^+), T_{1/2} = 1$	$2.5^{+1.7}_{-0.7} \text{ ms}^{**}, BR_{\alpha} = 10$	0 %.		
Table 9direct $\alpha$ emis $E_{\alpha}(c.m.)$	sion from 209m Th*, F $E_{\alpha}$ (lab)	Ex. = unk, $J_i^{\pi} = (I_{\alpha}(abs))$	$(13/2^+), T_{1/2} = J_f^{\pi}$	$2.5^{+1.7}_{-0.7} \text{ ms}^{**}, BR_{\alpha} = 10$ $E_{daughter}(^{205}\text{Ra})$	0 %. coincident γ-rays	$R_0 (fm)^@$	HF

** Weighted average of 8.123(25) MeV [2010He25], and 8.080(50) MeV [1996Ik01].

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dire	et $\alpha$ emission from ²⁰	05m Ra, Ex. = 278(31) ke	eV, $J_i^{\pi} = 13/2^{(+)}$ , $T_{1/2} =$	$= 182^{+38}_{-24} \text{ ms*}, BR_{\alpha}$	$= \approx 100 \%.$

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +29/2 nuclei.

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Observed and predicted $\beta$ -delayed particle	emission from the odd-2	Z, $T_z = +29/2$ nuclei.	$J^{\pi}$ values for ¹⁶³ Ho	¹⁶⁷ Tm, ¹⁷¹	¹ Lu, ¹⁷⁵ Ta, ¹⁷	⁷⁹ Re, ¹⁸³ Ir, a	nd ¹⁹¹ Tl are taken
from ENSDF. Unless otherwise stated, all (	O-values are taken from	[2021Wa16] or dedu	ced from values the	rein.			

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
162							
¹⁰⁵ Ho		7/2-	4570(50) y	0.003	-7.787(2)	-0.241(1)	[1983Ba32]
¹⁶⁷ Tm		$1/2^{+}$	9.25(2) d	0.746(1)	-6.762(1)	1.413(1)	[1970Ka23]
¹⁷¹ Lu		7/2+	8.22(3) d	1.478(2)	-5.322(2)	3.036(2)	[1970Ka23]
¹⁷⁵ Ta		7/2+	10.5(2) h	2.073(28)	-4.127(28)	4.473(28)	[1963Sa14]
¹⁷⁹ Re		$5/2^{+}$	19.5(1) m	2.711(27)	-3.275(58)#	5.473(25)	[1975Me20]
¹⁸³ Ir		5/2-	55(7) m	3.460(50)	-2.05(11)	6.668(29)	[1961Di04]
¹⁸⁷ Au		$1/2^{+}$	8.3(3) m*	3.657(27)	-1.145(28)	8.210(55)	[1983Ga01, 1979Be51]
¹⁹¹ Tl		$(1/2^+)$		4.309(23)	-0.738(8)	7.977(25)	
¹⁹⁵ Bi		$(9/2^{-})$	187(5) s	5.712(7)	1.623(15)	10.141(23)	[1985Co06]
^{195m} Bi	0.401(7)	$(1/2^+)$	87(1) s	6.113(10)	2.024(17)	10.542(24)	[1985Co06]
¹⁹⁹ At		(9/2-)	6.92(13) s	6.415(8)	3.262(28)	12.490(7)	[2013Ja06]
^{199m} At	$\approx 0.240$	$(1/2^+)$	0.31(8) s	≈6.655(8)	≈3.502(28)	≈12.710(7)	[2013Ja06]
²⁰³ Fr		$(9/2^{-})$	550(7) ms**	7.060(9)	4.183(28)	13.690(8)	[2013Ja06, 2005De01, 2005Uu02, 1980Ew03]
^{203m} Fr	$\approx 0.360$	$(1/2^+)$	43(4) ms	$\approx 7.420(9)$	≈4.543(28)	$\approx 14.050(8)$	[2013Ja06]
²⁰⁷ Ac		$(9/2^{-})$	$27^{+11}_{-6}$ ms	7.630(80)	5.104(63)	14.905(57)	[1998Es02]
²¹¹ Pa		(9/2-)	$3.8^{+4.6}_{-1.4}$ ms	8.18(11)	5.999(93)	16.113(91)	[2020Au04]

* Weighted average of 8.4(3) m [1983Ga01] and 8.0(4) m [1979Be51].

** Weighted average of 550(10) ms [2013Ja06], 560(15) ms [2005De01], 530(20) ms [2005Uu02], and 550(20) ms [1980Ew03].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +29/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
163110	5 196	12 404(1)	0.720(1)		
167m	3.480	13.494(1)	0.730(1)		
107 I m	4.908(1)	12.223(1)	1.410(1)		
^{1/1} Lu	4.354(2)	11.132(2)	2.290(2)		
¹⁷⁵ Ta	3.853(28)	10.106(28)	2.995(28)		
¹⁷⁹ Re	3.466(29)	9.448(25)	3.399(37)		
¹⁸³ Ir	2.882(33)	8.263(28)	3.957(35)		
¹⁸⁷ Au	2.453(31)	7.271(36)	4.748(30)	$pprox 2  imes 10^{-3}\% *$	[1968Si01]
¹⁹¹ Tl	2.201(18)	7.279(21)	4.321(24)		
¹⁹⁵ Bi	1.107(18)	5.126(9)	5.832(5)	0.01 - 0.05%	[1985Co06, 1993An19, 1990AnZR, 1989AnZF, 1978Va21,
					1974Le02, 1973LiYK, 1972Ga27, 1970Ta14, 1967Es05]
^{195m} Bi	0.706(19)	4.725(11)	6.233(9)	16 - 49%	[1985Co06, 1993An19, 1978Va21, 1974Le02, 1973LiYK,
					1972Ga27, 1970Ta14, 1967Es05]
199At	0.639(18)	3.714(10)	6.830(1)***	$92^{+3}$ %	[2013,Ja06, 1996Ta18, 1980Ew03, 2015We13, 2015We16,
				-0	1986Wo03, 1975BaYJ, 1967Tr04, 1967Tr06]
^{199m} At	$\approx 0.399(18)$	$\approx 3.474(10)$	$\approx 7.017(1)$	$\approx 1\%$	[2013Ja06]
²⁰³ Fr	0.138(19)	2.912(10)	7.275(4)	$\approx 100\% **$	[2013Ja06, 2005De01, 2005Uu02, 1980Ew03, 1967Va20
					2015We13, 2004DeZV, 1994Le051
^{203m} Fr	$\approx -0.222(19)$	$\approx 2.552(10)$	$\approx 7.635(4)$	20(4) %	[ <b>2013.Ja06</b> , 2005Uu02]
²⁰⁷ Ac	-0.292(59)#	2.122(57)#	7.855(18)@	$\approx 100\%$	[ <b>1998Es02, 1994Le05</b> 1998LuZV]
211 pa	-0.704(72)	1 371(80)	8 481(41)	100 %	$[2020A_004, 2006K_007]$
1 a	-0.70+(72)	1.571(09)	0.401(41)	100 /0	[2020Au04, 2000Au07]

* Value estimated by setting HF = 1 (see table 3).

** Based on short half-life.

*** Deduced from  $\alpha$  energy, 6.777(1) in [2021Wa16].

[@] Deduced from  $\alpha$  energy, 7.845(56)# in [2021Wa16].

## Table 3

direct $\alpha$ emission from ¹⁸⁷ Au*, $J_i^{\pi} = 1/2^+$ , $T_{1/2} = 8.3(3)s^{**}$ , $BR_{\alpha} = \approx 2 \times 10^{-3}\%^{***}$ .								
				100				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{183}\mathrm{Ir})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF	

4.793(20) 4.690(20)  $\approx 2 \times 10^{-3} \%^{***}$  (1/2⁺)

* All values from [1968Si08], except where noted.

** weighted average of 8.4(3) m [1983Ga01] and 8.0(4) m [1979Be51].

*** Value estimated by setting HF =1.

Table 4				
direct $\alpha$ emission from	195 Bi*, $J_{i}^{\pi} = (9/2^{-1})^{-1}$	), $T_{1/2} = 187(5)$ s,	$BR_{\alpha} = 0.01$ -	0.05%

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{191}\text{Tl})$	coincident	γ-rays	R ₀ (fm)	HF
5.534(5) 5.833(5)	5.420(5) 5.713(5)	100% 10(1)%	$\begin{array}{c} 0.9 \text{ - } 4.5 \times 10^{-4} \% \\ 0.9 \text{ - } 4.5 \times 10^{-5} \% \end{array}$	(9/2 ⁻ ) (1/2 ⁺ )	0.299 0.0			1.475(14) 1.475(14)	1.0 - 5.2 290 - 1400
* All val	ues from [19850	Co06].							
Table 5 direct $\alpha$ emis	sion from ^{195m} E	3i*, Ex. = 401	(7) keV, $\mathbf{J}_i^{\pi} = (1/2^+)$ ,	$T_{1/2} = 87(1) s,$	$BR_{\alpha} = 16 - 49\%.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{191}\text{Tl})$	coincident	tγ-rays	R ₀ (fm)	HF
5.893(5) 6.234(5)	5.772(5) 6.106(5)	0.16(2)% 100%	0.036 - 0.078 % 16 -49 %	(9/2 ⁻ ) (1/2 ⁺ )	0.341 0.0	0.341		1.475(14) 1.475(14)	15 - 45 0.73 - 2.2
* All val	ues from [19850	Co06].							
Table 6 direct $\alpha$ emis	ssion from ¹⁹⁹ At	$J_i^{\pi} = (9/2^-),$	$T_{1/2} = 6.92(13) s^*, t$	$BR_{\alpha} = 92^{+3}_{-8}\%^{**}$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(ab)$	$J_f^{\pi}$	$E_{daughter}(^{1}$	¹⁹⁵ Bi) coind	cident γ-rays	R ₀ (fm	) H	IF
6.830(1)	6.693(1)***	$92^{+3}_{-8}$	%** (9/2 ⁻ )	0.0			1.5084	(56) 2	.2(3)
* [2013J ** [1980 *** [199	a06]. DEw03]. D6Ta18].								
Table 7 direct $\alpha$ emis	sion from ^{199m} A	$At^*, Ex. = \approx 2$	240 keV, $J_i^{\pi} = (1/2^+)$ ,	$T_{1/2} = 0.31(8)$ s	$s, BR_{\alpha} = \approx 1\%.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\rm J}_f^\pi$	$E_{daughter}(^{195}\mathrm{B}$	i) coincide	ent γ-rays	R ₀ (fm)	HF	
≈ 6.613	pprox 6.480	pprox 1%	(1/2+)	0.401(7)			1.5084(5	6) ≈ 1	1.6
* All val	ues from [2013]	Ja06].							
Table 8 direct $\alpha$ emis	sion from ²⁰³ Fr.	$J_i^{\pi} = (9/2^-),$	$T_{1/2} = 550(7) \text{ ms*}, I$	$BR_{\alpha} = \approx 100 \%.$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}$ (abs	s) $J_f^{\pi}$	$E_{daughter}(^{199}$	At) coincid	dent γ-rays	R ₀ (fm)	HF	1
7.274(3)	7.133(3)**	$\approx 100$	% (9/2 ⁻ )	0.0			1.5178(9	95) 1.3	+0.3 -0.2
* Weighted average of 550(10) ms [2013Ja06], 560(15) ms [2005De01], 530(20) ms [2005Uu02], and 550(20) ms [1980Ew03]. ** Weighted average of 7.130(6) MeV [2013Ja06], 7.132(5) MeV [2005De01], 7.130(6) MeV [2005Uu02], and 7.130(5) MeV [1967Va20].									
** Weig	hted average of	7.130(6) MeV	/ [2013Ja06], 7.132(5	5) MeV [2005De	e01], 7.130(6) MeV	/ [2005Uu02], a	and 7.130(5)	) MeV [1967\	/a20].
** Weig <b>Table 9</b> direct $\alpha$ emis	hted average of ssion from $203m$ F	7.130(6) MeV $Fr^*, Ex. = \approx 3$	7 [2013Ja06], 7.132(2) 360 keV, $J_i^{\pi} = (1/2^+),$	5) MeV [2005De $T_{1/2} = 43(4) \text{ ms}$	e01], 7.130(6) MeV s, $BR_{\alpha} = 20(4)$ %.	/ [2005Uu02], a	and 7.130(5)	) MeV [1967\	/a20].

* All values from [2013Ja06].

7.246(5)

 $20(4) \% (1/2^+) \approx 0.240$ 

7.395(5)

 $1.3\substack{+0.6\\-0.4}$ 

1.5178(95)

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{203}\mathrm{Fr})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
7.855(18)	7.703(18)**	pprox 100%	(9/2-)	0.0	_	1.542(11)	$1.7\substack{+0.8 \\ -0.6}$
* [1998E ** Weigl <b>Table 11</b> direct α emis	5802]. hted average of 7.69 sion from ²¹¹ Pa*, J	P3(25) MeV [19 $\int_{1}^{\pi} = (9/2^{-}), T_{1/2}$	98Es02] and 7 = $3.8^{+4.6}_{-1.4}$ ms,	.712(25) meV [1994Le0 $BR_{\alpha} = 100 \%.$	5].		
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{207}\mathrm{Ac})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
8.481(40)	8.320(40)	100%	(9/2-)	0.0		1.508(27)	$1.7^{+2.3}_{-1.2}$

direct  $\alpha$  emission from ²⁰⁷Ac,  $J_i^{\pi} = (9/2^-)$ ,  $T_{1/2} = 27^{+11}_{-6}$  ms*,  $BR_{\alpha} = \approx 100$  %.

* All values from [2020Au04].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +15 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +15$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
162 D	0+	. 11	2 202(2)			
¹⁰² Dy	0	stable	-2.302(2)			
¹⁶⁶ Er	$0^+$	stable	-1.853(1)			
¹⁷⁰ Yb	$0^+$	stable	-0.969(1)			
¹⁷⁴ Hf	$0^+$	$2.0(4) \times 10^{15} \text{ y}$	-0.274(2)			[1961Ma05]
$^{178}W$	$0^+$	21.7(4) d*	0.190(50)#	-4.815(15)	2.738(15)#	[1964Sa16, 1963Ra14]
¹⁸² Os	$0^+$	21.9(1) h	0.840(100)	-3.664(22)	3.565(57)	[1958Fo47]
¹⁸⁶ Pt	$0^+$	2.10(5) h	1.308(27)	-2.348(22)	5.157(104)	[1991Be25]
¹⁹⁰ Hg	$0^+$	19.9(4) m**	1.463(16)	-2.190(19)	5.377(23)	[1964Ja05, 1961An02]
¹⁹⁴ Pb	$0^+$	12.0(5) m	2.730(22)	-0.435(23)	6.201(18)	[1987El09]
¹⁹⁸ Po	$0^+$	107(2) s***	3.900(30)	1.983(18)	9.039(22)	[1994Wa13, 1971Ho01, 1967Si09
²⁰² Rn	$0^+$	9.7(2) s [@]	4.320(30)	2.958(18)	10.674(33)	[1992Wa29, 1971Ho01]
²⁰⁶ Ra	$0^+$	244(13) ms ^{@@}	4.810(30)	3.986(19)	11.736(33)	[2021Ni08, 1987He10]
²¹⁰ Th	$0^+$	15.1(27) ms ^{@@@}	5.300(70)	4.912(20)	12.881(34)	[2023Ch23, 2010He25]
²¹⁴ U	$0^+$	$520^{+950}_{-210}\ \mu s$	5.721(84) ^a	5.772(28) ^a	13.996(65) ^a	[2021Zh22]

* Weighted average of 21.4(5) d [1964Sa16] and 22.0(5) d [1963Ra14].

** Weighted average of 20.0(5) m [1964Ja05] and 19.8(6) m [1961An02].

*** Weighted average of 105(3) s [1994Wa13], 107(3) s [1971Ho01] and 1.80(5) s [1967Si09].

[@] Weighted average of 9.5(2) s [1992Wa29], and 9.7(2) s [1971Ho01].

^(a) Weighted average of 248(18) ms [2021Ni08], and 240(20) ms [1987He10]. ^(a) 

 $^{\it a}$  From Q  $_{\alpha}$  of  $^{214}U$  and daughter values from [2021Wa16].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +15$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	BR _α	Experimental
¹⁶² Dv	8 008(1)	14 817(1)	0.084(1)		
166 Fr	7.315(1)	13.534(1)	0.004(1) 0.832(1)		
¹⁷⁰ Yh	6.778(1)	12 353	1.735(0)		
¹⁷⁴ Hf	6.253(2)	11.167(2)	2.494(2)	100%	[ <b>1961Ma05, 2020Ca15</b> , 2025BeXX, 2021Br09, 1960Ma29, 1959Ri34]
¹⁷⁸ W	5.981(15)	10.409(15)#	3.013(15)	10070	
¹⁸² Os	5.381(25)	9.551(22)	3.373(27)		
¹⁸⁶ Pt	4.818(35)	8.190(22)	4.320(18)	$pprox 1.4  imes 10^{-4}\%$	[1963Gr08]
¹⁹⁰ Hg	5.078(26)	8.128(17)	4.069(27)	$< 3.4  imes 10^{-7}\%$	
¹⁹⁴ Pb	4.020(19)	6.774(23)	4.738(17)	$7.3(29)  imes 10^{-6}\%$	[1987El09]
¹⁹⁸ Po	3.075(19)	4.703(19)	6.310(1)	58(2)%*	[1998Bo14, 1996Ta18, 1994Wa03, 1993Wa04, 1971Ho01,
					1967Si09, 2022We04, 2015We13, 2015We16, 2014Ma66,
					1993WaZO, 1989De18, 1984Da14, 1982Bo04, 1967Le21,
					1967Tr04, 1967Tr06, 1965Br17, 1965Si22, 1964Br23]
²⁰² Rn	2.774(19)	3.911(19)	6.774(2)	78(8)%	[2000Va34, 1992Wa29, 1987He10, 2015We16, 1996Ta18,
					1993Wa04, 1992WaZV, 1991Wa29, 1971Ho01, 1969Ha03,
					1967Va07, 1967Va17, 1965Nu04]
²⁰⁶ Ra	2.414(20)	3.042(19)	7.415(4)	$\approx 100\%^{**}$	[1996Le09, 1987He10, 1967Va22, 2021Ni08, 2021NiZW,
					1995Le41, 1968Lo15]
²¹⁰ Th	2.074(59)	2.246(21)	8.069(6)	$pprox 100\%^{**}$	[2023Ch23, 2010He25, 1995Le15, 1995Le41, 1995Uu01]
²¹⁴ U	1.758(65)***	1.508(28)***	8.696(18)***	100 %	[2021Zh22]

* Weighted average of 59(3)% [1998Bo04] and 57(2)% [1994Wa13, 1993Wa04].

** Based on short half-life.

*** From  $Q_{\alpha}$  of ²¹⁴U and daughter values from [2021Wa16].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$ E	Edaughter ( ¹⁷⁰ Yb)	coincident $\gamma$ -rays	$R_0$ (fm)	HF	
559(30)	2.500(30)	100 %	0+ 0	0.0		1.4833(91)	0.23(5)**	
* All val ** This u	ues from [1961M unphysically low	/la05]. value may indicate t	hat the actual	half-life is longer that	an reported in [1961Ma(	05]. Using a value of 9	$9 \times 10^{15}$ y gives	a HF = 1
able 4 irect $\alpha$ emis	sion from ¹⁸⁶ Pt*	$J_i^{\pi} = 0^+, T_{1/2} = 2.10$	$0(5) h^{**}, BR_{c}$	$\alpha = \approx 1.4 \times 10^{-4}\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{182}\mathrm{O}$	s) coincident $\gamma$ -r	ays $R_0$ (fm)	HF	
.323(20)	4.230(20)	$pprox 1.4  imes 10^{-4}\%$	6 0+	0.0		1.536(30)	$\approx 1.3$	
* All val ** [1991	ues from [1963C Be25].	Gr08], except where n	oted.					
Table 5 irect $\alpha$ emis	sion from ¹⁹⁴ Pb	*, $J_i^{\pi} = 0^+$ , $T_{1/2} = 12$ .	$.0(5)$ m, $BR_{\alpha}$	$= 7.3(29) \times 10^{-6}\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{190}\mathrm{H}$	(g) coincident $\gamma$ -r	ays R ₀ (fm)	HF	
.738(20)	4.640(20)	$7.3(29)  imes 10^{-6}$	% 0+	0.0		1.437(24)	$1.1\substack{+0.8 \\ -0.4}$	
* All val	ues from [1987F	21001						
		209].						
<b>Table 6</b> lirect $\alpha$ emis	ssion from ¹⁹⁸ Po,	$J_i^{\pi} = 0^+, T_{1/2} = 1076$	(2) s*, $BR_{\alpha}$ =	58(2)%**.				
<b>Table 6</b> irect $\alpha$ emis $C_{\alpha}(c.m.)$	sion from ¹⁹⁸ Po, $E_{\alpha}(\text{lab})$	$J_i^{\pi} = 0^+, T_{1/2} = 1070$ $I_{\alpha}(abs)$	$(2) s^*, BR_{\alpha} = J_f^{\pi}$	58(2)%**. <i>E_{daughter}</i> ( ¹⁹⁴ Pb)	coincident γ-rays	R ₀ (fm)	HF	
<b>Table 6</b> irrect $\alpha$ emis $Z_{\alpha}(c.m.)$ .309(1)	sion from ¹⁹⁸ Po, $E_{\alpha}(lab)$ 6.182(1)	$J_i^{\pi} = 0^+, T_{1/2} = 1070$ $I_{\alpha}(abs)$ $58(2)\%^{**}$	$(2) s^*, BR_{\alpha} = \frac{J_f^{\pi}}{0^+}$	58(2)%**. <i>E_{daughter}</i> ( ¹⁹⁴ Pb) 0.0	coincident γ-rays	R ₀ (fm) 1.4962(19)	HF 0.99(4)	
Fable 6         lirect $\alpha$ emis $\overline{E}_{\alpha}(c.m.)$ 5.309(1)         * Weight         * Weight	$E_{\alpha}(\text{lab})$ 6.182(1) ted average of 10 hted average of 5	$J_i^{\pi} = 0^+, T_{1/2} = 1076$ $I_{\alpha}(abs)$ $58(2)\%^{**}$ $05(3) \le [1994Wa13], 1$ $59(3)\% [1998Bo04] a$	$\frac{(2) \text{ s*, } BR_{\alpha}}{J_{f}^{\pi}}$ $0^{+}$ $107(3) \text{ s [197]}$ $107(2)\% [1]$	58(2)%**. <i>E_{daughter}</i> ( ¹⁹⁴ Pb) 0.0 1Ho01] and 1.80(5) s 994Wa13, 1993Wa04	coincident γ-rays  [1967Si09]. 4].	R ₀ (fm) 1.4962(19)	HF 0.99(4)	
<b>Fable 6</b> lirect $\alpha$ emis $\mathcal{E}_{\alpha}(c.m.)$ 5.309(1)         * Weight         * Weight         * Weight         Table 7         lirect $\alpha$ emis	sion from ¹⁹⁸ Po, $E_{\alpha}(\text{lab})$ 6.182(1) ted average of 10 hted average of 5 sion from ²⁰² Rn.	$J_i^{\pi} = 0^+, T_{1/2} = 1076$ $I_{\alpha} (abs)$ $58(2)\%^{**}$ $05(3) \text{ s } [1994\text{Wa}13], 13$ $9(3)\% [1998Bo04] \text{ a}$ $J_i^{\pi} = 0^+, T_{1/2} = 9.76$	$\frac{(2) \text{ s*, } BR_{\alpha}}{J_{f}^{\pi}}$ 0 ⁺ 107(3) s [197 nd 57(2)% [1 (2) s*, BR_{\alpha} =	<ul> <li>58(2)%**.</li> <li><i>E</i>_{daughter}(¹⁹⁴Pb)</li> <li>0.0</li> <li>1Ho01] and 1.80(5) s</li> <li>994Wa13, 1993Wa04</li> <li>78(8)%**.</li> </ul>	coincident γ-rays  [1967Si09]. 4].	R ₀ (fm) 1.4962(19)	HF 0.99(4)	
Fable 6         lirect $\alpha$ emis $\overline{z}_{\alpha}(c.m.)$ 5.309(1)         * Weight         ** Weight         fable 7         lirect $\alpha$ emis $\overline{z}_{\alpha}(c.m.)$	$\frac{E_{\alpha}(\text{lab})}{6.182(1)}$ ted average of 10 hted average of 5 sion from ²⁰² Rn. $E_{\alpha}(\text{lab})$	$J_{i}^{\pi} = 0^{+}, T_{1/2} = 1076$ $I_{\alpha}(abs)$ $58(2)\%^{**}$ $05(3) \le [1994Wa13], 1$ $59(3)\% [1998Bo04] = 0^{+}, T_{1/2} = 9.76$ $I_{\alpha}(rel)$	$\frac{(2) \text{ s*, } BR_{\alpha}}{J_{f}^{\pi}}$ $0^{+}$ $107(3) \text{ s [197]}$ $107(2)\% [1$ $(2) \text{ s*, } BR_{\alpha} = I_{\alpha}(\text{abs})$	$\frac{E_{daughter}(^{194}\text{Pb})}{0.0}$ 0.0 1Ho01] and 1.80(5) s 994Wa13, 1993Wa04 78(8)%**.	coincident γ-rays  [1967Si09]. 4]. <i>E</i> _{daughter} ( ¹⁹⁸ Po)	R ₀ (fm) 1.4962(19) coincident γ-rays	HF 0.99(4) R ₀ (fm)	HF
Fable 6lirect $\alpha$ emis $\Xi_{\alpha}(c.m.)$ 5.309(1)* Weight* Weight* WeightFable 7lirect $\alpha$ emis $\Xi_{\alpha}(c.m.)$ 5.954(5)5.775(1)	$E_{\alpha}(\text{lab})$ $E_{\alpha}(\text{lab})$ $6.182(1)$ $6.182(1)$ $E_{\alpha}(\text{lab})$ $E_{\alpha}(\text{lab})$ $E_{\alpha}(\text{lab})$ $5.836(5)^{***}$ $6.641(1)^{@}$	$J_{i}^{\pi} = 0^{+}, T_{1/2} = 1076$ $I_{\alpha} (abs)$ $58(2)\%^{**}$ $J_{5}(3) \le [1994Wa13], 1$ $J_{9}(3)\% [1998Bo04] = 0^{+}, T_{1/2} = 9.76$ $I_{\alpha} (rel)$ $1.8(6) \times 10^{-3}\%^{**}$ $100\%$	$\frac{(2) \text{ s*, } BR_{\alpha}}{J_{f}^{\pi}}$ $0^{+}$ $107(3) \text{ s [197]}$ $(2) \text{ s*, } BR_{\alpha} =$ $I_{\alpha}(\text{abs})$ $(3) \text{ stars}^{(2)} = 1.4(5)$ $78(8) \text{ stars}^{(3)}$	$\frac{E_{daughter}(^{194}\text{Pb})}{0.0}$ 0.0 1Ho01] and 1.80(5) s 994Wa13, 1993Wa04 78(8)%**. (i) J_{f}^{\pi} $\times 10^{-3}\%  0^{+}$ $\%^{**} \qquad 0^{+}$	coincident γ-rays  [1967Si09]. 4]. <i>E</i> _{daughter} ( ¹⁹⁸ Po) 0.816 0.0	R ₀ (fm) 1.4962(19) coincident γ-rays 0.211, 0.605 —	HF 0.99(4) R ₀ (fm) 1.5106(49) 1.5106(49)	HF $21^{+12}_{-6}$ 1.0(1)
<b>Fable 6</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 5.309(1)         * Weight         ** Weight <b>Fable 7</b> direct $\alpha$ emiss         E_{\alpha}(c.m.)         5.954(5)         5.775(1)         * Weight         *** [1987         @ [2000]	$\frac{E_{\alpha}(\text{lab})}{6.182(1)}$ ted average of 10 hted average of 10 hted average of 5 sion from ²⁰² Rn. $E_{\alpha}(\text{lab})$ 5.836(5)*** 6.641(1) [@] ted average of 9 'He10]. )2Wa29]. Va34].	$J_{i}^{\pi} = 0^{+}, T_{1/2} = 107i$ $I_{\alpha} (abs)$ $58(2)\%^{**}$ $J_{5}(3) \le [1994Wa13], 1$ $J_{9}(3)\% [1998Bo04] = 0^{+}, T_{1/2} = 9.7i$ $I_{\alpha} (rel)$ $1.8(6) \times 10^{-3}\%^{**}$ $100\%$ $5(2) \le [1992Wa29], a$	$\frac{(2) \text{ s*, } BR_{\alpha}}{J_{f}^{\pi}}$ $0^{+}$ $107(3) \text{ s [197]}$ $(2) \text{ s*, } BR_{\alpha} =$ $I_{\alpha}(\text{abs})$ $(3) \text{ stars}^{*} = 1.4(5)$ $78(8)$ $(3) \text{ stars}^{*} = 1.4(5)$ $78(8)$ $(3) \text{ stars}^{*} = 1.4(5)$ $78(8)$ $(4) \text{ stars}^{*} = 1.4(5)$ $78(8)$ $(5) \text{ stars}^{*} = 1.4(5)$ $78(8)$ $(6) \text{ stars}^{*} = 1.4(5)$ $(6) \text{ stars}^{*} = 1.4$	$\frac{E_{daughter}(^{194}\text{Pb})}{0.0}$ 0.0 1Ho01] and 1.80(5) s 994Wa13, 1993Wa04 78(8)%**. 3) J_{f}^{\pi} × 10 ⁻³ % 0 ⁺ %** 0 ⁺ 971Ho01].	coincident γ-rays  [1967Si09]. 4]. <i>E</i> _{daughter} ( ¹⁹⁸ Po) 0.816 0.0	R ₀ (fm)         1.4962(19)         coincident γ-rays         0.211, 0.605	HF 0.99(4) R ₀ (fm) 1.5106(49) 1.5106(49)	HF 21 ⁺¹² 1.0(1)
Fable 6direct $\alpha$ emis $E_{\alpha}(c.m.)$ 5.309(1)* Weight* WeightTable 7direct $\alpha$ emis $E_{\alpha}(c.m.)$ 5.954(5)5.775(1)* Weight*** [1987**** [1987@ [2000]Table 8direct $\alpha$ emis	$E_{\alpha}(lab)$ $E_{$	$J_{i}^{\pi} = 0^{+}, T_{1/2} = 107i$ $I_{\alpha} (abs)$ $58(2)\%^{**}$ $J_{5}^{5}(3) \le [1994Wa13], 1$ $J_{9}^{\pi} = 0^{+}, T_{1/2} = 9.7i$ $I_{\alpha} (rel)$ $1.8(6) \times 10^{-3}\%^{**}$ $100\%$ $5(2) \le [1992Wa29], a$ $J_{i}^{\pi} = 0^{+}, T_{1/2} = 244i$	$\frac{(2) \text{ s*, } BR_{\alpha}}{J_{f}^{\pi}}$ $0^{+}$ $107(3) \text{ s [197]}$ $(2) \text{ s*, } BR_{\alpha} = I_{\alpha} \text{ (abs)}$ $1.4(5)$ $78(8)$ $1.4(5)$ $78(8)$ $1.4(5)$ $78(8)$ $1.4(5)$ $78(8)$ $1.4(5)$ $78(8)$ $1.4(5)$ $78(8)$ $1.4(5)$ $78(8)$ $1.4(5)$ $78(8)$ $1.4(5)$ $78(8)$ $1.4(5)$ $78(8)$ $1.4(5)$ $78(8)$ $1.4(5)$ $78(8)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$ $1.4(5)$	$\frac{E_{daughter}(^{194} \text{Pb})}{0.0}$ $\frac{11001] \text{ and } 1.80(5) \text{ s}}{994 \text{ wa} 13, 1993 \text{ Wa} 04}$ $\frac{78(8)\%^{**}.}{3} \qquad \qquad$	<u>coincident γ-rays</u>  [1967Si09]. 4]. <u>E_{daughter}(¹⁹⁸Po) 0.816 0.0</u>	R ₀ (fm)         1.4962(19)         coincident γ-rays         0.211, 0.605	HF 0.99(4) R ₀ (fm) 1.5106(49) 1.5106(49)	HF 21 ⁺¹² ₋₆ 1.0(1)
Fable 6lirect $\alpha$ emis $Z_{\alpha}(c.m.)$ $3.309(1)$ * Weight* Weight* WeightTable 7lirect $\alpha$ emis $Z_{\alpha}(c.m.)$ $.9554(5)$ $.775(1)$ * Weight** [1987*** [1987 $@$ [2000]Table 8irect $\alpha$ emis $Z_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$J_{i}^{\pi} = 0^{+}, T_{1/2} = 107i$ $I_{\alpha}(abs)$ $58(2)\%^{**}$ $J_{5}(3) \le [1994Wa13], 1$ $J_{9}(3)\% [1998Bo04] = 0^{+}, T_{1/2} = 9.7i$ $I_{\alpha}(rel)$ $1.8(6) \times 10^{-3}\%^{**}$ $100\%$ $J_{i}^{\pi} = 0^{+}, T_{1/2} = 244i$ $I_{\alpha}(abs)$	$\frac{(2) \text{ s*, } BR_{\alpha}}{J_{f}^{\pi}} = \frac{J_{f}^{\pi}}{0^{+}}$ $107(3) \text{ s } [197]$ $107(3) \text{ s } [197]$ $(2) \text{ s*, } BR_{\alpha} = \frac{I_{\alpha}(\text{abs})}{I_{\alpha}(\text{abs})}$ $1000000000000000000000000000000000000$	$\frac{E_{daughter}(^{194} \text{Pb})}{0.0}$ $\frac{E_{daughter}(^{194} \text{Pb})}{0.0}$ $\frac{110011}{1} \text{ and } 1.80(5) \text{ s}}{994 \text{ wa} 13, 1993 \text{ Wa} 04}$ $\frac{78(8)\%^{**}}{78(8)\%^{**}}$ $\frac{5}{3} \qquad J_{f}^{\pi}$ $\times 10^{-3}\% \qquad 0^{+}$ $\frac{7}{6} \times 10^{-3}\% \qquad 0^{+}$ $\frac{7}{6} \times 10^{-3}\% \qquad 0^{+}$ $\frac{100\%}{6} \times 10^{-3}\% \qquad 0^{+}$ $\frac{100\%}{6} \times 10^{-3}\% \qquad 0^{+}$	coincident γ-rays  [1967Si09]. 4]. <i>E</i> _{daughter} ( ¹⁹⁸ Po) 0.816 0.0 0.0	R ₀ (fm)         1.4962(19)         coincident γ-rays         0.211, 0.605	HF 0.99(4) R ₀ (fm) 1.5106(49) 1.5106(49) HF	HF 21 ⁺¹² 1.0(1)

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{206}\mathrm{Ra})$	coincident γ-rays	R ₀ (fm)	HF	
8.071(6)	7.917(6)	$\approx 100\%$	$0^+$	0.0		1.507(11)	0.97(17)	
* Weight * [2010F Table 10 direct α emis	* Weighted average of 14(4) ms [2023Ch24], and 16.0(36) ms [2010He25]. * [2010He25]. Fable 10							
		$J_1 = 0^{-1}, T_{1/2} = 3^{-1}$	<u>20–210</u> μs, E	$R_{\alpha} = 100 \text{ ft}$	1	D (( )	IIF	
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$J_f^{\mathcal{R}}$	$E_{daughter}(^{210}1h)$	coincident γ-rays	$\kappa_0$ (fm)	HF	
8.696(18)	8.533(18)	$\approx 100\%$	$0^+$	0.0				

direct  $\alpha$  emission from ²¹⁰Th,  $J_i^{\pi} = 0^+$ ,  $T_{1/2} = 15.1(27)$  ms*,  $BR_{\alpha} = \approx 100\%$ .

* All values from [2021Zh22].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +15 nuclei.

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Observed and predicted $\beta$ -delayed particle emission from	n the odd- $Z$ , $T_z = +15$ nuclei.	$J^{\pi}$ values for ¹⁶⁴ Ho,	¹⁶⁸ Tm, ¹⁷² Lu,	¹⁷⁶ Ta, ¹⁸⁰ Re,	¹⁸⁴ Ir, ¹⁸⁸ Au, a	and ¹⁹² Tl are
taken from ENSDF. Unless otherwise stated, all Q-value	s are taken from [2021Wa16]	or deduced from valu	es therein.			

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
			1		1		
¹⁶⁴ Ho		$1^{+}$	29.0(5) m	0.987(1)	-7.674(4)	0.537(2)	[1972Ka19]
¹⁶⁸ Tm		3+	93.1(1) d	1.6772(2)	-6.322(6)	2.230(2)	[1968Ne02]
¹⁷² Lu		$4^{-}$	6.70(4) d	2.519(2)	-4.815(3)	3.828(2)	[1960Wi11]
¹⁷⁶ Ta		$(1)^{-}$	8.08(7) h	3.210(30)	-3.489(31)	5.465(31)	[1969Bo23]
¹⁸⁰ Re		(1)-	2.42(7) m	3.799(21)	-2.769(21)	6.314(21)	[1955Fi30]
¹⁸⁴ Ir		5-	3.14(2) h	4.642(28)	-1.090(29)	7.600(28)	[1982Al34]
¹⁸⁸ Au		$1^{-}$	8.84(60 m	5.450(6)	-0.111(28)	9.456(3)	[1972Fi12]
¹⁹² Tl		$(2^{-})$	9.4(2) m	6.140(40)	0.637(32)	9.524(32)	[ <b>1979To06</b> ]
¹⁹⁶ Bi		(3+)	308(12) s	7.339(26)	2.857(27)	11.578(29)	[1991Va04, 1992Hu04]
^{196m} Bi	0.256(6)*	(10 ⁻ )	240(3) s	7.595(27)	3.113(28)	11.834(30)	[1991Va04, 1992Hu04]
²⁰⁰ At		(3 ⁺ )	43(1) s	7.954(26)	4.521(27)	13.935(26)	[1992Hu04]
^{200m1} At	0.113(3)	$(7^{+})$	47(1) s	8.008(26)	4.688(27)	14.048(26)	[1992Hu04]
^{200m2} At	0.256(6)	$(10^{-})$	4.8(3) s**	9.067(26)	4.777(28)	14.191(27)	[1996Ta18, 1967Tr06]
²⁰⁴ Fr		(3+)	1.99(12) s	8.577(26)	5.481(27)	15.124(26)	[2022Ya27]
204m1 Fr	0.049(7)	$(7^{+})$	2.3(3) s***	8.626(27)	5.530(28)	15.173(27)	[2005Uu02, 1992Hu04]
204m2 Fr	0.189(7)	(10 ⁻ )	2.19(41) s	8.766(27)	5.4670(28)	15.313(27)	[2022Ya27]
²⁰⁸ Ac		(3+)	171(13) ms	9.030(70)	6.321(67)	16.306(65)	[2022Ya27]
^{208m} Ac	0.375(17)	$(10^{-})$	37.1(37) ms	9.405(72)	6.696(69)	16.681(67)	[2022Ya27]
²¹² Pa			$4.5^{+2.7}_{-1.3}$ ms	9.490(90)	7.164(103)	17.444(88)	[2020Au04]

* Deduced from the ²⁰⁰At  $\alpha$  decay energies. ** Weighted average of 6.3(5) s [1996Ta18] and 4.3(3) s [1967Tr06]. *** Weighted average of  $1.6^{+0.5}_{-0.3}$  s [2005Uu02], and 2.6(3) s [1992Hu04].

Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +15$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BR _α	Experimental
16411	5 000(1)	12 (70(2)	0.421(2)		
168m	5.889(1)	13.679(2)	0.431(2)		
172-	5.312(2)	12.820(2)	1.243(2)		
172Lu	4.718(2)	11.519(2)	2.151(3)		
¹⁷⁶ Ta	4.173(31)	10.373(31)	2.946(31)		
¹⁸⁰ Re	3.831(26)	9.817(56)	3.103(37)		
¹⁸⁴ Ir	3.236(57)	8.74(11)	3.802(35)		
¹⁸⁸ Au	2.975(24)	7.777(17)	4.815(28)		
¹⁹² Tl	2.569(39)	7.617(32)	4.074(32)		
¹⁹⁶ Bi	1.560(25)	5.649(28)	5.438(40)	$1.15(34) \times 10^{-3}$ %	[1991Va04, 1992Hu04]
^{196m} Bi	1.304(26)	5.393(29)	5.694(41)	$3.8(10) \times 10^{-4}$ %	[1991Va04, 1992Hu04]
²⁰⁰ At	1.038(25)	4.192(37)	6.596(1)	46(2)%*	[1998Bo14, 1996Ta18, 1992Hu04, 2005Uu02, 1995BiZZ,
					1975BaYJ, 1967Tr04, 1967Tr06]
^{200m1} At	0.925(25)	4.079(37)	6.709(2)	43(7)%	[1992Hu04, 2015We13, 2005Uu02, 1995BiZZ, 1975BaYJ,
					1967Tr04, 1967Tr06]
^{200m2} At	0.782(26)	3.936(38)	6.852(6)	10.5(3)%	[2005Uu02, 1996Ta18, 1992Hu04, 1967Tr06, 1995BiZZ,
					1975BaYJ, 1967Tr04]
²⁰⁴ Fr	0.498(25)	3.376(37)	7.170(2)	96(2)%	[2014Ly01, 1995BiZZ, 1992Hu04, 2005Uu02, 1974Ho27,
					1964Gr04]
204m1 Fr	0.449(26)	3.327(38)	7.219(7)	90(2)%	[2014Ly01, 1995BiZZ, 1992Hu04, 2005Uu02]
^{204m2} Fr	0.4309(26)	3.187(38)	7.359(7)	74(8)%	[2014Ly01, 1995BiZZ, 1992Hu04, 2005Uu02]
²⁰⁸ Ac	0.042(87)	2.570(70)	7.714(10)***	≈100%**	[2022Ya27, 1994Le15, 2014Ya19, 1998LuZV, 1996Ik01]
^{208m} Ac	-0.333(89)	2.195(72)	8.089(20)	$\approx 100\% **$	[2022Ya27, 1994Le15, 1998LuZV, 1996Ik01]
²¹² Pa	-0.431(123)	1.75(11)	8.411(59)	100%**	[2020Au04, 2014Ya19, 1997Mi03, 1997MiZX]

* Weighted average of 49(4)% [1998Bo14], 44(2)% [1996Ta18] and 57(6)% [1992Hu04].

** Based on short half-life.

*** Deduced from  $\alpha$  energy, 7.729(60) in [2021Wa16].

direct $\alpha$ emission from ¹⁹⁶ Bi*, $J_i^{\pi} = (3^+)$ , $T_{1/2} = 308(12)$ s, $BR_{\alpha} = 1.15(34) \times 10^{-3}$ %.									
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{m \pi}$	Edai	ughter ( ¹⁹² Tl)	coi	ncident γ-rays	R ₀ (fm)***	HF
5.260(10)	5.153(10)	$1.15(34) \times 10^{-3}$ %	(3+)	0.17	8(40)**			1.467(24)	$2.2^{+1.9}_{-1.1}$
* All va ** [201 *** Inte	llues from [1991 2Ba36]. erpolated betwee	Va04, 1992Hu04], exce n 1.437(24) fm ( ¹⁹⁴ Pb)	ept where no and 1.4962(	ted. (19) fm ( ¹⁹	⁹⁸ Po).				
Table 4 direct $\alpha$ emi	ssion from ^{196m} I	Bi*, Ex. = 256(6) keV,	$\mathbf{J}_{i}^{\pi} = (10^{-}), T_{i}^{\pi}$	$\Gamma_{1/2} = 240$	$D(3)$ s, $BR_{\alpha} =$	3.8(10)	$ imes 10^{-4}$ %.		
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{dat}$	ughter ( ¹⁹² Tl)	coi	ncident γ-rays	R ₀ (fm)***	HF
5.219(10)	5.112(10)	$3.8(10)  imes 10^{-4} \%$	(10 ⁻ )	0.32	204 + x**			1.467(24)	$3.1_{-1.5}^{+2.5}$
* All va ** [201 *** Inte	llues from [1991 2Ba36]. erpolated betwee	Va04, 1992Hu04], exce n 1.437(24) fm ( ¹⁹⁴ Pb)	ept where no and 1.4962(	ted. (19) fm ( ¹⁹	⁹⁸ Po).				
Table 5 direct $\alpha$ emi	ssion from ²⁰⁰ A	t, $\mathbf{J}_i^{\pi} = (3^+),  \mathbf{T}_{1/2} = 43($	1) s*, $BR_{\alpha}$ =	= 46(2)%*	*.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	Edaughter(	¹⁹⁶ Bi)	coincid	ent γ-rays	$R_0 (fm)^@$	HF
6.596(1)	6.464(1)*	46(2)%**	(3 ⁺ )	0.0				1.5034(53)	3.3(4)
* [1992 ** Weig *** [19 [@] Interp	Hu04]. ghted average of 96Ta18]. polated between	49(4)% [1998Bo14], 4 1.4962(19) fm ( ¹⁹⁸ Po)	4(2)% [1996 and 1.5106(4	5Ta18] and 49) ( ²⁰² Rr	1 57(6)% [199 1).	92Hu04]			
Table 6 direct $\alpha$ emi	ssion from ^{200m1}	At*, Ex. = 113(3) keV	$J_i^{\pi} = (7^+), T_i^{\pi}$	$\Gamma_{1/2} = 47($	1) s, $BR_{\alpha} = 4$	3(7)%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$ $I_{\alpha}(\text{ab})$	s) .	$J_f^{\pi}$	$E_{daughter}(^{19}$	⁶ Bi)	coincident γ-1	Tays $R_0$ (fm)*	* HF
6.435(5) 6.542(2) 6.709(3)	6.306(5) 6.411(2) 6.575(3)	0.17(4)%         0.073           100(16)%         43(7)           0.84(20)%         0.36(6)	(15)% % 5)%	$(10^{-})$ $(7^{+})$ $(3^{+})$	0.256(6) 0.054(2) 0.0			1.5034(5 1.5034(5 1.5034(5	$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$
* All va ** Inter	llues from [1992 polated between	Hu04], except where no 1.4962(19) fm ( ¹⁹⁸ Po)	oted. and 1.5106(	$(49) (^{202}R)$	n.				
Table 7 direct $\alpha$ emi	ssion from ^{200m2}	At, Ex. = 256(6) keV, .	$\mathbf{J}_i^{\pi} = (10^-), T$	$\Gamma_{1/2} = 4.86$	(3) s*, $BR_{\alpha}$ =	10.5(3)	%**.		
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	Edaugh	ter ⁽¹⁹⁶ Bi)	coinc	cident γ-rays	R ₀ (fm) [@]	HF
6.670(2)	6.537(2)***	10.5(3)%**	(10 ⁻ )	0.256(	(6)	_		1.5034(53)	3.1(4)
* Weigł ** [199	nted average of 6 2Hu04].	.3(5) s [1996Ta18] and	4.3(3) s [19	67Tr06].					

*** [1992Hu04].
 *** Weighted average of 6.534(6) MeV [2005Uu02], 6.538(3) MeV [1992Hu04] and 6.536(5) MeV [1996Ta18]. [1996Ta12] report 6.528(1) MeV, which is not consistent with the other measured values.
 @ Interpolated between 1.4962(19) fm (¹⁹⁸Po) and 1.5106(49) (²⁰²Rn.

direct $\alpha$ emission from	204 Fr, $J_{i}^{\pi} = (3^{+})^{10}$	), $T_{1/2} = 1.99(1$	2) s, $BR_{\alpha} = 96(2)\%^{**}$
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{200}\text{At})$	coincident γ-rays	$R_0 (fm)^@$	HF	
7.054(8) 7.172(5)	6.916(8)*** 7.031(5)***	≤0.6% 100%	$\leq 0.6\%$ 95(2)%	(3 ⁺ )	0.113(3) 0.0	_	1.5197(65) 1.5197(65)	≥18 2.4(4)	

* [2022Ya27].

** [1995BiZZ].

*** [1992Hu04].

[@] Interpolated between 1.5106(49) fm (²⁰²Rn) and 1.5287(42) fm (²⁰⁶Ra).

#### Table 9

direct $\alpha$ emission from $204m$	11 Fr*, Ex. = 49(7) keV, $J_i^{\pi}$	$T^{\tau} = (7^+), T_{1/2} = 2.3(3) \text{ s}^*,$	$BR_{\alpha} = 90(2)\%^{**}$ .
--------------------------------------	-------------------------------------------	---------------------------------------------------	--------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{200}\mathrm{At})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF
7.108(5) 7.219(8)	6.969(5)*** 7.077(8)	$100\% \le 0.7\%$	$89(2)\% \le 0.6\%$	(7 ⁺ ) (3 ⁺ )	0.113(3) 0.0		1.5197(65) 1.5197(65)	≥250 4.4(9)

Weighted average of  $1.6\substack{+0.5\\-0.3}$  s [2005Uu02] and 2.63) s [1992Hu04].

** [1995BiZZ].

*** [1992Hu04].

[@] Interpolated between 1.5106(49) fm (²⁰²Rn) and 1.5287(42) fm (²⁰⁶Ra).

## Table 10

direct  $\alpha$  emission from ^{204m2}Fr, Ex. = 189(7) keV,  $J_i^{\pi} = (10^-)$ ,  $T_{1/2} = 0.8(2)$  s*,  $BR_{\alpha} = 74(8)\%^{**}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{200}\text{At})$	coincident $\gamma$ -rays	$R_0 \; (fm)^@$	HF
7.155(4)	7.015(4)***	10.5(3)%**	(10 ⁻ )	0.256(6)		1.5197(65)	2.0(3)

* [2005Uu02].

** [1995BiZZ].

*** Weighted average of 7.017(6) MeV [2005Uu02] and 7.013(5) MeV [1992Hu04]. ^(a) Interpolated between 1.4962(19) fm (¹⁹⁸Po) and 1.5106(49) (²⁰²Rn.

#### Table 11

direct $\alpha$ emission fr	rom 208 Ac, $J_i^{\pi} =$	$(3^+), T_{1/2} = 1710$	(13) ms*, $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{204}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
7.630(15)	7.483(15)*	>5%	>5%	$(2^+, 4^+)$	0.079(21)		1.518(12)	<26
7.714(10)	7.566(10)**	100%	<95%	$(3^+)$	0.0		1.518(12)	2.5(8)

* [2022Ya27].

#### Table 12

direct  $\alpha$  emission from ^{208m}Ac, Ex. = 375(17) keV,  $J_i^{\pi} = (10^-)$ ,  $T_{1/2} = 37.1(37)$  ms*,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{204}\mathrm{Fr})$	coincident γ-rays	R ₀ (fm)***	HF
7.901(12)	7.749(12)**	100%	(10 ⁻ )	0.189(7)		1.518(12)	$2.0^{+0.7}_{-0.5}$

* [2022Ya27].

** Weighted average of 7.745(14) MeV [2022Ya27] and 7.758(20) MeV [1994Le02]. *** Interpolated between 1.5287(42) ( 206 Ra) and 1.507(11) ( 210 Th).

^{**} Weighted average of 7.483(15) MeV [2022Ya27] and 7.572(15) MeV [1994Le02]. *** Interpolated between 1.5287(42) ( 206 Ra) and 1.507(11) ( 210 Th).

direct  $\alpha$  emission from ²¹²Pa,  $J_i^{\pi} = T_{1/2} = 4.5^{+2.7}_{-1.3}$  ms*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{208}\mathrm{Ac})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF	

8.404(14) 8.245(14)** 100%

* [2020Au04]

** Weighted average of 8.240(20) MeV [2020Au04] and 8.250(20) MeV [2014Ya19].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$  = +31/2 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +31/2$  nuclei. J^{$\pi$} values for ¹⁶⁷Er, ¹⁷¹Yb, ¹⁷⁵Hf, ¹⁷⁹W, ¹⁸³Os, ¹⁸⁷Pt, ¹⁹¹Hg and ¹⁹⁵Pb are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
167 г.		7/0+	. 11	1.010(5)			
171 - H		112 '	stable	-1.010(5)			
^{1/1} Yb		$1/2^{-}$	stable	-0.097(1)			
¹⁷⁵ Hf		5/2-	70(2) d	0.684(2)	-4.826(2)	2.304(2)	[1963Ra14]
¹⁷⁹ W		$7/2^{-}$	37.00(17) m	1.062(15)	-4.149(15)	3.446(15)	[1969Bi10]
¹⁸³ Os		9/2+	13.0(5) h	2.150(50)	-2.707(50)	4.269(50)	[1960Ne03]
¹⁸⁷ Pt		3/2-	2.35(3) h	2.860(40)	-0.974(24)	6.699(25)	[1973Se13]
¹⁹¹ Hg		3/2-	49(10) m	3.206(23)	-0.574(22)	6.533(36)	[1974Va19]
¹⁹⁵ Pb		3/2-	$\approx 15 \text{ m}$	4.417(12)	1.157(6)	7.635(7)	[1982Hi04]
¹⁹⁹ Po		$(3/2^{-})$	312(6) s	5.559(12)	3.540(10)	10.492(12)	[1993Wa04]
^{199m} Po	0.312(2)	$(13/2^+)$	252(6) s	5.871(12)	3.852(10)	10.804(12)	[1993Wa04]
²⁰³ Rn		(3/2-)	44(2) s*	5.979(12)	4.469(10)	12.189(12)	[1996Ta18, 1971Ho01]
^{203m} Rn	0.364(2)	$(13/2^+)$	26.7(5) s	6.343(12)	4.833(10)	12.553(12)	[1996Ta18]
²⁰⁷ Ra		$(3/2^{-})$	1.2(2) s	6.360(60)	5.358(59)	13.252(59)	[1996Ta18, 1971Ho01]
^{207m} Ra	0.509(10)	$(13/2^+)$	55(7) ms**	6.869(61)	5.867(60)	13.761(60)	[2021Ni08, 1987He10]
²¹¹ Th		(3/2-)	$36^{+13}_{-6}$ ms***	6.73(10)	6.145(87)	14.301(88)	[2023Ch24, 1995Uu01]
^{211m} Th	0.769(21)	$(13/2^+)$	83(8) μs	7.50(23)	6.914(89)	15.070(90)	[2021Au03]
²¹⁵ U			$0.73^{+1.33}_{-0.29}$ ms	7.08(13)	6.91(11)	15.32(12)	[2015Ya13]

* Weighted average of 42(3) s [1996Ta18] and 45(2) s [1971Ho01].

** Weighted average of 55(9) ms [2021Ni08] and 55(10) ms [1987He10]. *** Weighted average of  $36^{+15}_{-8}$  ms [2023Ch24] and  $37^{+28}_{-11}$  ms [1995Uu01].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +31/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
167 г	7.509(1)	14.055(1)	0 ((7(1)		
171 yr	7.508(1)	14.255(1)	0.667(1)		
175110	6.800(1)	12.964	1.558		
179 MI	6.200(2)	11.508(2)	2.400(2)		
183 Q	5.986(54)	10.992(15)	2.762(15)		
187 D	5.51(11)	10.01(51)	3.207(52)		
¹⁰⁷ Pt	4.802(29)	8.457(24)	4.553(55)	<b>z</b> 10-6~	
¹⁹¹ Hg	5.047(23)	8.700(24)	3.669(33)	$< 5 \times 10^{-6}\%$	[ <b>1963Ka</b> 17]
¹⁹⁵ Pb	4.090(15)	7.254(16)	4.429(23)		
¹⁹⁹ Po	3.154(28)	5.071(7)	6.074(2)	7.5(3)%	[1996Ta18, 1993Wa04, 1971Ho01, 1968Go12, 1991Gr12
					1985St02, 1984Co13, 1967Le08, 1967Si04, 1967Ti04,
					1967Tr04, 1967Tr06, 1965Br17, 1965Br27, 1965Si22,
100					1965Ti03, 1964Br23]
^{199m} Po	2.842(28)	4.759(7)	6.386(3)	24.7(9)%*	[1996Ta18, 1993Wa04, 1967Le08, 2015We13, 2016We13,
					2014Ma66, 1991Gr12, 1985St02, 1984Co13, 1973BoXL,
					1971Ho01, 1968Go12, 1967Si09, 1967Ti04, 1967Tr06,
					1965Br17, 1965Br27, 1965Si22, 1965Ti03, 1964Br23,
					1962Be26, 1961Be25]
²⁰³ Rn	2.878(28)	4.241(8)	6.630(2)	66(9)%	[1996Ta18, 1993Wa04, 1978HoZZ, 1971Ho01, 1967Va07,
					1967Va17, 1965Nu04]
^{203m} Rn	2.514(28)	3.877(8)	6.994(3)	78(7)%	[1998Bo14, 1996Ta18, 1995Le04, 1993Wa04, 1967Va17,
					2015We13, 1995Le09, 1987He10, 1971Ho01, 1967Va07,
					1965Nu04]
²⁰⁷ Ra	2.528(65)	3.354(59)	7.272(5)***	obs [@]	[1967Va22, 2021Au03, 2021Ni08, 2021NiZW, 1995Uu01,
					1987He10]
^{207m} Ra	2.019(66)	2.845(60)	7.781(11)	26(20)%	[2021Ni08, 1996Le09, 1987He10, 2021Au03
					2021NiZW]
²¹¹ Th	2.18(11)	2.560(86)	7.941(10)@@	$\approx 100\%$ [@]	[2023Ch24, 1995Uu01, 2015Ya13, 2009LaZV, 1995Le15,
					1995LeZY]
211m Th	1.41(11)	1.791(89)	8.706(66)	4(3)%	[2021Au03]
²¹⁵ U	1.86(13)	1.81(10)	8.588(30)@@@	100%	[2015Ya13, 2016Zh33, 2015WaZT, 2014WaZU]

* Weighted average of 24(1)% [1993Wa04] and 27.5(20)% [1967Le08].

** Weighted average of 80(10)% [1998Bo14] and 75(10)% [1987He10].

*** Deduced from  $\alpha$  energy, 7.273(58) in [2021Wa16].

[@] Not measured, but estimated to be close to 100% based on half-life.

# ^{@@} Deduced from $\alpha$ energy, 7.937(63) in [2021Wa16]. ^{@@@} Deduced from $\alpha$ energy, 8.588(59) in [2021Wa16].

# Table 3

direct $\alpha$ emis	ssion from ¹⁹⁹ Po, J	$\prod_{i}^{\pi} = (3/2^{-}), T_{1/2}$	$= 312(6) \text{ s}^*, Bl$	$R_{\alpha} = 7.5(3)\%^*.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{195}\text{Pb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
6.074(2)	5.952(2)**	7.5(3)%*	(3/2 ⁻ )	0.0		1.4883(18)	1.96(12)	
* [1993' ** Weig	Wa04]. hted average of 5.9	953(2) MeV [199	96Ta18], 5.952(	2) MeV [1993Wa04] a	nd 5.952(2) MeV [1968G	012].		
<b>Table 4</b> direct $\alpha$ emis	ssion from ^{199m} Po,	Ex. = 312(2) Me	eV, $J_i^{\pi} = (13/2^+)$	), $T_{1/2} = 252(6) s^*$ , <i>BR</i>	$R_{\alpha} = 24.7(9)\%^{**}.$			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{195}\text{Pb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
6.183(1)	6.059(1)***	7.5(3)%*	(13/2 ⁺ )	0.2029(7)@		1.4883(18)	1.43(8)	
* [1993' ** Weig *** [199 @ [2014	Wa04]. hted average of 24 96Ta16]. Hu18].	4(1)% [1993Wa04	4] and 27.5(20)	% [1967Le08].				
Table 5 direct $\alpha$ emis	ssion from ²⁰³ Rn,	$\mathbf{J}_i^{\pi} = (3/2^-),  \mathbf{T}_{1/2}$	$= 44(2) s^*, BR$	$\alpha = 66(9)\%^{**}.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{199}\mathrm{Po})$	coincident γ-rays	R ₀ (fm)	HF	
6.630(2)	6.499(2)***	66(9)%**	(3/2 ⁻ )	0.0		1.45066(31)	1.4(3)	
* Weigh ** [197; *** Wei Table 6 direct α emis	nted average of 429 89HoZZJ. ighted average of 6 ssion from ^{203m} Rn.	3) [1996Ta18] ar 5.499(2) MeV [19 , Ex. = 364(2) M	nd 45(2) s [197] 996Ta18] and 6. eV, $J_i^{\pi} = (13/2^+)$	1Ho01]. 4993(25) MeV [1993W ), T _{1/2} = 26.7(5) s*, <i>B</i> .	Va04]. $R_{\alpha} = 78(7)\%^{**}.$			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	<i>E</i> _{daughter} ( ¹⁹⁹ Po)	coincident $\gamma$ -rays	R ₀ (fm)	HF	
6.682(1)	6.551(1)*	78(7)%**	(13/2+)	0.312(2)		1.4883(18)	1.18(14)	
* [1996 ** Weig	Ta18]. thed average of 80	)(10)% [1998Bo1	4] and 75(10)%	6 [1987He10].				
<b>Table 7</b> direct $\alpha$ emis	ssion from ²⁰⁷ Ra*,	$J_i^{\pi} = (3/2^-), T_{1/2}$	$_2 = 1.2(2)$ s, <i>BR</i>	$C_{\alpha} = \text{obs}^{**}.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$ .	$E_{daughter}(^{203}\mathrm{Rn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
7.272(5)	7.131(5)	obs**	(3/2-)	0.0		1.5158(39)	1.28(25)***	
* All va ** Not 1 *** Res	lues taken from [19 measured, but estin sult obtained using	967Va22]. nated to be close a BR of 100%	to 100% based	on half-life.				
Table 8 direct $\alpha$ emis	ssion from ^{207m} Ra,	, Ex. = 509(10) N	$1 \text{eV}, \mathbf{J}_i^{\pi} = (13/2)$	⁺ ), $T_{1/2} = 55(7) \text{ ms*}$ , <i>I</i>	$BR_{\alpha} = 26(20)\%^{**}.$			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{203}\mathrm{Rn})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF	
7.467(8)	7.323(8)**	26(20)%**	(13/2 ⁺ )	0.364(2)		1.5158(39)	$1.1\substack{+4.1 \\ -0.6}$	

 $\ast$  Weighted average of 55(9) ms [2021Ni08] and 55(10) ms [1987He10].

** [2021Ni08].

*** Weighted average of 7.331(15) MeV [1996Le09] and 7.320(10) MeV [1987He10].

#### Table 9

direct $\alpha$ emiss	sion from ²¹¹ Th, $J_i^{\pi}$	$= (3/2^{-}), T_{1/2}$	$= 36^{+13}_{-6} \text{ ms*},$	$BR_{\alpha} = \approx 100\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{207}\mathrm{Ra})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
7.941(10)	7.790(10)**	$\approx 100\%$	(3/2-)	0.0		1.5064(68)	$1.0\substack{+0.4 \\ -0.2}$	
* Weight ** Weigh <b>Table 10</b> direct α emiss	ed average of $36^{+1}_{-8}$ ated average of 7.78 sion from ^{211m} Th*,	⁵ ms [2023Ch2 88(14) MeV [20 Ex. = 769(21)	4] and $37^{+28}_{-11}$ m D23Ch24] and 7 MeV, $J_i^{\pi} = (13i)$	ns [1995Uu01]. 7.792(14) MeV [1995Uu /2 ⁺ ), T _{1/2} = 83(8) μs, <i>Bl</i>	01]. $R_{\alpha} = 4(3)\%.$			
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	E _{daughter} ( ²⁰⁷ Ra)	coincident $\gamma$ -rays	R ₀ (fm)	HF	
8.200(15)	8.045(15)	4(3)%	(13/2 ⁺ )	0.364(2)		1.5158(39)	$0.3^{+1.1}_{-0.2}$ **	
* All valu ** The lo	ues taken from [202 w HF value sugges	21Au03]. sts that the BR	is towards the l	ower value of the uncerta	ainty. A value of 1.4% fo	r the BR gives a H	F = 1.0.	
<b>Table 11</b> direct $\alpha$ emission	sion from 215 U*, J ⁷ _i	$T = , T_{1/2} = 0.7$	$3^{+1.33}_{-0.29}$ ms, $BR_{\alpha}$	= 100%.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{211}\mathrm{Th})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	

8.588(30) 8.428(30) 100%

* All values taken from [2015Ya13].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +31/2 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z = +31/2$  nuclei. J^{$\pi$} values for ¹⁶⁵Ho, ¹⁶⁹Tm, ¹⁷³Lu, ¹⁷⁷Ta, ¹⁸¹Re, ¹⁸⁵Ir, ¹⁸⁹Au, and ¹⁹³Tl are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
165 Ho		7/2-	$>6 \times 10^{16}  v$	-1 286(1)			[1956Po16]
¹⁶⁹ Tm		$1/2^+$	stable	-0.354(1)			
¹⁷³ Lu		$7/2^+$	499(5) d	0.670(2)	-6.796(6)	1.615(2)	[1962Bo12]
¹⁷⁷ Ta		7/2+	56.56(6) h	1.166(3)	-5.621(3)	3.412(3)	[1961We11]
¹⁸¹ Re		5/2+	19.9(7) h	1.717(13)	-4.873(13)	3.938(13)	[1968Sc27]
¹⁸⁵ Ir		5/2-	14.4(1) h	2.470(28)	-3.405(28)	5.473(28)	[1982Al34]
¹⁸⁹ Au		$1/2^{+}$	28.5(3) m*	2.887(22)	-2.526(22)	6.799(20)	[1970Fi16, 1966Fo13]
¹⁹³ Tl		$1/2^{+}$	21.6(6) m**	3.585(17)	-1.994(17)	6.567(12)	[1961An03, 1974Va23]
¹⁹⁷ Bi		$(9/2^{-})$	560(30) s	5.058(10)	0.520(15)	8.950(18)	[1991Va09]
^{197m} Bi	х	$(1/2^+)$	309(33) s	5.058(10)+x	0.520(15)+x	8.950(18)+x	[1985Co06]
²⁰¹ At		9/2-	85(2) s***	5.732(10)	2.292(24)	11.531(9)	[1996Ta18, 1975BaYJ, 1974Ho27]
²⁰⁵ Fr		9/2-	3.80(3) s	6.400(9)	3.276(24)	12.786(9)	[2005De01]
²⁰⁹ Ac		$(9/2^{-})$	$89^{+12}_{-9} \text{ ms}^{@}$	6.990(60)	4.221(57)	14.130(56)	[1996Ta18, 1975BaYJ, 1974Ho27]
²¹³ Pa		(9/2-)	$5.1^{+3.3}_{-1.2}$ ms ^{@@}	7.530(60)	5.066(61)	15.371(57)	[2020Au04, 1995Ni05]

* Weighted average of 28.3(5) m [1970Fi16] and 28.7(4) m [1966Fo13].

** Weighted average of 22.6(10) m [19/0110] and 21.0(4) m [19/001013]. ** Weighted average of 22.6(10) m [19/01An03] and 21.0(8) m [1974W23]. *** Weighted average of 83(2) s [1996Ta18], 87(3) s [1975BaYJ] and 88(5) s [1974Ho27]. [@] Weighted average of 98(20) ms [2014Ya19],  $82^{+18}_{-13}$  ms [1996Ik01] and  $91^{+21}_{-14}$  ms [1996Ik01]. [@] Weighted average of  $4.9^{+5.9}_{-1.8}$  ms [2020Au04] and  $5.3^{+4.0}_{-1.6}$  ms [1995Ni05].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +31/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
165110	6 210(1)	14 990(4)	0.120(1)		
169	0.219(1)	14.880(4)	0.139(1)		
Im	5.574(1)	13.573(5)	1.198(1)		
¹⁷³ Lu	4.915(2)	12.249(2)	1.969(2)		
¹⁷⁷ Ta	4.427(3)#	11.127(3)	2.741(3)		
¹⁸¹ Re	4.170(13)	10.738(13)	2.772(13)		
¹⁸⁵ Ir	3.372(28)	9.104(29)	3.757(31)		
¹⁸⁹ Au	3.050(21)	8.611(34)	4.329(34)	$< 3  imes 10^{-5}\%$	
¹⁹³ Tl	2.755(17)	8.257(8)	3.680(21)		
¹⁹⁷ Bi	1.628(11)	6.110(14)	5.365(11)		
^{197m} Bi	1.628(11)-x	6.110(14)-x	5.365(11)+x	15-95 %	[1985Co06, 1984Co13, 1974Le02, 1972Ga27, 1970Ta14]
²⁰¹ At	1.137(11)	4.570(13)	6.473(2)	61(3)%*	[1998Bo14, 1996Ta18, 1974Ho27, 2015We13, 2005De01
					2004DeZV, 1986Wo03, 1975BaYJ, 1970DaZM, 1970HoZT,
					1967Tr06]
²⁰⁵ Fr	0.629(11)	3.725(13)	7.055(2)	98.5(2)%	[2010De04, 2005De01, 1981Ri04, 1967Va20, 2015Ma63,
					2012Ja01, 2004DeZV, 1974Ho27, 1964Gr02, 1961Gr42]
²⁰⁹ Ac	0.172(57)	2.884(59)	7.730(55)	$\approx 100\%^{**}$	[2000He17, 1994Le05, 1968Va04, 2014Ya19, 1996Ik01]
²¹³ Pa	-0.254(58)	2.067(78)	8.384(12)	100%**	[2020Au04, 1995Ni05, 2000He17, 1996An21, 1995NiZR,
					1995NiZS]

* Weighted average of 59(3)% [1998Bo14] and 71(7)% [1974Ho27].

** Based on short half-life.

## Table 3

direct  $\alpha$  emission from ^{197*m*}Bi*, Ex. = unk.,  $J_i^{\pi} = (1/2^+)$ ,  $T_{1/2} = 309(33)$  s,  $BR_{\alpha} = 15-95$  %.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{193}\mathrm{Tl})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
5.900(5)	5.780(5)	15-95 %	(1/2+)	0.0		1.4900(31)	0.071-0.45

* All values taken from [2015Ya13].

Table	4
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201 .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{197}\mathrm{Bi})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.471(1)	6.342(1)***	61(3)%**	(9/2 ⁻ )	0.0		1.4955(33)	1.39(13)
* Weigh ** Weig *** [19	nted average of 83(2 ghted average of 59( 96Ta18].	) s [1996Ta18], 870 3)% [1998Bo14] a	(3) s [1975Ba' nd 71(7)% [19	YJ] and 88(5) s [1974He 974Ho27].	o27].		
<b>Table 5</b> lirect $\alpha$ emi	ssion from ²⁰⁵ Fr, $J_i^{\pi}$	= 9/2 ⁻ , T _{1/2} = 3.8	$B0(3)$ s*, $BR_{\alpha}$	= 98.5(2)%**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{m \pi}$	$E_{daughter}(^{201}\text{At})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
2.054(3)	6.342(3)***	98.5(2)%**	(9/2-)	0.0		1.5157(28)	1.64(11)
* [2005] ** [201] *** We Table 6 lirect α emi	De01]. 0De04]. ighted average of 6. ssion from 209 Ac, $J_i^2$	916(5) MeV [2005 ^r = (9/2 ⁻ ), T _{1/2} = 3	De01], 6.917( 89 ⁺¹² ₋₉ ms*, <i>BI</i>	5) MeV [1981Ri04] and $R_{\alpha} = \approx 100\%.$	1 6.917(5) MeV [1967Va2	20].	
* [2005 ** [201] *** Wei <b>able 6</b> irect α emi	De01]. 0De04]. ighted average of 6.9 ssion from ²⁰⁹ Ac, $J_i^2$ $E_{\alpha}(lab)$	916(5) MeV [2005 $r = (9/2^{-}), T_{1/2} = 3$ <i>I</i> _α (abs)	De01], 6.917( $89^{+12}_{-9} \text{ ms*}, BI$ $J_f^{\pi}$	5) MeV [1981Ri04] and $R_{\alpha} = \approx 100\%.$ $E_{daughter}(^{205}Fr)$	l 6.917(5) MeV [1967Va2	20].	HF
* [2005 ** [2010 *** Wei fable 6 lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 7.728(7)	De01]. 0De04]. ighted average of 6.9 ssion from ²⁰⁹ Ac, $J_i^2$ $E_{\alpha}(lab)$ 7.580(7)**	P16(5)  MeV  [2005] $T = (9/2^{-}), T_{1/2} = 3$ $I_{\alpha}(abs)$ $\approx 100\%$	De01], 6.917( $89^{+12}_{-9} \text{ ms*}, BI$ $J_f^{\pi}$ (9/2 ⁻ )	5) MeV [1981Ri04] and $R_{\alpha} = \approx 100\%.$ $E_{daughter}(^{205}\text{Fr})$ 0.0	1 6.917(5) MeV [1967Va2 coincident γ-rays 	20]. R ₀ (fm) 1.5050(73)	HF 1.1(3)
* [2005 ** [2014 *** Wei Fable 6 lirect $\alpha$ emi $E_{\alpha}(c.m.)$ ?.728(7) * Weigh ** Weig	De01]. 0De04]. ighted average of 6.9 ssion from ²⁰⁹ Ac, $J_i^j$ $E_{\alpha}(lab)$ 7.580(7)** ated average of 98(2) ghted average of 7.5'	916(5) MeV [2005 $r = (9/2^{-}), T_{1/2} = 3$ $I_{\alpha}(abs)$ $\approx 100\%$ 0) ms [2014Ya19], 77(10) MeV [2000	De01], 6.917( $89_{-9}^{+12} \text{ ms*}, BI$ $J_f^{\pi}$ (9/2 ⁻ ) $82_{-13}^{+18} \text{ ms [19]}$ He17], 7.581(	5) MeV [1981Ri04] and $R_{\alpha} = \approx 100\%.$ $E_{daughter}(^{205}Fr)$ 0.0 96Ik01] and 91 ⁺²¹ ₋₁₄ ms [ 15) MeV [1994Le05] and	1 6.917(5) MeV [1967Va coincident γ-rays  [1996Ik01]. nd 7.585(15) MeV [1968]	20]. <u>R₀ (fm)</u> 1.5050(73) Va04],	HF 1.1(3)
* [2005 ** [2011 *** Wei Fable 6 lirect $\alpha$ emi $E_{\alpha}(c.m.)$ 7.728(7) * Weigh ** Weig Fable 7 lirect $\alpha$ emi	De01]. 0De04]. ighted average of 6.9 ssion from ²⁰⁹ Ac, $J_i^r$ $E_{\alpha}(lab)$ 7.580(7)** nted average of 98(2 ghted average of 7.5° ssion from ²¹³ Pa, $J_i^{\pi}$	916(5) MeV [2005 $r = (9/2^{-}), T_{1/2} = 3$ $I_{\alpha}(abs)$ $\approx 100\%$ 0) ms [2014Ya19], 77(10) MeV [2000 $r = (9/2^{-}), T_{1/2} = 5$	De01], 6.917( $89^{+12}_{-9} \text{ ms*}, BI$ $J_f^{\pi}$ (9/2 ⁻ ) $82^{+18}_{-13} \text{ ms [19]}$ He17], 7.581( $5.1^{+3.3}_{-1.2} \text{ ms*}, B$	5) MeV [1981Ri04] and $R_{\alpha} = \approx 100\%.$ $E_{daughter}(^{205}\text{Fr})$ 0.0 96Ik01] and 91 ⁺²¹ ₋₁₄ ms [ 15) MeV [1994Le05] and $R_{\alpha} = 100\%.$	1 6.917(5) MeV [1967Va coincident γ-rays  1996Ik01]. nd 7.585(15) MeV [1968 ⁻	20]. <u>R₀ (fm)</u> 1.5050(73) Va04],	HF 1.1(3)

* Weighted average of  $4.9^{+5.9}_{-1.8}$  ms [2020Au04] and  $5.3^{+4.0}_{-1.6}$  ms [1995Ni05].

100%

** Weighted average of 8.210(20) MeV [2020Au04] and 8.236(15) MeV [1995Ni05],

 $(9/2^{-})$ 

0.0

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ =+16 nuclei.

Last updated 10/12/2023

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +16$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
169							
¹⁰⁸ Er		$0^+$	stable	-2.930(30)			
¹⁷² Yb		$0^+$	stable	-1.882(5)			
¹⁷⁶ Hf		$0^+$	stable	-1.194(1)			
$^{180}W$		$0^+$	$1.8(2) \times 10^{18} \text{ y}$	-0.703(2)			[2004Co26]
¹⁸⁴ Os		$0^+$	$1.12(23) \times 10^{13} \text{ y}$	-0.033(4)			[2014Pe22]
¹⁸⁸ Pt		$0^+$	10.2(3) d	0.524(9)	-3.891(5)	3.974(7)	[1963Gr08]
¹⁹² Hg		$0^+$	4.85(20) h	0.761(22)	-3.602(16)	3.909(18)	[1961Ja10]
¹⁹⁶ Pb		$0^+$	37(3) m	2.148(14)	-1.624(24)	4.999(18)	[1961Su01]
²⁰⁰ Po		$0^+$	11.6(1) m	3.429(24)	1.001(10)	8.130(14)	[1970Ra14]
²⁰⁴ Rn		$0^+$	75(1) s*	3.905(24)	2.052(9)	9.976(24)	[1971Ho01, 1967Va17]
²⁰⁸ Ra		$0^+$	1.2(2) s	4.393(15)	3.074(10)	11.178(24)	[1967Va22]
²¹² Th		$0^+$	31.7(13) ms	4.811(24)	3.990(11)	12.351(15)	[2010He25]
²¹⁶ U		$0^+$	$2.25^{+0.63}_{0.40}$ ms	5.240(40)	4.856(29)	13.342(36)	[2021Zh22]
^{216m} U	2.206(23)	8+	$0.89_{0.17}^{+0.27}$ ms	7.446(46)	7.062(37)	15.548(43)	[2021Zh22]

* Weighted average of 74(2) s [1971Ho01] and 75(2) s [1967Va17].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +16$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	Experimental
168	7,000(5)	14 092(1)	0.554(1)		
172 <b>Vh</b>	7.333(3)	14.905(1) 13.726(1)	1.309(0)		
176 <b>H</b> f	7.334(1) 6 700(1)	13.720(1) 12.210(1)	1.309(0)		
180 1	6.568(1)	12.210(1) 11.770(0)	2.234(1) 2.515(1)	100%	[2004Co26 20057d04 2004CoZV 2003Co01 2003Do05
**	0.508(1)	11.779(0)	2.313(1)	100 %	2002Bi16, 2002BiZZ, 2002DaZT]
¹⁸⁴ Os	5.732(8)	10.584(1)	2.959(2)	100%	[ <b>2014Pe22</b> , 1976Sp04]
¹⁸⁸ Pt	5.561(28)	9.399(5)	4.007(5)		-
¹⁹² Hg	5.503(16)	9.283(16)	3.385(16)		
¹⁹⁶ Pb	4.482(14)	7.742(8)	4.238(17)	$\leq 3  imes 10^{-5}\%$	[1963Ka17]
²⁰⁰ Po	3.433(13)	5.452(12)	5.982(2)	11.3(3)%*	[ <b>1996Ta18, 1993Wa04, 1967Le08</b> , 1992WaZV, 1970DaZM 1970Ra14, 1971Ho01, 1970Jo26, 1969Ha03, 1967Le08, 1967Le21, 1967Si09, 1967Tr04, 1967Tr06, 1965Br17, 1965Br27, 1965Si22, 1965Ti03, 1964Br23, 1962Be26, 1961Be25, 1961Fo05, 1954Bo391
²⁰⁴ Rn	3.096(13)	4.606(11)	6.547(2)	72(1)%**	[1996Ta18, 1993Wa04, 1971Ho01, 1967Va17, 2022Zh45, 2014WaZU, 1992WaZV, 1967Va07, 1965Nu04]
²⁰⁸ Ra	2.712(20)	3.717(12)	7.273(5)	obs	[ <b>1967Va22</b> , 2022Zh45, 2015Ma37, 2015Ma63, 2014WaZU, 1968Lo15]
²¹² Th	2.322(55)	2.910(14)	7.958(5)	$\approx 100\%$	[ <b>2010He25</b> , 2022Zh45, 2015De22, 2015Ma37, 1996Ik01, 1980Ve01]
²¹⁶ U	2.027(87)	2.206(30)	8.531(26)	100%	[2021Zh22, 2022Zh45, 2015De22, 2015WaZT, 2014WaZU]
^{216m} U	0.021(90)	0.000(38)	10.737(35)	100%	[ <b>2022Zh45</b> , 2021Zh22, 2016Zh33]

* Weighted average of 11.1(3)% [1993Wa04] and 12.2(6)% [1967Le08].

** Weighted average of 73(1)% [1993Wa04] and 70(2)% [1971Ho01].

*** Based on short half-life

## Table 3

direct  $\alpha$  emission from ¹⁸⁰W*,  $J_i^{\pi} = 0^+$ ,  $T_{1/2} = 1.8(2) \times 10^{18}$  y,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{176}\mathrm{Hf})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
2.5164(16)	2.4605(16)	100%	$0^+$	0.0		1.4631(61)	1.59(18)

* All values taken from [2004Co26].

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-u()	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\boldsymbol{\pi}}$	$E_{daughter}(^{196}\text{Pb})$	coincident γ-rays	R ₀ (fm)	HF
.983(2)	5.863(2)***	11.3(3)%**	$0^+$	0.0		1.4803(16)	1.007(28)
* [1970F ** Weig *** [199	Ra14]. hted average of 11.1( %Ta18].	(3)% [1993Wa04]	] and 12.2(6	5)% [1967Le08].			
<b>able 5</b> irect α emis	sion from ²⁰⁴ Rn, $J_i^{\pi}$	$= 0^+, T_{1/2} = 75(2)$	1) s*, <i>BR</i> α	= 72(1)%**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{200}\mathrm{Po})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
.5472(14)	6.4188(14)***	72(1)%**	$0^+$	0.0		1.5026(16)	1.014(20)
* Weigh ** Weig *** Weig	ted average of 74(2) s hted average of 73(1) ghted average of 6.42	s [1971Ho01] and )% [1993Wa04] a 20(2) MeV [1996	d 75(2) s [1 and 70(2)% Ta18], 6.41	967Va17]. [1971Ho01]. 89(25) MeV [1993Wa04	4] and 6.416(3) MeV [196	7Va17].	
<b>able 6</b> irect α emis	sion from ²⁰⁸ Ra*, $J_i^{\pi}$	$F = 0^+, T_{1/2} = 1.2$	$R(2)$ s, $BR_{\alpha}$	= obs**.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{204}\mathrm{Rn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
.273(5)	7.133(5)***	$pprox 100\%^{**}$	$0^+$	0.0		1.5029(36)	1.03(17)
** Not o	bserved, estimated to	b be $\approx 100\%$ base	ed on half-l	ife.			
** Not o F <b>able 7</b> lirect α emis	bserved, estimated to sion from ²¹² Th*, $J_i^{\pi}$	b be $\approx 100\%$ base $T = 0^+, T_{1/2} = 31$	ed on half-l .7(13) ms, <i>l</i>	ife. BR $_{\alpha} = \approx 100\%.$			
** Not o Fable 7 lirect $\alpha$ emis $\overline{C_{\alpha}(c.m.)}$	bserved, estimated to sion from ²¹² Th*, $J_i^{\pi}$ $E_{\alpha}(lab)$	b be $\approx 100\%$ base $\overline{T} = 0^+, T_{1/2} = 31$ $I_{\alpha}(abs)$	ed on half-l .7(13) ms, $I_f^{\pi}$	ife. $BR_{\alpha} = \approx 100\%.$ $E_{daughter}(^{208}\text{Ra})$	coincident γ-rays	R ₀ (fm)	HF
** Not o <b>Fable 7</b> lirect $\alpha$ emis $\overline{C}_{\alpha}(c.m.)$ 2.959(5)	bserved, estimated to sion from ²¹² Th*, $J_i^{\pi}$ $E_{\alpha}(lab)$ 7.809(5)	b be $\approx 100\%$ base $\overline{T} = 0^+, T_{1/2} = 31$ $I_{\alpha}(abs)$ $\approx 100\%$	ed on half-I .7(13) ms, $I$ $J_f^{\pi}$ $0^+$	ife. $BR_{\alpha} = \approx 100\%.$ $E_{daughter}(^{208}\text{Ra})$ 0.0	coincident γ-rays	R ₀ (fm) 1.5058(26)	HF 1.15(5)
** Not o <b>Fable 7</b> firect $\alpha$ emis $\overline{C_{\alpha}(\text{c.m.})}$ .959(5) * All val	bserved, estimated to sion from ²¹² Th*, $J_i^{\pi}$ $E_{\alpha}(1ab)$ 7.809(5) ues from [2010He25	b be $\approx 100\%$ base $\overline{I} = 0^+, T_{1/2} = 31$ $I_{\alpha}(abs)$ $\approx 100\%$ ].	ed on half-l .7(13) ms, $I$ $J_f^{\pi}$ $0^+$	ife. $BR_{\alpha} = \approx 100\%.$ $E_{daughter}(^{208}\text{Ra})$ 0.0	coincident γ-rays	R ₀ (fm) 1.5058(26)	HF 1.15(5)
** Not o Fable 7 lirect $\alpha$ emis $\mathcal{E}_{\alpha}(c.m.)$ 2.959(5) * All val Fable 8 lirect $\alpha$ emis	bserved, estimated to sion from ²¹² Th*, $J_i^{\pi}$ $E_{\alpha}(lab)$ 7.809(5) ues from [2010He25 sion from ²¹⁶ U*, $J_i^{\pi}$	b be $\approx 100\%$ base $I = 0^+, T_{1/2} = 31$ $I_{\alpha}(abs)$ $\approx 100\%$ i]. $I_{\alpha} = 0^+, T_{1/2} = 2.23$	ed on half-l .7(13) ms, $I_{f}^{\pi}$ 0 ⁺ $5_{0.40}^{+0.63}$ ms, $I_{f}^{-1}$	ife. $BR_{\alpha} = \approx 100\%.$ $E_{daughter}(^{208}\text{Ra})$ $0.0$ $BR_{\alpha} = 100\%.$	coincident γ-rays	R ₀ (fm) 1.5058(26)	HF 1.15(5)
** Not o <b>Fable 7</b> lirect $\alpha$ emis $E_{\alpha}(c.m.)$ 2.959(5) * All val <b>Fable 8</b> lirect $\alpha$ emis $E_{\alpha}(c.m.)$	bserved, estimated to sion from ²¹² Th*, $J_i^{\pi}$ $E_{\alpha}(lab)$ 7.809(5) ues from [2010He25 sion from ²¹⁶ U*, $J_i^{\pi}$ $E_{\alpha}(lab)$	b be $\approx 100\%$ base $I = 0^+, T_{1/2} = 31$ $I_{\alpha}(abs)$ $\approx 100\%$ ]. $I_{\alpha}(abs)$ $I_{\alpha}(abs)$	ed on half-I .7(13) ms, $I_{f}^{\pi}$ $0^{+}$ $5_{0.40}^{+0.63}$ ms, $I_{f}^{\pi}$	ife. $BR_{\alpha} = \approx 100\%.$ $E_{daughter}(^{208}\text{Ra})$ $0.0$ $BR_{\alpha} = 100\%.$ $E_{daughter}(^{212}\text{Th})$	coincident γ-rays —– coincident γ-rays	R ₀ (fm) 1.5058(26) R ₀ (fm)	HF 1.15(5) HF
** Not o Fable 7 lirect $\alpha$ emis $\overline{c}_{\alpha}(c.m.)$ * All val Fable 8 lirect $\alpha$ emis $\overline{c}_{\alpha}(c.m.)$ :.532(17)	bserved, estimated to sion from ²¹² Th*, $J_i^{\pi}$ $E_{\alpha}(lab)$ 7.809(5) ues from [2010He25 sion from ²¹⁶ U*, $J_i^{\pi}$ $E_{\alpha}(lab)$ 8.374(17)	b be $\approx 100\%$ base $I = 0^+, T_{1/2} = 31$ $I_{\alpha}(abs)$ $\approx 100\%$ ]. $I = 0^+, T_{1/2} = 2.25$ $I_{\alpha}(abs)$ 100%	ed on half-I .7(13)  ms, I $J_f^{\pi}$ $0^+$ $5_{0.40}^{+0.63} \text{ ms}, I$ $J_f^{\pi}$ $0^+$	ife. $BR_{\alpha} = \approx 100\%.$ $E_{daughter}(^{208}\text{Ra})$ $0.0$ $BR_{\alpha} = 100\%.$ $E_{daughter}(^{212}\text{Th})$ $0.0$	coincident γ-rays —— coincident γ-rays	R ₀ (fm) 1.5058(26) R ₀ (fm) 1.486(33)	HF 1.15(5) HF 0.48 ^{+0.14} _0.09
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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$  = +16 nuclei.

Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +16$ nuclei. J ^{$\pi$} values for ¹⁶⁶ Ho, ¹⁷⁰ Tm, ¹⁷⁴ Lu, ¹⁷⁸ Ta, ¹⁸² Re, ¹⁸⁶ Ir, ¹⁹⁰ Au, ¹⁹⁴ Tl ar	d
¹⁹⁸ Bi are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.	

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon_P}$	$Q_{\varepsilon \alpha}$	Experimental
¹⁶⁶ Ho*		0-	26.827(5) h	-1.854(1)			[1989Ab05]
¹⁷⁰ Tm** ¹⁷⁴ Lu		$1^{-}$ (1 ⁻ )	128.6(3) d 3 6(4) y	0.312(2) 1 374(2)	-8.288(20) -6.603(5)	2.787(1) 4 535(2)	[1968Re04] [1962Bo12]
¹⁷⁸ Ta		(1') 7 ⁻	2.45(5) h	1.840(50)#	-5.503(52)#	3.921(52)#	[1975Wa24]
¹⁸² Re		7+	64.3(5) h	2.800(100)	-4.296(102)	4.564(102)	[2011Bo01]
¹⁸⁰ Ir ¹⁹⁰ Au		$5^+$ 1 ⁻	16.64(3) h 42.8(10) m	3.828(17) 4.473(4)	-2.642(17) -1.673(13)	6.649(17) 7.742(4)	[1982AI34] [1973Jo11]
¹⁹⁴ Tl		2-	33.0(5) m	5.246(14)	-0.822(16)	7.944(14)	[2003Su30]
¹⁹⁸ Bi		$(2^+, 3^+)$	10.3(3) m	6.694(29)	1.691(31)	10.385(28)	[1982Hu04]
$^{202}At$ $^{202m1}At$	х	$(3^+)$ $(7^+)$	184(1) s 182(2) s	7.346(29) 7.346(29)+x	3.545(30) 3.545(30)+x	13.047(29) 13.047(29)+x	[1992Hu04] [1992Hu04]
^{202m2} At	0.3917(2) + x	$(10^{-})$	3.46(5) s	7.738(29)+x	3.937(30)+x	13.439(29)+x	[1992Hu04]
²⁰⁰ Fr ^{206m1} Fr	x	3(+) 7(+)	15.9(3) s*** 15.9(3) s***	7.886(29) 7.886(29)+x	4.449(30) 4.449(30)+x	14.270(29) 14.270(29)+x	[1981Ri04] [1981Ri04]
^{206m2} Fr	x + 0.531(7)	10(-)	0.7(1) s	8.417(30)+x	4.980(31)+x	14.801(30)+x	[2016Ly01, 1981Ri04]
²¹⁰ Ac ²¹⁴ Pa			350(50) ms 17(3) ms	8.320(60) 8.760(80)	5.257(63) 6.030(82)	15.472(63) 16.592(82)	[1968Va04] [2000He17, 1995Ni05, 1996An21]

* 100%  $\beta^-$  emitter.

*** 99.869(10)%  $\beta^-$ , 0.131(10)%  $\varepsilon$  emitter [2018Ba41]. *** Combination of T_{1/2} from ^{206gs}Fr and ^{206m1}Fr [1981Ri04].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +16$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
166110	6747(1)	15 542(2)	0.284(2)		
170	0.747(1)	13.343(2) 14.214(20)	0.364(2)		
174 m	0.103(1)	14.314(30)	0.850(1)		
174Lu	5.308(2)	12.775(6)	1.800(2)		
178Ta	5.007(52)#	11.794(52)#	2.547(52)#		
¹⁸² Re	4.50(10)	11.09(10)	2.73(12)#		
¹⁸⁶ Ir	3.655(17)	9.530(17)	3.850(10)		
¹⁹⁰ Au	3.653(11)	9.067(10)	3.914(17)	$< 1 \times 10^{-6}\%$	[1963Ka17]
¹⁹⁴ Tl	3.164(21)	8.743(21)	3.471(14)	$< 1  imes 10^{-7}\%$	[1963Ka17]
¹⁹⁸ Bi	1.917(28)	6.455(30)	5.139(31)		
²⁰² At	1.363(28)	4.802(36)	6.354(1)	9(1)%	[1992Hu04, 1975BaYJ, 1974Ho27, 2016Ly01, 1996Ta18,
					1970DaZM, 1967Tr04, 1967Tr06, 1963Ho18, 1961Fo04,
					1961La02]
^{202m1} At	1.363(28)	4.802(36)	6.354(1)	8.6(11)%*	[2016Lv01, 1996Ta18, 1992Hu04, 1975BaYJ, 1974Ho27,
	~ /	~ /	~ /		1970DaZM, 1967Tr04, 1967Tr06, 1963Ho18, 1961Fo04,
					1961La02]
^{202m2} At	1.363(28)	4.802(36)	6.354(1)	4.6(11)%	[2016Ly01, 1992Hu04]
²⁰⁶ Fr	0.826(28)	3.950(36)	6.923(3)	88.4(33)%	[2016Ly01, 1992Hu04, 1981Ri04, 2015Ma63, 2012Ly01
					1974Ho27, 1967Va20, 1964Gr04, 1961Gr42]
^{206m1} Fr	0.826(28)-x	3.950(36)-x	6.923(3)+x	84.7(15)%	[2016Ly01, 1992Hu04, 1981Ri04, 2015Ma63, 2012Ly01
					1974Ho27, 1967Va20, 1964Gr04, 1961Gr42]
^{206m2} Fr	0.295(29)-x	3.419(37)-x	7.436(8)+x	13(2)%	[2016Ly01, 1992Hu04, 1981Ri04, 2012Ly01]
²¹⁰ Ac	0.383(62)	3.149(63)	7.586(57)	$\approx 100\%^{**}$	[2000He17, 1968Va04, 2014Ya19, 1967Tr03]
²¹⁴ Pa	-0.051(82)	2.418(84)	8.271(52)	$\approx 100\%^{**}$	[2000He17, 1995Ni05, 1996An21, 1995NiZR, 1995NiZS]

* Weighted average of 8.5(15)% [2016Ly01] and 8.7(15)% [1992Hu04].

** Based on short half-life.

# Table 3

Table 5	
direct $\alpha$ emission from ²⁰² At, $J_i^{\pi} = (3^+)$ , T	$T_{1/2} = 184(1) \text{ s}^*, BR_{\alpha} = 9(1)\%^{**}.$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	Edaughter( ¹⁹⁸ Bi)	coincident $\gamma$ -rays	$R_0 \ (fm)^@$	HF
6.049(10)	5.929(10)*	≈0.04%	≈0.004%		0.425(10)		1.4915(23)	$\approx 220$
6.193(10)	6.070(10)*	$\approx 0.2\%$	$\approx 0.02\%$		0.161(10)		1.4915(23)	$\approx 670$
6.354(2)	6.228(2)***	100%	9(1)%	(3 ⁺ )	0.0		1.4915(23)	$6.5^{+0.9}_{-0.8}$
					2			0.0

* [1992Hu04]. ** [1974Ho27]. ***[1975BaYJ]. ** Interpolated between 1.4803(16) fm (²⁰⁰Po) and 1.5026(16) fm (²⁰⁴Rn).

# Table 4

direct $\alpha$ emi	ssion from ^{202m1} At	$J_{i}$ , Ex = unk., $J_{i}^{\pi} = (7)$	$(^+), T_{1/2} = 1$	$82(2) \text{ s}^*, BR_{\alpha} = 8.6(11)$	%**.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	Edaughter( ¹⁹⁸ Bi)	coincident γ-rays	$R_0 (fm)^@$	HF			
6.258(2)	6.134(2)***	8.6(11)%**	(7 ⁺ )	X		1.4915(23)	$2.7^{+0.5}_{-0.4}$			
* [1992] ** Weig *** Wei ** Inter	Hu04]. hted average of 8.3 ighted average of 6 polated between 1.	5(15)% [2016Ly01] .133(3) MeV [1996 4803(16) fm ( ²⁰⁰ Pc	and 8.7(15) (Ta18] and 6 () and 1.5026	% [1992Hu04]. .135(2) MeV [1975BaY 6(16) fm ( ²⁰⁴ Rn).	J].					
Table 5 direct $\alpha$ emis	ssion from ^{202m2} At	*, Ex = 391.7 keV	+ x, $J_i^{\pi} = (10)$	$T^{-}$ ), $T_{1/2} = 3.46(5)$ s, <i>BR</i>	$P_{\alpha} = 4.6(11)\%.$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	<i>E</i> _{daughter} ( ¹⁹⁸ Bi)	coincident $\gamma$ -rays	R ₀ (fm)**	HF			
6.404(5)	6.277(5)	4.6(11)%	(10 ⁻ )	0.249 + x		1.4915(23)	$0.39\substack{+0.13 \\ -0.08}$			
* All va ** Inter	lues from [1992Hu polated between 1.	04]. 4803(16) fm ( ²⁰⁰ Pc	o) and 1.5026	5(16) fm ( ²⁰⁴ Rn).						
<b>Table 6</b> direct $\alpha$ emission	ssion from ²⁰⁶ Fr, J _i	$T_{1/2}^{\pi} = 3(^+), T_{1/2} = 15$	.9(3) s*, <i>BR</i>	$\alpha = 88.4(33)\%^{**}.$						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{202}\text{At})$	coincident $\gamma$ -rays	$R_0 \left(fm\right)^@$	HF			
6.926(5)	6.792(5)***	88.4(33)%**	(3+)	0.0		1.5028(38)	$2.05\substack{+0.22\\-0.20}$			
* Comb ** [2010 *** Unr @ Interp Table 7	ination of $T_{1/2}$ from 6Ly01]. resolved doublet de polated between 1.5	m ^{206gs} Fr and ^{206m1} e-exciting the 3( ⁺ ) a 5026(16) fm ( ²⁰⁴ Rn	Fr [1981Ri0 and 7( ⁺ ) isor ) and 1.5029	4]. ners in ²⁰⁶ Fr [1992Hu04 (36) fm ( ²⁰⁸ Ra).	ŀJ.					
direct $\alpha$ emi	ssion from ^{206m1} Fr.	, Ex = unk., $J_i^{\pi} = 7($	$^{+}$ ), T _{1/2} = 15	$5.9(3)  \mathrm{s}^*$ , $BR_{\alpha} = 84.7(1)$	5)%**.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{202}\mathrm{At})$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF			
6.926(5)	6.792(5)***	84.7(15)%**	(7 ⁺ )	х		1.5028(38)	$2.16\substack{+0.22\\-0.20}$			
* Comb ** [2010 *** Uni @ Interp	* Combination of $T_{1/2}$ from ^{206gs} Fr and ^{206m1} Fr [1981Ri04]. ** [2016Ly01]. *** Unresolved doublet de-exciting the 3( ⁺ ) and 7( ⁺ ) isomers in ²⁰⁶ Fr [1992Hu04]. @ Interpolated between 1.5026(16) fm ( ²⁰⁴ Rn) and 1.5029(36) fm ( ²⁰⁸ Ra).									
Table 8 direct $\alpha$ emission	ssion from ^{206m2} Fr	Ex = 531(7)  keV	+ x, $J_i^{\pi} = 10($	⁻ ), $T_{1/2} = 0.7(1) s^*$ , <i>BR</i>	$\alpha = 13(2)\%^{**}.$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{202}\mathrm{At})$	coincident γ-rays	R ₀ (fm) [@]	HF			
7.067(5)	6.930(5)	13(2)%**	(10 ⁻ )	0.531(7) + x	0.531	1.5028(38)	$2.0^{+0.8}_{-0.6}$			
* [1981] ** [2016 *** [199	Ri04]. 6Ly01]. 92Hu04].									

^(a) Interpolated between 1.5026(16) fm ( 204 Rn) and 1.5029(36) fm ( 208 Ra).

direct $\alpha$ emission from ²¹⁰ Ac*, T _{1/2} = 350(50) ms, $BR_{\alpha} = \approx 100\%$ .												
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{206}\mathrm{Fr})$	coincident γ-rays	$R_0 (fm)^@$	HF					
7.607(8)	7.462(8)	pprox 100%			_	1.5044(44)	1.81(33)					
* All Val ** Interp <b>Table 10</b> direct α emiss	* All Values from [1968Va04]. ** Interpolated between 1.5029(36) fm ( ²⁰⁸ Ra) and 1.5058(26) fm ( ²¹² Th). <b>Table 10</b> direct $\alpha$ emission from ²¹⁴ Pa* T _{1 ($\alpha$} = 17(3) ms. $BR_{\alpha} = \approx 100\%$											
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{210}\mathrm{Ac})$	coincident γ-rays	$R_0 (fm)^@$	HF					
8.271(15)	8.116(15)	pprox 100%				1.496(33)	$1.4^{+1.5}_{-0.8}$					

* All values from [2000He17, 1996An21, 1995Ni02]. ** Interpolated between 1.5058(26) fm (²¹²Th) and 1.486(33) fm (²¹⁶U).

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Observed and predicted $\beta$ -delayed particle emission from the even-Z, $T_z = +33/2$ nuclei. J ^{$\pi$} values for ¹⁶⁹ Er, ¹⁷³ Yb, ¹⁷⁷ Hf, ¹⁸¹ W, ¹⁸⁵ Os, ¹⁸⁹ Pt, ¹⁹³ Hg, ¹⁹⁷ Pt	b and
²⁰¹ Po are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.	

Nuclide	Ex	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
169*		1/2-	0.26(4) 4	2 125(20)			[20048-04]
173 Vh		5/2-	9.30(4) u	-2.123(20) 1 205(4)			[20045004]
177116		312 7/2-	stable**	-1.293(4)			
181 337		//2 0/2 ⁺	120.05(2) 1	-0.49/(1)	5 742	1 725(2)	[1072] 402]
185 Q		9/2	120.95(2) d	0.205(2)	-5.745	1.725(2)	[19/3/NIy02] [2012X_05]
105 US		1/2	92.95(9) d	1.013(1)	-4.389(1)	3.208(2)	[2012Kr05]
¹⁸⁹ Pt		3/2-	10.87(12) h	1.980(14)	-2.621(10)	4.925(10)	[1964Le07]
¹⁹³ Hg		3/2-	3.80(15) h	2.343(14)	-2.063(16)	4.963(20)	[1974ViZS]
¹⁹⁷ Pb		3/2-	7.2(10) m***	3.609(14)	-0.208(6)	6.235(10)	[1980Hi04, 1979Ra04]
²⁰¹ Po		3/2-	15.8(3) m	4.908(13)	2.441(11)	9.408(14)	[1965Br17, 1967Le21]
^{201m} Po	0.4234(2)@	$13/2^{+}$	9(2) m	5.331(13)	2.864(11)	9.831(14)	[1965Br17, 1967Le21]
²⁰⁵ Rn		5/2-	170(4) s	5.275(13)	3.342(11)	11.294(13)	[1971Ho01]
²⁰⁹ Ra		5/2-	4.9(2) s ^{@@}	5.640(13)	4.225(12)	12.418(13)	[2008Ha12, 1967Va22]
²¹³ Th		5/2-	86(10) ms ^{@@@}	5.979(15)	5.030(14)	13.477(15)	[1980Ve01, 1968Va18]
²¹⁷ U			$15.6^{+21.3}_{-5.7}$ ms	5.920(80)#	5.383(81)#	14.405(81)#	[2000Ma65]
²²¹ Pu			-5.7	6.02(36)#	5.63(32)#	16.45(30)#	

* 100%  $\beta^-$  emitter.

**  $T_{1/2}$  reported as  $\geq 7.5 \times 10^{16}$  y [2020Ca15], due to non observation of  $\alpha$  decays from this nucleus. *** Weighted average of 10(2) m [1979Ra04] and 6.2(12) m [1980Hi04].

@ [2023Ko01].
@ Weighted average of 5.1(2) s [2008Ha12] and 4.7(2) s [1967Va22].
@ @ Weighted average of 80(10) ms [1980Ve01] and 125(25) ms [1968Va18].

# Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +33/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	Experimental
169	9 151(20)	15 599(4)	0.266(1)		
173 EF	8.151(30)	15.588(4)	0.200(1)		
175Yb	7.467(5)	14.411(1)	0.945		
¹⁷⁷ Hf	6.787(1)	12.763(1)	2.246(1)		
$^{181}W$	6.589(2)	12.349	2.222		
¹⁸⁵ Os	5.875(4)	11.018(1)	3.003(2)		
¹⁸⁹ Pt	5.413(14)	9.828(10)	3.912(10)		
¹⁹³ Hg	5.579(22)	9.942(16)	2.982(18)		
¹⁹⁷ Pb	4.538(13)	8.310(24)	3.892(16)		
²⁰¹ Po	3.440(23)	5.867(8)	5.799(2)	1.15(1)%	[1965Br17, 1967Le21, 1968Go12, 1993Wa04, 1986Br28,
					1970DaZM, 1970Jo26, 1970Ra14, 1967Le08, 1967Ti04,
					1967Tr04 1967Tr06 1963Ho18 1962Be26 1961Be25
					1961Fo05 1954Ro391
201mpo	3 440(23)	5 867(8)	5 700(2)	20(2)%	[1065Br17 1067Lo21 1068Co12 2015We13 1003Wo04
10	5.440(25)	5.807(8)	5.799(2)	2.9(2)70	$10960 \pm 29$ 10701 $\pm 26$ 10700 $\pm 14$ 10671 $\pm 0091$
205-					1980B128, 1970J020, 1970Ka14, 1907Le08]
²⁰⁵ Rn	3.123(23)	4.977(7)	6.386(2)	26(1)%*	[ <b>1993Wa04, 1971Ho01, 1967Va1</b> 7, 1971Jo19, 1967Va07,
					1965Nu04]
²⁰⁹ Ra	2.766(13)	4.085(7)	7.143(3)	$\approx 100\%^{**}$	[2003He06, 2008Ha12, 2001HeZY, 1997Mi03, 1968Lo15,
					1967Va22]
²¹³ Th	2.468(24)	3.290(10)	7.837(7)	100%**	[ <b>1980Ve01, 1968Va18</b> , 2000Ma65]
²¹⁷ U	2.142(84)	2.529(81)	8.426(80)	100%**	[2000Ma65, 2022Zh45, 2012WaZX, 2005Le42]
²²¹ Pu	1.83(30)#	1.94(30)#	10.53(31)#		

* Weighted average of 25(1)% [1993Wa04] and 35(3)% [1971Ho01].

** Based on half-life.

### Table 3

Table 5				
direct $\alpha$ emission	from ²⁰¹ Po, $J_i^{\pi}$ =	$= (3^{-}), T_{1/2} =$	15.8(3) m*, B	$R_{\alpha} = 1.15(1)\%^*$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{210}\mathrm{Ac})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.799(2)	5.684(2)	1.15(1)%*	(3-)	0.0		1.4762(18)	1.82(9)

* [1965Br17, 1967Le21]

** [1968Go12].

# Table 4

direct $\alpha$ emission from ²⁰¹ⁿ	Po, Ex. = $423.4(2)$ keV*	$J_i^{\pi} = (13^+), T_{1/2} = 9(2) r$	$m^{**}, BR_{\alpha} = 2.9(2)\%^{**}.$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{197}\mathrm{Pb})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF	
5.905(2)	5.787(2)	1.15(1)%*	(13 ⁺ )	0.3193(1)@	0.085, 0.234 [@]	1.4762(18)	1.29(31)	
* [2023] ** [196] *** [196] @ [2005]	Ko01]. 5Br17, 1967Le21 68Go12]. 5Hu03].	]						
Table 5 direct $\alpha$ emission	ssion from ²⁰⁵ Rn,	$J_i^{\pi} = (5^-), T_{1_i}$	$v_2 = 170(4) \text{ s*},$	$BR_{\alpha} = 26(1)\%^{**}.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{201}\text{Po})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
6.3855(25)	6.2609(25)	26(1)%	* (5 ⁻ )	0.00561(13)@	0.0056	1.4972(20)	1.23(8)	
* [1971] ** Weig *** [19 [@] α-trat <b>Table 6</b>	Ho01]. hted average of 2 93Wa04]. nsition assumed to	5(1)% [1993W	7a04] and 35(3) favored 5/2 ⁻ st	9% [1971Ho01]. ate in the ²⁰¹ Po daughter	r. Energy from [2023Ko	01].		
direct $\alpha$ emi	ssion from ²⁰⁹ Ra,	$J_i^{\pi} = (5^-), T_{1/2}$	$t_2 = 4.9(2) \text{ s}^*, I$	$BR_{\alpha} = \approx 100\%.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$ J	$E_{f}^{\pi} = E_{daughter} (^{205} \text{Rn})$	) coincident $\gamma$ -rays	$R_0$ (fm)	HF	
6.500(5) 6.754(5)) 7.140(10)	6.376(5)** 6.625(5)** 7.003(10)**	0.2% 0.5% 100%	$\approx 0.2\%$ $\approx 0.5\%$ $\approx 99.3\%$ (	5 ⁻ )	0.6337(11) 0.3870(5) 0.0	0.6337(11) 0.3870(5)	1.4945(33) 1.4945(33) 1.4945(33)	$\approx 2.2$ $\approx 8.8$ $\approx 1.25$
* Weigh ** [200]	nted average of 5.3 3He06].	l(2) s [2008Ha	12] and 4.7(2)	s [1967Va22].				
<b>Table 7</b> direct $\alpha$ emised	ssion from ²¹³ Th,	$J_i^{\pi} = (5^-), T_{1/2}$	$m_2 = 86(10) \text{ ms}^3$	*, $BR_{\alpha} = 100\%$ .				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{209}\mathrm{Ra})$	coincident γ-rays	R ₀ (fm)	HF	
7.824(10)	7.684(10)	100%	(5 ⁻ )	0.0		1.5022(41)	0.99(16)	
* Weigh ** Weig	nted average of 80 shted average of 7	(10) ms [1980 .690(10) MeV	Ve01] and 125( [1968Va18] ar	(25) ms [1968Va18]. nd 7.677(10) MeV [1980	Ve01].			
<b>Table 8</b> direct $\alpha$ emised	ssion from ²¹⁷ U*	$J_i^{\pi} = (5^-), T_{1_i}$	$y_2 = 15.6^{+21.3}_{-5.7}$ r	ms, $BR_{\alpha} = 100\%$ .				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{213}\mathrm{Th})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
8.155(20)	8.005(20)	100%	(5 ⁻ )	0.0		1.499(24)	$0.37^{+0.53}_{-0.21}$ **	

* All values from [2000Ma65].

** The unphysically low HF value may suggest that the half-life is longer than reported. A  $T_{1/2}$  of 42 ms at this energy gives a HF of 1.0.

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$  = +33/2 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_{z} = +33/2$  nuclei. J^{$\pi$} values for ¹⁷¹Tm, ¹⁷⁵Lu, ¹⁷⁹Ta, ¹⁸³Re, ¹⁸⁷Ir, ¹⁹¹Au, ¹⁹⁵Tl and ¹⁹⁹Bi are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon_P}$	$Q_{\mathcal{E} \alpha}$	Experimental
¹⁷¹ Tm*	1/2+	1 92(1) v	-1 492(1)			[ <b>1965F]02</b> ]
¹⁷⁵ Lu	$7/2^+$	stable	-0.470(1)			
¹⁷⁹ Ta	$7/2^+$	588(10) d	0.106(1)	-7.309(2)	1.913(1)	[1974Ch53]
¹⁸³ Re	5/2+	69.0(19) d**	0.556(8)	-6.668(8)	2.228(8)	[1958Fo47, 1958Ga17]
¹⁸⁷ Ir	3/2+	10.5(3) h	1.670(28)	-4.911(28)	4.391(28)	[1963Em02]
¹⁹¹ Au	3/2+	31.8(8) h	1.900(6)	-4.333(5)	4.996(5)	[1967Jo06]
¹⁹⁵ Tl	$1/2^{+}$	1.16(5) h	2.858(26)	-3.232(11)	5.118(12)	[ <b>1961Ju06</b> ]
¹⁹⁹ Bi	9/2-	27(1) m	4.434(13)	-0.558(13)	7.791(25)	[1964Si11]
²⁰³ At	9/2-	7.4(3) m	5.148(12)	1.299(18)	10.644(13)	[1961La02]
²⁰⁷ Fr	9/2-	14.9(1) s	5.786(18)	2.301(22)	12.037(18)	[ <b>1981Ri04</b> ]
²¹¹ Ac	(9/2-)	229(25) ms***	6.310(50)	3.198(55)	13.353(54)	[2000He17, 1968Va04]
²¹⁵ Pa	$(9/2^{-})$	14(2) ms	6.880(80)	4.082(84)	14.548(83)	[2000He17]
²¹⁹ Np	$(9/2^{-})$	$150^{+720}_{-70} \ \mu s$	6.140(90)	3.498(94)	16.091(92)	[2018Ya01]
²²³ Am		$5.2^{+12.0}_{-4.4}$ ms	6.58(42)#	4.14(30)#	16.98(30)#	[2105De22]

* 100%  $\beta^-$  emitter.

** Weighted average of 67.6(25) d [1958Fo47] and 71(3) d [1958Ga17].

*** Weighted average of 200(29) ms [2000He17], and 250(25) ms [1968Va04].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +33/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	S _p	$S_{2p}$	Qα	BR _α	Experimental
¹⁷¹ Tm ¹⁷⁵ Lu ¹⁷⁹ Ta ¹⁸³ Re	6.392(1) 5.510(1) 5.211(0) 4.852(8)	14.992(20) 13.488(5) 12.551(1) 11.949(8)	0.644(5) 1.620(2) 2.383(1) 2.123(8)		
^{18/} Ir	3.838(28)	10.308(28)	3.835(29)		
¹⁹⁵ Tl ¹⁹⁹ Bi ²⁰³ At	3.780(5) 3.260(11) 2.019(14) 1.510(14)	9.926(14) 9.328(14) 7.021(17) 5.312(16)	3.327(28) 3.218(12) 4.933(7) 6.210(1)	27(3)%*	[1998B014, 1996Ta18, 1975BaYJ, 1974H027, 1968G012, 1967Tr06, 1963H018, 1986W003, 1983SeZQ, 1970DaZM,
207 5	1.005(20)	4.440(01)	( 001/2)**	05/22/01 ***	1967Tr04, 1961Fo04, 1956Bu12, 1951Ba04]
²⁰⁷ Fr ²¹¹ Ac ²¹⁵ Pa	0.588(55) 0.180(80)	4.442(21) 3.652(55) 2.910(80)	6.901(3)** 7.624(6) [@] 8.241(7) ^{@@@}	$95(3)\%^{***} \approx 100\%^{@@}$ 100%	[1981K04, 1974H027, 1967Va20, 1964Gr04, 1961Gr42] [2000He17, 1968Va04, 2014Ya19] [2000He17, 1996An21, 1979Sc09, 2018Ya01, 1997Mi03,] 1095Ni7S1
²¹⁹ Np ²²³ Am	-0.253(93) -0.35(42)#	2.196(93) 1.79(36)#	9.207(41) 10.84(31)#	100%	[2018Ya01, 2015De22] [2015De22]

* Weighted average of 22(3)% [1998Bo14] and 31(3)% [1974Ho27].

** Deduced from  $\alpha$  energy, 6.889(20) MeV in [2021Wa16].

*** Weighted average of  $97^{+2}_{-3}$ % [1981Ri04] and 93(3)% [1974Ho27].

[@] Deduced from  $\alpha$  energy, 7.568(52) MeV in [2021Wa16].

^e[@] Based on half-life. [@][@][@] Deduced from  $\alpha$  energy, 8.240(60) MeV in [2021Wa16].

#### Table 3

direct $\alpha$ emission from ²⁰³ At, $J_{i}^{\mu} = (9/2^{-})$ , $T_{1/2} = 7.4(3)$ m [*] , $BR_{\alpha} = 27(3)$	)%**
----------------------------------------------------------------------------------------------------------------------------------------	------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{199}\mathrm{Bi})$	coincident $\gamma$ -rays	$R_0 \ (fm)^@$	HF	
6.210(1)	6.088(1)***	27(3)%**	(9/2-)	0.0		1.4873(17)	$1.24^{+0.22}_{-0.18}$	

* [1961La02].

** Weighted average of 22(3)% [1998Bo14] and 31(3)% [1974Ho27].

*** Weighted average of 6.088(2) MeV [1996Ta18], 6.089(3) MeV [1975BaYJ], 6.087(2) MeV [1968Go128], 6.086(3) MeV [19Tr06], and 6.085(1) MeV [1963Ho18] (adjusted to 6.088(1) in [1991Ry01].

Table 4 direct $\alpha$ emi	ssion from ²⁰⁷ Fr, J	$T_i^{\pi} = 9/2^-, T_{1/2} =$	= 14.9(1) s*, <i>B</i>	$R_{\alpha} = 95(3)\%^{**}.$			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi}$	$E_{daughter}(^{203}\mathrm{At})$	coincident γ-rays	$R_0 (fm)^@$	HF
6.901(3)	6.768(3)***	95(3)%**	9/2-	0.0		1.4973(32)	1.36(11)
* [1981 ** Weig *** Wei 6.766(5) Me	Ri04]. ghted average of 97 ighted average of 6 V [1967Va20] (adj	⁴⁺² % [1981Ri04 5.773(5) MeV [1 usted to 6.767(5	] and 93(3)% 967Va20] (ad ) in [1991Ry(	[1974Ho27]. justed to 6.774(5) in [19 )1],	991Ry01], 6.761(5) MeV	[1967Va20] (adju	usted to 6.762(5) in [1991Ry01], and
Table 5direct $\alpha$ emi	ssion from ²¹¹ Ac,	$\mathbf{J}_i^{\pi} = (9/2^-),  \mathbf{T}_{1/2}$	$_2 = 229(25) \text{ m}$	s*, $BR_{\alpha} = \approx 100\%$ .			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{207}\mathrm{Fr})$	coincident $\gamma$ -rays	$R_0 \; (fm)^@$	HF
7.624(6)	7.477(6)**	pprox 100%	(9/2-)	0.0		1.4960(28)	1.18(16)
* Weigh ** Weig	nted average of 200 ghted average of 7.	)(29) ms [2000H 472(10) MeV [2	[e17], and 250 000He17] and	(25) ms [1968Va04]. 1 7.480(8) MeV [1968V	a04].		
Table 6 direct $\alpha$ emi	ssion from ²¹⁵ Pa, J	$T_i^{\pi} = (9/2^-), T_{1/2}$	$s = 14(2) \text{ ms}^*,$	$BR_{\alpha} = 100\%.$			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{211}\mathrm{Ac})$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF
8.241(7)	8.088(7)**	27(3)%**	(9/2-)	0.0		1.557(16)	$1.1\substack{+0.6\\-0.4}$
* [2000 ** Weig	He17]. ghted average of 8.	091(15) MeV [2	000He17], 8.0	)88(10) MeV [1996An2	21], and 8.085(15) MeV [	1979Sc09].	
Table 7 direct $\alpha$ emi	ssion from ²¹⁹ Np*	$J_i^{\pi} = (9/2^-), T_1$	$_{/2} = 150^{+720}_{-70}$	$\mu$ s, $BR_{\alpha} = 100\%$ .			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi}$	$E_{daughter}(^{215}\mathrm{Pa})$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF
9.207(40)	9.039(40)	100%	(9/2-)	0.0		1.492(19)	$4.9^{+23.1}_{-2.9}$

* All values from [2018Ya01].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +17 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +17$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	Ex.	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
			/		*		
¹⁷⁰ Er		$0^+$	$\geq 4.1 \times 10^{+15} \text{ y}$	-3.870(50)			[2018Be25]
¹⁷⁴ Yb		$0^{+}$	stable	-3.080(40)			
¹⁷⁸ Hf		$0^{+}$	stable	-2.098(2)			
$^{182}W$		$0^+$	stable	-1.816(2)			
¹⁸⁶ Os		$0^+$	$2.0(11) \times 10^{+15} \text{ y}$	-1.073(1)			[1975Vi01]
¹⁹⁰ Pt		$0^{+}$	$6.65(28) \times 10^{11} \text{ y}$	-0.553(1)			[2011Be08]
¹⁹⁴ Hg		$0^+$	447(28) y	0.028(4)	-4.993(3)	2.145(3)	[2015Do01]
¹⁹⁸ Pb		$0^+$	2.4(1) h	1.461(12)	-2.816(9)	3.720(9)	[1959Ju39]
²⁰² Po		$0^+$	45.4(2) m	2.809(16)	0.040(16)	7.162(11)	[1970Ra14]
²⁰⁶ Rn		$0^+$	6.29(10) m*	3.306(16)	1.100(13)	9.193(16)	[1969Ha03, 1967Va17]
²¹⁰ Ra		$0^{+}$	3.7(2) s**	3.786(16)	2.095(14)	10.457(16)	[1968Lo15, 1967Va22]
²¹⁴ Th		$0^+$	$113^{+11}_{-9}$ ms	4.262(17)	3.060(14)	11.614(17)	[2022Zh45]
²¹⁸ U		$0^+$	$650^{+80}_{-70} \ \mu s$	3.245(23)	2.400(17)	13.036(19)	[2022Zh45]
218m U	2.112(14)	$8^+$	$390^{+60}_{50}$ µs	5.357(27)	4.512(22)	15.148(24)	[2022Zh45]
²²² Pu		$0^+$	-50 (	3.79(30)#	3.25(31)#	13.99(30)#	

* Weighted average of 5.67(17) m [1969Ha03] and 6.5(1) m [1967Va17].

* Weighted average of 3.8(2) s [1967Va22] and 3.6(2) s [1968Lo15].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +17$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
¹⁷⁰ Er	8.600(20)	16.13(14)	0.052(2)		
¹⁷⁴ Yb	7.977(4)	15 040(4)	0.738(1)		
¹⁷⁸ Hf	7.340(1)	13.522(1)	2.084(1)		
$^{182}W$	7.096(2)	13.045(2)	1.764(2)		
¹⁸⁶ Os	6.470(1)	11.873(1)	2.821(1)	100%	[ <b>1975Vi01</b> , 2020Be23, 1973ViZL]
¹⁹⁰ Pt	6.146(13)	10.747(1)	3.269(1)	100%	[2011Be08, 1987AI28, 2017Br04, 1997Ta33, 1986AIZT, 1966Ka23, 1961Ma05, 1963Gr08, 1961Gr37, 1961Ma05, 1961Pe23, 1956Pe16, 1954Po24, 1953Pe01]
¹⁹⁴ Hg	6.068(9)	10.473(4)	2.698(3)		, ,
¹⁹⁸ Pb	5.002(16)	8.819(9)	3.692(9)		
²⁰² Po	3.802(15)	6.269(13)	5.701(2)	1.93(6)%*	[ <b>1993Wa04, 1970Jo26, 1970Ra14, 1968Go12, 1967Le08,</b> <b>1967Ti10, 1967Tr06</b> , 1992WaZV, 1971Ho01, 1969Ha03, 1967Le21, 1967Tr04, 1965Br17, 1965Br27, 1964Br23, 1963Ho10, 1962Ax02, 1961Ax02, 1961Be25, 1961Fo05, 1954Ro39, 1951Ka14]
²⁰⁶ Rn	3.437(15)	5.370(13)	6.384(2)	62(3)%	[ <b>1993Wa04, 1971Go35, 1971Ho01, 1969Ha03, 1967Va17</b> , 2014Ma66, 1992WaZV, 1967Va07, 1965Nu04, 1957St10, 1954Bu67]
²¹⁰ Ra	3.064(15)	4.480(14)	7.151(3)	$\approx 100\%^{**}$	[ <b>2003He06</b> , <b>1967Va22</b> , 2015Ma37, 2001HeZY, 1997Mi03, 1968Lo15]
²¹⁴ Th	2.735(16)	3.684(15)	7.827(5)	100%	[ <b>2022Zh45</b> , <b>1980Ve01</b> , <b>1968Va18</b> , 2005Li17, 1984Sc13, 1968Va10]
²¹⁸ U	2.449(19)	2.982(18)	8.775(9)	100%	[ <b>2022Zh45</b> , <b>2021Zh22</b> , <b>2005Le42</b> , 2015Ma37, 2007Le14, 2006LeZR, 1994ApZY, 1994Ye08]
218m U	0.337(23)	0.870(24)	10.887(17)	100%	[ <b>2022Zh45, 2005Le42</b> , 2021Zh22, 2015Ma37, 2007Le14, 2006LeZR]
²²² Pu	2.14(36)#	2.53(32)#	10.74(30)#		

* Weighted average of 1.92(7)% [1993Wa04] and 2.00(15)% [1967Le08].

** Based half-life.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{182}W)$	coincident y	-rays	$R_{0}\left(fm\right)]$	HF	
≈2.82	≈2.76	100%	$0^+$	0.0	_		1.486(29)	1.0(5)	
* All va	alues taken from [1	975Vi01].							
<b>able 4</b> lirect $\alpha$ emi	ission from ¹⁹⁰ Pt, J	$T_i^{\pi} = 0^+, T_{1/2} = 6.5$	$5(3) \times 10^{11} \text{ y}^*,$	$BR_{\alpha} = 100\%.$					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\boldsymbol{\pi}}$	$E_{daughter}(^{186}\mathrm{Os})$	coinciden	t γ-rays	R ₀ (fm)]	HF
3.122 3.258	3.053** 3.190(10)	0.25(10)% 100%	0.25(10)%** 99.75(10)%**	$*    2^+    0^+$	0.137 0.0	0.137		1.486(29) 1.486(29)	$13^{+8}_{-4} \\ 1.04(4)$
* [2017 ** α w	'Br04]. as not observed, th	e decay branch wa	as determined t	hrough the obser	vation of 137-keV γ	ray from ¹⁹⁰ 1	Pt decay [201]	1Be08].	
f <b>able 5</b> lirect α emi	ission from ²⁰² Po,	$\mathbf{J}_i^{\pi} = 0^+,  \mathbf{T}_{1/2} = 43$	5.4(2) m*, $BR_{\alpha}$	= 1.93(6)%**.					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{198}\mathrm{Pb})$	coincident γ	'-rays	R ₀ (fm)]	HF	
5.701(1)	5.588(1)***	100%	$0^+$	0.0			1.4720(20)	1.013(32)	
* [1970 ** Weig *** We 5.587(5) Me	PRa14]. ghted average of 1. eighted average of eV [1967Ti10] and	92(7)% [1993Wat 5.589(3) MeV [ 5.578(3) MeV [19	04] and 2.00(15 1970Ra14] (adj 970Ra14] (adju	(i)% [1967Le08]. (usted to 5.588( (isted to 5.579(5))	3) MeV in [1991Ry( MeV in [1991Ry01]	01]), 5.590(5 ).	) MeV [1970	Jo26], 5.588(2)	MeV [1968C
* [1970 ** Weig *** We 5.587(5) Me <b>Γable 6</b> lirect α emi	Ra14]. ghted average of 1. eighted average of eV [1967Ti10] and ission from ²⁰⁶ Rn,	92(7)% [1993Wat 5.589(3) MeV [15 5.578(3) MeV [19 $J_i^{\pi} = 0^+, T_{1/2} = 6$	04] and 2.00(15 1970Ra14] (adj 970Ra14] (adju 29(10) m*, <i>BR</i>	(i)% [1967Le08]. insted to 5.588(2) sted to 5.579(5) $t_{\alpha} = 62(3)\%^{**}.$	3) MeV in [1991Ry( MeV in [1991Ry01]	01]), 5.590(5 ).	) MeV [1970	Jo26], 5.588(2)	MeV [1968C
* [1970 ** Wei ** Wei 5.587(5) Me 5.587(5) Me fable 6 lirect $\alpha$ emi	PRa14]. ghted average of 1. eighted average of $V$ [1967Ti10] and ission from ²⁰⁶ Rn, $E_{\alpha}$ (lab)	92(7)% [1993Wat 5.589(3) MeV [ 5.578(3) MeV [19 $J_i^{\pi} = 0^+, T_{1/2} = 6$ $I_{\alpha}$ (abs	D4] and 2.00(15 1970Ra14] (adj 970Ra14] (adju .29(10) m*, <i>BR</i> ) $J_f^{\pi}$	(i)% [1967Le08]. isusted to 5.588(2) sted to 5.579(5) $f_{\alpha} = 62(3)\%^{**}.$ $E_{daughter}(^{202}$	3) MeV in [1991Ry( MeV in [1991Ry01] Po) coincide	01]), 5.590(5 ). nt γ-rays	) MeV [1970 R ₀ (fm)]	Jo26], 5.588(2) HF	MeV [1968C
* [1970 ** Weig *** Weig *** Weig 5.587(5) Me 5.587(5) Me Fable 6 firect $\alpha$ emin $E_{\alpha}(c.m.)$ 5.3836(16)	PRa14]. ghted average of 1. eighted average of 2. (1967Ti10] and ission from 206 Rn, $E_{\alpha}$ (lab) 6.2597(16) ³	92(7)% [1993Wat 5.589(3) MeV [19 5.578(3) MeV [19 $J_i^{\pi} = 0^+, T_{1/2} = 6$ $I_{\alpha}$ (abs	04] and 2.00(15 1970Ra14] (adj 970Ra14] (adju .29(10) m*, <i>BR</i> ) $J_f^{\pi}$ 0 ⁺	(i)% [1967Le08]. insted to 5.588(2) sted to 5.579(5) $d\alpha = 62(3)\%^{**}.$ $E_{daughter}(^{202})$ 0.0	3) MeV in [1991Ry( MeV in [1991Ry01] Po) coincide	01]), 5.590(5 ). nt γ-rays	) MeV [1970 R ₀ (fm)] 1.4917(27	Jo26], 5.588(2) <u>HF</u> ) 1.11(6)	MeV [1968C
* [1970 ** Weig *** Weig 5.587(5) Me 5.587(5) Me firect $\alpha$ emi $E_{\alpha}(c.m.)$ 5.3836(16) * Weig ** [197 *** We	PRa14]. ghted average of 1. eighted average of 2. (1967Ti10] and ission from 206 Rn, $E_{\alpha}$ (lab) 6.2597(16) ² hted average of 5.6 (1Ho01]. eighted average of 6.6	92(7)% [1993Wat 5.589(3) MeV [19 5.578(3) MeV [19 $J_i^{\pi} = 0^+, T_{1/2} = 6$ $I_{\alpha}$ (abs *** 100% 7(17) m [1969Hat 5.2606(25) MeV [	D4] and 2.00(15 1970Ra14] (adj 970Ra14] (adju .29(10) m*, <i>BR</i> ) $J_f^{\pi}$ 0 ⁺ D3] and 6.5(1) n 1993Wa04], 6.2	(i)% [1967Le08]. iusted to 5.588(3 sted to 5.579(5) $b_{\alpha} = 62(3)\%^{**}.$ $E_{daughter}(^{202})$ 0.0 n [1967Va17]. 260(3) MeV [19]	<ol> <li>MeV in [1991Ry( MeV in [1991Ry01]</li> <li>coincide</li> <li><u>coincide</u></li> <li><u>coincide</u></li> </ol>	01]), 5.590(5 ). nt γ-rays	) MeV [1970 R ₀ (fm)] 1.4917(27 7Va17].	Jo26], 5.588(2) HF ) 1.11(6)	MeV [1968C
* [1970 ** Weig *** Weig 5.587(5) Me 5.587(5) Me fable 6 direct $\alpha$ emi 6.3836(16) * Weigl ** [197 *** We Fable 7 direct $\alpha$ emi	PRa14]. ghted average of 1. zighted average of 1. zighted average of 1. zighted average of 2. $E_{\alpha}(lab)$ $6.2597(16)^{2}$ hted average of 5.6 '1Ho01]. zighted average of 6 ission from ²¹⁰ Ra,	92(7)% [1993Wat 5.589(3) MeV [19 5.578(3) MeV [19 $J_i^{\pi} = 0^+, T_{1/2} = 6$ $I_{\alpha}$ (abs *** 100% 7(17) m [1969Hat 5.2606(25) MeV [ $J_i^{\pi} = 0^+, T_{1/2} = 3$	24] and 2.00(15 1970Ra14] (adj 970Ra14] (adju .29(10) m*, <i>BR</i> ) $J_f^{\pi}$ 0 ⁺ 03] and 6.5(1) π 1993Wa04], 6.2 .7(2) s*, <i>BR</i> _α =	i)% [1967Le08]. iusted to 5.588(3 sted to 5.579(5) $\frac{a}{\alpha} = 62(3)\%^{**}.$ $E_{daughter}(^{203})$ 0.0 n [1967Va17]. 260(3) MeV [197] ≈ 100%.	<ul> <li>3) MeV in [1991Ry0</li> <li>MeV in [1991Ry01]</li> <li>Po) coincide</li> <li>Po) coincide</li> <li>71Go35] and 6.258(3)</li> </ul>	01]), 5.590(5 ). nt γ-rays	) MeV [1970 <u>R₀ (fm)]</u> 1.4917(27 7Va17].	Jo26], 5.588(2) HF ) 1.11(6)	MeV [1968C
* [1970 ** Weig *** We 5.587(5) Me 5.587(5) Me fable 6 lirect $\alpha$ emi 5.3836(16) * Weigl ** [197 *** We fable 7 lirect $\alpha$ emi $E_{\alpha}(c.m.)$	PRa14]. ghted average of 1. zighted average of 1. zighted average of 1. ission from ²⁰⁶ Rn, $E_{\alpha}(lab)$ 6.2597(16) ² hted average of 5.6 '1Ho01]. zighted average of 6 ission from ²¹⁰ Ra, $E_{\alpha}(lab)$	92(7)% [1993Wat 5.589(3) MeV [1 5.578(3) MeV [1 $J_i^{\pi} = 0^+, T_{1/2} = 6$ $I_{\alpha}$ (abs *** 100% 7(17) m [1969Hat 5.2606(25) MeV [ $J_i^{\pi} = 0^+, T_{1/2} = 3$ $I_{\alpha}$ (abs)	$\begin{array}{c} 204] \text{ and } 2.00(15)\\ 1970Ra14] (adj)\\ 970Ra14] (adj)\\ 2970Ra14] (adj)\\ (2970Ra14] (adj)\\ (2970Ra14) (adj)\\ (29$	i)% [1967Le08]. iusted to 5.588(3 sted to 5.579(5) $\frac{i\alpha}{\alpha} = 62(3)\%^{**}.$ $E_{daughter}(^{203})$ 0.0 n [1967Va17]. 260(3) MeV [19] ≈ 100%. $E_{daughter}(^{206}Rn$	<ul> <li>3) MeV in [1991Ry0</li> <li>MeV in [1991Ry01]</li> <li>Po) coincide</li> <li>Po) coincide</li> <li>71Go35] and 6.258(3</li> <li>) coincident</li> </ul>	01]), 5.590(5 ). nt γ-rays 6) MeV [1967 γ-rays	) MeV [1970 R ₀ (fm)] 1.4917(27 Va17]. R ₀ (fm)]	Jo26], 5.588(2) HF ) 1.11(6) HF	MeV [1968C
* [1970 ** Weig *** We 5.587(5) Me 5.587(5) Me 6.100 fable 6 lirect $\alpha$ emi 5.3836(16) * Weigl ** [197 *** We fable 7 lirect $\alpha$ emi 5.26(c.m.)	PRa14]. ghted average of 1. eighted average of 1. eighted average of 1. eighted average of 206 Rn, E_{\alpha}(lab) 6.2597(16) ² hted average of 5.6 (1Ho01]. eighted average of 6 ission from ²¹⁰ Ra, E_{\alpha}(lab) 7.015(5)**	92(7)% [1993Wat 5.589(3) MeV [15 5.578(3) MeV [19 $J_i^{\pi} = 0^+, T_{1/2} = 6$ $I_{\alpha}$ (abs *** 100% 7(17) m [1969Hat 5.2606(25) MeV [ $J_i^{\pi} = 0^+, T_{1/2} = 3$ $I_{\alpha}$ (abs) 100%	$\begin{array}{c} 0.41 \text{ and } 2.00(15) \\ 1970Ra141 (adju) \\ 1970Ra141 (adju) \\ 1970Ra141 (adju) \\ 100000000000000000000000000000000000$	i)% [1967Le08]. iusted to 5.588(3 sted to 5.579(5) $\frac{i_{\alpha}}{i_{\alpha}} = 62(3)\%^{**}.$ $E_{daughter}(^{203})$ 0.0 m [1967Va17]. 260(3) MeV [19] ≈ 100%. $E_{daughter}(^{206}Rn)$ 0.0	<ul> <li>3) MeV in [1991Ry0]</li> <li>MeV in [1991Ry01]</li> <li>Po) coincide</li> <li></li> <li>71Go35] and 6.258(3</li> <li>) coincident</li> </ul>	01]), 5.590(5 ). nt γ-rays 6) MeV [1967 γ-rays	) MeV [1970 <u>R₀ (fm)]</u> 1.4917(27 /Va17]. <u>R₀ (fm)]</u> 1.4861(29)	Jo26], 5.588(2) HF ) 1.11(6) HF 0.90(5)	MeV [1968C
* [1970 ** Weig *** Weig 5.587(5) Me 5.587(5) Me 6.3836(16) * Weig ** [197 *** We <b>Table 7</b> direct $\alpha$ emi $E_{\alpha}(c.m.)$ 7.151(5) * Weig ** Weig	PRa14]. ghted average of 1. zighted average of 1. zighted average of 1. zighted average of 1. ission from ²⁰⁶ Rn, $E_{\alpha}(lab)$ 6.2597(16) ² hted average of 5.6 (1Ho01]. zighted average of 6 ission from ²¹⁰ Ra, $E_{\alpha}(lab)$ 7.015(5)** hted average of 3.8 ghted average of 7.	92(7)% [1993Wat 5.589(3) MeV [15 5.578(3) MeV [19 $J_i^{\pi} = 0^+, T_{1/2} = 6$ $I_{\alpha}$ (abs *** 100% 7(17) m [1969Hat 5.2606(25) MeV [ $J_i^{\pi} = 0^+, T_{1/2} = 3$ $I_{\alpha}$ (abs) 100% (2) s [1967Va22] 003(10) MeV [20	$\begin{array}{c} 0.41 \text{ and } 2.00(15) \\ 1970Ra141 (adju) \\ 1970Ra141 (adju) \\ 1970Ra141 (adju) \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000 \\ 1000$	i)% [1967Le08]. iusted to 5.588(3 sted to 5.579(5) $\frac{i_{\alpha}}{i_{\alpha}} = 62(3)\%^{**}.$ $E_{daughter}(^{202})$ 0.0 n [1967Va17]. 260(3) MeV [19] ≈ 100%. $E_{daughter}(^{206}$ Rn 0.0 068Lo15]. 018(5) MeV [19]	<ul> <li>3) MeV in [1991Ry0] MeV in [1991Ry01]</li> <li>Po) coincide</li> <li>Po) coincide</li> <li>71Go35] and 6.258(3</li> <li>coincident</li> <li>coincident</li> <li>0</li> </ul>	01]), 5.590(5 ). nt γ-rays 6) MeV [1967 γ-rays	) MeV [1970 <u>R₀ (fm)]</u> 1.4917(27 /Va17]. <u>R₀ (fm)]</u> 1.4861(29)	Jo26], 5.588(2) HF ) 1.11(6) HF 0.90(5)	MeV [1968C
* [1970 ** Weig *** Weig 5.587(5) Me 5.587(5) Me 5.587(5) Me 6.3836(16) * Weig ** [197 *** We Table 7 direct $\alpha$ emi $E_{\alpha}(c.m.)$ 7.151(5) * Weig ** Weig table 8 direct $\alpha$ emi	PRa14]. ghted average of 1. zighted average of 1. zighted average of 1. zighted average of 1. ission from ²⁰⁶ Rn, $E_{\alpha}(lab)$ 6.2597(16) ² hted average of 5.6 (1Ho01]. zighted average of 6.6 (1Ho01]. zighted average of 6.6 (1Ho01]. zighted average of 5.6 (1Ho01]. zighted average of 7. average	92(7)% [1993Wat 5.589(3) MeV [15 5.578(3) MeV [15 $J_i^{\pi} = 0^+, T_{1/2} = 6$ $I_{\alpha}$ (abs *** 100% 7(17) m [1969Hat 5.2606(25) MeV [ $J_i^{\pi} = 0^+, T_{1/2} = 3$ $I_{\alpha}$ (abs) 100% (2) s [1967Va22] 003(10) MeV [20 $J_i^{\pi} = 0^+, T_{1/2} = 1$	D4] and 2.00(15 1970Ra14] (adj 970Ra14] (adj 970Ra14] (adju .29(10) m*, <i>BR</i> ) $J_{f}^{\pi}$ 0 ⁺ 03] and 6.5(1) n 1993Wa04], 6.2 .7(2) s*, <i>BR</i> _{$\alpha$} = $J_{f}^{\pi}$ 0 ⁺ and 3.6(2) s [19 03He06] and 7. 13 ⁺¹¹ / ₋₉ ms*, <i>BR</i>	i)% [1967Le08]. iusted to 5.588(3 sted to 5.579(5) $\frac{i_{\alpha}}{i_{\alpha}} = 62(3)\%^{**}.$ $E_{daughter}(^{203})$ 0.0 n [1967Va17]. 260(3) MeV [19] ≈ 100%. $E_{daughter}(^{206}$ Rn 0.0 268Lo15]. 018(5) MeV [19] $\alpha = 100\%.$	<ul> <li>3) MeV in [1991Ry0]</li> <li>MeV in [1991Ry01]</li> <li>Po) coincide</li> <li></li> <li>71Go35] and 6.258(3</li> <li>) coincident</li> <li></li> <li>067Va22].</li> </ul>	01]), 5.590(5 ). nt γ-rays 6) MeV [1967 γ-rays	) MeV [1970 <u>R₀ (fm)]</u> 1.4917(27 /Va17]. <u>R₀ (fm)]</u> 1.4861(29)	Jo26], 5.588(2) HF ) 1.11(6) HF 0.90(5)	MeV [1968C

7.678(6)**

7.824(6)

* [2022Zh45]. ** Weighted average of 7.674(14) MeV [2022Zh45], 7.677(10) MeV [1980Ve01] and 7.680(10) MeV [1968Va18].

0.0

 $0^+$ 

100%

____

1.4986(56)

1.26(12)

$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{214}\mathrm{Th})$	coincident γ-rays	$R_0$ (fm)]	HF
8.773(8)	8.612(8)**	100%	$0^+$	0.0		1.512(14)	1.26(16)
* [2022Zh4 ** Weighte Table 10	15]. d average of 8.612(	14) MeV [2022]	Zh45] and 8	.612(9) MeV [2005Le42	].		

direct  $\alpha$  emission from ^{218m}U, ex. = 2.112(14) MeV,  $J_i^{\pi} = 8^+$ ,  $T_{1/2} = 390^{+60}_{-50} \,\mu s^*$ ,  $BR_{\alpha} = 100\%$ .

direct  $\alpha$  emission from ²¹⁸U,  $J_i^{\pi} = 0^+$ ,  $T_{1/2} = 650^{+80}_{-70} \,\mu s^*$ ,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{214}\mathrm{Th})$	coincident $\gamma$ -rays	$R_0$ (fm)]	HF
10.261(16) 10.885(11)	10.073(16)* 10.685(11)**	28(5)%* 100(5)%*	22(5)%* 78(5)%*	0+	0.629 0.0		1.512(14) 1.512(14)	$\begin{array}{c} 1.2^{+0.6}_{-0.4}\times10^{4}\\ 5.8(10)\times10^{4}\end{array}$

* [2022Zh45].

** Weighted average of 20.690(14) MeV [2022Zh45] and 10.678(17) MeV [2005Le42].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +17 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z = +17$  nuclei. J^{$\pi$} values for ¹⁷²Tm, ¹⁷⁶Lu, ¹⁸⁰Ta, ¹⁸⁴Re, ¹⁸⁸Ir, ¹⁹²Au, ¹⁹⁶Tl and ²⁰⁰Bi are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon  \alpha}$	Experimental
172 <b>T</b> m*	2-	63 6(3) h	0.801(5)			[1056Na08]
¹⁷⁶ Lu*	2 7-	$3.640(35) \times 10^{10} \text{ v}$	0.109(1)	-8.361(50)	0.676(4)	[2013Ko20]
¹⁸⁰ Ta**	1+	8.152(6) h	0.846(2)	-7.164(5)	2.132(2)	[1980Rv01]
¹⁸⁴ Re	(3 ⁻ )	35.43(16) d	1.486(4)	-6.215(4)	3.135(4)	[2022La12]
¹⁸⁸ Ir	1-	41.5(5) h	2.792(9)	-4.417(9)	4.936(9)	[1950Ch11]
¹⁹² Au	1-	4.94(10) h***	3.516(16)	-3.352(16)	5.940(16)	[1966Ny01, 1962Ma18]
¹⁹⁶ Tl	$2^{-}$	1.84(3) h	4.329(12)	-2.219(12)	6.367(12)	[1960Ju01]
²⁰⁰ Bi	$7^{+}$	36.4(5) m	5.880(25)	0.400(36)	9.030(23)	[1970DaZM]
²⁰⁴ At	$7^{+}$	9.1(1) m [@]	6.466(25)	2.361(26)	11.951(25)	[1963Ho18, 1970DaZM,
						1964Th07]
²⁰⁸ Fr	7+	58.6(3) s ^{@@}	6.990(15)	3.274(17)	13.251(15)	[1974Ho27, 1981Ri04]
²¹² Ac	$(7^{+})$	896(35) ms ^{@@@}	7.498(24)	4.151(25)	14.530(24)	[1968Va04, 2014Ya19]
²¹⁶ Pa		105(12) ms	7.525(27)	4.504(28)	15.598(27)	[1996An21]
²²⁰ Np		$25^{+14}_{-7} \ \mu s$	7.46(11)#	4.603(76)	17.752(33)#	[2019Zh23]
²²⁴ Am		, ·	7.98(50)#	5.31(41)#	17.82(41)#	

* 100%  $\beta^-$  emitter.

** Decays by 22.1(14)%  $\beta^+$ , 77.9(14)%  $\beta^-$  emitter [2013Ko20].

*** Weighted average of 4.85(10) h [1966Ny01] and 5.03(10) h [1962Ma18].

[@] Weighted average of 9.3(2) m [1963Ho18], 9.1(2) m [1970DaZM], and 8.9(2) m [1964Th07].

[@] Weighted average of 58.0(3) s [1974Ho27] and 59.1(3) s [1981Ri04].

^{@@@} Weighted average of 880(35) ms [2014Ya19] and 930(50) ms [1968Va04].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +17$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	BRα	Experimental
172 <b>Tm</b>	6.945(5)	15 714(50)	0.261(30)		
176 J II	5 976(1)	14 096(45)	1 566(6)		
180 Ta	5 760(2)	13.174(3)	2.024(2)		
184 <b>R</b> e	5.100(2) 5.143(4)	12.367(4)	2.024(2) 2.289(5)		
¹⁸⁸ Ir	4 415(9)	10.996(9)	3450(10)		
192 Au	4 363(16)	10.597(16)	3 148(18)		
¹⁹⁶ T1	3 772(26)	9 863(12)	2 851(20)		
²⁰⁰ Bi	2.428(24)	7 420(24)	4.701(26)		
²⁰⁴ At	1.853(23)	5,702(27)	6.070(1)	4.52(4)%	[1981Va27, 1968Go12, 1967Tr06, 1963Ho18, 1961La02
	11000(20)	01102(21)	01070(1)	110=(1)/0	2014Ma66 1981Va29 1981VaZT 1975BaYL 1974Ho27
					1970DaZM, 1967Tr04, 1964Th071
²⁰⁸ Fr	1.319(13)	4.803(18)	6.785(25)	80(3)%*	[1981Ri04, 1974Ho27, 1967Va20, 2019Zh23, 2003At01,
					1971ReZE, 1964Gr04, 1961Gr42]
²¹² Ac	0.821(22)	3.935(26)	7.540(24)	$\approx 100\%^{**}$	[2014Ya19, 2000He17,1968Va04, 2019Zh23, 2015Ma63]
²¹⁶ Pa	0.387(25)	3.187(28)	8.099(11)	$\approx 100\%^{**}$	[2000He17, 2019Zh23, 1998Ik01, 1998MiZW, 1996An21,
	. ,		. ,		1979Sc09, 1971Su14]
²²⁰ Np	0.110(33)	2.752(36)	10.226(18)	100%	[2019Zh23]
²²⁴ Am	0.15(50)#	2.59(40)#	10.36(40)#		

* Weighted average of 90(4)% [1981Ri04] and 74(3)% [1974Ho27].

** Not measured, based on half-life.

direct $\alpha$ emis	ssion from ²⁰⁴ At, J	$\pi_i = 7^+, T_{1/2} = 9$	0.1(1) m*, <i>BR</i>	$\alpha = 4.52(4)$ %	%**.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daugh}$	_{ter} ( ²⁰⁰ Bi)	coincident	γ-rays	R ₀ (fm	)]	HF	
6.070(1)	5.951(1)***	4.52(4)%*	* 7+	0.0				1.4809	(34)@	2.02(10	5)
* Weigh ** [196] *** Wei 5.953(3) MeV @ Interp	ted average of 9.3( ILa02]. ghted average of 5 V [1981Va27]. olated between 1.4	2) m [1963Ho13 5.952(2) MeV [1 5720(20) fm ( ²⁰²	8], 9.1(2) m [ 968Go12], 5 Po) and 1.49	1970DaZM], .948(3) MeV 17(27) fm ( ²⁰	, and 8.9(2) n ⁷ (adjusted to ⁹⁶ Rn).	n [1964Th07]. 9 5.951(3) MeV	' in [199	1Ry01]) [19	53Ho18], 5	.947(3) M	leV [1967Tr06] and
Table 4 direct $\alpha$ emission	ssion from ²⁰⁸ Fr, $J_i^{\pi}$	$\tau = (7^+), T_{1/2} =$	58.6(3) s*, B	$R_{\alpha} = 80(3)\%$	ó**.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	Edaughte	$r(^{204}At)$	coincident γ	-rays	R ₀ (fm)	]	HF	
6.771(5)	6.641(5)***	80(3)%**	7+	0.0				1.4889(	40) [@]	$1.78\substack{+0.2\\-0.1}$	20 8
*** Wei [1974Ho27] [@] Interp <b>Table 5</b> <u>direct α emis</u>	ighted average of 90 ighted average of 6 and 6.636(5) MeV iolated between 1.4 ssion from ²¹² Ac, J	(4)% [1961R04] (6.647(5) MeV (a) (adjusted to 6.6 (917(27) fm ( ²⁰⁶ ) $\frac{\pi}{i} = (7^+), T_{1/2} = 1$	adjusted to 6. 37(5) MeV ir Rn) and 1.48	(1974H027) 647(5) MeV h [1991Ry01] 61(29) fm ( ² ) *, $BR_{\alpha} = \approx 1$	j. in [1991Ry( ]) [1981Ri04 ¹⁰ Ra). .00%.	01]) [1967Va20 ].	0], 6.636	(5) MeV (ac	justed to 6	.637(5) M	feV in [1991Ry01]
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}$	²⁰⁸ Fr)	coincident γ-ra	ays	$R_0$ (fm)]		HF	
7.517(6)	7.375(6)**	100%	(7 ⁺ )	0.0				1.4924(63	)***	$1.98\substack{+0.3 \\ -0.2}$	2 8
* Weigh ** Weig *** Inte	ted average of 880 hted average of 7.3 rpolated between 1	(35) ms [2014Y 373(10) MeV [2 .4861(29) fm ( ²	a19] and 930( 000He17] and ¹⁰ Ra) and 1.4	(50) ms [196 1 7.377(8) M 1986(56) fm	8Va04]. eV [1968Va( ( ²¹⁴ Th).	)4].					
Table 6 direct $\alpha$ emis	ssion from ²¹⁶ Pa*,	$T_{1/2} = 105(12)$	ms**, $BR_{\alpha} =$	$\approx 100\%.$							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^2$	²¹² Ac) co	oincident	γ-rays	$R_0$ (fm)]		HF
7.940(15) 7.962(15) 8.098(15)	7.793(15) 7.815(15) 7.948(15)	8(2)% 88(12)% 100(8)%	4(1)% 45(5)% 51(4)%	(7+)	0.158 0.1336(3) 0.0	0. 0.	158 1336(3)		1.505(15) 1.505(15) 1.505(15)	*** *** ***	$\begin{array}{c} 35^{+22}_{-14} \\ 3.7^{+1.8}_{-1.4} \\ 9^{+4}_{-3} \end{array}$
* All val ** [1996 *** Inte	lues from [2000He 5An21]. rpolated between 1	25], except whe .4986(56) fm ( ²	re noted. ¹⁴ Th) and 1.5	512(14) fm( ²	¹⁸ U).						
Table 7direct $\alpha$ emission	ssion from ²²⁰ Np*,	$T_{1/2} = 25^{+14}_{-7} \mu$	s, $BR_{\alpha} = 100$	%.							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	Edaughter	( ²¹⁶ Pa)	coincident $\gamma$ -	-rays	R ₀ (fm)	]	HF	
10.226(18)	10.040(18)	100%		0.0**				1.512(3	9)***	$80^{+100}_{-50}$	
* All val ** $\alpha$ is a	lues from [219Zh2] assumed to feed the	3]. e ground state of	²¹⁶ Pa.								

*** Interpolated between 1.512(14) fm (²¹⁸U) and 1.511(36) fm (²²²Pu).

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Observed and predicted $\beta$ -delayed particle emission from the even-	Z, $T_z = +35/2$ nuclei.	$J^{\pi}$ values for 171 Tm	, ¹⁷⁵ Lu, ¹⁷⁹	¹⁸³ Re,	¹⁸⁷ Ir, ¹⁹¹ Au,	¹⁹⁵ Tl ¹⁹⁹ Bi and
²¹¹ Ra are taken from ENSDF. Unless otherwise stated, all Q-values	are taken from [2021]	Wa16] or deduced fro	m values th	herein.		

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon_P}$	$Q_{arepsilon lpha}$	Experimental
175 77 *	(7/2-)	4 105(1) 1	2 200(50)			
170 Y D*	(7/2)	4.185(1) d	-2.390(50)			[1989AD05]
$^{1/9}$ Hf	9/2+	$\geq 2.7 \times 10^{18} \text{ y}$	-1.404(5)			[2021Br09]
$^{183}W$	$1/2^{-}$	$\geq$ 6.7 $ imes$ 10 ²⁰ y	-1.072(2)			[2011Be39]
¹⁸⁷ Os	$1/2^{-}$	$\geq$ $3.2  imes 10^{15}$ y	-0.002			[2020Be23]
¹⁹¹ Pt	3/2-	2.817(4) d**	1.010(4)	-4.279(4)	3.093(4)	[2000Mo05, 1994Pa16]
¹⁹⁵ Hg	1/2-	10.69(3) h***	1.554(23)	-3.542(23)	3.271(23)	[2015Do01, 2001Li17]
¹⁹⁹ Pb	3/2-	103.0(14) m	2.828(29)	-1.566(7)	4.910(7)	[2014Pa07]
²⁰³ Po	5/2-	34.8(5) m [@]	4.214(14)	1.341(6)	8.324(28)	[1970DaZM, 1970Jo26, 1967Le21]
²⁰⁷ Rn	5/2-	555(10) s	4.593(13)	2.265(6)	10.465(14)	[1971Ho01]
²¹¹ Ra	5/2-	13(2) s ^{@@}	4.972(13)	3.148(7)	11.634(13)	[2019Zh54, 1968Lo15, 1967Va22]
²¹⁵ Th	$(1/2^{-})$	12(2) s	4.891(14)	3.540(8)	12.637(14)	[1968Va18]
²¹⁹ U	$(9/2^+)$	$60(7) \ \mu s$	4.710(70)	3.640(17)	14.840(18)	[2019Zh54]
²²³ Pu			5.46(31)#	4.56(30)#	15.11(31)#	

* 100%  $\beta^-$  emitter.

** Weighted average of 2.862(7) d [2000Mo05] and 2.802(4) d [1994Pa16].

*** Weighted average of 10.84(3) h [2015Do01] and 10.53(3) h [2001Li17].

[@] Weighted average of 36.7(5) m [1970DaZM], 33(1) m [1970Jo26] and 29(1) m [1967Le21].

[@] Weighted average of 10(3) s [2019Zh54], 1592) s [1968Lo15] and 12(2) s [1967Va22].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +35/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BR _α	Experimental
175 Vh	8 120(45)	15 62(20)	0.597(1)		
¹⁷⁹ Hf	7.414(2)	14.055(1)	1.808(1)		
$^{183}W$	7.414(2) 7.224(2)	13.541(2)	1.600(1) 1.672(2)		
¹⁸⁷ Os	6.581(1)	12.409(1)	2.722(1)		
¹⁹¹ Pt	6.234(4)	11.289(4)	3.096(4)		
¹⁹⁵ Hg	6.090(23)	11.112(23)	2.260(24)		
¹⁹⁹ Pb	4.992(10)	9.269(8)	3.357(24)		
²⁰³ Po	3.849(15)	6.618(15)	5.496(5)	0.11(2)%	[1970Ra14, 1968Go12, 1967Le21, 1970DaZM, 1967Ti04,
					1963Be28, 1962Be26, 1961Be25, 1961Fo05, 1959AtXX,
					1951Ka03]
²⁰⁷ Rn	3.484(14)	5.691(11)	6.251(2)	23(2)%	[ <b>1993Wa04, 1971Go35, 1971Ho01</b> , 1971Jo19, 1967Va07,
					1967Va17, 1967Va20, 1957St10, 1954Bu67]
²¹¹ Ra	3.114(14)	4.805(11)	7.042(3)	pprox 100%*	[2003He06, 2019Zh54, 2007Le14, 1968Lo15, 1967Va22]
²¹⁵ Th	2.801(15)	4.002(12)	7.665(4)	$\approx 100\%^*$	[2005Ku31, 2007Le14, 2000He17, 1989He03, 1968Va18,
					1968Va10]
²¹⁹ U	2.643(22)	3.488(17)	9.950(12)	100%*	[2019Zh54, 2007Le14, 2006LeZR, 2005Le42, 1994AnZY,
					1994Ye08, 1993An07]
²²³ Pu	2.44(30)#	2.98(31)#	10.40(30)#		

* Not measured. Based on half-life.

### Table 3

Table 5	
direct $\alpha$ emission from ²⁰³ Po, $J_i^{\pi} = 5/2^-$ , T	$_{1/2} = 34.8(5) \text{ m}^*, BR_{\alpha} = 0.11(2)\%^{**}.$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{199}\text{Pb})$	coincident $\gamma$ -rays	$R_0 (fm)$ ]	HF
5.492(3)	5.384(3)***	0.11(2)%**		0.0		1.4673(21)	$1.15^{+0.29}_{-0.20}$

* Weighted average of 36.7(5) m [1970DaZM], 33(1) m [1970Jo26] and 29(1) m [1967Le21].

** [1967Le21].

*** [1970Ra14, 1968Go12].

### **Table 4** direct $\alpha$ emission from ²⁰⁷Rn, $J_i^{\pi} = 5/2^-$ , $T_{1/2} = 555(10)$ s*, $BR_{\alpha} = 23(2)\%^*$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{203}\text{Po})$	coincident $\gamma$ -rays	$R_0$ (fm)]	HF
6.113(4) 6.188(3) 6.2502(25)	5.995(4) 6.068(3) 6.1294(25)**	0.10(3)% 0.66(2)% 100%	0.023(7)% 0.15(1)% 23(2)%	(1/2 ⁻ ) (3/2 ⁻ ) 5/2 ⁻	0.137 0.063 0.0	0.063	1.4836(40) 1.4836(40) 1.4836(40)	$260^{+130}_{-70} \\ 84(11) \\ 1.05(13)$

* [1971Ho01].

** [1993Wa04]

#### Table 5

direct $\alpha$ emission from ²¹¹	Ra*, $J_i^{\pi} = 5/2^-$ , $T_{1/2} =$	= 13(2) s**, $BR_{\alpha} = \approx 100\%$
----------------------------------------------	----------------------------------------	--------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)^{***}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{207}\mathrm{Rn})$	coincident $\gamma$ -rays	R ₀ (fm)]	HF
6.376(5)	6.255(5)	0.06%	≈0.06%	$(9/2^{-})$	0.6650(1)	0.6650(1)	1.4790(30)	4.3
6.437(10)	6.315(10)	0.04%	≈0.04%	(,,= )	0.6016(3)	0.6016(3)	1.4790(30)	12
6.442(10)	6.32(10)	$7  imes 10^{-5}\%$	$pprox 7  imes 10^{-5}\%$		0.5691(3)	0.5691(3)	1.4790(30)	90
6.755(5)	6.627(5)	0.08%	$\approx 0.08\%(1/2^{-}, 3/2^{-})$		0.2830(1)	0.1200, 0.1629, 0.2830(1)	1.4790(30)	120
6.919(5)	6.788(5)	1%	$\approx 1\%$	$3/2^{-}$	0.1200(1)	0.1200(1)	1.4790(30)	40
7.040(5)	6.907(5)	100%	$\approx 99\%$	5/2-	0.0		1.4790(30)	1.14(20)

* All values from [2003He06], except where noted.

** Weighted average of 10(3) s [2019Zh54], 1592) s [1968Lo15] and 12(2) s [1967Va22].

*** No uncertainties are given in [2003He06].

#### Table 6

Table	0						
direct of	$\alpha$ emission	from ²¹⁵ Tl	$h^*, J_i^{\pi} = (1)$	$1/2^{-}$ ), T _{1/}	$_2 = 1.2(2)$ s	$s^{**}, BR_{\alpha} =$	$\approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{211}\text{Ra})$	coincident γ-rays	R ₀ (fm)]	HF
7.373(7) 7.474(5) 7.532(4) 7.666(5)	7.236(7) 7.335(5) 7.392(4) 7.523(5)	1.9(8)% 15.4% 100% 76.9%	1.0(4)% 8%*** 52%*** 40%***	(3/2 ⁻ ) (3/2 ⁻ ) (1/2 ⁻ ) 5/2( ⁻ )	0.2951(3) 0.1945(1) 0.1339(1) 0.0	0.2951(3) 0.0609(3), 0.1945(1) 0.1339(1)	1.4841(35) 1.4841(35) 1.4841(35) 1.4841(35)	$31^{+30}_{-13}$ 9 2.2 8

* All values from [2005Ku31], except where noted.

** [1968Va18].

*** No uncertainties are given in [2003He06].

### Table 7

direct $\alpha$ emission	from ²¹⁹ U*, $J_i^{\pi}$	$= (9/2^+), T_{1/2} =$	$= 60(7) \ \mu s, BR_{0}$	x = 100%

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{215}\text{Th})$	coincident γ-rays	R ₀ (fm)]	HF
9.142(17) 9.418(17) 9.945(15)	8.975(17) 9.246(17) 9.763(15)	$7.3^{+4.2}_{-3.0}\%$ $4.8^{+4.4}_{-2.4}\%$ $100(11)\%$	$\begin{array}{c} 6.5^{+3.7}_{-2.6}\%\\ 4.3^{+3.9}_{-2.1}\%\\ 89.2(9.8)\end{array}$	(3/2 ⁻ ) (5/2 ⁻ ) (1/2 ⁻ )	0.807(23) 0.527(23) 0.0		1.516(14) 1.516(14) 1.516(14)	$\begin{array}{c} 19^{+31}_{-9} \\ 1.1^{+6.9}_{-0.7} \times 10^3 \\ 110^{+50}_{-40} \end{array}$

* All values from [2019Zh45].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +35/2 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +35/2$  nuclei. J^{$\pi$} values for ¹⁷³Tm, ¹⁷⁷Lu, ¹⁸¹Ta, ¹⁸⁵Re, ¹⁸⁹Ir, ¹⁹³Au, ¹⁹⁷Tl and ²⁰¹Bi are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
150							
¹⁷³ Tm*		$(1/2^+)$	8.24(8) h	-2.60(20)#			[1963Or01]
¹⁷⁷ Lu*		$7/2^{+}$	6.7479(7) d	-1.398(1)			[1990Ab02]
¹⁸¹ Ta		$7/2^{+}$	stable	-1.036(2)			
¹⁸⁵ Re		$5/2^{+}$	stable	-0.431(1)			
¹⁸⁹ Ir		$3/2^{+}$	13.1(1) d**	0.537(13)	-6.722(13)	2.513(13)	[1975Ba35, 1964Le07, 1963Gr22]
¹⁹³ Au		3/2+	17.65(15) h	1.075(9)	-5.858(9)	3.157(9)	[1968Sv01]
¹⁹⁷ Tl		$1/2^{+}$	2.84(4) h	2.186(14)	-4.504(14)	3.701(14)	[1961Ju05]
²⁰¹ Bi		9/2-	107.4(21) m***	3.842(18)	-1.671(13)	6.686(13)	[1970DaZM, 1956St05]
²⁰⁵ At		9/2-	26.0(5) m [@]	4.537(16)	0.372(15)	9.862(18)	[1970DaZM, 1968Go12, 1961La02]
²⁰⁹ Fr		9/2-	51.3(8) s	5.159(15)	1.399(15)	11.314(15)	[1996Xu02]
²¹³ Ac		9/2-	731(17) ms	5.795(15)	2.368(15)	12.657(15)	[2000He17]
²¹⁷ Pa		9/2-	3.6(2) ms ^{@@}	4.849(16)	1.616(16)	14.284(16)	[2002He29, 1996An21]
^{217m} Pa	1.8839(3)	$29/2^+$	1.08(3) ms	6.733(16)	3.500(16)	16.168(16)	[2002He29]
²²¹ Np				5.39(21)#	2.34(20)#	15.28(20)#	
²²⁵ Am				6.09(50)#	3.07(40)#	15.45(41)#	

* 100%  $\beta^-$  emitter.

** Weighted average of 13.1(1) d [1975Ba35], 13.3(1) d [1964Le07] and 13.2(2) d [1963Gr22].

*** Weighted average of 106.2(24) m [1970DaZM] and 111(4) m [1956St05].

[@] Weighted average of 27.2(6) m [1970DaZM], 25.0(5) m [1968Go12] and 26.2(5) m [1961La02].

[@] Weighted average of 3.8(2) ms [2002He29] and 3.4(2) ms [1996An21].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +35/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	Experimental
173 m		16.00/60>#	0.115(01)		
¹⁷⁵ Tm	7.062(6)	16.32(60)#	0.115(21)		
177/Lu	6.182(1)	14.651(50)	1.447(5)		
¹⁸¹ Ta	5.949(2)	13.958(5)	1.520(2)		
¹⁸⁵ Re	5.403(1)	13.103(2)	2.195(2)		
¹⁸⁹ Ir	4.601(13)	11.811(138)	2.944(13)		
¹⁹³ Au	4.405(9)	11.274(9)	2.620(15)		
¹⁹⁷ Tl	3.817(14)	10.365(14)	2.626(16)		
²⁰¹ Bi	2.467(16)	7.948(30)	4.500(6)		
²⁰⁵ At	1.932(16)	6.038(18)	6.020(2)	15.1(16)%*	[1974Ho27, 1968Go12, 1961La02, 1970DaZM, 1963Ho18,
					1963Uh01, 1961Fo04, 1954Bu67, 1951Ba14]
²⁰⁹ Fr	1.416(15)	5.133(17)	6.777(4)	89(3)%	[1974Ho27, 1967Va20, 1964Gr04, 1964Gr04]
²¹³ Ac	0.949(16)	4.297(17)	7.498(4)	$\approx 100\%$	[200He17, 1968Va04, 1961Gr42]
²¹⁷ Pa	0.533(17)	3.554(18)	8.489(4)	100%	[2002He29, 2008DoZZ, 2002HeZV, 1998Ik01, 1998MiZW,
	· · ·				1996An21, 1996AnZY, 1995NiZS, 1978ReZZ, 1977ScZC,
					1968Va18]
217m Pa	-1.351(17)	1.670(18)	10.373(4)	100%	[2002He29, 2008DoZZ, 2002HeZV, 1998Ik01, 1998MiZW,
					1996An21, 1996AnZY, 1995NiZS, 1978ReZZ]
²²¹ Np	0.39(22)#	3.25(21)#	10.43(20)#		
²²⁵ Am	0.18(50)#	2.85(41)#	10.06(45)#		

* Weighted average of 10(2)% [1974Ho27] and 18.4(16)% [1961La02]. ** Not measured, inferred from half-life.

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#### Table 3

direct $\alpha$ emission from ²⁰⁵ At, $J_i^{\pi} = 9/2^-$ , $T_{1/2} = 26.0(5)$ m*, $BR_{\alpha} = 15.1(16)\%^{**}$ .								
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{201}\mathrm{Bi})$	coincident $\gamma$ -rays	$R_0$ (fm)]	HF	
6.019(2)	5.902(2)***	15.1(16)%@	9/2-	0.0		1.4771(25)	$0.98\substack{+0.15 \\ -0.13}$	

* Weighted average of 27.2(6) m [1970DaZM], 25.0(5) m [1968Go12] and 26.2(5) m [1961La02].

** Weighted average of 10(2)% [1974Ho27] and 18.4(16)% [1961La02].

*** Weighted average of 5.901(5) MeV [1974Ho27], 5.903(2) MeV [1968Go12] and 5.896(4) MeV (adjusted to 5.899(4) MeV in [1991Ry01])[1974Ho27].

[@] Weighted average of 10(2)% [1974Ho27] and 18.4(16)% [1961La02].

E(am)	E (lab)	L (abc)	īπ	F.	(205  At)	agingidant & rays	$\mathbf{P}_{-}$ (fm)]	ЦЕ
$E_{\alpha}(c.m.)$	$L_{\alpha}(\text{Iab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}$	Ldaug	hter( At)	conicident y-rays	$\mathbf{K}_0$ (IIII)]	пг
6.777(5)	6.647(5)***	⁴ 89(3)% ⁶	[@] 9/2 ⁻	0.0			1.4808(14)	1.30(14)
* All v ** [199 *** 6.6	alues from [1974 96Xu02]. 646(5) MeV in [1	Ho27], except v 974Ho27], moo	where noted. lified to 6.647	7(5) MeV in [	1991Ry01].			
Table 5 direct $\alpha$ em	ission from ²¹³ A	$c^*, J_i^{\pi} = 9/2^-, T_i$	$\Gamma_{1/2} = 731(17)$	) ms, $BR_{\alpha}$ =	$\approx 100\%.$			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi}$	Edaught	_{er} ( ²⁰⁹ Fr)	coincident γ-rays	R ₀ (fm)]	HF
7.502(8)	7.361(8)**	pprox 100%	9/2-	0.0	-		1.4852(44)	1.29(15)
* All v	alues from [2000	)He17], except v	where noted.					
<b>Table 6</b> direct α em	ission from ²¹⁷ P	$a^*, J_i^{\pi} = (9/2^-),$	$T_{1/2} = 3.6(2)$	ms**, $BR_{\alpha}$	= 100%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{213})$	Ac) coincident	γ-rays R ₀ (fm	h)] HF
7.855(5)	7.710(5)	0.3(2)%	0.3(2)%	$(13/2^{-})$	0.6343	0.6343(1)	1.4908	$3(17)$ $7^{+15}_{-2}$
7.873(5)	7.728(5)	0.3(2)%	0.3(2)%	$(13/2^{-})$	0.6130	0.6125(8)	1.4908	$8(17)$ $8^{+18}_{-4}$
8.021(5)	7.873(5)	0.4(2)%	0.4(2)%		0.4665	0.4661(20)	1.4908	$8(17)$ $17^{+20}_{-7}$
8.494(5)	8.337(5)	100 (1)%	99(1)%	(9/2 ⁻ )	0.0		1.4908	$3(17)$ $1.67^{+0.32}_{-0.28}$
* All v: ** Wei	alues from [2002 ghted average of	2He29], except v 3.8(2) ms [200	where noted. 2He29] and 3	.4(2) ms [199	96An21].			
T-1-1-7	0 0							
direct $\alpha$ em	ission from ^{217m}	Pa*. Ex. = 1.88	39(3) MeV. J?	$\tau = (29/2^+)$	$\Gamma_{1/2} = 1.08(3) \text{ m}_{2}$	s. $BR_{\alpha} = 100\%$ .		
		,		( ),	1/2 (0) m	-, α		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{213}\mathrm{A}$	c) coincident $\gamma$ -r	ays $R_0$ (fm)	] HF
8.462(5)	8.306(5)	15.3(29)% %	11(2)%	$(21/2^{-})$	1.8842	0.450, 0.613,	0.821 1.4908(	17) $3.7^{+1.2}_{-0.9}$
9.712(5)	9.533(5)	8.3(15)%	6(1)%	$(13/2^{-})$	0.6343	0.634	1.4908(	17) $1.00^{+0.29}_{-0.23} \times 10^4$
9.731(5)	9.552(5)	12.5(15)%	9(1)%	$(13/2^{-})$	0.613	0.613	1.4908	17) $7.5^{+1.8}_{-1.5} \times 10^3$

direct  $\alpha$  emission from ²⁰⁹Fr*,  $J_i^{\pi} = 9/2^-$ ,  $T_{1/2} = 51.3(8)$  s**,  $BR_{\alpha} = 89(3)\%$ .

* All values from [2002He29], except where noted.

2.8(14)%

100(8)%

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0.4665

0.0

0.466

 $7^{+8}_{2} \times 10^{4}$ 

 $1.9^{+0.4}_{-0.3} \times 10^4$ 

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2(1)%

72(4)%

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +18$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$Q_{arepsilonlpha}$	Experimental
¹⁷⁶ Yb		$0^+$	$\geq 1.6 \times 10^{17} \text{ y}$	-4.12(10)			[1996De60]
¹⁸⁰ Hf		$0^+$	$\geq 1  imes 10^{18}  ext{ y}$	-3.100(70)			[2020Da04]
$^{184}W$		$0^+$	$\geq 8.9 \times 10^{21} \text{ y}$	-2.866(26)			[2004Co26]
¹⁸⁸ Os		$0^+$	$\geq$ 3.3 $\times$ 10 ¹⁸ y	-2.120			[2020Be23]
¹⁹² Pt		$0^+$	$>6 \times 10^{16} { m y}$	-1.453(2)			[2011Be08]
¹⁹⁶ Hg		$0^{+}$	stable	-0.697(3)			
²⁰⁰ Pb		$0^+$	21.5(4) h	0.796(12)	-3.994(10)	2.463(10)	[1955Be12]
²⁰⁴ Po		$0^+$	3.52(1) h*	2.305(14)	-0.844(12)	6.281(12)	[1970Ra14, 1965AnZZ, 1961La02]
²⁰⁸ Rn		$0^+$	1461(8) s	2.815(14)	0.201(12)	8.566(14)	[1971Ho01]
²¹² Ra		$0^+$	13.0(2) s	3.317(13)	1.268(12)	9.846(14)	[1974Ho27]
²¹⁶ Th		$0^+$	26.3(2) ms**	2.149(14)	0.478(13)	11.390(14)	[2019Zh45, 2005Ku31, 2000He17]
^{216m} Th	2.045(9)	$8^+$	140(5) µs***	4.194(17)	2.523(16)	13.435(17)	[2019Zh45, 2005Ku31, 2000He17]
²²⁰ U				2.74(10)#	1.26(12)#	12.44(10)#	, .
²²⁴ Pu				3.25(30)#	1.946(31)#	12.58(30)#	

* Weighted average of 3.57(2) h [1970Ra14], 3.50(1) h [1965AnZZ] and 3.53(3) h [1961La02].

** Weighted average of 26.3(5) ms [2019Zh45], 26.0(2) ms [2005Ku31] and 27.0(3) ms [2000He17].

*** Weighted average of 135(4) µs [2005Ku31] and 140(5) µs [2000He17].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +18$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
176 <b>Vb</b>	8 470(50)	16 12(30)#	0.566(4)		
180 <b>H</b> f	8.000(5)	$10.12(30)\pi$ 14.680(7)	1.287(1)		
184 337	7.701(2)	14.080(7) 14.224(6)	1.207(1) 1.640(2)		
188	7.701(2) 7.210(0)	14.234(0) 12.207(1)	1.049(2) 2.142(1)		
192 Dt	7.210(0) 6.860(2)	13.207(1) 12.150(2)	2.143(1) 2.424(2)		
1961	0.809(2)	12.139(2)	2.424(3)		
200 PI	6.548(3)	11.644(3)	2.038(4)		
²⁰⁰ Pb	5.480(30)	9.874(10)	3.150(10)		
²⁰⁴ Po	4.105(16)	6.978(11)	5.485(1)	0.660(7)%	[1970Ra14, 1970DaZM, 1967Ti04, 1965AnZZ,
					1971Go35, 1970Jo26, 1969Go23, 1967Le08,
					1967Le21, 1967Ti04, 1963Be28, 1961Fo05,
					1961La02, 1955Mo68, 1954Ro39, 1951Ka03,
					1951Ka37]
²⁰⁸ Rn	3.717(16)	6.045(11)	6.261(2)	63(3)%*	[1971Go35, 1971Ho01, 1993Wa04, 1957St10,
					1955Mo68, 1955Mo69, 1953AsZZ]
²¹² Ra	3.347(16)	5.172(11)	7.032(2)	$pprox 94\%^{**}$	[2003He06, 2001HeZY, 1982Bo04, 1974Ho27,
					1973BoXL, 1968Lo15, 1967Va22, 1961Gr42]
²¹⁶ Th	3.021(17)	4.372(12)	8.072(4)	100%	[2005Ku31, 2000He17, 2019Zh45, 2014Ya19,
					2005KuZZ, 2005Li17, 2001Ha46, 1968Va10,
					1968Va18]
^{216m} Th	0.976(19)	2.327(15)	10.117(10)	2.8(4)%	[2005Ku31, 2019Zh45, 2005KuZZ, 2001Ha46,
		(-)			2000He17, 1983Hi08]
²²⁰ U	2.86(12)#	3.93(10)#	10.29(10)#		
²²⁴ Pu	2.67(31)#	3.57(30)#	9 84(32)#		
- 4	(01)//	2.2.2.(20)			

* Weighted average of 67(3)% [1971Go35] and52(5)% [ 1971Ho01].

** Deduced by setting the HF of the  $\alpha$  decay of ²¹²Ra to the ground state of ²⁰⁸Rn equal to 1.0.

5.485(2)											
	5.377(2)***	0.660(7)%	**	0+ 0.	0				1.4625(22)	1.017	7(11)
* Weigh ** [1965 *** Wei [1970DaZM]	ted average of 3 5AnZZ]. ghted average of and 5.379(5) M	.57(2) h [1970Ra ff 5.379(3) MeV leV [1967Ti04].	14], 3.50 (adjusted	(1) h [1965] to 5.378(3)	AnZZ] ar ) MeV in	nd 3.53( n [1991]	3) h [1961La( Ry01]) [1970]	)2]. Ra14], 5.375(	(5) MeV (adj	justed to 5.3	74(5) MeV in [1991Ry01
<b>Table 4</b> direct $\alpha$ emis	ssion from ²⁰⁸ Rr	h, $\mathbf{J}_i^{\pi} = 0^+, \mathbf{T}_{1/2} =$	= 31461(8	) s*, $BR_{\alpha}$ =	63(3)%*	**.					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	i	$T_{\alpha}(abs)$		$\mathrm{J}_f^\pi$	$E_{daughter}(^{204})$	Po) coinc	ident γ-rays	$R_0$ (fm)]	HF
5.577(4) 6.259(3)	5.470(4)*** 6.139(3)***	$\begin{array}{l} 4.7(4)\times 10^{-3} \\ 100\%^{***} \end{array}$	6*** (	$3.0(10) \times 10$ $53(3)\%^{**}$	0-3%	${2^+\atop0^+}$	0.684 0.0	0.684		1.4755(5) 1.4755(5)	2) 12.1(12) 2) 0.97(5)
* [1971] ** Weig *** [197	Ho01]. hted average of 71Go35].	67(3)% [1971Go	935] and 5	2(5)% [ 197	71Ho01].						
Table 5 direct $\alpha$ emis	ssion from ²¹² Ra	$J_i^*, J_i^{\pi} = 0^+, T_{1/2}$	= 13.0(2)	s**, $BR_{\alpha}$ =	=≈94%.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	E	daughter(	²⁰⁸ Rn)	coincident $\gamma$ -	rays R ₍	₀ (fm)]	HF
6.390(5) 7.031(5)	6.269(5)) 6.898(5)	pprox 0.05% 100%	$\approx 0.047$ $\approx 94\%$	2 ⁺ 0 ⁺	0. 0.	.635 .0		0.635	1.4 1.4	4718(31) 4718(31)	$\approx 6.0$ 1.0***
* All val ** [1974 *** An (	lues from [2003] 4Ho27]. even-even g.s to	He06] unless oth g.s. α decay sho	erwise sta ould have	ted. a HF =1.0. 3	Setting th	he $BR_{\alpha}$ :	= 94% gives t	his value. Us	ing a $BR_{\alpha} = 1$	100% results	s in a HF of 0.935(14).
Table 6 direct $\alpha$ emis	ssion from ²¹⁶ Th	h, $\mathbf{J}_i^{\pi} = 0^+,  \mathbf{T}_{1/2} =$	= 26.3(2)	ms*, $BR_{\alpha} =$	100%.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs$	)	$\mathbf{J}_f^{\pi}$	$E_{daug}$	_{thter} ( ²¹² Ra)	coincident	γ-rays ]	R ₀ (fm)]	HF
7.442(4) 8.072(5)	7.304(4)** 7.923(5)**	100.0(4)% 0.0054(3)%	99.46( 0.54(3	40)%*** )%***	$2^+_{0^+}$	0.629 0.0	93(1)	0.6293(1)		1.4695(14) 1.4695(14)	1.73(12) 1.013(9)
* Weigh ** [2005 *** [200	ted average of 2 5Ku31]. 00He17].	6.3(5) ms [20192	Zh45], 26	0(2) ms [20	05Ku31]	and 27	.0(3) ms [200	0He17].			
Table 7 direct $\alpha$ emis	ssion from ^{216m} T	Th, Ex. = 2.045(9	) MeV, $J_i^2$	$F = 8^+, T_{1/2}$	= 140(5)	) μs*, B	$BR_{\alpha} = 2.8(9)\%$	o <b>**</b> .			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	Edaug	hter (212 I	Ra) coin	cident γ-rays	$R_0$ (fm)	)] HI	F
8.150(10) 9.488(12) 10.117(10)	7.999(10) 9.312(12) 9.930(10)	18(3)% 18(4)% 100(5)%	13(2)% 13(3)% 74(4)%	${8^+ \over 2^+ \over 0^+}$	1.967 0.629 0.0	7(13) 93(1)	0.62	93(1)	1.4695( 1.4695( 1.4695(	$\begin{array}{ccc} (14) & 2.0 \\ (14) & 9^+ \\ (14) & 3.7 \end{array}$	$5^{+1.6}_{-0.8}$ ${}^{6}_{-0.8}$ ${}^{3}_{-3} \times 10^{3}$ ${}^{7}_{-1.0} \times 10^{4}$
* All val	lues from [2005]	Ku31], except wl	nere notec	l. 1 140(5) µs	[2000He	171					

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +18nuclei.

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +18$ nuclei. J ^{$\pi$} values for ¹⁷⁸	⁸ Lu, ¹⁸² Ta,	¹⁸⁶ Re, ¹⁹⁰ Ir	; ¹⁹⁴ Au,	198Tl and 2	⁰² Bi are taken
from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values	therein.				

Nuclide	$J^{\pi}$	Ex.	$T_{1/2}$	$Q_{\varepsilon}$	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
¹⁷⁸ Lu*		$1^{(+)}$	28.4(2) m	-0.661(7)			[1973Or03]
¹⁸² Ta*		3-	114.740(24) d	-0.381(6)			[1973Vi13]
¹⁸⁶ Re		$1^{-}$	3.7186(5) d	0.581(1)	-7.822(14)	1.697(6)	[2004Sc04]
¹⁹⁰ Ir		$4^{-}$	11.78(10) d	1.954(1)	-6.063(8)	3.330(2)	[1975Ba35]
¹⁹⁴ Au		1-	38.02(10) h	2.548(2)	-4.965(2)	4.071(2)	[1992Si02]
¹⁹⁸ Tl		2-	5.3(5) h	3.426(8)	-3.678(8)	4.806(8)	[1954Mi16]
²⁰² Bi		$5^{+}$	1.71(2) h***	5.190(15)	-0.859(20)	7.779(14)	[1970DaZM, 1966KaZY]
²⁰⁶ At		$(5^{+})$	29.3(4) m	5.749(14)	1.337(14)	11.076(14)	[1977Li16]
²¹⁰ Fr		6+	3.18(6) m	6.261(14)	2.251(14)	12.420(14)	[2005Ku06]
²¹⁴ Ac		$5^{+}$	8.2(2) s	6.341(15)	2.699(14)	13.613(14)	[1968Va04]
²¹⁸ Pa		(8-)	108(5) µs@	6.283(21)	2.658(21)	16.132(19)	[2020Zh01, 2000He17]
218m Pa	0.080(11)	$(1^{-})$	$135^{+62}_{-32} \mu s$	6.363(24)	2.738(24)	16.212(22)	[2020Zh01]
²²² Np		. /	$380^{+260}$ ns	7.000(60)	3.611(71)	16.483(39)	[2020Ma27
²²⁶ Am			-110	7.34(36)#	4.06(31)#	16.27(30)#	L · · ·

* 100  $\beta^-$  emitter.

** 92.5(1)%  $\beta^-$ , 7.5(1)%  $\varepsilon$  emitter.

*** Weighted average of 1.67(2) h [1966KaZY] and 1.79(3) h [1970DaZM].

[@] Weighted average of 107(5) µs [2020Zh01] and 113(10) µs [2000He17].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +18$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$\mathbf{S}_{2p}$	Qα	$BR_{\alpha}$	Experimental
1781	( ( 10/2)	15 55(10)	1 100(45)		
182-	6.640(2)	15.55(10)	1.102(45)		
¹⁸² Ta	6.317(2)	14.332(71)	1.482(3)		
¹⁸⁶ Re	5.828(1)	13.666(26)	2.078(2)		
¹⁹⁰ Ir	5.056(1)	12.315(1)	2.749(1)		
¹⁹⁴ Au	5.021(2)	11.954(2)	2.117(2)		
¹⁹⁸ Tl	4.277(8)	10.968(8)	2.258(8)		
²⁰² Bi	2.769(20)	8.282(15)	4.353(16)		
²⁰⁶ At	2.207(17)	6.371(16)	5.887(5)	0.87(8)%*	[1981Va27, 1981Va29, 1977VaZT, 1961La02,
					1970DaZM, 1969Ba69, 1969BaZM, 1968Go12,
					1964Th07, 1963Ho18, 1961Fo04]
²¹⁰ Fr	1.691(17)	5.452(16)	6.671(5)	71(4)%	[2005Ku06, 2022Ha06, 2014Ma66, 2000RuZZ,
					1972KeYY, 1971ReZE, 1967Va20, 1964Gr04,
					1961Gr42]
²¹⁴ Ac	1.201(17)	4.629(16)	7.352(2)	89(3)%	[2004Ku24, 1968Va04, 2000He17, 1961Gr42]
²¹⁸ Pa	0.845(21)	4.078(20)	9.791(12)	100%	[2020Zh01, 2000He17, 1996An21, 1979Sc09,
					1995AnZY, 1995NiZS, 1978ReZZ]
^{218m} Pa	0.765(24)	3.998(23)	9.871(16)	100%	[2020Zh01]
²²² Np	0.534(82)	3.582(41)	10.200(34)	100%	[2020Ma27
²²⁶ Am	0.62(42)#	3.64(30)#	9.27(30)#		-

* A value of 0.88(8)% was reported in [1961La02]. This value was deduced using an  $\alpha$  branching ratio of 5(1)% [1955M008] for the decay of ²⁰⁶Po. [1981Va27] report a value of 0.70(14)% for the  $\alpha$  branching of ²⁰⁶At, using using an  $\alpha$  branching ratio of 5.2(4)% [1971Go35] for the decay of ²⁰⁶Po. Adjusting the value of [1961La02] using the ²⁰⁶Po  $\alpha$  branching ratio of [1971Go35] results in a value of 0.92(8)%. The weighted average of 0.70(14)% and 0.92(8)% is adopted here. In addition, note that [1967Le08] list an  $\alpha$  branching ratio of 5.45% for ²⁰⁶Po with no uncertainty reported.

Table 3	
direct $\alpha$ emission from ²⁰⁶ At, Ex. = 2.045(9) MeV, $J_i^{\pi} = (5^+)$ , T	$T_{1/2} = 29.3(4) \text{ m}^{**}, BR_{\alpha} = 0.87(8)\%^{**}$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@}$	$E_{daughter}(^{202}\mathrm{Bi})$	coincident γ-rays [@]	$R_0 (fm)^{@@}$	HF
5.816(2)	5.703(2)	100%	0.83(8)%	(5+)	0.072(4)		1.4690(56)	$2.0^{+4}_{-3}$
5.848(3) 5.881(3)	5.734(3)	1.2(3)%	$9.6(28) \times 10^{-3}\%$	$(4^+)$	0.041(5)	.041	1.4690(56)	$240^{+110}_{-70}$ $170^{+50}$
5.888(4)	5.774(4)	0.9(3)%	$7.8(27) \times 10^{-3}\%$	5+	0.0		1.4690(56)	$460^{+260}_{-140}$

* All values from [1981Va27], except where noted.

** [1977Li16].

*** A value of 0.88(8)% was reported in [1961La02]. This value was deduced using an  $\alpha$  branching ratio of 5(1)% [1955Mo08] for the decay of ²⁰⁶Po. [1981Va27] report a value of 0.70(14)% for the  $\alpha$  branching of ²⁰⁶At, using using an  $\alpha$  branching ratio of 5.2(4)% [1971Go35] for the decay of ²⁰⁶Po. Adjusting the value of [1961La02] using the ²⁰⁶Po  $\alpha$  branching ratio of [1971Go35] results in a value of 0.92(8)%. The weighted average of 0.70(14)% and 0.92(8)% is adopted here. In addition, note that [1967Le08] list an  $\alpha$  branching ratio of 5.45% for ²⁰⁶Po with no uncertainty reported.

[@] [2008Zh05].

[@] Interpolated between 1.4625(22) fm ( 204 Po) and 1.4755(52) fm ( 208 Rn).

#### Table 4

direct  $\alpha$  emission from ²¹⁰Fr,  $J_i^{\pi} = 6^+$ ,  $T_{1/2} = 3.18(6)$  m*,  $BR_{\alpha} = 71(4)\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{206}\mathrm{Ra})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
6.015(5)**	5 000(5)**	>0.010(5)%	>0.0071(36)%		0 6573(2)**	0.6263(3)** 0.6515(3)**	1 4737(61)	~32+34
6.231(7)	6.112(7)	>0.0017(9)%	>0.0071(30)% >0.0012(6)%		0.4442(5)	0.442(5)	1.4737(61)	$< 32_{-12} < 1.8(3) \times 10^3$
6.333(4)	6.212(4)	>0.022(3)%	>0.016(2)%		0.3404(1)	0.3404(1)	1.4737(61)	$<380^{+100}_{-80}$
6.348(5)**	6.227(5)**	>0.010(2)%	>0.0071(15)%		0.3223(1)**	0.3223(1)**	1.4737(61)	$< 1.0^{+0.3}_{-0.2} \times 10^{3}$
6.471(5)**	6.348(5)**	>0.0041(13)%	>0.0029(9)%		0.2009(5)**	0.1953(2)**	1.4737(61)	$< 1.1^{+0.6}_{-0.3} \times 10^4$
6.524(4)	6.400(4)	>0.034(7)%	>0.024(5)%		0.1480(1)	0.1169(3)**, 0.1480(1)	1.4737(61)	$< 1.6^{+0.5}_{-0.4} \times 10^{3}$
6.533(4)**	6.409(4)**	>0.014(4)%	>0.010(3)%		0.1376(3)**	0.1065(2)**, 0.1376(3)**	1.4737(61)	$<4.3^{+2.0}_{-1.2}\times10^{3}$
6.545(4)	6.420(4)	>0.030(5)%	>0.021(4)%		0.1263(1)	0.1207(3)**, 0.1263(1)	1.4737(61)	$<2.2^{+0.6}_{-0.5} \times 10^{3}$
6.672(5)	6.545(5)	100%	70.9(40)%	(5 ⁺ )	0.0		1.4737(61)	$2.13_{-0.31}^{+0.35}$

* All values from [2005Ku06].

** Tentatively assigned.

*** Interpolated between 1.4755(52) fm (²⁰⁸Rn) and 1.4718(31) fm (²¹²Ra).

## Table 5

direct  $\alpha$  emission from ²¹⁴Ac*,  $J_i^{\pi} = 5^+$ ,  $T_{1/2} = 8.2(2) \text{ s**}$ ,  $BR_{\alpha} = 89(3)\%^{**}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{210}\mathrm{Fr})$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF
6.601(15)	6.478(15)	> 0.0043(15)%	>0.0020(7)%		0.7537(7)	0.7537(7)	1.4707(34)	$<\!270^{+1460}_{-80}$
6.639(15)	6.515(15)	> 0.0041(15)%	>0.0020(7)%		0.7134(7)	0.7134(7)	1.4707(34)	$<390^{+230}_{-110}$
6.732(7)	6.606(7)	>0.0122(24)%	>0.0059(12)%		0.6225(2)	0.6225(2)	1.4707(34)	$<310^{+90}_{-60}$
6.752(7)	6.626(7)	>0.0087(22)%	>0.0042(11)%		0.6014(2)	0.6014(2)	1.4707(34)	$<530^{+210}_{-130}$
6.829(5)	6.701(5)	0.26(4)%	0.125(18)%		0.5259(1)	0.2814(1), 0.3166(2), 0.3301(1),	1.4707(34)	$35^{+8}_{-6}$
						0.3867(2), 0.4630(2), 0.5259(1)		0
6.912(7)	6.783(7)	>0.028(8)%	>0.013(4)%		0.4442(2)	0.4442(2)	1.4707(34)	$< 680^{+280}_{-170}$
6.992(6)	6.861(6)	>0.167(4)%	>0.080(18)%		0.3639(2)	0.1546(1), 0.2247(1), 0.3639(2)	1.4707(34)	$<\!230^{+80}_{-50}$
7.009(5)	6.878(5)	>0.24(9)%	>0.116(18)%		0.3464(1)	0.3464(1)	1.4707(34)	$<180_{-30}^{+40}$
7.010(6)	6.879(6)	>0.057(15)%	>0.027(7)%		0.3395(1)	0.3395(1)	1.4707(34)	$< 810^{+310}_{-190}$
7.020(6)	6.889(6)	>0.100(19)%	>0.048(9)%		0.3330(1)	0.3330(1)	1.4707(34)	$< 500^{+140}_{-100}$
7.111(5)	6.978(5)	2.04(56)%	0.98(27)%		0.2442(1)	0.1814(1), 0.2442(1)	1.4707(34)	$52^{+22}_{-13}$
7131(7)***	6998(7)***	>0.074(37)%***	>0.036(18)%		0.2551(2)***	0.1625(1)***, 0.2551(2)***	1.4707(34)	$<1.7^{+1.8}_{-0.6} \times 10^{3}$
7.145(5)	7.011(5)	>0.81(8)%	>0.39(4)%		0.2090(1)	0.14640(1), 0.2090(1)	1.4707(34)	$< 176^{+29}_{-24}$
7.157(5)	7.023(5)	>0.65(10)%	>0.312(5)%		0.1955(1)	0.1331(1), 0.1955(1)	1.4707(34)	$<250^{+60}_{-40}$
7.216(4)	7.081(4)	77.8(45)%	37.4(22)%		0.1390(1)	0.0763(1), 0.1390(1)	1.4707(34)	3.3(4)
7.289(6)	7.153(6)	?	?		0.0626(1)	0.0626(1)	1.4707(34)	
7.352(3)	7.215(3)	100(5)%	48(2)%		0.0		1.4707(34)	7.9(8)

* All values from [2004Ku24], except where noted.

** [1968Va04], the  $I_{\alpha}$  value is reported as a lower limit.

*** Tentatively assigned.

[@] Interpolated between 1.4718(31) fm ( 2128 Ra) and 1.4695(14)  216 Th

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${\sf J}_f^{\pi}$	$E_{daughter}(^{214}\mathrm{Ac})$	coincident γ-rays	$R_0 \ (fm)^@$	HF
9.712(8) 9.792(8)	9.534(8)** 9.612(8)***	40(3)%** 100%	29(2)% 71(4)%	(4 ⁺ ) (5 ⁺ )	0.092 0.0	0.092	1.495(21) 1.495(21)	$220^{+130}_{-80}\\150^{+180}_{-50}$

direct  $\alpha$  emission from ²¹⁸Pa,  $J_i^{\pi} = (8^-)$ ,  $T_{1/2} = 108(5) \ \mu s^*$ ,  $BR_{\alpha} = 100\%$ .

* Weighted average of 107(5) µs [2020Zh01] and 113(10) µs [2000He17].

** Weighted average of 9.524(16) MeV; 26(2)% [2020Zh01], 9.544(15) MeV; 35(5)% [2000He17], 9.530(15) MeV; 31(4)% [1996An21] and 9.535(15) MeV; 35(10)% [1979Sc09].

*** Weighted average of 9.610(14) MeV; 74(5)% [2020Zh01], 9.616(15) MeV; 65(7)% [2000He17], 9.610(15) MeV; 69(4)% [1996An21] and 9.614(15) MeV; 365(10)% [1979Sc09].

[@] Interpolated between 1.4695(14) fm  216 Th and 1.521(15) fm  220 U.

#### Table 7

direct $\alpha$ emission from ^{218m} Pa*, Ex. = 80(11) keV, $J_i^{\pi}$	$T = (1^{-}), T_{1/2} = 135^{+62}_{-32} \ \mu s, BR_{\alpha} = 100\%$
----------------------------------------------------------------------------------	-----------------------------------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{214}\mathrm{Ac})$	coincident γ-rays	R ₀ (fm)***	HF
9.775(21) 9.872(15)	9.596(21)** 9.691(15)***	100%	≈100%	(4 ⁺ ) (5 ⁺ )	0.092 0.0	0.092	1.495(21) 1.495(21)	$200^{+140}_{-120}$

* All values from [2020Zh01].

** Tentatively assigned.

*** Interpolated between 1.4695(14) fm ²¹⁶Th and 1.521(15) fm ²²⁰U.

### Table 8

direct  $\alpha$  emission from ²²²Np*, T_{1/2} = 380⁺²⁶⁰₋₁₁₀ ns, BR_{$\alpha$} = 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{218}\text{Pa})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF	
10.200(33)	10.016(33)	100%	29(2)%	(8 ⁻ )	0.0		1.503(50)	$0.9^{+1.8}_{-0.7}$

* All values from [2020Ma27].

** Interpolated between 1.521(15) fm ²²⁰U and 1.484(48) fm ²²⁴Pu,

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Observed and predicted $\beta$ -delayed particle e	mission from the even-2	$Z, T_z = +37/2$	nuclei. J $^{\pi}$ value	es for ¹⁷⁷ Yb	, ¹⁸¹ Hf,	¹⁸⁵ W, ¹⁸⁹ O	s, ¹⁹³ Pt,	197Hg, and 2	⁰¹ Pb are taken
from ENSDF. Unless otherwise stated, all Q	-values are taken from	2021Wa16] c	or deduced from	n values the	rein.				

Nuclide	$J^{\pi}$	Ex.	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
¹⁷⁷ Yb*		$9/2^{+}$	1.911(3) h	-3.42(20)#			[1989Ab18]
$^{181}{ m Hf}^{*}$		$1/2^{-}$	43.39(8) d**	-2.61(13)			[1966Br20, 1960Li14
$^{185}W*$		$3/2^{-}$	75.1(3) d	-1.994(14)			[1972Em01
¹⁸⁹ Os		$3/2^{-}$	$>3.5 \times 10^{15} \text{ y}$	-1.008(8)			[2020Be23
¹⁹³ Pt		$1/2^{-}$	50(9) y	0.0566(3)	-5.886(2)	1.075(8)	[1971Ra18
¹⁹⁷ Hg		$1/2^{-}$	64.14(5) h	0.600(3)	-5.185(3)	1.571(3)	[1966El09
²⁰¹ Pb		5/2-	9.33(3) h	1.910(19)	-3.057(14)	3.444(14)	[1981An11
²⁰⁵ Po		$5/2^{-}$	5.79(2) h	3.544(11)	0.299(10)	7.234(17)	[1983He09]
²⁰⁹ Rn		$5/2^{-}$	28.5(10) m	3.943(11)	1.239(10)	9.700(11)	[1971Go35]
²¹³ Ra		$1/2^{-}$	2.73(5) m	3.900(11)	1.716(10)	10.804(11)	[2017Lo13]
^{213m} Ra	1.770(5)	$17/2^{-}$	2.20(5) ms	5.670(12)	3.486(11)	12.574(12)	[2006Ku26]
²¹⁷ Th		$(9/2^+)$	247(2) µs***	3.503(15)	1.625(13)	13.335(12)	[2005Ku31, 2002He29, 2009QiZZ]
²²¹ U			0.66(14) µs	4.150(0)	2.541(73)	13.393(73)	[2015Kh09]
²²⁵ Pu			· /·	4.68(31)#	3.27(30)#	13.50(31)#	

* 100  $\beta^-$  emitter

** Weighted average of 42.29(10) d [1966Br20] and 42.45(8) d [1960Li14].

*** Weighted average of 257(2) µs [2005Ku31], 237(2) µs [2002He29] and 247(3) µs [2009QiZZ].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +37/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
177 <b>V</b> I	8.00/10)	16.01(40)#	0.24(20)#		
181116	8.90(10) 8.015(71)	10.91(40)#	0.24(20)#		
185337	8.013(71) 7.827(2()	13.34(20)#	1.139(1)		
189 Q-	7.857(20)	14.082(50)	1.390(2)		
105 US	7.259	13.661(1)	1.976(1)		
195Pt	6.933	12.662(1)	2.082(1)		
¹⁹⁷ Hg	6.690(3)	12.324(3)	1.515(3)		
²⁰¹ Pb	5.513(15)	10.303(14)	2.844(14)		
²⁰⁵ Po	4.164(14)	7.313(12)	5.325(10)	0.074(16)%	[ <b>1970Jo26, 1967Ti01, 1951Ha83</b> , 1970DaZM,
					1951Ka37]
²⁰⁹ Rn	3.760(13)	6.373(12)	6.155(2)	17(2)%	[1971Go35, 2017Lo13, 1993Wa04, 1971Jo19,
					1955Mo68, 1955Mo69, 1952Mo23]
²¹³ Ra	3.427(13)	5.477(12)	6.862(2)	87(2)%	[2017Lo13, 2006Ku26, 2005KuZV, 1976Ra37,
					1970TaZS, 1968Lo15, 1967Va22, 1961Gr42,
					1955Mo68]
^{213m} Ra	1.657(14)	3.707(13)	8.632(5)	0.6(4)%	[ <b>2006Ku26</b> , 1976Ra37]
²¹⁷ Th	3.233(14)	4.904(13)	9.435(4)	100%	[2005Ku31, 2002He29, 2019Zh54, 2009QiZZ,
					2005Li17, 2005YeZZ, 2000He17, 2000Ni02,
					2000NiZY, 1973HaZO, 1969MaZT, 1968Va10,
					1968Va18]
²²¹ U	3.047(74)	4.521(92)	9.889(71)	100%	[2015Kh09
²²⁵ Pu	3.02(30)#	4.32(31)#	9.36(31)#		-

## Table 3

direct  $\alpha$  emission from ²⁰⁵Po,  $J_i^{\pi} = 5/2^-$ ,  $T_{1/2} = 5.79(2)$  h*,  $BR_{\alpha} = 0.074(16)\%^{**}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{201}\text{Pb})$	coincident $\gamma$ -rays	R ₀ (fm)]	HF
5.326(7)	5.222(7)***	0.074(16)%**	5/2-	0.0		1.4586(16)	$2.1\substack{+0.6\\-0.4}$

* [1983He09]. ** [1951Ha83].

*** Weighted average of 5.224(10) MeV [1970Jo26] and 5.220(10) MeV [1967Ti04].

Table 4	
direct $\alpha$ emission from ²⁰⁹ Rn*, $J_i^{\pi} = 5/2^-$ , T ₁	$_{1/2} = 28.5(10) \text{ m}, BR_{\alpha} = 17(2)\%.$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{205}\text{Po})^{**}$	coincident γ-rays**	R ₀ (fm)]	HF
5.770(3)	5.660(3)	0.024(2)%	0.0041(6)%		0.384	0.154, 0.230, 0.384	1.4662(37)	$87^{+20}_{-15}$
6.002(3)	5.887(3)	0.22(2)%	0.037(6)%		0.154	0.154	1.4662(37)	$117^{+27}_{-21}$
6.013(3)	5.898(3)	0.14(2)%	0.024(4)%		0.143	0.143	1.4662(37)	$210_{-40}^{+60}$
6.157(3)	6.039(3)	100	16.9(20)%		0.0		1.4662(37)	$1.3^{+0.3}_{-0.2}$

* All values from [1971Go35], except where noted.

** [2020Ko17].

#### Table 5

direct  $\alpha$  emission from ²¹³Ra,  $J_i^{\pi} = 1/2^-$ ,  $T_{1/2} = 2.83(5)$  m*,  $BR_{\alpha} = 89(2)\%$ *.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})^*$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{209}\mathrm{Rn})$	coincident γ-rays	$R_0$ (fm)]	HF
6.349(6)	6.230(6)	0.7(3)%	0.44(17)%	(5/2-)	0.5113	0.1106(2), 0.1830(2), 0.2152(2), 0.2181(2), 0.2964(2), 0.3283(1), 0.5113(3)	1.4638(22)	$4.5^{+3.2}_{-1.4}$
6.536(4)	6.413(4)	0.7(3)%	0.44(17)%	3/2-	0.3283	0.1106(2), 0.2181(2), 0.3283(1)	1.4638(22)	$27^{+19}_{-8}$
6.647(3)	6.522(3)	13.9(22)%	8.3(13)%	$3/2^{-}$	0.2149	0.106(1), 0.1106(2), 0.2152(2)	1.4638(22)	$4.1_{-0.7}^{+0.9}$
6.752(3)	6.625(3)	100(4)%	59.6(22)%	$1/2^{-}$	0.1103	0.1103	1.4638(22)	1.49(10)
6.862(3)	6.733(3)	30.7(31)%	18.3(18)%	5/2-	0.0		1.4638(22)	13.0(15)

* [2017Lo13].

** [2006Ku26].

### Table 6

direct $\alpha$ emission from $\frac{1}{2}$	^{213m} Ra, Ex. =	= 1.770(5) MeV, J	$\frac{\pi}{i} = 17/2^{-}, T$	$_{1/2} = 2.20(5) \text{ ms}^*$	$BR_{\alpha} = 0.6(4)\%^*$
---------------------------------------------	---------------------------	-------------------	-------------------------------	---------------------------------	----------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})^*$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{209}\mathrm{Rn})$	coincident $\gamma$ -rays	$R_0$ (fm)]	HF
8.426(9) 8.517(7) 8.630(4)	8.268(9)** 8.357(7)*** 8.468(4) [@]	5.2(21)%** 43(29)%*** 100%	0.021(16)% 0.17(12)% 0.41(27)%	3/2 ⁻ 1/2 ⁻ 5/2 ⁻	0.2149 0.1103 0.0	0.106(1), 0.1106(2), 0.2152(2) 0.1103	1.4638(22) 1.4638(22) 1.4638(22)	$\begin{array}{c} 1.7^{+6.2}_{-0.8}\times10^{4}\\ 4^{+10}_{-2}\times10^{3}\\ 3^{+2}_{-2}\times10^{3} \end{array}$

* [2006Ku26].

** Weighted average of 8.270(20) MeV; 4(2)% [2006Ku26] and 8.266(10) MeV (adjusted to 8.267(10) in [1991Ry01]); 3(2)% [2006Ku26].

*** Weighted average of 8.355(9) MeV; 33(13)% [2006Ku26] and 8.358(10) MeV (adjusted to 8.359(10) in [1991Ry01]); 28(6)% [2006Ku26].

[@] Weighted average of 8.469(6)(6) MeV; 63(13)% [2006Ku26] and 8.467(5) MeV (adjusted to 8.468(5) in [1991Ry01]); 69(7)% [2006Ku26].

## Table 7

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{213}\mathrm{Ra})$	coincident $\gamma$ -rays	$R_0 (fm)$ ]	HF
8.616(5) 8.890(5) 9.437(5)	8.457(5)** 8.726(5)*** 9.263(5) [@]	3.8(2)%** 1.7(1)%*** 100%	3.5(1)% 1.6(1)% 95.0(3)%	(3/2 ⁻ ) (5/2 ⁻ ) 1/2 ⁻	0.8221 0.5461 0.0	0.8221(1) 0.5461(1)	1.5091(22) 1.5091(22) 1.5091(22)	24.3(14) 286(23) 106(6)

*** Weighted average of 257(2) µs [2005Ku31], 237(2) µs [2002He29] and 247(3) µs [2009QiZZ].

** Weighted average of 8.460(7) MeV,  $I_{\alpha}(\text{rel}) = 3.1(2)\%$  [2005Ku31] and 8.455(5) MeV,  $I_{\alpha}(\text{rel}) = 3.9(1)\%$  [2002He29].

*** Weighted average of 8.727(8) MeV,  $I_{\alpha}$  (rel) = 1.6(1)% [2005Ku31] and 8.725(5) MeV,  $I_{\alpha}$  (rel) = 1.9(1)% [2002He29].

[@] Weighted average of 9.269(9) MeV, [2005Ku31] and 9.261(5) MeV [2002He29].

#### Table 8

direct $\alpha$ emission	firect $\alpha$ emission from ²²¹ U*, $T_{1/2} = 0.66(14) \ \mu$ s, $BR_{\alpha} = 100\%$ .								
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{217}\mathrm{Th})$	coincident $\gamma$ -rays	R ₀ (fm)]	HF		
9.889(50)	9.710(50)	100%	(9/2+)	0.0		1.525(15)	$1.1\substack{+0.5 \\ -0.4}$		

* All values from [2015Kh09].

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +37/2$ nuclei. J ^{$\pi$} values for ¹⁷⁹ Lu, ¹⁸³ Ta, ¹⁸⁷ I	Re, ¹⁸⁷ Ir, ¹⁹⁵ Au, ¹⁹	⁹⁹ Tl and ²⁰³ Bi are taken
from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.		

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
170-	= 10 ±	1 70/01				10/20.003
Lu*	7/2+	4.59(6) h	-2.42(20)#			[1963St08]
¹⁸³ Ta*	$7/2^{+}$	5.1(1) d**	-2.010(30)			[1953Du20, 1955Po26]
¹⁸⁷ Re*	5/2+	$4.12(13) \times 10^{10} \text{ y}$	-1.313(1)			[2001Ga01]
¹⁹¹ Ir	$3/2^{+}$	stable	-0.314(1)			
¹⁹⁵ Au	$3/2^{+}$	186.01(6) d	0.227(1)	-7.324(2)	1.403(1)	[2012Fu06]
¹⁹⁹ Tl	$1/2^{+}$	7.42(8) h	1.487(28)	-5.768(28)	2.310(28)	[1960Ju03]
²⁰³ Bi	9/2-	11.76(5) h	3.262(14)	-2.833(13)	5.596(13)	[1960St01]
²⁰⁷ At	9/2-	1.80(3) h**	3.918(14)	-0.488(15)	9.134(14)	[1962Th08, 1969Ba69, 1968GuZX]
²¹¹ Fr	9/2-	3.10(2) m	4.615(14)	0.543(14)	10.580(14)	[1971ReZE]
²¹⁵ Ac	(9/2-)	170(10) ms	3.499(14)	-0.300(15)	12.361(14)	[1968Va04]
²¹⁹ Pa	(9/2-)	$60^{+28}_{-15}$ ns	4.120(90)	0.443(90)	13.626(70)	[2017Su18]
²²³ Np		$2.15^{+1.00}_{-0.52} \ \mu s$	4.61(10)	1.31(12)	13.77(10)	[2017Su18]
²²⁷ Am		0.52	5.41(22)#	2.07(23)#	13.71(21)#	

* 100  $\beta^-$  emitter

** Weighted average of 1.80(5) h [1962Th08], 1.82(4) h [1969Ba69] and 1.77(5) h [1968GuZX].

Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +37/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental	
¹⁷⁹ Lu	6.671(8)	16.07(20)#	0.827(50)			
¹⁸³ Ta	6.533(6)	15.07(13)	1.341(5)			
¹⁸⁷ Re	5.997(1)	14.400(14)	1.652(2)			
¹⁹¹ Ir	5.290(1)	13.308(8)	2.083(1)			
¹⁹⁵ Au	5.096(1)	12.609(2)	1.717(2)			
¹⁹⁹ Tl	4.394(28)	11.498(28)	2.083(28)			Ì
²⁰³ Bi	2.873(13)	8.922(19)	4.110(31)			
²⁰⁷ At	2.328(13)	6.740(13)	5.872(3)	obs*	[1969Go23, 1951Ba14]	
²¹¹ Fr	1.825(13)	5.834(13)	6.662(3)	87(3)%	[2005Ku06, 2022Ha06, 1971ReZE, 1969Gr04,	
					1967Va20, 1961Gr42]	
²¹⁵ Ac	1.351(13)	4.993(13)	7.746(3)	99.91(2)%	[2004Ku24, 1968Va04, 2017Su18, 2003KuZX,	Ì
					2000He17]	
²¹⁹ Pa	1.072(70)	4.697(71)	10.128(69)	100%	[ <b>2017Su18</b> , 1987FaZS]	
²²³ Np	0.903(98)	4.29(10)	9.650(45)	100%	[2017Su18]	
²²⁷ Am	0.74(28)#	4.02(22)#	9.10(22)#			

* [1951Ba14] reports the branching ratio as  $\approx 10\%$ .

### Table 3

direct  $\alpha$  emission from ²⁰⁷At, J^{$\pi$} = 9/2⁻, T_{1/2} = 1.80(3) h*, BR_{$\alpha$} = obs**.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{203}\mathrm{Bi})$	coincident γ-rays	R ₀ (fm)]	HF
5.872(3)	5.759(3)***	obs**	9/2-	0.0		1.4651(131)	≈1.10

* Weighted average of 1.80(5) h [1962Th08], 1.82(4) h [1969Ba69] and 1.77(5) h [1968GuZX]. ** "No serious attempt has been made to determine the degree of alpha-branching of At²⁰⁷. The best estimate from the alpha-particles of At²⁰⁷ and the yield of Po²⁰⁷ is 10 percent alpha-branching." [1951Ba14].  $\approx 10\%$  is used for the branching ratio in determining the HF value.

*** [1969GoZX].

Table 4	
direct $\alpha$ emission from ²¹¹ Fr*, J ^{$\pi$} = 9/2 ⁻ , T _{1/2} = 3.10(2) m**, BR _{$\alpha$}	= 87(3)%

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{207}\text{At})$	coincident γ-rays	R ₀ (fm)]	HF
5.979(6) 6.019(7) 6.319(5) 6.663(4)	5.866 (6) 5.905(7) 6.199 (5) 6.537 (4)	>0.009(5)% >0.006(4)% >0.041(13)% 100%	>0.0078(44)% >0.0052(35)% >0.036(11)% >87(3)%	(13/2–) (11/2–) (7/2–) (9/2–)	0.6867(6) 0.6439(5) 0.3445(2) 0.0	0.6867(6) 0.6439(5) 0.3445(2)	1.4643(27) 1.4643(27) 1.4643(27) 1.4643(27)	<16 <40 <120 1.33(10)

* All values from [2005Ku06], except where noted.

** [1971ReZE].

## Table 5

direct $\alpha$ emission from ²¹⁵ A	$z^*, J^{\pi} = (9/2^-), T_{1/2} =$	$170(10) \text{ ms}^{**}, BR_{\alpha}$	= 99.91(2)%**.
------------------------------------------------	-------------------------------------	----------------------------------------	----------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{211}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)]	HF
7 007(7)	6 877(7)	0.026(4)%	0.026(4)%	$(7/2^{-})$	0 7392(4)	0 3426(5) 0 7392(4)	1 4626(13)	$132^{+3.4}$
7.091(5)	6.959(5)	0.07(1)%	0.07(1)%	$(112^{-})$ $(13/2^{-})$	0.6526(2)	0.6526(2)	1.4626(13)	$10.3^{+2.54}_{-1.9}$
7.111(6)	6.979(6)	0.007(4)%	0.007(4)%	$(5/2^{-})$	0.6331(2)	0.2372(4), 0.6331(2)	1.4626(13)	$120^{+180}_{-50}$
7.162(5)	7.029(5)	0.12(1)%	0.12(1)%	$(11/2^{-})$	0.5832(1)	0.5832(1)	1.4626(13)	10.8(12)
7.243(7)	7.108(7)	0.007(4)%	0.007(4)%	$(5/2^{-})$	0.5059(2)	0.1101(4), 0.5059(2)	1.4626(13)	$400^{+500}_{-200}$
7.348(5)	7.211(5)	0.20(2)%	0.20(2)%	$(7/2^{-})$	0.3958(1)	0.3958(1))	1.4626(13)	$130_{-5}^{+6}$
7.744(4)	7.600(4)	100%	99.48(7)%	(9/2-)	0.0		1.4626(13)	1.26(9)

* All values from [2004Ku24], except where noted.

** [1968Va04].

*** Tentative assignment [2004Ku24].

## Table 6

9.650(44)

direct $\alpha$ emission from ²¹⁹	9 Pa*, J ^{$\pi$} = (9/2 ⁻ ), T _{1/2} =	$= 60^{+28}_{-15}$ ns, $BR_{\alpha} =$	100%
----------------------------------------------	-------------------------------------------------------------------------------------	----------------------------------------	------

100%

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{215}\mathrm{Ac})$	coincident γ-rays	$R_0$ (fm)]	HF		
10.162(37)	9.976(37)	100%	(9/2-)	0.0		1.5346(88)	$0.9\substack{+0.5\\-0.3}$		
* All values	from [2017Su18	].							
<b>Table 7</b> direct $\alpha$ emission	<b>Table 7</b> direct $\alpha$ emission from ²²³ Np*, T _{1/2} = 2.15 ^{+1.00} _{-0.52} $\mu$ s, $BR_{\alpha}$ = 100%.								
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{219}\mathrm{Pa})$	coincident $\gamma$ -rays	R ₀ (fm)]	HF		

 $0.3\substack{+0.4 \\ -0.2}$ 

1.507(32)

* All values from [2017Su18].

9.477(44)

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 $(9/2^{-})$ 

0.0

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +19 nuclei.

Last updated 1/13/23

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +19$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
182 <b>LIF</b> *		$0^+$	$8.00(0) \times 10^{6} \mathrm{m}$	4 28(20)#			[2004Wa16]
186W		$0^+$	stable $(3) \times 10^{\circ}$ y	-3.900(60)			[2004 0010]
¹⁹⁰ Os		$0^{+}$	stable	-3.125(5)			
¹⁹⁴ Pt		$\overset{\circ}{0^+}$	stable	-2.228(1)			
¹⁹⁸ Hg		$0^+$	stable	-1.374(1)			
²⁰² Pb		$0^{+}$	$5.25(28) \times 10^4 \text{ y}$	0.040(4)	-5.567(4)	1.215(4)	[1981Na15]
²⁰⁶ Po		$0^+$	8.8(1) d	1.840(9)	-1.707(4)	5.367(4)	[1956Jo34]
²¹⁰ Rn		$0^+$	144(6) m	2.367(9)	-0.528(5)	7.999(9)	[1971Go35]
²¹⁴ Ra		$0^+$	2.47(2) s**	1.051(10)	-1.500(6)	9.640(9)	[2009MuZV, 2006Ku26]
^{214m} Ra	1.865(30)	$8^+$	68.6(20) µs	2.916(10)	0.365(6)	11.505(9)	[2006Ku26]
²¹⁸ Th		$0^+$	117(5) ns***	1.520(60)	-0.812(13)	10.900(14)	[1982Ch29, 1973Ha32, 1973No09]
²²² U		$0^+$	4.7(7) μs	2.21(10)	0.044(53)	10.997(78)	[2015Kh09]
²²⁶ Pu		$0^+$		2.81(23)#	0.97(20)#	11.14(22)#	

* 100%  $\beta^-$  emitter.

** Weighted average of 2.485(25) s [2009MuZV] and 2.46(3) s [2006Ku26].

*** Weighted average of 125(5) ns [1982Ch29], 122(8) ns [1973Ha32] and 96(7) ns [1973No09].

Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +19$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
182 LLF	8 54(12)	15.01/20)#	1 202(0)		
186 337	8.34(13) 8.402(14)	15.91(30)#	1.203(9)		
190 O	8.405(14)	13.387(40)	1.110(0)		
¹⁹⁰ Os	8.018(8)	14.618(3)	1.376(1)		
¹⁹⁴ Pt	7.513(1)	13.456(2)	1.523(0)		
¹⁹⁸ Hg	7.104(0)	12.888(1)	1.381(1)		
²⁰² Pb	6.049(15)	11.015(4)	2.589(4)		
²⁰⁶ Po	4.412(6)	7.657(4)	5.327(1)	5.2(4)%	[1971Go35, 1970Ra14, 1968Go11, 1970AfZZ, 1967Le08,
					1967Ti04, 1961Fo05, 1956Bu12, 1955Mo68, 1951Ka37,
					1947Te011
²¹⁰ Rn	4.010(7)	6.713(4)	6.159(2)	96(1)%	[ <b>1971Go35, 1955Mo68</b> , 1955Mo69, 1952Mo23]
²¹⁴ Ra	3.642(7)	5.826(6)	7.273(3)	$\approx 100\%$	[2006Ku26, 2015Kh09, 2009MuZV, 2000He17, 1974Ho27,
					1968Lo15, 1961Gr42]
214m Ra	1.777(7)	3.961(6)	9.138(3)	0.09(7)%	[2006Ku26]
²¹⁸ Th	3.625(15)	5.503(13)	9.849(9)	100%	[1973No09, 2018Br13, 2015Kh09, 1982Ch29, 1973Ha32,
					1973Hi06]
²²² U	3.391(79)	4.995(54)	9.416(8)*	100%	[2023Lu04, 2015Kh09, 1983Hi12]
²²⁶ Pu	3.28(22)#	4.69(20)#	8.93(22)#		

* From  $\alpha$  decay of ²²²U. 9.481(51) MeV in [2021Wa16].

### Table 3

direct $\alpha$ emissio	lirect $\alpha$ emission from ²⁰⁶ Po, J ^{$\pi$} = 0 ⁺ , T _{1/2} = 8.8(1) d*, BR _{$\alpha$} = 5.2(4)%***.												
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{202}\text{Pb})$	coincident $\gamma$ -rays	R ₀ (fm)]	HF						
5.327(2)	5.223(2)**	5.2(4)%***	$0^+$	0.0		1.4547(10)	1.05(8)						

* [1956Jo14].

** Weighted average of 5.224(2) MeV [1968Go11] and 5.222(3) MeV [1970Ra14].

*** From [1971Go35]. [1967Le08] reports 5.45% with no error bar.

|--|

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$		${ m J}_f^\pi$	$E_{daughter}(^2$	²⁰⁶ Po)	coincident γ-ray	s $R_0$ (fm)]	HF
5.455(3) 6.155(3)	5.351(3)* 6.038(3)	$\begin{array}{l} 5.6(3)\times 10^{-3}\%\\ 100\%\end{array}$	* $5.4(3) \times 96(1)\%$	10 ⁻³ %	${0^+ \over 0^+}$	0.700(4) 0.0		0.700	1.4568(22) 1.4568(22)	6.7(4) 0.97(2)
* [1971 ** [195	1Go35]. 55Mo68].									
Table 5 direct $\alpha$ em	ission from ²¹⁴ R	a*, $J^{\pi} = 0^+$ , $T_{1/2}$	= 2.47(2) s**, <i>B</i> F	$R_{\alpha} = \approx 100$	0%.					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	E _{daugh}	ter( ²¹⁰ Rn	coinc	ident γ-rays	R ₀ (fm)]	HF
6.629(5) 7.271(4)	6.505(5) 7.135(4)	0.16(3)% 100%	0.16(3)% 99.84(3)%	$2^+_{0^+}$	0.6439 0.0	)	0.643	39	1.4557(12) 1.4557(12)	$\begin{array}{c} 2.6^{+0.6}_{-0.4} \\ 0.997(8) \end{array}$
* All v ** Wei	alues from [2006 ghted average of	Ku26], except wh 2.485(25) s [2009	ere noted. MuZV] and 2.46	6(3) s [200	6Ku26].					
Table 6 direct $\alpha$ em	ission from ^{214m}	Ra*, Ex. = 1.865.2	$2 \text{ keV}, J^{\pi} = 8^+, T$	_{1/2} = 68.6	(20) µs, B	$R_{\alpha} = 0.09(7)$	7)%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$ I	_α (abs)	${ m J}_f^\pi$	$E_{daugh}$	ter( ²¹⁰ Rn	coincid	lent γ-rays	R ₀ (fm)]	HF
7.429(30) $\approx 8.509$ 9.120(30)	$7.290(30) \\ \approx 8.350^{**} \\ 8.950(30)$	6.6(33)%50.18(3)%0100%9	.4(46) × 10 ⁻³ % .16(3)% 1(6)%	${8^+ \over 2^+ \over 0^+}$	1.710( 0.6439 0.0	30) )	0.2031 0.6439	, 0.6439, 0.8178	1.4557(12) 1.4557(12) 1.4557(12)	$\begin{array}{c} 14(12) \\ >6 \times 10^{3} \\ 8  {}^{+30}_{-4} \times 10^{3} \end{array}$
* All v ** tent	alues from [2006 atively assigned	Ku26], except wh [2006Ku26].	ere noted.							
Table 7 direct $\alpha$ em	ission from ²¹⁸ Tl	h, $J^{\pi} = 0^+$ , $T_{1/2} =$	117(5) ns*, $BR_{\alpha}$	= 100%.						
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	Edaughte	r( ²¹⁴ Ra)	coinc	cident γ-ra	$R_0$ (fm)	)] HF	
9.846(10)	9.665(10)*	** 100%	$0^+$	0.0				1.5487(	(30) 0.95(4	ł)
* Weig ** [197	hted average of 1 73No09].	125(5) ns [1982Ch	29], 122(8) ns [1	973Ha32]	and 96(7)	ns [1973No	009].			
Table 8 direct $\alpha$ em	ission from ²²² U	$J^{\pi} = 0^+, T_{1/2} = 4$	4.7(7) $\mu$ s*, $BR_{\alpha}$ =	= 100%.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi}$	Edaughter	( ²¹⁸ Th)	coinci	ident γ-ray	$R_0$ (fm)	] HF	
9.416(8)	9.246(8)**	100%	$0^+$	0.0				1.529(1	5) 0.70(10	)
* [2015	5Kh091.									

** [2023Lu04].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +19 nuclei.

Last updated 1/13/24

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +19$  nuclei. J^{$\pi$} values for ¹⁸⁰Lu, ¹⁸⁴Ta, ¹⁸⁸Re, ¹⁹²Ir, ¹⁹⁶Au, ²⁰⁰Tl and ²⁰⁴Bi are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	Ex.	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
100							
¹⁸⁰ Lu*		$5^{+}$	5.7(1) m	-1.96(31)#			[1973KaYQ]
¹⁸⁴ Ta*		$(5^{-})$	8.7(1) h	-1.340(3)			[1955Bu80]
¹⁸⁸ Re*		$1^{-}$	0.70846(14) d	-0.349(3)			[2004Sc04]
¹⁹² Ir**		$4^{+}$	73.831(8) d	1.047(2)	-7.774(10)	1.407(3)	[1980Ho17]
196Au***		$2^{-}$	6.1669(6) d	0.687(3)	-6.735(3)	2.319(4)	[2001Li17]
²⁰⁰ Tl		$2^{-}$	26.1(1) h	2.456(6)	-5.242(6)	3.172(6)	[1962Ja10]
²⁰⁴ Bi		$6^{+}$	11.22(10) h	4.464(9)	-2.174(9)	6.432(9)	[1960St21]
²⁰⁸ At		$6^{+}$	1.63(3) h	4.999(9)	0.296(9)	10.215(9)	[1964Th07]
²¹² Fr		$5^{+}$	20.3(3) m [@]	5.143(9)	0.842(9)	11.528(9)	[1973GoZX, 1950Hy27]
²¹⁶ Ac		$1^{-}$	443(7) μs	4.858(12)	0.543(12)	14.384(10)	[2000He17]
²²⁰ Pa		$(1^{-})$	0.75(4) µs ^{@@}	5.589(20)	1.420(54)	14.562(17)	[2023Lu04, 2021Ma66, 2020Ma27,
							2019Ya04, 2017Hu08
^{220m1} Pa	0.124(40)	(3 ⁻ )	$233^{+108}_{-56}$ ns	5.589(20)	1.544(67)	14.686(43)	[2021Ma66]
^{220m2} Pa	0.274(62)		$69^{+330}_{-30}$ ns	5.589(20)	1.694(82)	14.836(75)	[2018Hu13]
²²⁴ Np			$38^{+26}_{-11} \mu s$	6.290(30)	2.406(81)	14.918(32)	[2018Hu13]
²²⁸ Am				6.74(20)#	2.98(22)#	14.68(20)#	

* 100%  $\beta^-$  emitter.

** 92.24(4)%  $\beta^-$ , 4.76(4)%  $\varepsilon$  emitter [2012Ba36]. *** 97.0(3)%  $\beta^-$ , 93(3)%  $\varepsilon$  emitter [2007Hu13].

[@] Weighted average of 20.6(3) m [1973GoZX] and 19.3(5) m [1950Hy27].

[@] Weighted average of 0.83(7) μs [2023Lu04], 0.75(8) μs [2021Ma66], 0.73(11) μs [2020Ma27], 0.91(10) μs [2019Ya04] and 0.90(13) μs [2017Hu08].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +19$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
1801 11	7 33(21)#	17 04(31)#	0.27(12)		
¹⁸⁴ Ta	6.845(40)	$17.04(31)\pi$ 15.65(20)	1.412(75)		
¹⁸⁸ Re	6402(1)	14 987(60)	1.398(26)		
¹⁹² Ir	5,729(1)	13 831(5)	1.356(20)		
¹⁹⁶ Au	5.634(3)	13.185(3)	1.272(3)		
²⁰⁰ Tl	4.790(6)	12.044(6)	1.667(6)		
²⁰⁴ Bi	3.148(11)	9.243(9)	3.976(11)		
²⁰⁸ At	2.613(11)	7.020(12)	5.751(2)	0.56(5)%	[1981Va27, 1981Va29, 1970GoZZ, 1950Hy27, 1981VaZM,
					1981VaZN, 1981VaZO, 1980VaZT, 1963Uh01]
²¹² Fr	2.050(11)	6.122(12)	6.529(2)	44(4)%*	[2005Ku06, 1981Va27, 1981Va29, 1950Hy27, 1980VaZT,
					1974Ho27, 1973GoZX, 1971ReZE, 1966Va21, 1955Mo69,
					1953AsZZ]
²¹⁶ Ac	1.671(12)	5.470(13)	9.241(3)	100%	[2004Ku24, 2021Ma66, 2018Hu13, 2017Hu08, 2005Li17,
					2000He17, 1970To18, 1969MaZT, 1968Va18, 1966Ro12]
²²⁰ Pa	1.473(58)	5.150(59)	9.704(11)	100%	[2023Lu04, 2021Ma66, 2020Ma27, 2019Ya04, 2019Zh54,
					2017Hu08, 1987FaZS]
^{220m1} Pa	1.349(70)	5.026(71)	9.828(41)	100%	[2021Ma66]
^{220m2} Pa	1.199(85)	4.876(86)	9.976(63)	100%	[2018Hu13]
²²⁴ Np	1.302(66)	4.610(91)	9.329(30)	100%	[2018Hu13]
²²⁸ Am	1.21(22)#	4.55(23)\$	8.39(20)#		

* based on the K-xray/ $\alpha$  ratio of 1.3(1)% [1950Hy01].

## Table 3 direct $\alpha$ emission from ²⁰⁸At, $J^{\pi} = 6^+$ , $T_{1/2} = 1.63(3)$ h*, $BR_{\alpha} = 0.56(6)\%^{**}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	$J_f^{\pi @}$	$E_{daughter}(^{204}\mathrm{Bi})^{@}$	coincident γ-rays [@]	$R_0 (fm)^{@@@}$	HF
≈5.615 5.696(2) 5.736(4) 5.752(3)	≈5.507 ^{@@} 5.586(2) 5.626(4) 5.641(3)	$\approx 0.2^{@@}\%$ 0.9(1)% 2.2(2)% 100(3)%	$pprox 1.1  imes 10^{-3}\%$ 4.9(8) $ imes 10^{-3}\%$ 1.2(2) $ imes 10^{-2}\%$ 0.54(6)%	$7^+$ $4^+$ $6^+$	0.137 0.0534(2) 0.0151(1) 0.000	0.0534(2)	1.4558(24) 1.4558(24) 1.4558(24) 1.4558(24)	$\begin{array}{c} 420\\ 250^{+50}_{-40}\\ 160^{+40}_{-30}\\ 4.2^{+0.7}_{-0.5}\end{array}$

* [1964Th07].

** Based on the ratio of K x-ray/ $\alpha$  from ²⁰⁸At [1950Hy27].

*** [1981Va27, 1981Va29], except where noted.

^(a) [2010Ch02]. ^(a) @ [19010GoZZ]. Not observed in [1981Va27, 1981Va29], but may have been below statistical threshold. ^(a) @ [Interpolated between 1.4547(10) fm (²⁰⁶Po) and 1.4568(22) fm (²¹⁰Rn).

# Table 4

direct  $\alpha$  emission from ²¹²Fr, J^{$\pi$} = 5⁺, T_{1/2} = 20.3(3) m^{*}, BR_{$\alpha$} = 44(4)%^{**}.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{208}\mathrm{At})^{@@@}$	coincident γ-rays ^{@@@}	$R_0 (fm)^@$	HF
5.848(6)	5.738(6)@@@	$\approx 0.005\%^{@@@}$	≈0.002%		0.6817	0.6871	1.4563(25)	$\approx 200$
5.940(6)	5.828(6)	0.13(8)%	0.022(13)%		0.5879	0.0235, 0.0401, 0.0503, 0.5879	1.4563(25)	$22^{+35}_{-9}$
						0.1245, 0.1479, 0.1635, 0.1699,		
						0.2037, 0.2199, 0.2272, 0.2601,		
						0.2835, 0.3047, 0.3613, 0.4406,		
						0.5242, 0.5879		
6.098(4)	5.983(4) ^{@@}	0.19(3)%	0.031(5)%		0.4295	0.0235, 0.0401, 0.0719, 0.1245	1.4563(25)	$90^{+40}_{-20}$
						0.1479, 0.1635, 0.2023, 0.2037,		
						0.2272, 0.2816, 0.3577, 0.4058		
6.194(3)	6.077(3)	2.5(3)%	0.40(6)%		0.3347	0.0235, 0.0401, 0.2170, 0.3112, 0.3347	1.4563(25)	$17.9^{+3.5}_{-2.7}$
6.245(3)	6.127(3)	3.4(3)%	0.57(7)%		0.2835	0.0235, 0.0401, 0.0503, 0.1699, 0.2199	1.4563(25)	21.0(23)
						0.2601, 0.2835		
6.292(4)	6.173(4)@@	3.4(3)%	0.57(7)%		0.2372	0.0235, 0.0401, 0.1736, 0.2137	1.4563(25)	$34^{+6}_{-5}$
6.303(3)	6.184(3)	4.2(4)%	0.69(8)%		0.2272	0.0235, 0.0401, 0.1635, 0.2037, 0.2272	1.4563(25)	$30_{-4}^{+5}$
6.383(3)	6.263(3)	100(5)%	16.5(16)%	$5^{+}$	0.1479	0.0235, 0.1245, 0.1479	1.4563(25)	2.79(31)
6.458(3)	6.336(3)@@	27(2)%@@	4.4(5)%	$(3^+)$	0.1139	0.0235, 0.0401, 0.0503	1.4563(25)	14(2)
6.464(3)	6.342(3)	8.0(6)%	1.32(15)%	7+	0.0719	0.0719	1.4563(25)	$73^{+11}_{-9}$
6.507(3)	6.384(3)	64(3)%	10.6(10)%	$(5^{+})$	0.0235	0.0235	1.4563(25)	14.4(6)
6.528(3)	6.405(3)	59(3)%	9.7(9)%	6+	0.0		1.4563(25)	19.6(23)

* Weighted average of 20.6(3) m [1973GoZX] and 19.3(5) m [1950Hy27].

*** Weighted average of 20.0(3) in [19/3002X] and 19.5(3) in [19/301927]. *** Based on the K-xray/ $\alpha$  ratio of 1.3(1)% [1950Hy01]. *** Weighted average of values from [2005Ku06] and [1981Va27, 1981Va29]. @ Interpolated between 1.4568(22) fm (²¹⁰Rn) and 1.4557(12) fm (²¹⁴Ra).

^{@@} [1981Va27, 1981Va29]. ^{@@@} [2005Ku06].

## Table 5 direct $\alpha$ emission from ²¹⁶Ac*, J^{$\pi$} = 1⁻, T_{1/2} = 443(7) $\mu$ s**, BR $_{\alpha}$ = 100%.

				- 77				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	$J_f^{n}$	$E_{daughter}(^{212}\mathrm{Fr})$	coincident $\gamma$ -rays	$R_0 (fm)^{***}$	HF
7.904(6)	7.758(6)	0.023(6)%	0.011(3)%		1.3753(3)	0.0826(1), 0.4368(6), 0.8558(7), 0.9382(1), 1.2931(4), 1.3753(3)	1.5022(32)	$230^{+100}_{-60}$
7.923(15)	7.776(15)	> 0.0020(8)%	>0.0010(4)%		1.356(2)	1.356(2)	1.5022(32)	$< 1.6 \times 10^{3}$
7.994(15)	7.846(15)	0.033(6)%	0.016(3)%		1.2871(8)	1.2871(8)	1.5022(32)	<300
8.041(10)	7.892(10))	0.043(4)%	0.021(2)%		1.2399(4)	1.2399(4)	1.5022(32)	<310
8.074(15)	7.924(15)	0.0027(4)%	0.0013(2)%		1.2095(5)	1.2095(5)	1.5022(32)	$< 6.3 \times 10^{3}$
8.152(15)	8.001(15)	> 0.0049(33)%	>0.0024(16)%		1.1299(5)	0.0826(1), 1.0475(9), 1.1299(5)	1.5022(32)	$< 5.8 \times 10^{3}$
8.267(9)	8.114(9)	>0.0041(6)%	>0.002 0(3)%		1.0087(4)	1.0087(4)	1.5022(32)	${<}1.6 imes10^4$
8.341(5)	8.187(5)	1.5(1)%	0.74(2)%		0.9382(1)	0.0826(1), 0.8558(7), 0.9382(1)	1.5022(32)	68(6)
8.426(5)	8.270(5)	2.9(2)%	1.40(7)%		0.8537(1)	0.0826(1), 0.3529(2), 0.4183(1),	1.5022(32)	69(7)
8.503(7)	8.346(7)	>0.21%	<0.1%		0.7773(2)	0.5007(1), 0.7713(1), 0.8537(1) 0.0826(1), 0.2766(2), 0.4183(1), 0.5007(1), 0.6948(1), 0.7773(1)	1.5022(32)	>140
8.670(7)	8.509(7)	>0.035(2)%	>0.017(1)%		0.6106(2)	0.6106(2)	1.5022(32)	${<}2.3 imes10^4$
8.675(6)	8.514(6)	> 0.23(4)%	>0.11(2)%		0.6062(1)	0.0826(1), 0.1058(2), 0.4183(1), 0.5007(1), 0.5237(1), 0.6062(1)	1.5022(32)	$< 3.7 \times 10^{3}$
8.697(15)	8.536(15)	> 0.25(4)%	>0.12(2)%		0.5750(4)	0.0826(1), 0.4924(1), 0.5750(4)	1.5022(32)	$< 4.1 \times 10^{3}$
8.738(6)	8.576(6)	> 0.94(10)%	>0.46(5)%	$(7)^{+}$	0.542(1)	0.542(1)	1.5022(32)	$< 1.3 \times 10^{3}$
8.743(6)	8.581(6)	> 1.05(12)%	>0.51(6)%		0.5363(1)	0.0826(1), 0.4539(1), 0.5363(1)	1.5022(32)	$< 1.2 \times 10^{3}$
8.779(6)	8.616(6)	0.47(10)%	0.23(5)%		0.5007(1)	0.0826(1), 0.4183(1), 0.5007(1)	1.5022(32)	$3.4^{+1.1}_{-0.7} \times 10^3$
9.199(7)	9.029(7)	100(3)%	48.8(10)%	$(4^{+})$	0.0826(1)	0.0826(1)	1.5022(32)	177(15)
9.277(7)	9.105(7)	97(2)%	47.5(5)%	$5^{+}$	0.0		1.5022(32)	288(25)

* All values from [2004Ku24], except where noted. Previous works [2000He17, 1970To18, 1968Va18] had assigned  $\alpha$ 's as decaying from both a 1⁻ ground state and a 9⁻ isomer. [2004Ku24] demonstrated that all  $\alpha$ 's could be accounted for using HF and coincident  $\gamma$ -rays.

** [2000He17].

*** Interpolated between 1.4557(12) fm (²¹⁴Ra) and 1.5487(30) ²¹⁸Th

#### Table 6

direct  $\alpha$  emission from ²²⁰Pa, J^{$\pi$} = (1⁻), T_{1/2} = 0.75(4)  $\mu$ s*, BR_{$\alpha$} = 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{216}\mathrm{Ac})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
9.719(6)	9.542(6)	100%	1-	0.0		1.539(15)	$1.4^{+0.5}_{-0.4}$

* Weighted average of 0.83(7) µs [2023Lu04], 0.75(8) µs [2021Ma66], 0.73(11) µs [2020Ma27], 0.91(10) µs [2019Ya04] and 0.90(13) µs [2017Hu08].

** [2023Lu04].

*** Interpolated between 1.5487(30) fm ²¹⁸Th and 1.529(15) fm ²²²U.

# Table 7

direct  $\alpha$  emission from ^{220m2}Pa*, Ex. = 124(40) keV, J^{$\pi$} = (3⁻), T_{1/2} = 233⁺¹⁰⁸₋₅₆ ns, BR_{$\alpha$} = 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{216}\mathrm{Ac})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF
9.843(40)	9.664(40)	100%	1-	0.0		1.539(15)	0.8(5)

* All values from [2021Ma66]. They assign a  $J^{\pi} = (3^{-})$ . However the HF indicates a unhindered decay, suggesting  $1^{-}$  as a more likely value. ** Interpolated between 1.5487(30) fm ²¹⁸Th and 1.529(15) fm ²²²U.

#### Table 8

direct  $\alpha$  emission from ^{220m2}Pa*, Ex. = 274(62) keV, T_{1/2} = 69⁺³³⁰₋₃₀ ns, BR_{$\alpha$} = 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{216}\mathrm{Ac})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF
9.993(62)	9.811(62)	100%	1-	0.0		1.539(15)	$0.5^{+2.4}_{-0.3}$

* All values from [2021Ma66]. They assign a  $J^{\pi} = (3^{-})$ . However the HF indicates a unhindered decay, suggesting  $1^{-}$  as a more likely value. ** Interpolated between 1.5487(30) fm ²¹⁸Th and 1.529(15) fm ²²²U.

### **Table 9** direct $\alpha$ emission from ²²⁴Np*, $T_{1/2} = 38^{+26}_{-11} \mu$ s, $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{220}\mathrm{Pa})$	coincident γ-rays	R ₀ (fm)**	HF
9.029(62) 9.303(20)	8.868(62) 9.137(20)	≈20% 100%	0.17(17)% 83(51)%	0.0	0.274(62)	1.503(50)	$1.503(50) \\ 0.3^{+1.0}_{-0.2}$	$0.3^{+8.5}_{-0.2}$

* All values form [2018Hu13].

** Interpolated between 1.521(15) fm ( 220 U) and 1.484(48) fm ( 224 Pu).

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Observed and predicted $\beta$ -delayed part	rticle emission from the even- $Z$ ,	$T_z = +39/2$ nuclei.	$I^{\pi}$ values for ¹⁸³	³ Hf, ¹⁸⁷ W,	¹⁹¹ Os, ¹⁹⁵	Pt, 199Hg, and	⁰³ Pb are taken from
ENSDF. Unless otherwise stated, all C	)-values are taken from [2021Wa	16] or deduced from	m values thereir	1.			

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
100						
¹⁸³ Hf*	$(3/2^{-})$	1.018(2) h	-3.570(90)			[2006Vo12]
$^{187}W*$	3/2-	23.80(3) h	-3.010(60)			[2019Kr02]
191 Os*	9/2-	15.4(1) d	-2.045(10)			[1967Ag07]
¹⁹⁵ Pt	$1/2^{-}$	stable	-1.102(1)			
¹⁹⁹ Hg	$1/2^{-}$	stable	-0.452(1)			
²⁰³ Pb	5/2-	51.95(1) h	0.975(6)	-4.730(7)	1.882(7)	[2001Li17]
²⁰⁷ Po	5/2-	350.3(41) m	2.909(7)	-0.649(7)	6.191(7)	[1974Pa05]
²¹¹ Rn	$1/2^{-}$	14.6(2) h	2.892(7)	-0.091(7)	8.874(7)	[1972As11]
²¹⁵ Ra	$(9/2^+)$	1.67(1) ms	2.214(10)	-0.437(12)	11.754(8)	[2000He17]
²¹⁹ Th	$(9/2^+)$	1.03(3) µs**	2.890(80)	0.528(57)	11.720(57)	[2017Su18, 2015Kh09, 1973Ha32]
²²³ U	$(7/2^+)$	$62^{+14}_{-10} \mu s$	3.71(10)	1.553(60)	12.051(78)	[2020Su02]
²²⁷ Pu		$0.78^{+0.39}_{-0.19}$ s	4.19(13)#	2.15(10)#	12.01(13)#	[2024WaXX]
²³¹ Cm		5.19	4.86(42)#	3.05(30)#	12.27(31)#	

* 100%  $\beta^-$  emitter.

** Weighted average of 1.09(8)  $\mu$ s [2017Su18], 0.97(4)  $\mu$ s [2015Kh09] and 1.05(3)  $\mu$ s [1973Ha32].

Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +39/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	Experimental	
1920						
¹⁸⁵ Hf	8.80(20)	16.77(30)	0.93(20)#			
$^{187}W$	8.585(60)	16.162(64)	0.955(30)			
¹⁹¹ Os	8.101(5)	15.16(20)	1.084(1)			
¹⁹⁵ Pt	7.551(1)	13.977(2)	1.176(1)			
¹⁹⁹ Hg	7.254(1)	13.704(1)	0.823(1)			
²⁰³ Pb	6.095(7)	11.702(7)	2.335(7)			
²⁰⁷ Po	4.406(10)	7.953(7)	5.216(3)	0.0210(18)%	[1974Pa05, 1970AfZZ, 1971Go35, 1967Ti04, 1955Mo68,	
					1951Ka37, 1947Ho06, 1947Te01]	
²¹¹ Rn	4.072(10)	6.967(7)	5.965(1)	26(1)%	[1971Go35, 1970AfZZ, 1955Mo68, 1955Mo69, 1952Mo23]	
²¹⁵ Ra	3.799(11)	6.350(8)	8.862(2)	100%	[1970To18, 1968Va18, 2020Su02, 2015Kh09, 2005Li17,	
			. ,		2000He17, 1970TaZS, 1969MaZT, 1961Gr43]	
²¹⁹ Th	3.677(81)	6.005(57)	9.507(11)*	100%	[2020Ma27, 2017Su18, 1973Ha32, 2020Su02, 2020Wa16,	
					2015Kh09, 1973HaVQ, 1973HaWU]	
²²³ U	3.308(105)	5.473(60)	9.158(17)	100%	[2020Su02, 1994AnZY, 1993AnZS, 1991An10, 1991An13]	
²²⁷ Pu	3.34(14)#	5.18(10)#	8.338(28)**	$\approx 100\%$	-	[2024WaXX
²³¹ Cm	2.89(33)#	4.70(31)#	8.08(31)#			

* Deduced from  $\alpha$  energy, 9.506(56) in [2021Wa16]. ** Deduced from  $\alpha$  energy, 8.30(12)# in [2021Wa16].

#### Table 3

direct $\alpha$ emission from ²⁰⁷ Po.	$J^{\pi} = 5/2^{-1}$	$T_{1/2} = 350.3(41)$	) m*. $BR_{\alpha} =$	$0.0210(18)\%^*$
--------------------------------------------------	----------------------	-----------------------	-----------------------	------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{203}\text{Pb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.2158(25)	5.1150(25)**	0.0210(18)%*	5/2-	0.0		1.44219(87)	1.41(13)

* [1974Pa05].

** [1970AfZZ].

Table 4	
direct $\alpha$ emission from ²¹¹ Rn, $J^{\pi} = 1/2^{-1}$	$T_{1/2} = 14.6(2) h^{**}, BR_{\alpha} = 26(1)\%$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	Edaughter( ²⁰⁷ Po)***	coincident $\gamma$ -rays***	R ₀ (fm)	HF
5 153(4)	5.055(4)	$1.0(3) \times 10^{-3}\%$	$1.6(5) \times 10^{-4}\%$	9/2-	0 8144	0 8144	1 4456(24)	22+12
5.279(3)	5.179(3)	$4.1(3) \times 10^{-3}\%$	$6.7(6) \times 10^{-4}\%$	5/2-	0.6858	0.0686, 0.0973, 0.1679, 0.2365, 0.2928, 0.3244, 0.3929, 0.4491, 0.6172	1.4456(24)	27.6(28)
5.378(3)	5.276(3)	0.024(2)%	$0.39(3) \times 10^{-3}\%$	7/2-	0.5883	0.5883	1.4456(24)	16.7(16)
5.572(3)	5.466(3)	0.022(2)%	$0.36(3) \times 10^{-3}\%$	3/2-	0.3930	0.0686, 0.1565, 0.1679, 0.2365, 0.3244, 0.3929	1.4456(24)	196(19)
5.725(3)	5.616(3)	4.3(3)%	0.70(6)%	3/2-	0.2365	0.0686, 0.1679, 0.2365	1.4456(24)	6.3(6)
5.895(2)	5.783(2)	100(2)%	16.4(7)%	$1/2^{-}$	0.0686	0.0686	1.4456(24)	1.78(12)
5.963(2)	5.850(2)	54(2)2%	8.8(4)%	5/2-	0.0		1.4456(24)	6.9(5)

* All values from [1971Go35], except where noted.

** [1972As11].

*** [2011Ko ].

## Table 5

direct $\alpha$ emission from ²¹⁵ Ra	$J^{\pi} = (9/2^+), T_{1/2} =$	$1.67(1) \text{ ms}^*, BR_{\alpha} = 100\%$
-------------------------------------------------	--------------------------------	---------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)^{***}$	$\mathbf{J}_{f}^{\pi@}$	$E_{daughter}(^{211}\mathrm{Rn})^{@}$	coincident γ-rays [@]	R ₀ (fm)	HF
8.031(6) 8.326(6) 8.864(4)	7.882(6) 8.171(6) 8.699(4)	3.1(5)% 1.4(5)% 100(1)%	3.0(5)% 1.3(5)% 95.7(10)%	(3/2 ⁻ ) 5/2 ⁻ 1/2 ⁻	0.8335(2) 0.5399(2) 0.0	0.8335(2) 0.5399(2)	1.4995(24) 1.4995(24) 1.4995(24)	$17^{+4}_{-3} \\ 280^{+180}_{-80} \\ 105(6)$

* [2000He17].

** Weighted average of values from [1970To18] and [1968Va18], adjusted as recommended by [1991Ry01].

*** [1968Va18].

@ [2013Si17].

### Table 6

direct  $\alpha$  emission from ²¹⁹Th,  $J^{\pi} = (9/2^+)$ ,  $T_{1/2} = 1.03(3) \ \mu s^*$ ,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(abs)^{***}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{215}\mathrm{Ra})$	coincident γ-rays	R ₀ (fm)	HF
9.507(11)	9.333(11)	100%	(9/2+)	0.0		1.5769(37)	2.7(3)

* Weighted average of 1.09(8) µs [2017Su18], 0.97(4) µs [2015Kh09] and 1.05(3) µs [1973Ha32].

** Weighted average of 9.338(24) MeV [2020Ma27], 9.327(15) MeV [2017Su189] and 9.340(20) MeV [1973Ha32].

## Table 7

direct  $\alpha$  emission from ²²³U*,  $J^{\pi} = (7/2^+)$ ,  $T_{1/2} = 62^{+14}_{-10} \ \mu$ s,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$ E	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{219}\mathrm{Th})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
8.913(16) 8	8.753(16)	100(31)%	65(20)%	$(7/2^+)$	0.244(23)		1.5402(90)	$1.0^{+0.9}_{-0.5}$

* All values from [2020Su02].

# Table 8

direct $\alpha$ emission from ²²⁷ Pu*, $J^{\pi} = (7/2^+)$ , $T_{1/2} = 0.78^{+0.39}_{-0.19}$ s, $BR_{\alpha} = \approx 100\%$ .												
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{219}\mathrm{Th})$	coincident γ-rays	R ₀ (fm)	HF				
8.337(28)	8.191(28)	$\approx 100\%$	65(20)%		0.0?		1.499(35)	$18^{+24}_{-14}$				

* All values from [2024YaXX].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +39/2 nuclei.

Last updated 1/21/24

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +39/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
195							
¹⁸⁵ Ta*		$(7/2^+)$	49.5(15) m	-3.070(7)			[1955Po26]
¹⁸⁹ Re*		5/2+	23.4(4) h	-2.17(20)#			[1965Bl06]
¹⁹³ Ir		3/2+	stable	-1.142(2)			
¹⁹⁷ Au		3/2+	stable	-0.720(1)			
²⁰¹ Tl		1/2+	3.0380(17) d	0.482(14)	-7.230(30)	0.814(14)	[2004De02]
²⁰⁵ Bi		9/2-	14.91(7) d	2.705(5)	-4.008(5)	4.172(5)	[2004Ku33]
²⁰⁹ At		9/2-	5.41(5) h	3.482(5)	-1.303(5)	8.461(5)	[1968GuZX]
²¹³ Fr		9/2-	34.14(6) s	2.142(6)	-2.215(5)	10.387(5)	[2013Fi08]
²¹⁷ Ac		9/2-	69(4) ns	2.813(13)	-1.558(12)	11.973(12)	[1985De14]
^{217m1} Ac	1.1466(4)**	$(15/2^{-}, 17/2^{-})$	<4 ns	3.960(13)	-0.411(12)	13.120(12)	[1985De14, 1982GoZU]
^{217m2} Ac	1.514(30)***	$(19/2^{-}, 21/2^{-})$	8(2) ns	4.327(33)	-0.044(32)	13.487(32)	[1985De14, 1973No02]
^{217m3} Ac	2.0122(7)	$(29/2)^+$	740(40) ns	4.825(13)	-0.454(12)	13.985(12)	[1985De14]
²²¹ Pa		9/2-	4.9(8) µs	3.440(60)	-0.658(60)	12.060(60)	[1995AnZY]
²²⁵ Np			$0.31^{+0.75}_{-13}$ ms	4.250(90)	0.467(92)	12.253(92)	[2019Mi08, 2015De22]
²²⁹ Am			$0.9^{+2.1}_{-0.7}$ s	4.79(12)	1.07(15)#	12.38(11)	[2015De22]
²³³ Bk			$21^{+48}_{-17}$ s	5.48(25)#	2.06(38)#	12.95(24)#	[2015De22]

* 100%  $\beta^-$  emitter.

** [1985De14] report the energy of this  $\alpha$ -emitting level as either 1.150 MeV (15/2⁻) or 1.147 (17/2⁻). The value of 1.1466(4) is from [2018Si ] based on the  $\gamma$  cascade form the (29/2⁺) isomer. *** [1985De14] report the energy of this  $\alpha$ -emitting level as either 1.498 MeV (19/2⁻) or 1.529 (21/2⁻).

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +39/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	Experimental
185 Ta	7 184(42)	16 256(81)	0.98(13)		
189 R.e	6.600(9)	15 661(56)#	0.98(13)		
¹⁹³ Ir	5.943(2)	14.764(10)	1.018(8)		
¹⁹⁷ Au	5.743(2) 5.784(1)	14.025(1)	0.972(1)		
²⁰¹ T1	4 966(14)	12.665(14)	1.534(14)		
²⁰⁵ Bi	3 245(5)	9.882(4)	3.690(15)		
209 At	2.704(5)	7.407(5)	5.757(2)	3 6(7)%	[2017Lo13, 1969Go23, 1968GuZX 1963Ub01 1956HuXX
	21/01(0)	////(0)	01101(2)	510(1)/0	1955Mo68, 1951Ba141
²¹³ Fr	2.184(6)	6.485(5)	6.905(1)	99.45(3)%	[ <b>2016Pr08, 2005Ku06</b> , 2019Mi08, 2017Lo13, 2013Fi08,
					2012Mo08, 1982Bo04, 1976RaZG, 1974Ho27, 1973BoXL,
					1971ReZG, 1967Va20, 1964Gr04, 1961Gr42]
²¹⁷ Ac	1.878(14)	6.194(13)	9.832(10)	100%	[1985De14, 2019Mi08, 1982GoZU, 1982SaZO, 1981MaYW,
					1977BaYU, 1973No02, 1973No09, 1972No06]
^{217m1} Ac	0.731(14)	5.047(13)	10.979(10)	0.27(4)%	[1985De14, 1982GoZU, 1982SaZO, 1972No06]
^{217m2} Ac	0.364(33)	4.680(33)	11.346(32)	0.46(13)%	[1985De14, 1982GoZU, 1973No02]
^{217m3} Ac	-0.134(14)	4.182(13)	11.844(10)	4.51(17)%	[1985De14, 1982GoZU, 1982SaZO, 1981MaYW, 1973No02, 1972No06]
²²¹ Pa	1.604(61)	5.773(79)	9.248(58)	100%	[1995AnZY, 1989Mi17, 2019Mi08, 1989MiZK, 1989MiZZ,
					1987MiZO, 1983Hi12]
²²⁵ Np	1.414(93)	5.30(12)	8.818(70)	100%	[2015De22, 1994Ye08, 2019Mi08, 1994AnZY, 1993AnZS,
					1993AnZY
²²⁹ Am	1.222(30)*	4.716(82)*	8.132(20)*	$\approx 100\%$	[2015De22]
²³³ Bk	0.586(31)**	4.212(38)#	7.906(20)**	obs	[2015De22]

* Deduced from  $\alpha$  energy. S_p = 1.22(11)# MeV, S_{2p} = 4.98(13)# MeV, Q_{$\alpha$} = 8.137(54# MeV) in [2021Wa16].

** Deduced from  $\alpha$  energy.  $S_p = 0.85(31)$ # MeV,  $Q_{\alpha} = 8.17(21)$ # MeV) in [2021Wa16].

Table 3				
direct $\alpha$ emission from $\frac{2}{3}$	209 At, $J^{\pi} = 9/2^{-}$ ,	$T_{1/2} = 5.41(5) h$	*, $BR_{\alpha} = 3.6(7)\%$ **	

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	Edaughter ( ²⁰⁵ Bi)	coincident $\gamma$ -rays	R ₀ (fm)	HF	
5.216(2)	5.116(2)@	0.10(5)%@	0.0036(9)		0.542(4)		1.4432915)	$2.5^{+3.0}_{-0.0}$	
5.758(4)	5.648(4)	100%	3.697)%	9/2-	0.0		1.4432915)	$1.8_{-0.3}^{+0.5}$	
* [1968 ** [201	GuZX]. 7Lo13].								

** [1969Go23]. @ Only reported in [1969Go23].

#### Table 4

(11001 11011 11, 5 - 5/2, 11/7) = 54.14(0) + 5.00(7)	direct $\alpha$	emission	from ²¹³ Fr,	$J^{\pi} = 9/2^{-}, T$	1/2 = 34.14(6)	$s^*, BR_{\alpha} =$	99.45(3)%*
------------------------------------------------------	-----------------	----------	-------------------------	------------------------	----------------	----------------------	------------

$E_{\alpha}(\text{c.m.})^{***}$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{209}\mathrm{At})$	coincident γ-rays	R ₀ (fm)	HF
4.083(2)	4.007(2)	weak	weak	(5/2,7/2)	2.8206(10) 0.8554(5), 0.8675(5)	0.4083(5), 0.6894(5),		
5.806(2)	5.697(2)	0.010(5)%	0.010(5)%	$(7/2)^{-}$	1.0977(7)	0.4083(5), 0.6894(5)	1.4450(19)	$0.25^{+0.25@@@}_{0.0}$
5.823(2)	5.713(2)	0.020(3)%	0.020(3)%	(5/2,7/2)-	1.0812(7)	0.4083(5), 0.6729(5)	1.4450(19)	$0.15_{-0.2}^{+0.3}@@@$
6.115(2)	6.000(2)	0.020(10)%	0.020(10)%	(9/2)-	0.7890(7)	0.3807(5), 0.4083(5)	1.4450(19)	$4^{+4}_{-1}$
6.158(2)	6.043(2)	0.040(6)%	0.040(6)%	7/2-	0.7457(5)	0.7457(5)	1.4450(19)	$2.8^{+0.5}_{-0.4}$
6.327(2)	6.208(2) [@]	0.070(11)%	0.070(11)%	$11/2^{-}$	0.5770(5)	0.5770(5)	1.4450(19)	$8.9^{+1.7}_{-1.3}$
6.496(2)	6.374(2) [@]	0.12(2)%	0.12(2)%	7/2-	0.4083(5)	0.4083(5)	1.4450(19)	$27^{+6}_{-4}$
6.904(2)	6.775(2)@@	100%	99.23(3)%	9/2-	0.0		1.4450(19)	1.31(6)

* [2013Fi08].

** [2005Ku06].

*** Deduced from table 2 and figure 8 in [2016Pr08]. The authors list  $\gamma$ -ray intensities and energies following the  $\alpha$  decay of ²¹³Fr. Note that  $\alpha$ 's are not directly measured in this work, and are deduced assuming a  $Q_{\alpha}$  of 6.9040(18) MeV for ²¹³Fr.

^(e)  $\alpha$  also observed in [2005Ku06]. ^(e) ^(e) Weighted average of 6.775(4) MeV [2005Ku06] and 6.775(2) MeV [1982Bo04].

@@@ Unphysically low HF indicate that the apparent  $\beta$  branching reported in [2016Pr08] for these levels is too high, likely due to the levels being fed from above (*i.e.* pandemonium).

### Table 5

direct $\alpha$ emis	direct $\alpha$ emission from ²¹⁷ Ac, $J^{\pi} = 9/2^{-}$ , $T_{1/2} = 69(4)$ ns*, $BR_{\alpha} = 100\%$ .											
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\rm J}_f^\pi$	$E_{daughter}(^{213}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)	HF					
9.831(10)	9.650(10)**	100%	9/2-	0.0		1.5460(33)	0.98(10)					

* From [1985De14]. [1973No09] reported a half-life of 111(7) ns, which results in a HF equal to 1.58(17). The g.s. to g.s.  $\alpha$ -decay is expected to be unhindered. Therefore, the value from [1985De14] is adopted.

** [1973No09].

## Table 6

lirect $\alpha$ emission from ^{217m1} Ac, Ex. = 1.1466(4)**, $J^{\pi} = (15/2^{-}, 17/2^{-}), T_{1/2} = <4 \text{ ns}^{***}, BR_{\alpha} = 0.27(4)\%.$											
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{213}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)	HF				
10.982(15)	10.780(15)	100%	9/2-	0.0	_	1.5460(33)	$>3.8 \times 10^{3}$				

* All values from [1985De14], except where noted.

*** [1985De14] report the energy of this  $\alpha$ -emitting level as either 1.150 MeV (15/2⁻) or 1.147 (17/2⁻). The value of 1.1466(4) is from [2018Si ] based on the  $\gamma$  cascade form the (29/2⁺) isomer.

*** [1982GoZU].

## Table 7 direct $\alpha$ emission from ${}^{217m^2}$ Ac*, Ex. = 1.514(30)**, $J^{\pi} = (19/2^-, 21/2^-)$ , $T_{1/2} = 8(2)$ ns***, $BR_{\alpha} = 0.46(13)\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{213}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
11.346(15)	11.137(15)	0.46(13)%	9/2-	0.0		1.5460(33)	$1.9^{+1.4}_{-0.8}  imes 10^4$

* All values from [1985De14], except where noted.

** [1985De14] report the energy of this  $\alpha$ -emitting level as either 1.498 MeV (19/2⁻) or 1.529 (21/2⁻).

*** [1973No02].

## Table 8

direct $\alpha$ emission from ²¹⁷	m3 Ac*, Ex. = 2.0122(7), J	$T^{\pi} = (29/2^{-}), T_{1/2} =$	$740(40)$ ns, $BR_{\alpha} = 4.51(17)\%$ .
----------------------------------------------	---------------------------------	-----------------------------------	--------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{213}\mathrm{Fr})$	coincident γ-rays	$R_0$ (fm)	HF
10.739(10) 11.346(15) 11.843(15)	10.541(10)) 11.137(15) 11.625(15)	100(4)% 11.3(32)% 2.95(50)%	4.07(16)% 0.46(13)% 0.12(2)%	13/2 ⁺ 7/2 ⁻ 9/2 ⁻	1.105 0.498 0.0	1.105 0.498	1.5460(33) 1.5460(33) 1.5460(33)	$\begin{array}{l} 1.7^{+1.1}_{-0.5}\times10^{5}\\ 1.8^{+1.1}_{-0.5}\times10^{7}\\ 4.3^{+2.6}_{-1.3}\times10^{8} \end{array}$

* All values from [1985De14], except where noted.

## Table 9

direct  $\alpha$  emission from ²²¹Pa,  $J^{\pi} = 9/2^{-}$ ,  $T_{1/2} = 4.9(8) \ \mu s^*$ ,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{217}\mathrm{Ac})$	coincident γ-rays	R ₀ (fm)	HF
9.245(21)	9.078(21)	100%	9/2-	0.0		1.5671(97)	1.3(4)

* [1995AnZY].

** Weighted average of 9.075(30) MeV [1995AnZY] and 9.080(30) MeV [1989Mi17].[

## Table 10

direct  $\alpha$  emission from ²²⁵Np,  $T_{1/2} = 0.31^{+0.75}_{-13}$  ms*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{221}\mathrm{Pa})$	coincident γ-rays	R ₀ (fm)	HF
8.786(20)	8.630(20)	100%	9/2-	0.0		1.534(15)	$0.7^{+1.6}_{-0.3}$

* From [2019Mi08]. Using this half-life gives a HF equal to  $0.7^{+1.6}_{-0.3}$ , indicating an unhindered transition. [2015De22] report a value of  $3.8^{+7.6}_{-2.7}$  ms which gives a HF of  $8^{+3}_{-1}$ . ** [1994Ye08].

#### Table 11

Table 11			
direct $\alpha$ emission fr	om ²²⁹ Am*,	$T_{1/2} = 0.9^{+2.1}_{-0.7} s$ ,	$BR_{\alpha} = \approx 100\%^{**}$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	$E_{daughter}(^{225}Np)$	coincident $\gamma$ -rays	R ₀ (fm)	HF			
8.132(20)	7.990(20)	100%		0.0		1.534(15)	$1.0^{+2.9}_{-0.9}$			
* All values from [2015De22]. ** Only $\alpha$ decay observed.										
Table 12 direct $\alpha$ emiss	ion from ²³³ Bk*, T	$\Gamma_{1/2} = 21^{+48}_{-17}$ s, B	$BR_{\alpha} = \text{obs.}$							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	$E_{daughter}(^{229}\text{Am})$	coincident $\gamma$ -rays	R ₀ (fm)	HF			
7.906(20)	7.770(20)	obs		0.0		1.525(46)	***			
* All valu ** Only o	tes from [2015De2] $\chi$ decay observed.	2].	4							

*** Using a BR of 100%, a HF of  $4^{+10}_{-4}$  is obtained.

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +20 nuclei.

Last updated 2/20/24

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +20$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

	-						
Nuclide	$J^{n}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental	
104							
¹⁸⁴ Hf*	$0^{+}$	4.12(5) h	-5.20(20#			[1973Wa18]	
$^{188}W*$	$0^+$	69.78(12) d	-4.76(20)#			[2014Un01]	
¹⁹² Os	$0^{+}$	stable	-4.290(70)				
¹⁹⁶ Pt	$0^{+}$	stable	-3.210(40)				
²⁰⁰ Hg	$0^{+}$	stable	-2.463(27)				
²⁰⁴ Pb	$0^{+}$	$> 1.4  imes 10^{20}  ext{ y}$	-0.7638(2)			[2013Be16]	
²⁰⁸ Po	$0^+$	2.888 y	1.401(2)	-2.306(1)	4.452(2)	[1966Ha29]	
²¹² Rn	$0^{+}$	24.8(5) m**	-0.031(4)			[1971Go35, 1968Cr02]	
²¹⁶ Ra	$0^+$	182(10) ns	0.320(9)	-2.829(10)	9.495(8)	[1973No09]	
²²⁰ Th	$0^+$	10.2(4) µs***	0.946(15)	-1.993(15)	9.294(14)	[2019Pa45, 1973Ha32]	
²²⁴ U	$0^{+}$	396(17) µs	1.880(17)	-0.932(17)	9.574(16)	[2014Lo10]	
²²⁸ Pu	$0^{+}$	$1.1^{+2.0}_{-0.5}$ s	2.28(10)#	-0.226(25)	9.821(25)#	[2003Ni10]	
²³² Cm	$0^{+}$	0.0	2.91(36)#	0.74(20)#	10.08(23)#		

* 100%  $\beta^-$  emitter

** Weighted average of 22.0(10) m [1971Go35] and 25.5(5) m [1968Cr02].

Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +20$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
¹⁸⁴ Hf	9.072(89)	17.18(40)#	0.80(30)#		
¹⁸⁸ W	9.061(56)#	16.822(51)#	0.407(40)		
¹⁹² Os	8.821(10)	16.091(35)	0.361(4)		
¹⁹⁶ Pt	8.241(1)	14.787(2)	0.813(2)		
²⁰⁰ Hg	7.698(1)	14.177(2)	0.716(1)		
²⁰⁴ Pb	6.6375(3)	12.342(1)	1.969(1)		
²⁰⁸ Po	4.704(2)	8.262(1)	5.216(1)	99.9958(4)%	[1993Sa14, 1970Ra14, 1969Go23, 1967Ti04, 1966Ha29,
					1955Mo68, 1953AsZZ, 1951Ka03, 1951Ka37, 1947Te01]
²¹² Rn	4.301(4)	7.284(3)	6.385(3)	100%	[1971Go35, 2003Ni10, 2003NiZV, 1970AfZZ, 1970TaZS,
					1968Cr02, 1963Uh01, 1959Ka15, 1955Mo68, 1952Mo23,
					1950Hy27]
²¹⁶ Ra	4.316(11)	6.967(12)	9.526(7)	100%	[1973No09, 2017Su18, 1975No09, 1972No06, 1961Gr43]
²²⁰ Th	4.169(53)	6.534(17)	8.973(11)	100%	[ <b>2019Pa45, 1973Ha32</b> , 1991AnZZ, 1973HaWU]
²²⁴ U	3.884(77)	6.038(18)	8.628(7)	100%	[2014Lo10, 2003Ni10, 2003NiZV, 1994AnZY, 1994Ye08,
					1993AnZS, 1993ToZW, 1992To02, 1992ToZV, 1991An10,
					1991An13, 1990AnZU]
²²⁸ Pu	3.760(80)	5.799(26)	7.940(18)	$\approx 100\%*$	[1994An02, 1994Ye08, 2004NiZZ, 2003Ni10, 2003NiZV,
					2001NiZY, 1994AnZX, 1994AnZY]
²³² Cm	3.37(36)#	5.18(20)#	7.80(20)#		

* Based on short half-life.

#### Table 3

direct  $\alpha$  emission from ²⁰⁸Po*,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 2.888$  y,  $BR_{\alpha} = 99.9958(4)\%^{**}$ 

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{204}\text{Pb})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
4.303(15) 5.215(2)	4.220(15) 5.115(2)***	$\begin{array}{c} 2.4(7)\times 10^{-4}\%\\ 100\% \end{array}$	$2.4(7)  imes 10^{-4}\%$ 99.9958(4)%**	$2^+_{0^+}$	0.899 [@] 0.0	0.899 [@]	1.42967(74) 1.42967(74)	$0.54^{+0.22@@}_{-0.12}$ 0.98(2)

* All values from [1966Ha29], except where noted.

** [1993Sa14] report a BR $_{\epsilon}$  equal to 0.0042(4)%.

*** Weighted average from [1991Ry01] based on 5.114(3) MeV [1970Ra14] (modified to 5.113(3) MeV), 5.116(2) MeV [1969Go23], 5.118(5) MeV [1967Ti04] (modified to 5.120(3) MeV), 5.110(5) MeV [1966Ha29] and 5.108(3) MeV [1953AsZZ] (modified to 5.114(3) MeV).

@ [2010Ch02].
 @ @ This unphysically low HF value may indicate that the branching ratio is too high or that the reported transition is incorrect.

## **Table 4** direct $\alpha$ emission from ²¹²Rn*, $J^{\pi} = 0^+$ , $T_{1/2} = 24.8(5)$ m**, $BR_{\alpha} = 100\%$ **

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{208}\text{Po})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.996(3)	5.883(3)	0.050(5)%	0.050(5)%	$2^{+}$	0.687	0.687	1.4343(25)	$1.43_{-0.16}^{+0.19}$
6.382(3)	6.262(3)	100%	99.95(5)%	$0^+$	0.0		1.4343(25)	1.01(2)

* All values from [1971Go35], except where noted.

** Weighted average of 22.0(10) m [1971Go35] and 25.5(5) m [1968Cr02].

*** This low HF value may indicate that the branching ratio is too high or that the reported transition is incorrect.

Table	5
Lanc	~

direct $\alpha$ emission from ²	216 Ra*, $J^{\pi} = 0^+$ , $T_{1/2} = 1$	$182(10) \text{ ns}, BR_{\alpha} = 100\%$
--------------------------------------------	-----------------------------------------------	-------------------------------------------

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{212}\mathrm{Rn})$	coincident γ-rays	$R_0$ (fm)	HF
9.525(8)	9.349(8)	100%	$0^{+}$	0.0		1.5433(36)	1.05(6)

* All values from [1973No09].

#### Table 6

direct $\alpha$ emission from ²	20 Th, $J^{\pi} = 0^+$	$T_{1/2} = 10.2(4)$	$\mu s^*, BR_{\alpha} = 100\%$
--------------------------------------------	-----------------------------	---------------------	--------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{216}\mathrm{Ra})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
8.969(13)	8.806(13)**	100%	$0^+$	0.0		1.6051(43)	2.53(10)***

* Weighted average of 10.4(4) µs [2019Pa45] and 9.7(6) µs [1973Ha32].

** Weighted average of 8.813(13) MeV [2019Pa45] and 8.790(20) MeV [1973Ha32].

*** Expect this transition to be an unhindered  $0^+ \rightarrow 0^+$ . The reason for the larger HF is unknown.

#### Table 7

direct  $\alpha$  emission from ²²⁴U*,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 396(17) \ \mu$ s,  $BR_{\alpha} = 100\%$ 

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{220}\mathrm{Th})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
8.242(18) 8.633(8)	8.095(11) 8.479(8)	3.5(8)% 100%	3.4(8)% 96.6(8)%	$2^+_{0^+}$	0.387(2) 0.0	0.387(2)	1.5514(30) 1.5514(30)	$2.2^{+0.7}_{-0.5}$ $1.009(10)$

* All values from [2014Lo10].

## Table 8

direct $\alpha$ emission from ²²⁸ P	$T_{\rm u}, J^{\pi} = 0^+, T_1$	$_{1/2} = 1.1^{+2.0}_{-0.5} \text{ s*}, BR$	$\alpha = \approx 100\%$
------------------------------------------------	---------------------------------	---------------------------------------------	--------------------------

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{224}\text{U})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.949(20)	7.810(20)**	≈100%	$0^{+}$	0.0		1.480(42)	$1.1^{+2.0}_{-0.5}$

* [2003Ni10].

* [1994An02, 1994Ye08].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +20 nuclei.

Last updated 2/20/24

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +20$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	$BR_{\varepsilon F}$	Experimental
105								
¹⁸⁶ Ta*		(3 ⁻ )	10.390(27) m	-2.180(80)				[1995ItZY]
¹⁹⁰ Re*		$(2)^{-}$	2.96(1) h	-1.210(40)				[1973DeWI]
¹⁹⁴ Ir*		1-	19.37(1) h	-0.097(2)				[2016Kr06, 1972Em01]
¹⁹⁸ Au*		$2^{-}$	2.6971(20) d	0.323(2)	-8.606(20)	0.429(2)		[2008Ku09]
²⁰² Tl		$2^{-}$	12.23(2) d	1.365(1.8)	-6.869(4)	1.499(3)		[1995Co19]
²⁰⁶ Bi		$6^{+}$	6.243(3) d	3.757(8)	-3.496(8)	4.892(8)		[1961Br19]
²¹⁰ At		$(5^{+})$	8.440(79) h	3.981(8)	-1.002(8)	9.388(8)		[2003HaZT]
²¹⁴ Fr		$(1^{-})$	5.0(2) ms	3.361(12)	-1.668(10)	12.570(9)		[1968To10]
214m Fr	0.121(7)	(8 ⁻ )	3.35(5) ms	3.486(14)	-1.547(12)	12.691(11)		[1968To10]
²¹⁸ Ac		$(1^{-})$	1.12(3) µs**	4.210(60)	-0.753(58)	12.746(58)		[2021Hu18, 2019Mi08, 2019Ya04,
								2017Su18, 2015Kh09, 1989De06,
								1989Mi17, 1983Sc23]
²²² Pa			$2.76^{+0.43}_{-0.33}$ ms	4.860(90)	0.24(10)	12.994(87)		[2021Hu18]
²²⁶ Np			43(5) ms***	5.49(10)	1.17(13)	13.19(10)		[2019Mi08, 1990Ni05]
²³⁰ Am			$32^{+22}_{-9}$ s	5.94(14)#	1.78(18)#	13.12(14)#	>30%	[2017Wi13, 2016Ka13, 2010KaZV]
²³⁴ Bk			$19_{-4}^{+6}$ s	6.67(15)#	2.82(19)#	14.04(15)#		[2016Ka13]
			-					

* 100%  $\beta^-$  emitter.

** Weighted average of  $0.87^{+0.18}_{-0.07} \ \mu s$  [2021Hu18], 1.8(1)  $\mu s$  [2019Mi08], 1.04(12)  $\mu s$  [2019Ya04], 0.98(12)  $\mu s$  [2017Su18], 0.96(5)  $\mu s$  [2015Kh09], 1.31(12)  $\mu s$  [1989De06], 1.06(9)  $\mu s$  [1989Mi17] and 1.21(18)  $\mu s$  [1983Sc23].

*** Weighted average of 43(5) ms [2019Mi08] and 31(8) ms [1990Ni05].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +20$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
186 Ta	7 577(88)	16 89(21)	0.74(21)		
¹⁹⁰ Re	7.06(20)	16 25(20)	0.600(60)		
¹⁹⁴ Ir	6 426(2)	15.521(71)	0.626(5)		
¹⁹⁸ Au	6.450(1)	14.723(38)	0.526(1)		
²⁰² Tl	5.607(2)	13.318(27)	1.175(2)		
²⁰⁶ Bi	3.547(8)	10.260(8)	3.527(8)		
²¹⁰ At	2.895(8)	7.680(8)	5.631(1)	0.18(2)%	[1981Va27, 1981Va29, 1977VaZT, 1969Go23, 2003HaZT,
					1975Ja09, 1975JaZF, 1968GuZX, 1955Mo68, 1953AsZZ]
²¹⁴ Fr	2.551(9)	6.908(9)	8.589(4)	100%	[1970To18, 2021Hu18, 2019Mi08, 2016Fa11, 2015Kh09,
					2005Ku06, 2005Li17, 1989AnZL, 1968To10, 1968Va18]
214m Fr	2.430(11)	6787(11)	8.710(8)	100%	[1970To18, 2016Fa11, 2005Ku06, 1966Ro12]
²¹⁸ Ac	2.328(58)	6.698(58)	9.379(10)*	100%	[2021Hu18, 2017Su18, 1970Bo13, 2021Hu19, 2019Mi17,
					2019Ya04, 2015Kh09, 1989De06, 1989Mi17, 1989MiZK,
					1989MiZZ, 1988MiZJ, 1983Sc23, 1970Bo13, 1970VaZZ]
²²² Pa	2.165(87)	6.257(87)	8.789(65)	100%	[2021Hu18, 2019Mi08, 1995AnZY, 1979Sc09, 1970Bo13,
					1970VaZZ]
²²⁶ Np	1.84(10)	5.62(10)	8.328(54)	$\approx 100\%$	[2019Mi08, 1994AnZY, 1994Ye08, 1993AnZS, 1990Ni05]
²³⁰ Am	1.81(16)#	5.53(18)#	7.63(10)#		
²³⁴ Bk	1.19(17)#	4.60(34)#	8.100(50)	$>\!80\%$	[2016Ka13, 2003MoZT, 2010KaZV, 2003MoZX]

* Deduced from  $\alpha$  energy, 9.384(57) MeV in [2021Wa16].

#### Table 3

direct  $\alpha$  emission from ²¹⁰At*,  $J^{\pi} = (5^+)$ ,  $T_{1/2} = 8.440(79)$  h**,  $BR_{\alpha} = 0.18(2)\%$ ***

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@}$	<i>E</i> _{daughter} ( ²⁰⁶ Bi)	coincident γ-rays [@]	$R_0 \ (fm)^{@@}$	HF
5.275(4)	5.175(4)	0.7(2)%	$3.8(12)  imes 10^{-4}$ %	$(3,4)^+$	0.356	0.338	1.4320(26)	$66^{+30}_{-17}$
5.344(3)	5.242(3)	2.8(4)%	$1.6(3) \times 10^{-3} \%$	$(4^+, 5^+)$	0.288		1.4320(26)	$36^{+8'}_{-6}$
5.4640(13)	5.3599(13)	91(5)%	0.050(7)%	$5^{+}$	0.167	0.106, 0.167	1.4320(26)	$5.3^{+0.9}_{-0.7}$
5.492(2)	5.387(2)	15.0(10)%	$8.3(11)  imes 10^{-3}$ %	7+	0.140	0.141	1.4320(26)	$44^{+8}_{-6}$
5.5485(15)	5.4428(15)	93(5)%	0.051(6)%	(5 ⁺ )	0.083	0.083	1.4320(26)	$14.1^{+2.3}_{-1.9}$
5.562(2)	5.456(2)	1.3(2)%	$7.2(13)  imes 10^{-4}$ %	(3 ⁺ )	0.069		1.4320(26)	$1.2^{+0.4}_{-0.3} \times 10^3$
5.5714(15)	5.4653(15)	23.6(10)%	0.013(2)%	$4^{+}$	0.060		1.4320(26)	$73^{+12}_{-10}$

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	direct	$\alpha$ emission	from ²¹⁰ At*	$, J^{\pi} = ($	(5 ⁺ ), T	1/2 = 8.4400	(79) h**,	$BR_{\alpha} = 0.18(2)$	1%***
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5.6314(13)	5.5241(13)	100(3)%	0.055(6)%	$6^{+}$	0.0		1.4320(26)	$35^{+5}_{-4}$
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* All values from [1977VaZT, 1981Va27, 1981Va29], except where noted.

** [2003HaZT].

*** [1969Go23].

@ [2008Ko21].

[@][@] Interpolated between 1.42967(74) fm (²⁰⁸Po) and 1.4343(25) fm (²¹²Rn).

Table	4
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lirect $\alpha$ emission from ²¹⁴ Fr*, $J^{\pi}$ =	$(1^{-}), T_{1}$	$_{1/2} = 5.0(2) \text{ ms}^{**}, BR_{\alpha} =$	100%
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_{f}^{\pi@@}$	$E_{daughter}(^{210}\mathrm{At})^{@@}$	coincident γ-rays ^{@@}	$R_0 (fm)^{@@@}$	HF
7.549(5) 7.752(8)	7.408(5) 7.607(8)	$\approx 0.3\%$ $\approx 1\%$	$\approx 0.3\%$ $\approx 1\%$	(3+)	1.0367 0.8378	0.073, 0.424, 0.496, 0.540, 0.946	1.4888(44) 1.4888(44)	$\approx 31 \\ \approx 40$
8.090(8) 8.519(5) 8.588(5)	7.939(8) 8.360(5) 8.428(5)	≈1% 5.2(2)% 100.(5)%	$\approx 1\%$ 4.8(2)% [@] 93.0(5)% [@]	$(4^+)$ $(4^+)$ $(5^+)$	0.4962(1) 0.073(1) 0.0	0.073	1.4888(44) 1.4888(44) 1.4888(44)	$\approx 420$ 1.33(15) × 10 ³ 107(11)

* All values from [1970To18], except where noted.

** [1968To10].

*** Adjusted by +2.3 keV in [1991Ry01].

[@] [2016Fa11].

@@ [2014Ba41].

@@@ Interpolated between 1.4343(25) fm ( 212 Rn) and 1.5433(36) fm ( 216 Ra).

#### Table 5

direct  $\alpha$  emission from ^{214m}Fr*, Ex. = 121(7) keV,  $J^{\pi} = (8^{-})$ ,  $T_{1/2} = 3.35(5)$  ms,  $BR_{\alpha} = 100\%$ 

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_{f}^{\pi@@}$	$E_{daughter}(^{210}\mathrm{At})^{@@}$	coincident γ-rays ^{@@@}	$R_0 (fm)^b$	HF
7 401(5)	7 241(5)	0.10	0.050		1 229(7)4		1 4999/44	75
7.481(5)	7.341(5)	0.1%	0.05%		1.228(7)		1.4888(44)	75
7.739(5)	7.594(5)	1.0%	0.5%		0.966(2)	0.966(2)	1.4888(44)	51
7.859(5)	7.712(5)***	2.2%	1.1%		0.8469(3)	0.0728(2), 0.7747(4), 0.8469(3)	1.4888(44)	54
8.104(6)	7.953(6)				0.6035(5)	0.0728(2), 0.5307(4)	1.4888(44)	
8.131(5)	7.979(5)	1.4%	0.7%	$(7^{+})$	0.5767(3)	0.5767(3)	1.4888(44)	540
8.177(6)	8.024(6)@			(3+)	0.5311(4)	0.0728(2), 0.4583(3)	1.4888(44)	
8.199(5)	8.046(5)	1.8%	0.9%	$(6^{+})$	0.5074(2)	0.0728(2), 0.4231(6), 0.5074(2)	1.4888(44)	660
8.211(5)	8.058(6)@			$(4^{+})$	0.4966(6)	0.0728(2), 0.4231(6), 0.4966(6)	1.4888(44)	
8.636(5)	8.475(5)***	100%	50.9%	$(4^{+})$	0.0728(2)	0.0728(2)	1.4888(44)	180
8.709(5)	8.546(5)***	90.4%	46.0%	$(5^{+})$	0.0		1.4888(44)	300

* All values from [1968To10], except where noted. Uncertainties for  $I_{\alpha}$  are not given.

** Energy values from [1968To10] are adjusted by +0.8 keV in [1991Ry01].

*** Weighted average of values from [1968To10] and [2005Ku06].

[@]  $\alpha$  not observed. Deduced in [2005Ku06] from  $\alpha$ - $\gamma$  coincidences.

@@ [2014Ba41]. @@@ [2005Ku06].

^{*a*} Deduced from  $\alpha$  energies [1968To10]. ^{*b*} Interpolated between 1.4343(25) fm (²¹²Rn) and 1.5433(36) fm (²¹⁶Ra).

## Table 6

direct  $\alpha$  emission from ²¹⁸Ac,  $J^{\pi} = (1^{-})$ ,  $T_{1/2} = 1.12(3) \ \mu s^*$ ,  $BR_{\alpha} = 100\%$ 

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_{f}^{\pi@@}$	$E_{daughter}(^{214}\mathrm{Fr})^{@@}$	coincident γ-rays ^{@@}	$R_0 (fm)^{@@@}$	HF
9.379(10)	9.207(10)	100%	(1 ⁻ )	0.0		1.5742(56)	2.9(4)

* Weighted average of 0.87^{+0.18}_{-0.07} μs [2021Hu18], 1.8(1) μs [2019Mi08], 1.04(12) μs [2019Ya04], 0.98(12) μs [2017Su18], 0.96(5) μs [2015Kh09], 1.31(12) μs [1989De06], 1.06(9) μs [1989Mi17] and 1.21(18) μs [1983Sc23].
** Weighted average of 9.917(15) MeV [2021Hu18], 9.919(15) MeV [2017Su18] and 9.205(15) MeV [1970Bo13].

*** Interpolated between 1.5433(36) fm ( 216 Ra) and 1.6051(43) fm ( 220 Th).

## **Table 7** direct $\alpha$ emission from ²²²Pa*, $T_{1/2} = 2.76^{+0.43}_{-0.33}$ ms, $BR_{\alpha} = 100\%$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{218}\mathrm{Ac})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
8.206(18)	8.058(18)	23%	5.7%		0 589		1.5783(52)	27
8.401(16)	8.250(16)	77%	19.2%		0.393		1.5783(52)	30
8.491(16)	8.338(16)	58%	14.4%		0.303		1.5783(52)	72
8.592(16)	8.437(16)	80%	19.9%		0.203		1.5783(532)	100
8.681(16)	8.525(16)	64%	15.9%		0.113		1.5783(52)	220
8.794(15)	8.636(15)	100%	24.9%	$(1^{-})$	0.0		1.5783(52)	280

* All values from [2021Hu18], except where noted.

** No uncertainties were reported [2021Hu18].

*** Interpolated between 1.6051(43) fm (²²⁰Th) and 1.5514(30) fm (²²⁴U).

## Table 8

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direct \alpha emission from <sup>226</sup>Np*, T<sub>1/2</sub> = 43(5) ms**, BR<sub>\alpha</sub> = \approx 100%
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{222}\text{Pa})$	coincident $\gamma$ -rays	$R_0 \ (fm)^@$	HF
8.134(20) 8.236(20)	7.990(20) 8.090(20)	***	***		0.193(28) 0.091(28)		1.516(42) 1.516(42)	$\approx 3$ $\approx 5$
8.327(20)	8.180(20)	***	***		0.0 ^{@@}		1.516(42)	$\approx 10$

* All values from [2019Mi08], except where noted.

** Weighted average of 43(5) ms [2019Mi08] and 31(8) ms [1990Ni05].

*** Text from [2019Mi08]: "For ²²⁶Np, the  $\alpha$ 1 events (Fig. 4 top right energy panel) show a broad energy distribution E=(7.9 – 8.4) MeV, however with the signature for three different  $\alpha$ -decay transitions with comparable intensities at 7.98(2), 8.09(2) and 8.18(2) MeV. This could correspond to either single  $\alpha$  decay activities or to  $\alpha$ -decay+conversion electron summing." In the aforementioned Fig. 4, there are  $\approx$  6 counts in each peak.

[@] Interpolated between 1.5514(30) fm (²²⁴U) and 1.480(42) (²²⁸Pu).

^{@@} Transition is assumed to feed the ground state.

#### Table 9

direct $\alpha$ emission from ²³⁴ Bk*, T	$_{1/2} = 19^{+6}_{-4}$ s, $BR_{\alpha} = > 80\%^{**}$
-----------------------------------------------------	--------------------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{230}\mathrm{Am})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7 753(20)	7 620(20)	***	***		0 345(28)			
7.895(20)	7.760(20)	***	***		0.203(28)			
7.997(20)	7.860(20)	***	***		0.101(28)			
8.098(20)	7.960(20)	***	***		$0.0^{@}$			

* All values from [2016Ka13], except where noted.

** [2003MoZT].

*** Fig. 2a in [2016Ka13] shows the  $\alpha$  spectrum of ²³⁴Bk. The four peaks present each have  $\approx$  5 counts each.

[@] Transition is assumed to feed the ground state.

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Observed and predicted $\beta$ -delayed part	ticle emission from the e	even- $Z, T_z = +$	-41/2 nuclei. J $\pi$	values for ¹⁸⁵ H	If, ¹⁸⁹ W,	¹⁹³ Os, ¹⁹	⁷ Pt, ²⁰¹ Hg, ar	nd ²⁰⁵ Pb are tak	en from
ENSDF. Unless otherwise stated, all Q	-values are taken from	2021Wa16] or	r deduced from	values therein.					

Nuclide	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
185116*		25(6) m	4.26(21)#			[1002V-01]
189377*	$(2/2^{-})$	5.3(0) III 11.7(5) m	-4.30(31)#			[19931001] [1007V ₂ 02]
193 <b>O</b> e*	(3/2)	11.7(3) III 20.820(18) h	-3.63(26)#			[1997 1a05] [2012Kn05]
197 D+*	3/2 1/2-	29.830(18) II 10.8015(10) h	-3.100(40)			[2012K105] [1002Ap12]
201 Hg	3/2-	19.0915(19) II	-2.130(20) 1.262(3)			[1992All15]
205 ph	5/2-	1.51(4) v	0.051(1)	6 360(1)	0.206(3)	[1079D_009]
209 Po	$\frac{3}{2}$	1.31(4) y 128 7(3) y	1.803(2)	-1.906(1)	5.030(2)	[ <b>2007Co07</b> 2015Po03 2014Co16]
$^{213}Rn$	$(9/2^+)$	120.7(3) y 19 5(1) ms	0.884(6)	-2.616(3)	10.138(4)	[2007C007, 20151005, 2014C010] [2000He17]
$^{217}Ra$	$(9/2^+)$	$17.3(1) \mu s^{**}$	1 575(9)	-1 653(9)	10.130(4) 10.044(9)	[200011017] [2019Va04_2019Mi08_1990AnZIJ_1970Va13]
²²¹ Th	$(7/2^+)$	$1.7(1) \mu$ s 1.73(3) ms***	2.410(60)	-0.621(11)	10.200(10)	[2001Ku07, 1993AnZS, 1970To07]
²²⁵ U		72(4) ms [@]	3.020(80)	0.087(14)	10.416(58)	[2019Mi08, 2001Ku07, 2000He17]
²²⁹ Pu		90(10) s	3.59(12)	0.886(62)	10.61(10)	[2002CaZU]
²³³ Cm		$23^{+13}_{-6}$ s	4.01(14)#	1.643(83)#	11.07(13)#	[2010Kh06]
²³⁷ Cf		0.8(2) s	4.73(25)#	2.796(99)#	12.23(15)#	[2010Kh06]
²⁴¹ Fm		0.73(6) ms	5.33(38)#	3.94(30)#	13.50(38)#	[2008Kh10]

* 100%  $\beta^-$  emitter.

** Weighted average of 1.4(4) μs [2019Ya04], 2.5(2) μs [2019Mi08], 1.7(1) μs [1990AnZU] and 1.6(2) μs [1970Va13].
*** Weighted average of 1.73(3) ms [2001Ku07], 1.9(1) ms [1993AnZS] and 1.68(6) ms [1970To07].
@ Weighted average of 63(7) ms [2019Mi08], 84(4) ms [2001Ku07] and 59⁺⁵₋₂ ms [2000He17].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +41/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	BR _{SF}	Experimental
185	0.04/04) //	1= 00/11				
¹⁰⁵ Hf	9.31(21)#	17.90(41)#	0.34(31)#			
¹⁸⁹ W	9.19(28)#	17.39(28)#	0.09(21)#			
¹⁹³ Os	9.095(71)	16.796(42)	-0.01(20)#			
¹⁹⁷ Pt	8.273(38)	15.486(56)	0.550(2)			
²⁰¹ Hg	7.711(27)	14.852(2)	0.332(1)			
²⁰⁵ Pb	6.713	13.079(1)	1.467(1)			
²⁰⁹ Po	4.785(2)	8.492(1)	4.979(1)	99.55(1)%		[1996Sc24, 1989Ma05, 1966Ha29, 1969Go23, 1953AsZZ,
						1951Ka03, 1951Ka37]
²¹³ Rn	4.357(4)	7.841(3)	8.245(3)	$\approx 100\%$		[2001Ku07, 2000He17, 2021Hu19, 2019Mi08, 2005Li17,
			. ,			1970TaZS, 1970Va13, 1970VaZZ, 1966Ro12, 1961Gr43]
²¹⁷ Ra	4.370(8)	7.519(9)	9.161(6)	100%		[1970To07, 1970Va13, 2021Hu19, 2019Ya04, 2019Mi08,
						1970VaZZ,1969ToXX, 1961Gr43]
²²¹ Th	4.093(10)	7.032(10)	8.625(4)	100%		[2020Pa44, 2021Hu19, 2019Mi08, 2019Ya04, 2015Li17,
	× /					2014Lo10, 2003Ni10, 2001Ku07, 2000He17, 1993AnZS,
						1990An19, 1990AnZO, 1990AnZU, 1970To07, 1970Va13,
						1970VaZZ, 1969MaZT]
²²⁵ U	3.779(12)	6.591(13)	8.007(6)	$\approx 100\%$		[2001Ku07, 2000He17, 2019Mi08, 2003Ni10, 1994AnZY,
	× /					1994Ye08, 1993AnZS, 1992To02, 1992ToZV, 1990YeZY,
						1989An13, 1989HeZK, 1989HeZZ, 1988AnZS1
²²⁹ Pu	3.72(12)#	6.228(61)	7.590(20)**	50(20)%	<7%*	[2010Kh06, 2002CaZU, 2002CaZZ, 1994An02, 1994AnZX
	0112(12)	0.220(01)	(10)0(20)	20(20)/0	(170	1994AnZY 1994Ye081
²³³ Cm	3 42(31)#	5 593(84)#	7 473(20)***	20(10)%		[2010Kb06 2002CaCU 2002CaZZ]
237 Cf	2.42(31)#	A 65(14)#	8 220(54)	70(10)%	30(10)%	[2010Kh06]
241 Em	2.09(37)#	$7.05(14)\pi$ 2.56(22)#	8 856(22)#	<140%*	> 780L	[2010151100] [2008/2510]
гш	2.29(47)#	5.50(52)#	0.030(32)#	< 14%0**	>10%	[2000KII10]

* Not observed.

** Deduced from  $\alpha$  decay. 7.598(60) MeV in [2021Wa16].

*** Deduced from  $\alpha$  decay. 7.473(54) MeV in [2021Wa16].

Table 3

direct $\alpha$ emission from ²⁰⁹ Po, J ^{$\pi$} = 1/2 ⁻ , T _{1/2} = 1	$28.7(3)$ y*, $BR_{\alpha} = 99.55(1)\%^{**}$ .
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@@}$	$E_{daughter}(^{205}\text{Pb})^{@@}$	coincident γ-rays ^{@@}	R ₀ (fm)	HF
4.190(15) 4.394(15)	4.110(15) 4.310(15)	$\begin{array}{l} 5.7(42)\times 10^{-4}\%^{***}\\ 1.5(4)\times 10^{-4}\%^{***} \end{array}$	$\begin{array}{l} 5.6(42)\times 10^{-4}\%\\ 1.5(4)\times 10^{-4}\%\end{array}$	3/2-	0.787(15) 0.576(4) ^{@@}	0.2605, 0.2628 , 0.3134, 0.5739, 0.5763	1.41923(39) 1.41923(39)	${}^{1.1^{+3.3}_{-0.6}}_{160^{+60}_{-40}}$
4.707(5) 4.977(2)	4.617(5) 4.882(2) [@]	0.56(1)% 100%	0.551(6)%** 98.56 (1)%**	3/2 ⁻ 5/2 ⁻ , 1/2 ⁻	0.263 ^{@@} 0.0, 0.0023 ^{@@}	0.2605, 0.2628	1.41923(39) 1.41923(39)	6.33(9) 1.536(21)

* [2007Co07].

** [1996Sc24].

*** [1966Ha29].

[@]  $\alpha$  energy is a weighted average of 4.877(5) MeV [1966Ha29] and 4.883(2) MeV [1989Ma05]. This peak is an unresolved transition that feeds both the 5/2⁻ ground state and a low-lying state 1/2⁻ at 2.3 keV [1996Sc24]. Due to the change in respective spins and the low HF (treating it as one transition), it appears that the majority of the  $\alpha$  transitions fred the 2.3 keV state. [@] [2020Ko17].

## Table 4

direct  $\alpha$  emission from ²¹³Rn,  $J^{\pi} = (9/2^+), T_{1/2} = 19.5(1)$  ms*,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})^*$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	$E_{daughter}(^{209}\text{Po})$	*** coincident γ-rays*	** R ₀ (fm)	HF		
7.393(4) 7.700(4) 8.245(3)	7.254(4) 7.555(4) 8.090(3)	1.1(1)% 0.68(7)% 100%	1.1(1)% 0.67(7)% 98.2(2)%	3/2 ⁻ 5/2 ⁻ 1/2 ⁻	0.854 0.545 0.0	0.854 0.545 —	1.4842(25 1.4842(25 1.4842(25	$\begin{array}{l} \begin{array}{c} 22(2) \\ 350^{+50}_{-40} \\ 96(5) \end{array}$		
* [2000He17]. ** [2001Ku07]. *** [2015Ch30].										
<b>Table 5</b> direct $\alpha$ em	ission from ²¹⁷ R	a, $J^{\pi} = (9/2^+),$	$T_{1/2} = 1.7(1) \mu$	$s^*, BR_{\alpha} = 1$	.00%.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daug}$	$_{ghter}(^{213}\mathrm{Rn})$	coincident $\gamma$ -rays R ₀	(fm) HI	F		
9.161(6)	8.992(6)**	100%	(9/2+)	0.0		1.5	5544(25) 1.8	36(16)		

* Weighted average of 1.4(4) µs [2019Ya04], 2.5(2) µs [2019Mi08], 1.7(1) µs [1990AnZU] and 1.6(2) µs [1970Va13].

** Weighted average of 8.990(8) MeV [1970To07] and 8.995(10) MeV [1970Va13].

## Table 6

direct $\alpha$ emission fr	om 221 Th*, J $^{\pi} = 0$	$(7/2^+), T_{1/2} = 1.7$	$73(3) \text{ ms}^{**}, BR_{\alpha}$	= 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{217}\mathrm{Ra})$	coincident γ-rays	R ₀ (fm)	HF
7.878(3)	7,735(3)	7.8(3)%	4.7(2)%	$(7/2^+)$	0.753	0.177. 0.227. 0.331. 0.526. 0.576. 0.753	1.5811(30)	4,9(4)
8.098(8)	7.951(8)	0.23(5)%	0.14(3)%	$(13/2^+)$	0.540	0.540	1.5811(30)	$740^{+230}_{-160}$
8.298(3)	8.148(3)	100(1)%	60.3(7)%	$(11/2^+)$	0.331	0.177, 0.331	1.5811(30)	7.1(5)
8.399(3)	8.247(3)	2.5(2)%	1.5(1)%	$(7/2,9/2)^{-}$	0.227	0.227	1.5811(30)	560(60)
8.564(16)***	8.409(16)***	12%***		0.063			1.5811(30)	370
8.627(3)	8.471(3)	55.4(9)%	33.4(4)%	$(9/2^+)$	0.0		1.5811(30)	106(7)

* All values from [2020Pa44], except where noted.

** Weighted average of 1.73(3) ms [2001Ku07], 1.9(1) ms [1993AnZS] and 1.68(6) ms [1970To07].

*** Tentatively assigned by [2021Hu19], with the comment "the small peak at 8409 keV may stem from the internal conversion effect." In addition, [1990An19] reports peaks at 8.265(10) MeV ( $I_{\alpha} = 4$ ) and 8.375(10) MeV ( $I_{\alpha} = 11$ ), with no spectra are shown in this work. No levels at 63, 98, or 210 keV have been observed in ²⁰⁸Pb( $^{13}C,4n\gamma$ ) [1983Lo16] or ²⁰⁸Pb( $^{12}C,3n\gamma$ ) [1991Dr08, 1984Ro20, 1984Su10] reactions (as detailed in [2018Ko01]).

direct $\alpha$ emis	sion from ²²⁵ U, 7	$\Gamma_{1/2} = 72(4) \text{ ms}^*$	$BR_{\alpha} = \approx 100$	)%.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(2)$	²²¹ Th)	coincident	γ-rays	R ₀ (fm)	HF
7.762(12)	7.624(12)	9(4)%	5(2)%	$(11/2^+)^@$	0.2509(3)	<u>@</u>	0.2509 [@]		1.5454(32)	$8^{+6}_{-3}$
7.970(12) 8.010(6)	7.828(12) 7.867(6)	64(5)% 100(7)%	37(5)% 58(4)%	(7/2 ⁺ )	0.040(21) 0.0				1.5454(32) 1.5454(32)	$4.9^{+1.4}_{-1.2} 4.2(5)$
* Weigh ** Weig *** [200 [@] [2007.	ted average of 63 hted average of v 00He17]. Ja05].	(7) ms [2019Mi0 alues from [2001	8], 84(4) ms [2 Ku07] and [20	2001Ku07] an 000He17].	d $59^{+5}_{-2}$ ms [200	00He17].				
<b>Table 8</b> direct $\alpha$ emised	sion from ²²⁹ Pu*	$T_{1/2} = 90(10) s$	**, $BR_{\alpha} = 50($	20)%.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	E _{daughter} (	( ²²⁵ U)	coincident	γ-rays	R ₀ (fm)	HF	
7.590(20)	7.457(20)	50(20)%		0.0				1.509(24	) $22^{+25}_{-13}$	
* All val ** [2002	ues from [2010K CaZU].	h06], except whe	ere noted.							
<b>Table 9</b> direct $\alpha$ emised	sion from ²³³ Cm	*, $T_{1/2} = 23^{+13}_{-6}$ s	$BR_{\alpha} = 20(10)$	))%.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	$E_{daughter}(^{22}$	⁹ Pu)	coincident	γ-rays	R ₀ (fm)	HF
7.381(20) 7.473(20)	7.254(20) 7.345(20)	${}^{43}_{-34}^{+47}\% \\ 100(43)\%$	$6^{+7}_{-5}\%$ 14(9)%		0.092(28) 0.0				1.502(33) 1.502(33)	${\substack{1-1\\-1\\1+5\\-1}}$
* All val	ues from [2010K	h06].								
Table 10 direct $\alpha$ emis	sion from ²³⁷ Cf*	$T_{1/2} = 0.8(2) s,$	$BR_{\alpha} = 70(10)$	%.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{23}$	³³ Cm)	coincident 7	γ-rays	R ₀ (fm)	HF	
8.220(20)	8.081(20)	70(10)%		0.0				1.471(55)	$0.3^{+0.8}_{-0.3}$	
* All val	ues from [2010K	h06].								

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z$	= +41/2 nuclei. $J^{\pi}$ values for ¹⁸⁷ Ta, ¹⁹¹ Re, ¹⁹⁵ Ir, ¹⁹⁹ Au, ²⁰³ Tl and ²⁰⁷ Bi and taken from
ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16	or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
¹⁸⁷ Ta ¹⁹¹ Re ¹⁹⁵ L		$(7/2^+)$ $(1/2^+, 3/2^+)$ $2/2^+$	283(10) s 9.8(5) m 2.20(17) h	-3.90(21)# -3.170(40)			[2022Mu10] [1953At24] [2013Bi14]
¹⁹⁹ Au		$3/2^+$ $3/2^+$	2.29(17) li 3.129(11) d	-2.180(00) -1.705(2)			[2013B114] [1969La34]
²⁰³ Tl ²⁰⁷ Bi ²¹¹ At		1/2 ⁺ 9/2 ⁻ 9/2 ⁻	stable 31.35(4) y 7.214(7) h	-0.492(1) 2.397(2.1) 0.785(2.5)	-5.090(2) -4.144(2)	2.790(3) 8.380(3)	[2002Un02] [1961Ap01]
²¹⁵ Fr ^{215m1} Fr ^{215m2} Fr ^{215m3} Fr	0.835 1.146 1.446	$9/2^{-}$ (13/2 ⁺ ) (15/2 ⁻ ) (19/2 ⁻ )	86(5) ns 30(8) ns 30(5) ns	1.487(9) 2.322(9) 2.633(9) 2.933(9)	-3.592(8) -2.727(8) -2.446(8) -2.146(8)	10.326(7) 11.161(7) 11.472(7) 11.772(7)	[1984De16] [1984Sc25] [1984De16] [1984De16]
$\frac{215m^4}{219}$ Fr $\frac{219}{223}$ Pa	1.579	(23/2 ⁻ ) 9/2 ⁻	30(5)  ns 11.8(15) $\mu \text{s}$ 5 4(4) ms*	3.066(9) 2.180(50) 2.950(80)	-2.013(8) -2.779(52) -1.573(76)	11.905(7) 10.314(52) 10.519(76)	[1982GoZU] [1989Mi17] [2019Mi08, 1999Ho28, 1995AnZY, 1970Bo13]
²²⁷ Np ²³¹ Am ²³⁵ Bk ²³⁹ Es			510(60) ms	3.530(80) 4.10(30)# 4.76(41)# 5.43(32)#	-0.744(78) -0.12(31)# 1.02(43)# 2.13(39)#	10.769(77) 10.94(30)# 12.04(40)# 13.19(33)#	[1990Ni05]

* Weighted average of 7(1) ms [2019Mi08], 4.9(5) ms [1999Ho28], 5(1) ms [1995AnZY] and 6.5(10) ms [1970Bo13].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +41/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	Experimental
1877-	7 7(0(7()	17.51(21)#	0.20((08)		
191 D	7.760(76)	17.51(31)#	0.396(98)		
105 r	1.2/1(3/)	16.97(20)#	0.120(57)		
¹⁹⁵ Ir	6.546(2)	16.039(39)	0.233(10)		
¹⁹⁹ Au	6.479(2)	15.408(20)	0.174(1)		
²⁰³ Tl	5.705(1)	13.939(3)	0.908(1)		
²⁰⁷ Bi	3.558(2)	10.812(2)	3.282(2)		
²¹¹ At	2.983(2)	7.967(2)	5.982(1)	41.80(8)%*	[1985La17, 1978Ya04, 1975Ja04, 1969Go23, 2009Vi09,
					2003HaZT, 2001Ch66, 2000ChZU, 2000OgZU, 1977YaZG,
					1970AfZZ, 1968GuZX, 1963Uh01, 1961Ap01, 1955Mo68,
					1953AsZZ, 1953Ho49, 1953Hy83, 1951Ne02, 1940Co01,
					1940Co02]
²¹⁵ Fr	2.651(11)	7.680(8)	9.540(7)	100%	[1984Sc25, 1984De16, 2019Mi08, 1982GoZU, 1982SaZO,
					1974Ni02, 1973HaVQ, 1973HaZO, 1973HiYZ, 1972No06,
					1971HyZX, 1970VaZZ]
^{215m1} Fr	1.816(11)	6.845(8)	10.375(7)	3.8(15)%	[1984Sc25]
^{215m2} Fr	1.505(11)	6.534(8)	10.686(7)	0.8(1)%	[1984Sc25, 1984De16]
^{215m3} Fr	1.205(11)	6.234(8)	10.986(7)	4.1(3)%	[1984Sc25, 1984De16, 1982GoZU]
^{215m4} Fr	1.072(11)	6.101(8)	11.119(7)	3.6(3)%	[1984Sc25, 1984De16, 1982GoZU, 1982SaZO]
²¹⁹ Ac	2.365(52)	7.323(52)	8.825(10)**	100%	[1989Mi17, 2019Mi08, 1989MiZK, 1989MiZZ, 1988MiZJ,
	. ,				1970Bo13, 1970VaZZ]
²²³ Pa	2.154(76)	6.771(94)	8.343(8)***	100%	[1995AnZY, 1970Bo13, 2019Mi08, 1999Ho28, 1993AnZS,
					1970VaZZ]
²²⁷ Np	2.039(78)	6.36(11)	7.816(14)	$\approx 100\%^{@}$	[ <b>1990Ni05</b> , 1994AnZY, 1994Ye08, 1993AnZS, 1990An19,
- · <b>r</b>		0.000(00)			1990AnZO, 1990YeZY]
²³¹ Am	1.81(30)#	5.97(32)#	7.41(31)#		
²³⁵ Bk	1.24(40)#	5.09(42)#	7.94(50)#		
²³⁹ Es	0.94(42)#	4.16(38)#	8.44(50)#		

* Weighted average of 41.94(16)% [1985La17], 41.74(10)% [1978Ya04] and 41.8(2)% [1969Go23].

** Deduced from  $\alpha$  decay. 8.826(51) MeV in [2021Wa16].

*** Deduced from  $\alpha$  decay. 8.343(55) MeV in [2021Wa16].

[@] No other decay observed.

$E_{\rm c}$ (cm)	F. (lab)***	L (rel)	L (abs)	Iπ@	E (207 Bi)@	coincident v rave@	$\mathbf{R}_{0}$ (fm)	HE
$E_{\alpha}(c.m.)$	$L_{\alpha}(1ab)^{max}$	$I_{\alpha}(101)$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{-}$	Edaughter(  B1)	conicident $\gamma$ -rays	<b>K</b> ₀ (11fl)	пг
5.240(2)	5.141(2)	0.0023(8)%	0.00097(33)%	7/2-	0.7247(1)	0.7427	1.4216(13)	$33^{+17}_{-8}$
5.311(2)	5.210(2)	0.0086(19)%	0.0036(8)%	11/2-	0.6698(1)	0.6698	1.4216(13)	$18^{+3}_{-3}$
5.979(2)	5.866(2)	100%	41.80(8)%**	9/2	0.0		1.4216(13)	1.52(6)
* [1961 ** Wei *** [19 @ [1975	Ap01]. ghted average of 4 69Go23]. 5Ja04].	1.94(16)% [1985]	La17], 41.74(10)	% [1978Ya04]	and 41.8(2)% [1969C	bo23].		
<b>Fable 4</b> direct $\alpha$ emi	ission from ²¹⁵ Fr*	$f_{2}, J^{\pi} = (9/2^{-}), T_{1/2}$	$_2 = 86(5) \text{ ns}, BR$	$\alpha = 100\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{211}\text{A})$	t) coincident γ	rays R ₀ (fm)	HF	
9.547(10)	9.369(10)	100%	9/2-	0.0	_	1.5387(31)	1.03(10)	
* All va	alues from [1984D	De16].						
Table 5 direct $\alpha$ emi	ission from ^{215m1} F	Fr*, Ex. = 0.835 M	fleV, $J^{\pi} = (13/2^+)$	), $T_{1/2} = , BR_{\alpha}$	= 3.8(15)%.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\boldsymbol{\pi}}$	$E_{daughter}(^2$	¹¹ At) coincide	ent $\gamma$ -rays R ₀ (fm	h) HF	
10.353(30)	10.160(30	) 100%	9/2-	0.0		1.5387	(31)	
* All va	alues from [1984S	c25].						
Table 6 direct $\alpha$ emi	ission from ^{215m2} F	Fr*, Ex. = 1.146 N	$1 eV^*, J^{\pi} = (15/2)$	$(-), T_{1/2} = 30(8)$	) ns*, $BR_{\alpha} = 0.8(1)\%$	**.		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{211}\mathrm{A}$	t) coincident γ	rays R ₀ (fm)	HF	
10.692(20)	10.493(20)	100%	9/2-	0.0		1.5387(31)	$9^{+4}_{-3} \times 10^{2}$	3
* [1984 ** [198	De16]. 4Sc25].							
<b>Table 7</b> direct α emi	ission from ^{215m3} F	Fr, Ex. = 1.446 Me	$eV^*, J^{\pi} = (19/2^-)$	), $T_{1/2} = 30(5)$	ns, $BR_{\alpha} = 4.1(3)\%$ .			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	E _{daughter} ( ²¹¹ At)	coincident γ-r	ays $R_0$ (fm)	HF	
10.994(15)	10.789(15)	100%	9/2-	0.0		1.5387(31)	5.8(12) × 10	3
	De16]							
* [1984 ** [198	4Sc25].							
* [1984 ** [198 <b>Table 8</b> direct α emi	ission from ^{215m4} F	Fr, Ex. = 1.579 Mo	$eV^*, J^{\pi} = (23/2^-)$	), T _{1/2} = 30(5),	$BR_{\alpha} = 3.6(3)\%.$			
* [1984 ** [198 <b>Table 8</b> direct $\alpha$ emi	4Sc25]. ission from 215m4 F $E_{\alpha}$ (lab)	Fr, Ex. = 1.579 Mo $I_{\alpha}(abs)$	$eV^*, J^{\pi} = (23/2^-)$ $J_f^{\pi} = E$	), $T_{1/2} = 30(5)$ , $C_{daughter}(^{211}At)$	$BR_{\alpha} = 3.6(3)\%.$ coincident $\gamma$ -ra	ys R ₀ (fm)	HF	

* [1984De16]. ** [1984Sc25].

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{215}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
8.825(10)	8.664(10)**	100%	9/2-	0.0		1.5853(28)	1.79(27)

* All values from [1989Mi17], except where noted.

direct  $\alpha$  emission from ²¹⁹Ac*,  $J^{\pi} = (9/2^{-})$ ,  $T_{1/2} = 11.8(15) \ \mu s$ ,  $BR_{\alpha} = 100\%$ .

** From [1989Mi17], which has the highest statistics. [1970Bo13] report one peak at 8.665(10) MeV. [2019Mi17] report 2 peaks at 8.520(40) and 9.160(40) MeV. However, no spectra is shown, or relative ratios where reported.

#### Table 10

direct $\alpha$ emission from	223 Pa, T _{1/2} :	$= 5.4(4) \text{ ms}^*$	$BR_{\alpha} = 100\%$
-------------------------------	---------------------------------	-------------------------	-----------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{219}\mathrm{Ac})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
8.149(8) 8.343(8)	8.003(8)** 8.193(8)***	100(5)% 75(7)%	57(3)% [@] 43(3)% [@]	9/2-	0.194(11) 0.0		1.5543(24) 1.5543(24)	2.3(3) 11.3(14)

* Weighted average of 7(1) ms [2019Mi08], 4.9(5) ms [1999Ho28], 5(1) ms [1995AnZY] and 6.5(10) ms [1970Bo13].

- ** Weighted average of 8.000(15) MeV [1995AnZY] and 8.005(10) MeV [1970Bo13].
- *** Weighted average of 8.190(15) MeV [1995AnZY] and 8.195(10) MeV [1970Bo13].

@ [1995AnZY].

## Table 11

direct  $\alpha$  emission from ²²⁷Np*, T_{1/2} = 510(60) ms, BR_{$\alpha$} =  $\approx$  100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{223}\text{Pa})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
7.787(20) 7.815(20)	7.650(20) 7.677(20)	≈33% 100%	≈25%** ≈75%**		0.028(20) 0.0		1.510(23) 1.510(23)	≈2.7 ≈1.1

* All values from [1990Ni05].

** Estimated by evaluator based on Fig. 2 in [1990Ni05].

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +21$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{arepsilon lpha}$	Experimental
100							
¹⁹⁸ Pt		$0^{+}$	stable	-4.19(20)#			
²⁰² Hg		$0^+$	stable	-2.992(23)			
²⁰⁶ Pb		$0^{+}$	stable	-1.532(1)			
²¹⁰ Po		$0^+$	138.3787(16) d*	-1.161(1)			[1964EiZZ, 1954Ei20, 1953Cu46]
²¹⁴ Rn		$0^{+}$	259(3) ns	-0.941(10)			[2019Pa45]
214m1 Rn	1.473	$6^{+}$	1.0(3) ns	0.532(10)	-3.482(10)	9.520(9)	[1983Dr08, 1981Go06]
214m2 Rn	1.557	$8^{+}$	4.8(3) ns	0.616(10)	-3.398(10)	9.604(9)	[1983Dr08,1981Go06]
²¹⁸ Ra		$0^+$	25.99(10) µs	-0.414(11)			[2019Pa45]
²²² Th		$0^+$	1.964(2) ms	0.581(11)	-3.050(11)	7.719(11)	[2016Pa28]
²²⁶ U		$0^{+}$	271(6) ms*	1.295(16)	-2.270(12)	8.282(12)	[2018Mi11, 2002CaZU, 2001Ku07, 2000He17]
²³⁰ Pu		$0^+$	102(10) s	1.700(60)	-1.567(16)	8.474(18)	[2002CaZU]
²³⁴ Cm		$0^{+}$	51(12) s	2.26(16)#	-0.618(57)	9.061(58)#	[2002CaZU]
²³⁸ Cf		$0^{+}$	21(2) ms	3.06(39)#	0.74(31)#	10.39(34)#	[1995La09]
²⁴² Fm		$0^+$	$< 4 \mu s$	3.60(48)#	1.78(43)#	11.76(48)#	[2008Kh10]

* Weighted average of 138.3763(17) d [1964EiZZ] and 138.4005(51) d [1954Ei20].

** Weighted average of 270(10) ms [2018Mi11], 258(13) ms [2002CaZU], 260(20) ms [2001Ku07] and 281(9) ms [2000He17].

 Table 2

 Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +21$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	S _p	$S_{2p}$	Qα	BRα	BF _{SF}	Experimental
¹⁹⁸ Pt	8.929(20)	16.205(40)	0.106(3)			
²⁰² Hg	8.234(3)	15.324(20)	0.134(2)			
²⁰⁶ Ph	7.254(1)	13.673(1)	1 135(1)			
²¹⁰ Po	4.983(1)	8 782	5 408	100%		[2023Av04, 2018Sb12, 1973Go39, 1960Fe04, 20157b41
10		0.702	01100	10070		$2014P_001$ 2012 $D_008$ 2001 $Gi12$ 1999 $Oh02$ 1997 $Ka59$
						1987Fr06 1961Be13 1961Rv05 1960Rv01 1958Ba45
						1958Si78, 1958Wh09, 1957Ag15, 1955Mo68, 1954Br07
						1952Ba20, 1951Ka03, 1951Ka37, 1949Me54, 1934Le01,
						1933Ro03, 1902Ma02, 1898Cu021
²¹⁴ Rn	5.029(10)	8.528(9)	9.208(9)	100%		[ <b>1970To07. 1970Va13</b> . 2019Pa45, 2018Mi11, 1986Ki13.
			,			1981Go06, 1970TaZS, 1970VaZZ]
²¹⁴ Rn	3.556(10)	7.055(9)	10.681(9)	obs		[1981Go06]
²¹⁴ Rn	3.472(10)	6.971(9)	10.765	4.3(7)%		[1981Go06]
²¹⁸ Ra	4.958(12)	8.186(11)	8.540(3)	100%		[ <b>2019Pa45</b> , 2018Mi11, 1986Ki13, 1986To02, 1970To07.
						1970Va13, 1970VaZZ]
²²² Th	4.617(58)	7.647(13)	8.133(3)	100%		[2016Pa28, 2018Mi11, 2005Li17, 2002CaZU, 2002CaZZ,
						2000He17, 1991AnZZ, 1990AnZT, 1990AnZU, 1970To07,
						1970Va13, 1970VaZZ]
²²⁶ U	4.317(83)	7.245(15)	7.701(4)	$\approx 100\%$		[2002CaZU, 2001Ku07, 2000He17, 1999Gr28, 2018Mi11
						2003MoZT, 2002CaZZ, 1998Gr19, 1994AnZY, 1994Ye08,
						1991An10, 1990An22, 1990AnZT, 1989An13, 1988AnZS,
						1973Vi10, 1972MiZK, 1972MiZL, 1972MiZN, 1972ViZQ]
²³⁰ Pu	4.16(10)	6.866(20)	7.178(9)	$\approx 100\%$		[2002CaZU, 2007KhZQ, 2003MoZT, 1999Gr28, 1999GrZY,
						1994AnZY, 1994Ye08, 1993AnZS, 1990An22, 1990AnZT,
						1990YeZY]
²³⁴ Cm	3.85(12)#	6.216(24)	7.365(9)	pprox 27%	pprox 2%	[2010Kh06,2002CaZU, 2002CaZZ]
²³⁸ Cf	3.22(38)#	5.15(30)#	8.13(30)	< 5%*	>95%	[ <b>2010Kh06</b> , 2001Og08, 1995La09]
²⁴² Fm	2.78(46)#	4.17(40)#	8.697(50)#		**	

* Not observed.

** SF reported by [1975Te01] with a  $T_{1/2} = 0.8(2)$  ms. However, this was not observed in [2008Kh10], leading to the conclusion that the  $T_{1/2}$  was less than < 4  $\mu$ s. The events observed in [1975Te01] were likely from the SF decay of ²⁴¹Fm ( $T_{1/2} = 0.73(6)$  ms [2008Kh10]).

direct $\alpha$ emi	ssion from ²¹⁰ Po,	$J^{\pi} = 0^+, T_{1/2} =$	138.3787(16) d*, J	$BR_{\alpha} = 100\%$	<i>b</i> .				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi@@}$	$E_{daughter}(^{20}$	⁶ Pb) ^{@@} coinc	ident γ-rays ^{@@}	R ₀ (fm)	HF
4.613(5) 5.40733(7)	4.525(5)** 5.30433(7) [@]	0.00122(3)% 100%	0.00122(3)%** 99.99878(3)%	$* 2^+ 0^+$	0.803 0.0	0.803	3	1.40879(38) 1.40879(38)	1.34(11) 0.997929(12)
* Weigh ** [196 *** [20 @ Repo @@ [200	nted average of 13 0Fe04]. 18Sh12]. rted as 5.30451(7 08Ko21].	8.3763(17) d [19 ) MeV in [1973G	64EiZZ] and 138. o39], modified to	4005(51) d [ 5.30433(7) r	1954Ei20]. meV in [1999R	y01].			
<b>Table 4</b> direct $\alpha$ emission	ssion from ²¹⁴ Rn	, $J^{\pi} = 0^+$ , $T_{1/2} =$	259(3) ns*, $BR_{\alpha}$ =	= 100%.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{21}$	¹⁰ Po) c	oincident γ-rays	R ₀ (fm)	HF	
9.208(9)	9.036(9)**	100%	$0^+$	0.0	-		1.5340(25	i) 0.999	(12)
* [2019] ** Weig	Pa45]. hted average of 9	0.040(20) MeV [1	970To07] and 9.03	35(10) MeV	[1970Va13].				
Table 5         direct $\alpha$ emistive	ssion from ^{214m1} F	Rn, $J^{\pi} = (6^+)$ , Ex.	= 1.473 MeV*, T	$T_{1/2} = 1.0(3)$	$ns^{**}, BR_{\alpha} = c$	bs***.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(a)$	bs) $J_f^{\pi}$	$E_{daught}$	_{ter} ( ²¹⁰ Po)	coincident γ-r	ays ^{@@} R ₀	(fm)	HF
10.659(30)	10.460(30	)***	$0^+$	0.0			1.5	5340(25)	
* [2014] ** [198 *** [199	Ba41]. 7Dr08]. 81Go06].								
Table 6 direct $\alpha$ emis	ssion from ^{214m2} F	Rn, $J^{\pi} = (8^+)$ , Ex.	= 1.557 MeV*, T	$T_{1/2} = 4.8(3)$	$ns^{**}, BR_{\alpha} = 4$	.3(7)%***.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	E _{daught}	_{ter} ( ²¹⁰ Po)	coincident γ-ra	$R_0$ (1	fm) H	F
10.832(30)	10.630(30)	** 4.3(7)9	$6^{***}$ 0 ⁺	0.0			1.534	40(25) 79	$90^{+210}_{-150}$
* [2014] ** [198 *** [199	Ba41]. 7Dr08]. 81Go06].								
<b>Table 7</b> direct $\alpha$ emised	ssion from ²¹⁸ Ra	*, $J^{\pi} = 0^+$ , $T_{1/2} =$	= 25.99(10) μs, Bk	$R_{\alpha} = 100\%.$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi**}$	$E_{daughter}(^{200}$	⁵ Pb)** coin	cident γ-rays**	R ₀ (fm)	HF
7.859(40) 8.537(4)	7.715(40) 8.381(4)	0.123(11)% 100%	0.123(11)% 99.88(6)%	$\begin{array}{c}2^+\\0^+\end{array}$	0.695(1) 0.0	0.69	5(1)	1.5655(13) 1.5655(13)	6.3(8) 0.998(4)

* All values from [2019Pa45], except where noted. ** [2021Zh35].

Table 8	
direct $\alpha$ emission from ²²² Th*, $J^{\pi} = 0^+$ , $T_{1/2} = 1.964(2)$ ms, $BR_{\alpha} =$	100%

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{218}\mathrm{Ra})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
7.274(4) 7.337(4) 7.743(3)	7.143(4) 7.205(4) 7.603(3)	0.014(4)% 0.018(3)% 1.84(1)%	0.014(4)% 0.018(3)% 1.81(1)%	$(1^{-})$ $3^{-}$ $2^{+}$	0.858(5) 0.7932(2)** 0.3889(1)**	0.858(5) 0.3522(1), 0.3889(1)** 0.3889(1)**	1.5571(17) 1.5571(17) 1.5571(17)	$12^{+5}_{-3} \\ 15.7^{+3.2}_{-2.3} \\ 3.551(20)$
8.133(3)	7.986(3)	100%	98.16(5)%	$0^+$	0.0		1.5571(17)	1.0430(12)

* All values from [2019Pa45], except where noted.

** [2019Si39].

### Table 9

direct $\alpha$ emission from ²²⁶ U, $J^{\pi} = 0^+$ , $T_{1/2} = 271(6)$ ms*, $BR_{\alpha} = \approx$	100%
-------------------------------------------------------------------------------------------------------------------	------

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$J_f^\pi$	$E_{daughter}(^{222}\mathrm{Th})$	coincident γ-rays	$R_0$ (fm)	HF
7.455(20) 7.516(4) 7.700(3)	7.323(20)** 7.383(4)*** 7.564(3) [@]	3.7(12)% 18.3(38)% 100%	3(1)% 15(3)% 82(5)%	$(1^{-})$ $2^{+}$ $0^{+}$	0.245(20) 0.1829(2) [@] [@] 0.0	0.1829(2) ^{@@}	1.5394(34) 1.5394(34) 1.5394(34)	$\begin{array}{c} 4.2^{+2.3}_{-1.3} \\ 1.4^{+0.4}_{-0.3} \\ 1.05(8) \end{array}$

* Weighted average of 270(10) ms [2018Mi11], 258(13) ms [2002CaZU], 260(20) ms [2001Ku07] and 281(9) ms [2000He17].

** [2000He17].

*** Weighted average of 7.384(7) MeV [2001Ku07], 7.374(10) MeV [2000He17], and 7.385(5) MeV [1999Gr28].

[@] Weighted average of 7.560(10) MeV [2002CaZU], 7.566(4) MeV [2001Ku07], 7.555(10) MeV [2000He17], and 7.565(5) MeV [1999Gr28]. @@ [2023Si22].

### Table 10

direct  $\alpha$  emission from ²³⁰Pu*,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 102(10)$  s,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{226}\mathrm{U})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.123(15) 7.182(10)	6.999(15) 7.057(10)	23(5)% 100(5)%	19(4)% 81(4)%	$2^+_{0^+}$	0.059(18) 0.0		1.5375(56) 1.5375(56)	$2.6^{+1.1}_{-0.8}$ $1.01(11)$

* All values from [2002CaZU], except where noted.

### Table 11

direct $\alpha$ emission from ²³⁴ Cm*, $J^{\pi} = 0^+$ , T	$_{1/2} = 51(12)$ s, $BR_{\alpha} = \approx 27\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{230}\mathrm{Pu})$	coincident γ-rays	R ₀ (fm)	HF
7.365(10)	7.239(10)	$\approx 27\%$	$0^+$	0.0		1.491(25)	$\approx 0.49^{**}$

* All values from [2010Kh06, 2002CaZU].

** The unphysically low HF may indicate that the value of  $\approx 27\%$  is too high (a value of 13% gives a HF = 1).

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +1/2 nuclei.

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +21$  nuclei.  $J^{\pi}$  values for ²⁰⁴Tl and ²⁰⁸Bi are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	$BR_{\beta_F}$	Experimental
²⁰⁴ T1*		2-	3 794(2) v**	0.344(1)	-8 492(3)	-0 172(20)		[1970Ha32, 1969Bo24, 1968Ho07, 1965Ap07]
²⁰⁸ Bi		$\frac{2}{5^{+}}$	$3.68(4) \times 10^5 \text{ v}$	2.878(2)	-5.125(6)	3.395(2)		[1964Ha07]
²¹² At		$(1^{-})$	314.5(21) ms***	1.741(2)	-4.058(6)	10.695(3)		[1976FrZO, 1970Re02]
$^{212m}At$	0.229(3)	(9-)	112.6(9) ms [@]	1.970(4)	-3.829(7)	10.924(4)		[1976FrZO, 1970Re02]
²¹⁶ Fr		(1 ⁻ )	0.7(2) µs	2.718(7)	-3.061(8)	10.916(4)		[1970Bo13]
^{216m1} Fr	0.1333(1)	(3 ⁻ )	71(5) ns	2.851(7)	-2.928(8)	11.049(4)		[1971EpZY]
^{216m2} Fr	0.219(5)	(9-)	850(30) ns	2.937(9)	-2.842(9)	11.135(6)		[2007Ku30]
²²⁰ Ac			26.4(2) ms	3.472(10)	-2.162(9)	11.066(8)		[1990An19]
²²⁴ Pa		(5 ⁻ )	844(19) ms ^{@@}	3.867(12)	-1.252(10)	11.165(11)		[1996Li05, 1997Wi15]
²²⁸ Np			61.4(15) s	4.61(10)#	-0.29(10)#	11.41(10)#	0.020(9)%	[1994Kr13, 1978SoZZ, 1976SoZT]
²³² Am			79(2) s	5.06(30)#	0.51(30)#	11.78(30)#	0.069(10)%	[1990Ha28, 1989HaZO, 1978Ha05]
²³⁶ Bk			$22^{+13}_{-6}$ s	5.69(36)#	1.63(36)#	12.76(36)#	4(2)%	[2017Ko02]
²⁴⁰ Es			5(2) s	6.24(37)#	2.69(42)#	13.95(37)#	4.8(18)%	[2017Ko02]
²⁴⁴ Md			$\approx 6 \text{ s}$	6.63(43)#	3.56(43)#	15.18(38)#		[2020Po07]
^{244m} Md	Х		$0.4^{+0.4}_{-0.1}$ s	6.63(43)#+x	3.56(43)#+x	15.18(38)#+x		[2020Po07]

* Decays by 97.08(7)%  $\beta^-$  and 2.92(7)%  $\beta^+$  [1990Sc08]. ** Weighted average of 3.793(5) y [1970Ha32], 3.774(5) y [1969Bo24], 3.825(3) y [1968Ho07] and 3.754(4) y [1965An07].

*** Weighted average of 314(3) ms [1976FrZO] and 315(3) ms [1970Re02].

[@] Weighted average of 115(2) ms [1976FrZO] and 112(1) ms [1970Re02].

^{@@} Weighted average of 790(60) ms [1996Li05] and 850(20) ms [1997Wi15].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +21$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$S_{2p}$	Qα	BRα	Experimental
²⁰⁴ T1	6 366(1)	14 571(23)	0.469(27)		
²⁰⁸ Bi	3.707(2)	11,195(2)	3.051(2)		
²¹² At	3.485(2)	8.414(2)	7.817(1)	100%	[1976FrZO, 1970Re02, 2009Vi09, 2007Ku30, 1999Ho28,
					1996Li37, 1975FrZR, 1968Va18, 1963Jo09, 1961Gr431
212m At	3.256(4)	8.185(4)	8.046(3)	$\approx 100\%$	[1976FrZO, 1970Re02, 2009Vi09, 2007Ku30, 1999Ho28,
	. ,	. ,			1996Li37, 1975FrZR, 1968Va18, 1963Jo09, 1961Gr43]
²¹⁶ Fr	3.149(7)	8.228(5)	9.174(3)	100%	[2007Ku30, 1970Bo13, 2003Ni10, 1996Li37, 1970VaZZ]
^{216m1} Fr	3.016(7)	8.095(5)	9.307(3)	>50%	[1996Li37, 1971EpZY]
^{216m2} Fr	2.930(9)	8.0098(7)	9.393(6)	100%	[2007Ku30]
²²⁰ Ac	2.939(9)	7.894(7)	8.348(4)	pprox 100%	[1997Sh09, 2007Ku30, 2003Ni10, 1971EpZY, 1971HyZX,
					1970Bo13]
²²⁴ Pa	2.812(11)	7.337(9)	7.694(4)	$\approx 100\%$	[1996Li05, 2003Ni10, 1997Sh09, 1997Wi15, 1993AnZS,
					1990An19, 1990AnZQ, 1989AnZL, 1987FaZT, 1970Bo13]
²²⁸ Np	2.51(10)#	6.79(10)#	7.54(10)#	40(11)%	[2003Ni10, 2004NiZZ, 2003NiZV, 1994Kr13]
²³² Am	2.18(30)#	6.40(31)#	7.17(32)#		
²³⁶ Bk	1.76(38)#	5.50(39)#	7.70(20)#	$\approx 17\%$	[ <b>2020Po07</b> , 2017Ko02]
²⁴⁰ Es	1.27(39)#	4.57(45)#	8.259(63)	70(10)%	[2017Ko02, 2020Kh08, 2020Po07]
²⁴⁴ Md	1.01(40)#	3.78(45)#	8.947(79)	$\approx 100\%$	[2020Po07, 2020Kh08]
^{244m} Md	1.01(40)#-x	3.78(45)#-x	8.947(79)+x	$\approx 100\%$	[2020Po07]

### Table 3

direct  $\alpha$  emission from ²¹²At*,  $J^{\pi} = 1^{-}$ ,  $T_{1/2} = 314.5(21)$  ms**,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{208}\mathrm{Bi})^{@}$	coincident γ-rays [@]	$R_0(fm)^{@@}$	HF
6.7488(8)	6.6215(8)	0.162(7)%	0.135(6)%	3+	1.0691(1)	0.0630, 0.4357, 0.4674, 0.0630, 0.4357, 0.4674, 0.5384, 0.5701, 0.6015, 1.0062, 1.0693	1.4714(45)	$28.9^{+3.3}_{-3.0}$
6.796(1)	6.668(1)***	0.06(2)%	0.05(2)%	4+	1.020(1)		1.4714(45)	$120^{+80}_{-40}$
6.859(5)	6.730(5)	0.07(2)%	0.06(2)%	4+	0.9590(1)	0.0630, 0.3257, 0.5701, 0.6015, 0.8960, 0.9590	1.4714(45)	$170_{-50}^{+90}$
6.884(2)	6.754(2)***	0.14(4)%	0.12(3)%	3+	0.9363(1)	0.063, 0.873, 0.936	1.4714(45)	$100^{+40}_{-20}$

Table 3 direct  $\alpha$  emission from ²¹²At*,  $J^{\pi} = 1^{-}$ ,  $T_{1/2} = 314.5(21) \text{ ms**}$ ,  $BR_{\alpha} = 100\%$ .

6.8878(12)	6.7578(12)	0.08(2)%	0.07(2)%	$2^{+}$	0.9249(1)	0.063, 0.2918, 0.5701,	1.4714(45)	$190^{+80}_{-50}$
						0.8618		
6.929(2)	6.798(2)	0.058(6)%	0.048(5)%	$5^{+}$	0.8864(1)	0.063, 0.8233, 0.8864	1.4714(45)	$390^{+60}_{-50}$
7.1844(4)	7.0488(4)	0.48(2)%	0.40(2)%	3+	0.6331(1)	0.063, 0.5701	1.4714(45)	360(40)
7.2156(3)	7.0795(3)	0.71(1)%	0.59(1)%	4+	0.6015(1)	0.063, 0.5384, 0.6015	1.4714(45)	$316^{+33}_{-30}$
7.3057(5)	7.1679(5)	0.180(9)%	0.150(7)%	$6^{+}$	0.5103(1)	0.5103	1.4714(45)	210(24)
7.7539(2)	7.6076(2)	18.5(7)%	15.4(6)%	$4^{+}$	0.0630(1)	0.063	1.4714(45)	650(70)
7.8165(2)	7.6690(2)	100.0(7)%	83.2(6)%	$5^{+}$	0.0		1.4714(45)	186(19)

* All values from [1976FrZO], except where noted.

** Weighted average of 314(3) ms [1976FrZO] and 315(3) ms [1970Re02].

*** [1970Re02].

[@] [2007Ma45]. Only those transition > 10% are listed.

[@] Interpolated between 1.40879(38) fm ( 210 Po) and 1.5340(25) fm ( 214 Rn).

Table 4

direct  $\alpha$  emission from ²¹²At*, Ex. = 229(3) keV,  $J^{\pi} = 9^-$ ,  $T_{1/2} = 112.6(9)$  ms**,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{208}\mathrm{Bi})^{***}$	coincident γ-rays***	$R_0 (fm)^@$	HF
6.9436(8)	6.8126(8)	0.53(6)%	0.36(4)%	6+	1.0951(1)	0.063, 0.2078, 0.8233, 0.8864	1.4714(45)	$21^{+4}_{-3}$
7.0807(15)	6.9471(15)	0.077(10)%	0.052(7)%	4+	0.9590(1)	0.0630, 0.3257, 0.5701, 0.6015, 0.8960, 0.9590	1.4714(45)	$440^{+90}_{-70}$
7.1570(2)	7.022(2)	0.19(3)%	0.13(2)%	5+	0.8864(1)	0.063, 0.8233, 0.8864	1.4714(45)	$310^{+70}_{-50}$
7.3902(9)	7.2508(9)	0.56(12)%	0.38(8)%	$7^{+}$	0.6506(1)	0.1401, 0.5103, 0.6506	1.4714(45)	$670^{+200}_{-140}$
7.1844(4)	7.0488(4)	0.48(2)%	0.40(2)%	3+	0.6331(1)	0.063, 0.5701	1.4714(45)	720(80)
7.4116(7)	7.2718(7)	0.53(12)%	0.36(8)%	$5^{+}$	0.6283(1)	0.063, 0.5262	1.4714(45)	$830^{+260}_{-180}$
7.4388(15)	7.2984(15)	0.10(1)%	0.07(1)%	4+	0.6015(1)	0.063, 0.5384, 0.6015	1.4714(45)	$5.2^{+1.1}_{-0.9} \times 10^3$
7.5298(6)	7.3877(6)	0.52(3)%	0.35(2)%	$6^{+}$	0.5103(1)	0.5103	1.4714(45)	$2.1(2) \times 10^3$
7.9769(2)	7.8264(2)	100.0(9)%	67.6(6)%	$4^{+}$	0.0630(1)	0.063	1.4714(45)	$242^{+24}_{-22}$
8.0394(2)	7.8877(2)	45.4(8)%	30.7(5)%	$5^{+}$	0.0		1.4714(45)	810(80)

* All values from [1976FrZO], except where noted.

** Weighted average of 115(2) ms [1976FrZO] and 122(1) ms [1970Re02].

*** [2007Ma45]. Only those transition >10% are listed. @ Interpolated between 1.40879(38) fm (^{210}Po) and 1.5340(25) fm (^{214}Rn).

### Table 5

direct  $\alpha$  emission from ²¹⁶Fr*,  $J^{\pi} = (1^{-})$ ,  $T_{1/2} = 0.7(2) \ \mu s^{**}$ ,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{212}\text{At})***$	coincident γ-rays***	R ₀ (fm) [@]	HF
8.977(15) 9.028(15)	8.811(15) 8.861(15)	$\approx 0.2\%$ 0.5(2)%	$\approx 0.2\%$ 0.5(2)%	$(3^{-})$ $(2^{-})$	0.2053 0.1603	0.045, 0.1603 0.1603	1.5498(28) 1.5498(28)	$\approx 250$ $130^{+150}_{-60}$
9.174(5)	9.004(5)	100%	99.3(10)%	(1-)	0.0		1.5498(28)	$1.6(5)^{-00}$

* All values from [1996Li37], except where noted.

** [1970Bo13].

*** [2020Au03].

 $^{@}$  Interpolated between 1.5340(25) fm ( 214 Rn) and 1.5655(13) fm ( 218 Ra.

#### Table 6

Table 0					
direct $\alpha$ emission from	216m1 Fr*, Ex. =	$133.3(1)$ keV, $J^{\pi}$	$T = (3^{-}), T_{1/2} =$	= 71(5) ns**,	$BR_{\alpha} = \approx 50\%^{***}.$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{212}\mathrm{At})^{@}$	coincident γ-rays [@]	$R_0 (fm)^{@@}$	HF
9.102(8)	8.933(8)	$\approx 50\%^{***}$	(3 ⁻ )	0.2053	0.045, 0.1603	1.5498(28)	≈0.21 ^{@@@}

* All values from [1996Li37], except where noted.

** [1971EpZY].

*** [2007Wu02].

@ [2020Au03].

 $^{@\,@}$  Interpolated between 1.5340(25) fm ( $^{214}Rn)$  and 1.5655(13) fm ( $^{218}Ra.$  $^{@\,@\,@}$  The reason for the unphysically low HF value is unknown.

### Table 7

direct $\alpha$ emis	ssion from ^{216m1} Fi	r*, Ex. = 219(8)	keV, $J^{\pi} = (9^{-})^{2}$	), $T_{1/2} = 850(30)$ ns, $BR_{\alpha}$	= 100%.		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{212}\mathrm{At})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF
9.169(5)	9.000(5)	100%	(9 ⁻ )	0.2239		1.5498(28)	1.85(13)

* All values from [2007Ku30], except where noted.

** Interpolated between 1.5340(25) fm ( 214 Rn) and 1.5655(13) fm ( 218 Ra.

### Table 8

direct  $\alpha$  emission from ²²⁰Ac*, T_{1/2} = 26.4(2) ms**, BR_{$\alpha$} =  $\approx$  100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{m \pi}$	$E_{daughter}(^{216}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
7.763	7.622	15%	4%	(3)	0.5814	0.0374, 0.0579, 0.0786, 0.1210, 0.1333, 0.1210, 0.1333, 0.1210, 0.1333, 0.1600	1.5613(21)	61
						0.1722, 0.3270, 0.3902, 0.4484		
7.776	7.635	15%	4%	(4,5 ⁻ )	0.5867	0.0349, 0.0579, 0.1333, 0.3427,	1.5613(21)	50
						0.3780		
7.794	7.652	35%	9%	(3)-	0.5507	0.0374, 0.0536, 0.0643, 0.0786,	1.5613(21)	34
						0.349, 0.579, 0.1333, 0.2067,		
						0.2544, 0.2964, 0.3014		
7.806	7.664	15%	4%	(3,4,5 ⁻ )	0.5394	0.0349, 0.0579, 0.0928, 0.1333,	1.5613(21)	83
						0.3129		
7.812	7.670	31%	8%	(3,4,5)	0.5320	0.0349, 0.0374, 0.0579, 0.0786,	1.5613(21)	44
						0.0928, 0.1233, 0.1333, 0.1373,		
						0.1600, 0.1878, 0.1828, 0.2437,		
						0.2678		
7.852	7.709	42%	11%	$(3,4,5^{-})$	0.4934	0.0349, 0.0374, 0.0579, 0.0643,	1.5613(21)	42
						0.0786, 0.1333, 0.1490, 0.1531,		
						0.2036, 0.2437, 0.2678		
7.936	7.792	38%	10%	$(2,3,4,5^{-})$	0.4093	0.0374, 0.0786, 0.1333, 0.1600	1.5613(21)	84
7.995	7.850	19%	5%	(2,3,4)	0.3492	0.0786, 0.1333, 0.1373		
8.000	7.855	100%	26%	$(4,5^{-})$	0.3442	0.0374, 0.0579, 0.0786, 0.0928,	1.5613(21)	51
						0.0948, 0.1182, 0.1333, 0.1531		
8.091	7.944	$\approx 8\%$	$\approx 2\%$	(2)	0.2544	0.1210, 0.1333	1.5613(21)	$1.22 \times 10^{3}$
8.119	7.971	15%	4%	$(4)^{-}$	0.2261	0.0349, 0.0579, 0.1333	1.5613(21)	740
8.154	8.006	12%	3%	(5)-	0.1912	0.0579, 0.1333	1.5613(21)	$1.25  imes 10^3$
8.204	8.055	15%	4%	$(0)^{-}$	0.1416	0.1416	1.5613(21)	$1.31 \times 10^{3}$
8.212	8.063	8%	2%	(3-)	0.1333	0.1333	1.5613(21)	$2.8  imes 10^3$
8.346	8.194	15%	4%	$(1^{-})$	0.0		1.5613(21)	$3.3 \times 10^{3}$

* All values from [1997Sh09], except where noted. No uncertainties were reported in [1997Sh09].

** [1990An19].

*** Interpolated between 1.5655(13) fm ( 218 Ra and 1.5571(17) fm ( 222 Th).

### Table 9

direct  $\alpha$  emission from ²²⁴Pa*, T_{1/2} = 844(19) ms**,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{220}\mathrm{Ac})$	coincident γ-rays	R ₀ (fm)***	HF
7 281	7 151	<0.1%	<0.05%		0.4120	0.0138 0.3080 0.4120	1 5/83(38)	>530
7.201	7.151	0.3%	0.2%		0.3561	0.0280 0.0407 0.0678 0.2476	1.5483(38)	210
1.550	7.205	0.570	0.270		0.5501	0.2874, 0.3158	1.5465(56)	210
7.357	7.226	0.1%	0.1%		0.3354	0.0138, 0.0407, 0.1510, 0.1705, 0.	1.5483(38)	500
						1820, 0.1842, 0.2947, 0.3350		
7.381	7.249	0.1%	0.1%		0.3120	0.0138, 0.2982	1.5483(38)	600
7.430	7.297	2.9%	2%	$(4^{+})$	0.2632	0.0280, 0.0407, 0.0678, 0.1095,	1.5483(38)	45
						0.1131, 0.1547, 0.1945		
7.459	7.326	2.1%	1.5%	$(5^{+})$	0.2339	0.0280, 0.0407, 0.1651	1.5483(38)	75
7.509	7.375	3.6%	2.5%	(3 ⁻ )	0.1842	0.0138, 0.1705, 0.1842	1.5483(38)	67
7.540	7.405	17.1%	12%	$(2^{-})$	0.1530	0.0138, 0.1392, 0.1530	1.5483(38)	18
7.543	7.408	5.7%	4%	(4-)	0.1502	0.0407, 0.1095	1.5483(38)	55

### Table 9 direct $\alpha$ emission from ²²⁴Pa*, T_{1/2} = 844(19) ms**, BR_{$\alpha$} = $\approx$ 100%.

7.579	7.444	3.6%	2.5%	$(1^{-})$	0.1133	0.1133	1.5483(38)	116
7.584	7.449	5.7%	4%	(3 ⁻ )	0.1085	0.0407, 0.0678,	1.5483(38)	76
7.624	7.488	100%	70%	(5-)	0.0687	0.0280, 0.0407	1.5483(38)	5.9

* All values from [1996Li05], except where noted. No uncertainties were reported in [1996Li05].

** Weighted average of 790(60) ms [1996Li05] and 850(20) ms [1997Wi15]. *** Interpolated between 1.5571(17) fm (²²²Th) and 1.5394(34) fm (²²⁶U).

### Table 10

direct	α	emission	from	²²⁸ Np*,	$T_{1/2}$	= 61.	4(14) s'	*, $BR_{\alpha}$	=40(1	1)%*
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{224}\text{Pa})$	coincident γ-rays	R ₀ (fm)***	HF
7.250	7.123**	40(11)%				1.5385(66)	$6.8^{+3.0}_{-1.8}$

* [1994Kr13].

** Average of 5 events identified by  $\alpha$ - $\alpha$  chains [2003Ni10, 2004NiZZ, 2003NiZV] (See Fig. 1f in [2003Ni10]). This is likely several unresolved peaks. *** Interpolated between 1.5394(34) fm (²²⁶U) and 1.5375(56) (²³⁰Pu).

#### Table 11

uncer a emission nom $DK$ , $\Gamma_1/2 = 22$ 6 S ² , $DK\alpha = \sim 17/6$	direct $\alpha$ emi	ission from	²³⁶ Bk, T ₁ /	$r_2 = 22^{+13}_{-6}$	$s^*, BR_{\alpha}$	= ≈ 17 %
-----------------------------------------------------------------------------------------	---------------------	-------------	-------------------------------------	-----------------------	--------------------	----------

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{232}\mathrm{Am})$	coincident γ-rays	R ₀ (fm)***	HF	
7.447(14)	7.321(14)**	$\approx 17\%^*$				1.515(26)	pprox 0.5	
* [2017K ** [2020] *** Inter	002]. Po07]. polated between 1.5	375(56) ( ²³⁰ Pu) a	nd 1.491(25)	fm ( ²³⁴ Cm).				
Table 12 direct $\alpha$ emiss	sion from 240 Es, T $_{1/2}$	$_{2} = 5(2) \text{ s}, BR_{\alpha} =$	70(10) %.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi} = E_{daught}$	er ⁽²³⁶ Bk) coincider	nt γ-rays	$R_0$ (fm)	HF
8.227(30) 8.329(30)	8.090(30) 8.190(30)	$\approx 25\%$ 100%	≈14% ≈56%					
* All valu	ues from [2017Ko02	].						
Table 13 direct $\alpha$ emiss	sion from 244 Md, T ₁	$_{/2} = \approx 6 \text{ s}, BR_{\alpha} =$	$\approx 100\%.$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{m{\pi}}$	E _{daughter} ( ²⁴⁰ Es)	coincident $\gamma$ -rays	R ₀ (fm)	HF	
8.446(19)	8.308(19)	pprox 100%						
* All valu	ues from [2020Po07]	].						
Table 14 direct $\alpha$ emiss	sion from ^{244m} Md, E	x. = unk., T _{1/2} =	$0.4^{+0.4}_{-0.1}$ s, <i>BR</i> _c	$a = \approx 100\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{240}\mathrm{Es})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
8.807(23)	8.663(23)	$\approx 100\%$						
* All yob	100 from [2020Bo07	1						

All values from [2020Po07].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +43/2 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +43/2$  nuclei.  $J^{\pi}$  values for ²⁰⁴Tl and ²⁰⁸Bi are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide		$J^{\pi}$	Ex.	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\mathcal{E}\alpha}$	$\mathrm{BR}_{\beta_F}$	Experimental
²⁰⁷ Pb		1/2-	stable	-1.418(5)					
²¹¹ Po		9/2+	516(3) ms	-0.573(5)			[1974Ba29]		
^{211m} Po	1.453(10)	$(25/2^+)$	25.2(5) s	0.880(11)	-3.540(10)	7.630(12)	[1974Ba29]		
²¹⁵ Rn		$9/2^{+}$	$2.3(1) \mu s$	0.088(9)	-3.988(6)	8.265(8)	[1970Va13]		
²¹⁹ Ra		$(7/2)^+$	8.6(17) ms*	0.777(10)	-3.113(7)	8.226(10)	[2018Sa45]		
^{219m} Ra	0.0166(2)**	$(11/2)^+$	10(3) ms	0.793(10)	-3.096(7)	8.243(10)	[2018Sa45]		
²²³ Th		$(5/2^+)$	660(10) ms	1.560(10)	-2.224(9)	8.344(11)	[1970Va13]		
²²⁷ U		$(3/2^+)$	1.1(1) m	2.215(11)	-1.442(10)	8.795(11)	[1969Ha32]		
²³¹ Pu		$(3/2^+)$	8.6(5) m	2.680(60)	-0.595(22)	9.053(23)	[1999La14]		
²³⁵ Cm		$(5/2^+)$	$300^{+250}_{-100}$ s	3.39(12)#	0.38(10)#	9.97(12)#	[2020Kh10]		
²³⁹ Cf		$(5/2^+)$	28(2) s	3.95(24)#	1.47(12)#	11.15(13)#	[2020Kh10]		
²⁴³ Fm		$(7/2^{-})$	231(9) ms	4.57(25)#	2.64(13)#	12.64(24)#	[2020Kh10		

* Weighted average of 10(3) ms and 8(2) ms [2018Sa45].

** [2021Si21].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +43/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	BR _S F	Experimental
²⁰⁷ Pb ²¹¹ Po	7.488(1) 4.930(1)	14.742(4) 9.396(1)	0.392(1) 7.595(1)	100%		[ <b>2001Ch66, 1969Go23</b> , 2000ChZU, 2000ChZX, 2000OgZR, 1989Ku08, 1989KuZE, 1988KuZR, 1985La17, 1982Bo14,
						1978Ya04, 1975Ja04, 1974Ba29, 1970Va13, 1969Ha32, 1968GuZX, 1963Uh01, 1962Pe15, 1958To25, 1955Mo68, 1954Je11, 1954Sp32, 1954Wi26, 1953AsZZ, 1952Me13]
^{211m} Po	3.477(10)	7.943(10)	9.048(10)	99.984(4)%		[ <b>1989Ku08, 1962Pe15</b> , 1989KuZE, 1988KuZR, 1982Bo14, 1974Ba29, 1954Je11, 1954Sp32]
²¹⁵ Rn	5.079(7)	9.093(7)	8.839(6)	100%		[1970Va13, 2018Sa45, 1970VaZZ, 1969Ha32, 1952Me13]
²¹⁹ Ra	. 4.955(8)	8.843(8)	8.138(3)	100%		[ <b>1994Sh02</b> , 2018Sa45, 1993AnZS, 1989An13, 1987El02, 1970Va13, 1970VaZZ, 1969Ha32, 1952Me13
^{219m} Ra	4.937(8)	8.826(8)	8.155(3)	100%		[2018Sa45]
²²³ Th	4.525(9)	8.156(9)	7.567(4)	100%		[ <b>1992Li09</b> , 1990An19, 1990AnZQ, 1989An13, 1989AnZL, 1988AnZS, 1987El02, 1970Va13, 1970VaZZ, 1969Ha32, 1952Me13]
²²⁷ U	4.278(14)	7.843(10)	7.235(3)	pprox 100%		[ <b>2015Ka24</b> , 1991Ho05, 1990JoZU, 1986BuZP, 1970Va13, 1969Ha32, 1952Me13]
²³¹ Pu	4.217(59)	7.480(23)	6.839(20)	$10^{+7}_{-3}\%$		[ <b>1999La14</b> , 2007KhZQ]
²³⁵ Cm	3.74(19)#	6.62(12)#	7.116(14)*	$1.0^{+0.7}_{-0.5}\%$		[2020Kh10, 2007KhZQ
²³⁹ Cf	3.30(28)#	5.62(14)#	7.766(8)**	65(3)%		[ <b>2020Kh10</b> , 1981Mu12]
²⁴³ Fm	2.77(29)#	4.59(21)#	8.691(8)***	91(3)%	9(1)%	[2020Kh10, 2008Kh10, 1981Mu12]

* Deduced from  $\alpha$  energy, 7.28(10)# in [2021Wa16].

** Deduced from  $\alpha$  energy, 7.763(63) in [2021Wa16].

*** Deduced from α energy, 8.689(51) in [2021Wa16].

### Table 3 direct $\alpha$ emission from ²¹¹Po, $J^{\pi} = 9/2^+$ , $T_{1/2} = 516(3)$ ms*, $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\mathrm{rel})^{@}$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{207}\mathrm{Pb})^{@@}$	coincident γ-rays ^{@@}	R ₀ (fm)	HF
5.961 6.6970(25) 7.0250(25) 7.594(3) * [1974 ** [200 *** [19 @ [1978 @@ [20	5.848** 6.5700(25)*** 6.8920(25)*** 7.450(3)*** Ba29]. 1Ch66]. 69Go23]. 3Ya04]. 11Ko04].	$8.1(10) \times 10^{-4}\%$ 0.59(1)% 0.61(1)% 100	$8.1(10) \times 10^{-4}\%^{**}$ 0.58(1)% 0.60(1)% 98.82(1)%	13/2 ⁺ 3/2 ⁻ 5/2 ⁻ 1/2 ⁻	1.6333 0.8978 0.5697 0.0	0.5697, 1.0637 0.8978 0.5697	1.46528(11) 1.46528(11) 1.46528(11) 1.46528(11)	$10.3^{+1.6}_{-1.3}$ 16.10(34) 244(5) 112(3)

### Table 4

direct $\alpha$ emission from ^{211m} Po	, Ex. = 1.453(10) MeV, $J^{\pi} = (25/2^+)$ , 7	$\Gamma_{1/2} = 25.2(5) \text{ s}^*, BR_{\alpha} = 99.984(4)\%^{**}$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})^{@}$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{207}\mathrm{Pb})^{@@}$	coincident γ-rays ^{@@}	R ₀ (fm)	HF
7.41((15)	7.075(15)	1000	010	12/2+	1 (222	0.5607 1.0627	1 4(529(11)	1 (0(1())) 103
7.416(15)	7.275(15)	100%	91%	13/2+	1.6333	0.5697, 1.0637	1.46528(11)	$1.60(16) \times 10^{-5}$
8.149(15)	7.995(15)	1.82(3)%	1.66(3)%	3/2-	0.8978	0.8978	1.46528(11)	$1.36(4) \times 10^{7}$
8.465(15)	8.305(15)	0.27(2)%	0.25(2)%	5/2-	0.5697	0.5697	1.46528(11)	$6.8(6) \times 10^8$
9.046(10)	8.875(10)	7.74(15)%	7.04(14)%	$1/2^{-}$	0.0		1.46528(11)	$6.1(4) \times 10^{8}$

* [1974Ba29].

** [1989Ku08].

- *** Values taken from [1962Pe15], adjusted by +5 keV in [1991Ry01]. @ [1962Pe15].

^{@@} [2011Ko04].

### Table 5

Table 5			
direct $\alpha$ emission from	$J^{215}$ Rn*, $J^{\pi} = 9/2^+$ , T ₁	$/2 = 2.3(1) \ \mu s$ ,	$BR_{\alpha}=100\%.$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{211}\text{Po})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
8.839(8)	8.675(8)	100%	9/2+	0.0		1.5499(42)	1.69(18)

* Al values from [1970Va13], unless noted otherwise.

#### Table 6

direct  $\alpha$  emission from ²¹⁹Ra,  $J^{\pi} = (7/2)^+$ ,  $T_{1/2} = 8.6(17)$  ms**,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{215}\mathrm{Rn})$	coincident γ-rays	R ₀ (fm)	HF
7.330(5)	7.196(5)	3.2%	2.0%	7/2+	0.806	0 2140, 0 3160, 0 490, 0 5920, 0 8052	1,5597(35)	3.5
7.822(3)	7.679(3)	100%	62%	$11/2^+$	0.316	0.316	1.5597(35)	4.4
7.846(10)	7.703(10)	2.3%	1.4%	$(11/2)^{-}$	0.2906	0.2906	1.5597(35)	230
7.925(10)	7.780(10)	$\approx 0.8\%$	$\approx 0.5\%$		0.2140	0.2140	1.5597(35)	$\approx 1.1 \times 10^3$
8.138(3)	7.989(3)	55%	34%	9/2+	0.0		1.5597(35)	70

* All values from [1994Sh02], except where noted. ** Weighted average of 10(3) ms and 8(2) ms [2018Sa45].

### Table 7

direct $\alpha$	emission	from 2	²¹⁹ Ra*, Ex.	$= 0.0166(2)^{3}$	$*, J^{\pi} =$	$(11/2)^+$	$T_{1/2} =$	: 10(3) ms,	$BR_{\alpha}$	= 100%.
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{215}\mathrm{Rn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.823(20)	7.680(20)	100%	11/2+	0.316	0.316	1.5597(35)	3.6(11)

* All values from [2018Sa45], except where noted.

** [2021Si21].

### **Table 8** direct $\alpha$ emission from ²²³Th*, $J^{\pi} = (5/2)^+$ , $T_{1/2} = 660(10)$ ms**, $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	<i>E</i> _{daughter} ( ²¹⁹ Ra)	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.052	6.928	0.7%	0.4%		0.5155(10)	0.0972(1), 0.1138(1), 0.4017(10)	1.5478(22)	18
7.098	6.973	1.1%	0.6%		0.4707(7)	0.0382(3), 0.0972(1), 0.1138(1),	1.5478(22)	18
						0.3188(7), 0.3569(7)		
7.124	6.998	2.7%	1.5%		0.4450(5)	0.0382(3), 0.088, 0.0972(1),	1.5478(22)	8.9
						0.2930(5), 0.3050(5), 0.3313(5)		
7.146	7.020	0.5%	0.3%		0.4217(12)	0.4217(12)	1.5478(22)	54
7.163	7.037	3.4%	1.9%		0.4047(2)	0.0382(3), 0.088,	1.5478(22)	9.9
						0.0972(1), 0.1520(1), 0.2528(2),		
						0.2647(2), 0.353		
7.245	7.117	1.3%	0.7%		0.3206(7)	0.0382(3), 0.0972(1), 0.1520(1),	1.5478(22)	54
						0.1688(5), 0.2680(10), 0.3206(8)		
7.417	7.286	47.7%	26.4%	$(7/2^+)$	0.1520(3)	0.0382(3), 0.0972(1), 0.1520(1)	1.5478(22)	5.6
7.429	7.298	100%	55.3%	$(9/2^+)$	0.1400(3)	0.0520(3), 0.088, 0.1400(3)	1.5478(22)	2.9
7.454	7.323	23.9%	13.2%	$(5/2^+)$	0.1138(1)	0.1138(1)	1.5478(22)	35
7.565	7.432	1.8%	$\approx 1\%$	7/2+	0.0		1.5478(22)	$\approx 480$

* All values from [1992Li09], except where noted. Uncertainties were not given for  $\alpha$  energies and intensities. ** [1970Va13].

### Table 9

direct  $\alpha$  emission from ²²⁷U*,  $J^{\pi} = (3/2)^+$ ,  $T_{1/2} = 1.1(1)$  m**,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^{@}$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{223}\mathrm{Th})$	coincident γ-rays	R ₀ (fm)	HF
6.746(7)	6.627(7)	2(2)%	1(1)%	(3/2+, 5/2+, 7/2+)	0.4888(6)	0.0513, 0.4374, 0.4888	1.5316(43)	$5^{+54}_{-3}$
6.839(8)	6.718(8)	12(3)%	5(1)%	$(1/2^+, 3/2^+, 5/2^+)$	0.3955(7)	0.0513, 0.0850, 0.1492,	1.5316(43)	$2.6^{+1.0}_{-0.7}$
						0.2471, 0.2589, 0.3104,		
						0.3955		
6.864(4)	6.743(4)	14(3)%	6(1)%	$(1/2^+, 9/2^+)$	0.3702(3)	0.3702	1.5316(43)	$2.7^{+0.9}_{-0.7}$
6.924(4)	6.802(4)	40(10)%	17(3)%	(5/2+)	0.3104(3)	0.0513, 0.2589, 0.3104	1.5316(43)	$1.7^{+0.6}_{-0.4}$
6.987(3)	6.864(3)	100(17)%	42(7)%	$(3/2^+)$	0.2471(3)	0.2471	1.5316(43)	$1.2_{-0.3}^{+0.4}$
7.026(5)	6.902(5)	48(12)%	20(4)%	$(7/2^+)$	0.2089(5)	0.0513, 0.1574, 0.2089	1.5316(43)	$3.5^{+1.3}_{-0.9}$
7.183(3)	7.056(3)	10(10)%	4(4)%	$(7/2^+)$	0.0515(4)	0.0513	1.5316(43)	69(9)
7.234(3)	7.107(3)	14(10)%	6(4)%	(5/2 ⁺ )	0.0		1.5316(43)	$70^{+160}_{-30}$

* All values from [2015Ka24], except where noted.

# ** [1969Ha32].

### Table 10

direct $\alpha$ emission from ²³¹ Pu*, J	$T^{\pi} = (3/2)^+, T_{1/2} = 8$	$.6(5) \text{ m}, BR_{\alpha} = 10^{+7}_{-3}\%$
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{227}\mathrm{U})$	coincident γ-rays	R ₀ (fm)	HF
6.838(30)	6.720(30)	$10^{+7}_{-3}\%$	(3/2+)	0.0		1.512(28)	$1.1\substack{+2.9 \\ -0.6}$

* All values from [1999La14].

### Table 11

direct  $\alpha$  emission from ²³⁵Cm,  $J^{\pi} = (5/2)^{+*}$ ,  $T_{1/2} = 300^{+250}_{-100}$  s*,  $BR_{\alpha} = 1.0^{+0.7}_{-0.5}\%$ *.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{231}\mathrm{Pu})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
6.796(14)	6.680(14)**	100%	≈0.7%*	(5/2+)	0.320(20)		1.505(16)	$\approx 0.8$
7.116(14)	6.995(14)***	pprox 40%	≈0.3%*	$(3/2^+)$	0.0		1.505(16)	$\approx 40$

* [2020Kh10].

** Weighted average of 6.690(20) MeV [2020Kh10] and 6.670(20) MeV [2007KhZQ].

*** Weighted average of 7.010(20) MeV [2020Kh10] and 6.980(20) MeV [2007KhZQ].

Table 12					
direct $\alpha$ emission from	$^{239}Cf^*, J^{\pi} =$	$(5/2)^+, T_{1/2} =$	28(2) s. J	$BR_{\alpha} = 650$	3)%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi}$	$E_{daughter}(^{235}\mathrm{Cm})$	coincident $\gamma$ -rays	R ₀ (fm)	HF		
7.766(8)	7.636(8)	65(3)%	(5/2)+	0.0		1.504(21)	$0.8\substack{+0.5 \\ -0.3}$		
* All val	* All values taken from [2020Kh10].								
Table 13 direct $\alpha$ emis	sion from ²⁴³ Fm*	$J^{\pi} = (7/2)^{-}, \mathrm{T}_{1}$	$_{/2} = 231(9) \text{ ms},$	$BR_{\alpha} = 91(3)\%.$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	$E_{daughter}(^{239}\mathrm{Cf})$	coincident γ-rays	R ₀ (fm)	HF		
8.691(8)	8.546(8)	65(3)%	(5/2)+	0.0		1.511(39)	$1.1\substack{+1.7 \\ -0.37}$		

* All values taken from [2020Kh10], except where noted.

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +43/2 nuclei.

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +43/2$  nuclei. zThe  $J^{\pi}$  value for ²⁰⁵Tl are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	Qε	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
205							
²⁰³ Tl		$1/2^{-}$	stable	-1.533(4)			
²⁰⁹ Bi		9/2-	$2.01(8) \times 10^{19} \text{ y}$	-0.644(1)			[2012Be06]
²¹³ At		9/2-	110(20) ns	0.074(5)	-5.751(5)	8.610(5)	[1970Bo13]
²¹⁷ Fr		9/2-	22(5) µs	0.656(8)	-5.231(7)	8.543(7)	[ <b>1970Bo13</b> ]
²²¹ Ac		$5/2^{-}$	52(2) ms	1.570(60)	-4.240(57)	8.448(57)	[ <b>1970Bo13</b> ]
²²⁵ Pa		5/2-	1.8(3) s	2.050(50)	-3.166(82)	8.968(82)	[1970Bo13]
²²⁹ Np			4.0(2) m	2.59(10)	-2.411(101)	9.066(101)	[1968Ha14]
²³³ Am			3.2(8) m	3.23(13)#	-1.36(15)#	9.65(12)#	[2000Sa52]
²³⁷ Bk				3.96(24)#	-0.12(26)#	10.73(24)#	
²⁴¹ Es			$4.3^{+2.4}_{-1.2}s$	4.57(29)#	0.94(28)#	12.22(24)#	[2020Kh09]
²⁴⁵ Md			$330_{-80}^{+150}$ ms	5.13(33)#	2.01(32)#	13.57(31)#	[2020Kh09]
$^{245m}Md$	х	$(1/2^{-})$	$0.9^{+0.6}_{-0.3}$ ms	5.13(33)#	2.01(32)#	13.57(31)#	[1996Ni09]

Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +43/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	BRα	BR _{SF}	Experimental
205 mi	( 420(1)	15 255(2)	0.155(2)			
209 D	0.420(1)	15.255(3)	0.155(3)	1000		100100 AC 00000 11 10500 WW 10510 101
205 B1	3.799(1)	11.802(5)	3.137(1)	100%		[2012Be06, 2003De11, 1952RiXX, 1951Fa10]
²¹³ At	3.499(5)	9.298(7)	9.254(5)	100%		[1988Hu08, 1970Ha14, 2022Pa09, 2009Vi09, 1970VaZZ,
						1968Ha14, 1951Ke53]
²¹⁷ Fr	3.228(9)	9.007(9)	8.469(4)	100%		[1970Bo13, 1988Hu08, 2022Pa09, 1990An19, 1990AnZL,
						1990AnZQ, 1990AnZU, 1989AnZL, 1970VaZZ, 1968Ha14,
						1951Ke53]
²²¹ Ac	3.030(57)	8.664(57)	7.791(57)	100%		[2023Re08, 2022Pa09, 1993AnZS, 1989AnZL, 1988Hu08,
						1978IbZZ, 1970Bo13, 1970VaZZ, 1968Ha14, 1951Ke53]
²²⁵ Pa	2.928(82)	8.046(82)	7.401(59)	$\approx 100\%$		[2023Re08, 2022Pa09, 2000Sa52, 1988Hu08, 1987HuZV,
						1978IbZZ, 1970Bo13, 1970VaZZ, 1968Ha14, 1951Ke53]
²²⁹ Np	2.71(10)	7.61(10)	7.015(23)*	68(11)%		[ <b>2004Sa05</b> , 2000Sa52, 1968Ha14]
²³³ Am	2.37(12)#	6.92(13)#	6.898(17)**	>3%		[2000Sa52, 2004Sa05, 2003Na10, 2002AsZX, 2000TsZX]
²³⁷ Bk	1.93(23)#	5.99(24)#	7.50(20)#			
²⁴¹ Es	1.38(23)#	4.93(31)#	8.259(17)	obs		[2020Kh08, 1996Ni09, 1994HoZW, 1985HiZU]
²⁴⁵ Md	0.93(33)#	4.00(33)#	8.824(20)***	obs		[2020Kh08, 1996Ni09, 1994HoZW]
$^{245m}Md$	0.93(33)#-x	4.00(33)#-x	9.01(12)#+x		obs	[ <b>1996Ni09</b> , 2020Kh08]

* Deduced from  $\alpha$  energy, 7.020(59) MeV in [2021Wa16].

** Deduced from  $\alpha$  energy, 7.059(53)# MeV in [2021Wa16]. ** Deduced from  $\alpha$  energy, 9.01(12)# MeV in [2021Wa16].

#### Table 3

direct $\alpha$ emission from ²⁰⁹ Bi, $J^{\pi} = 9/2^{-1}$	$T_{1/2} = 2.01(8) \times$	$10^{19} \text{ y*}, BR_{\alpha} = 100 \%$
-----------------------------------------------------------------------	----------------------------	--------------------------------------------

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{205}\mathrm{Tl})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
2.933 3.137(2)***	2.877** 3.077(2)	12(3)% 100%	12(3)% 98.8(3)%	3/2 ⁺ 1/2 ⁺	0.2037 [@] 0.0	0.2037 [@]	1.485(11) 1.485(11)	$280^{+140}_{-90}\\1.3^{0.4}_{-0.3}\times10^3$

* [2012Be06].

**  $\alpha$  branch from calorimetric studies [2012Be06].

*** [2003De11].

[@] [2020Ko17].

$\frac{\text{direct } \alpha \text{ emis}}{\alpha \text{ emis}}$	direct $\alpha$ emission from ²¹³ At, $J^{\pi} = 9/2^-$ , $T_{1/2} = 110(20)$ ns*, $BR_{\alpha} = 100 \%$ .							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{209}\mathrm{Bi})$	coincident γ-rays	R ₀ (fm)	HF	
9.254(5)	9.080(5)**	100%	9/2-	0.0		1.5279(14)	0.99(18)	
* [1970] ** [1988	3o13]. 3Hu08].							
Table 5 direct $\alpha$ emis	ssion from ²¹⁷ Fr, $J^{\pi}$	= 9/2 ⁻ , T _{1/2} = 2	22(5) μs*, BR	<i>α</i> = 100 %.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{213}\text{At})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
8.468(5)	8.312(5)**	100%	9/2-	0.0		1.5657(36)	1.21(29)	
* [1970] ** [1988	3o13]. 3Hu08].							
Table 6								

direct  $\alpha$  emission from ²²¹Ac*,  $J^{\pi} = 5/2^{-}$ ,  $T_{1/2} = 52(2)$  ms*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{***}$	${f J}_f^\pi$	$E_{daughter}(^{217}\mathrm{Fr})$	coincident γ-rays	R ₀ (fm)	HF
7 208(15)	7.078(15)				0.5790	0.0878 0.2004 0.2830 0.4018 0.5700	1 5555(37)	
7.208(13)	7.167(0)				0.3790	0.0078, 0.2094, 0.2830, 0.4918, 0.5790	1.5555(37)	
7.299(9) 7.421(6)	7.287(6)				0.4918	0.1556 0.2094 0.3647	1.5555(37)	
7.509(4)	7.207(0) 7.373(4)	13(3)%	9(2)%	$(7/2^{-})$	0.3047	0.0443 0.2314 0.2757	1.5555(37)	7 3+3.0
7.555(4)	7 418(4)	15(5)70	)(2)/0	$(n_{2})$	0.2314	0.2314	1.5555(37)	7.5-2.0
7.575(4)	7 438(4)	28(3)%	20(2)%	$(5/2^{-})$	0.2094	0.2094	1.5555(37)	$5.4^{+1.3}$
7.686(4)	7.547(4)	20(0)/0	20(2)/0	(0/2 )	0.0988	0.0988	1.5555(37)	-1.1
7.783(4)	7.642(4)	100(8)%	71(4)%	9/2-	0.0		1.5555(37)	7.2(10)

* All values from [2023Re08], except where noted. ** [1970Bo13]. *** Taken from [2022Pa09], no  $I_{\alpha}$  were reported in [2023Re08].

### Table 7

iubic /			
direct $\alpha$ emission from	225 Pa*, $J^{\pi} = 5/2^{-}$	, $T_{1/2} = 1.8(3) s^*$ ,	$BR_{\alpha} = \approx 100\%$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{217}\mathrm{Fr})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
7.164(5)	7.037(5)	3.2(19)%	1.7(1)%	7/2+	0.2237	0.0195, 0.0274, 0.0571, 0.0641, 0.0724, 0.0754, 0.0915, 0.1218, 0.1293, 0.1323, 0.1497, 0.1966, 0.02237	1.5390(31)	10.8(21)
7.206(2)	7.078(2)	5.7(6)%	3.0(3)%	5/2+	0.1800	0.0195, 0.0274, 0.0641, 0.0724, 0.0887, 0.0915, 0.1526, 0.1607, 0.1800	1.5390(31)	8.8 ^{+2.7} -2.2
7.238(6)	7.109(6)	8.7(10)%	4.6(5)%	5/2+	0.1497	0.0195, 0.0274, 0.0571, 0.0641, 0.0724, 0.0915, 0.1218, 0.1293, 0.1497	1.5390(31)	$7.4^{+2.4}_{-1.9}$
7.298(2)	7.168(2)	20.9(9)%	11.1(4)%	5/2-	0.0915	0.0195, 0.0274, 0.0641, 0.0724, 0.0915	1.5390(31)	5.0(9)
7.360(2) 7.389(2)	7.229(2) 7.258(2)	50.2(16)% 100(3)%	26.6(7)% 53.0(10)%	7/2 ⁻ 5/2 ⁻	0.0274 0.0	0.0274	1.5390(31) 1.5390(31)	3.5(7) 2.2(4)

* All values from [2023Re08], except where noted. ** [1970Bo13].

direct $\alpha$ emis	sion from ²²⁹ Np*, T	$T_{1/2} = 4.0(2) \text{ m}^{**}$	$BR_{\alpha} = 68(1$	1)%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$J_f^{\boldsymbol{\pi}}$	E _{daughter} ( ²²⁵ Pa)	coincident γ-rays	R ₀ (fm)	HF
7.015(23)	6.893(23)	68(11)%	5/2-	0.0***		1.5306(54)	$1.4_{0.4}^{+0.5}$
* All val ** [1968 *** Assu	ues from [2004Sa05 Ha14]. imed to decay to the	], except where r	noted.				
<b>Table 9</b> direct $\alpha$ emises	sion from ²³³ Am*, 7	$\Gamma_{1/2} = 3.2(8) \text{ m}, 1$	$BR_{\alpha} = > 3\%$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${ m J}_f^{m \pi}$	$E_{daughter}(^{229}\mathrm{Np})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.898(17)	6.780(17)	> 3%		0.0**		1.489(37)	<0.5
Table 10         direct $\alpha$ emis $E_{\alpha}(c.m.)$	sion from ²⁴¹ Es, $T_{1/}$ $E_{\alpha}$ (lab)	$I_{\alpha}(abs)$ $I_{\alpha}(abs)$	$\alpha = \text{obs.}$ $J_f^{\pi}$	<i>E_{daughter}</i> ( ²³⁷ Bk)	coincident γ-rays	R ₀ (fm)	HF
8.253(14)	8.117(14)**			0.0***			
* [2020K ** Weigh *** Assu <b>Table 11</b> direct α emis	Kh08]. nted average of 8.12 nmed to decay to the sion from ²⁴⁵ Md*, <i>J</i>	0(20) MeV [2020 ground state. $t^{\pi} = 5/2^{-}, T_{1/2} =$	0Kh08] and 8 : 330 ⁺¹⁵⁰ ms ³	.113(20) MeV [1996Ni09] **, $BR_{\alpha}$ = obs.	].		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi} = E_{daughter}(^{241}\mathbf{E})$	$rac{1}{2}$ s) coincident $\gamma$ -rays	R ₀ (fm)	HF
8.778(20) 8.824(20)	8.635(20) 8.680(20)			0.046(28) 0.0***			
* All val ** [2020 *** Assu	ues taken from [199 Kh08]. 1med to decay to the	6Ni09], except w	here noted.				

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +22 nuclei.

Last updated 5/28/25

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +22$  nuclei.  $J^{\pi}$  values for ²⁰⁴Tl and ²⁰⁸Bi are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$Q_{\epsilon \alpha}$	Experimental
			·				
²⁰⁸ Pb		$0^+$	stable	-4.999(2)			
²¹² Po (ThC')		$0^+$	294.965(178) ns	-2.252(2)			[2022Be20]
^{212m1} Po	1.4764(2)*	$(8^{+})$	17.1(2) ns	-0.776(2)			[1978Li14]
^{212m2} Po	2.930(10)*	$(18^{+})$	45.1(6) s	0.678(2)	-4.235(2)	6.886(2)	[1962Pe15]
²¹⁶ Rn		$0^+$	29(4) µs	-2.003(7)			[2018Sa45]
²²⁰ Ra		$0^{+}$	18(2) ms	-1.210(8)			[2000He17]
²²⁴ Th		$0^+$	1.05(2) s	-0.239(10)			[1978IbZZ]
²²⁸ U		$0^+$	9.1(2) m	0.296(14)	-3.874(14)	6.561(14)	[1961Ru06]
²³² Pu		$0^+$	33.7(5) m	1.00(10)#	-2.734(17)#	7.012(17)#	[2000La25, 1973Ja06]
²³⁶ Cm		$0^+$	410(50) s	1.81(12)#	-1.618(27)	8.07(10)#	[2010Kh06]
²⁴⁰ Cf		$0^{+}$	1.00(12) m***	2.32(15)#	-0.45(15)#	9.52(12)#	[1995La09, 1980Vi04]
²⁴⁴ Fm		$0^+$	3.12(8) ms	2.94(27)#	0.69(27)#	10.88(25)#	[2008Kh10]
²⁴⁸ No		$0^+$		3.74(29)#	1.73(29)#	12.24(29)#	
²⁵² Rf		$0^+$	$60^{+90}_{-30}$ ns				[2025Kh01]

* [2020Au03].

** Weighted average of 33.1(8) m [2000La25] and 34.1(7) m [1973Ja06].

*** Weighted average of 0.9(2) m [1995La09] and 1.06(15) m [1980Vi04].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +22$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	$S_{2p}$	Qα	$BR_{\alpha}$	BR _{SF}	Experimental
²⁰⁸ Pb	8.003(5)	15.381(20)	0.517(1)			
²¹² Po (ThC')	5.799(5)	10.219(1)	8.9542(1)	100%		[2023Sa32, 1991Ry01, 1974Hu15, 1971De52, 1971Gr17, 1961Ry02,
						2022Be20, 2018Sa45, 2018So16, 2017Ap03, 2014Be39, 2013Be31,
						2012Be14, 2003Da24, 2001MoZV, 1982Bo04, 1976GiZM, 1975Sa06,
						19/3B0AL, 19/2KyZX, 1965Le08, 1960Em01, 1960Ha19, 1960Ky01, 1057E-08, 1052H-00, 1040M-54, 1040W-01, 1048Ch01, 1048Hi21
						1937Eco, 1955Ha09, 1949Mc54, 1949Va01, 1948Ch01, 1948Ch01, 1948H21,
212m1 Po	4.323(5)	8.743(1)	10.4306(2)	$\approx 42\%$		[ <b>1984Es01, 1978Li14</b> , 1979LiZP]
^{212m2} Po	2.869(11)	7.289(10)	11.884(10)	99.93(2)%		[1989Ku08, 1976FrZO, 1962Pe15]
²¹⁶ Rn	5.779(9)	9.855(6)	8.198(6)	100%		[ <b>1970Va13</b> , 2018Sa45, 1961Ru06, 1960Ru02, 1952Or03, 1949Me54]
²²⁰ Ra	5.634(10)	9.523(8)	7.594(5)	100%		[1970Va13, 1961Ru06, 2018Sa45, 2000He17, 1990An19,
						1990AnZQ, 1989An13, 1988AnZS, 1978IbZZ, 1952Or03,
						1950OrZZ, 1949Me54]
²²⁴ Th	5.118(12)	8.903(10)	7.299(6)	$\approx 100\%$		[2000He17, 1970Va13, 1961Ru06, 1989An13, 1988AnZS,
						1978IbZZ, 1973ScXO, 1973ScXP, 1960Ru02, 1952Or03,
228	1 000 (1 5)	0.556(1.4)	( 000/0)	. 050		1949Me25]
²²⁰ U	4.899(15)	8.556(14)	6.800(9)	> 95%		[ <b>1961Ru06</b> , 1960Ru02, 1952Or03, 1951Me10, 1950OrZZ,
232 Du	4 552(54)	7 922(17)	6716(10)	<2001		[1949]ME34]
²³⁶ Cm	4.332(34)	7.852(17)	0.710(10)	$\leq 20\%$		[1975Ja00, 2000La25, 1952O105, 1950O1ZZ]
240 Cf	4.001(30)	7.073(19)	7.007(3)	18(2)% 08 5(22)%	1 5(2)0%	[2010KH00, 2010ASZA] [2010As7X 2010Kb06 1005La00 1080V/04 1070S(10]
²⁴⁴ Em	3.33(21)#	5.00(20)#	7.711(4) 8.55(20)#	98.3(23)%	1.3(2)%	[2010ASZA, 2010KII00, 1995La09, 1980 VI04, 19705I19] $[20008Kb10, 2013Sy77, 2012Sy77, 1082Bo21, 1082Bo7N]$
1,111	5.07(29)#	5.00(20)#	0.55(20)#	<u>1</u> /0	/71/0	1980Vin4 1979Ga06 1978GaZW 1975Oc021
²⁴⁸ No	2.54(31)#	4.08(23)#	9.30(10)#			1900 Holl, 1979 Gubb, 1970 Gubbl, 1970 Ggbb]
²⁵² Rf					100%	[2025Kh01]

### Table 3

direct  $\alpha$  emission from ²¹²Po, J^{$\pi$} = 0⁺, T_{1/2} = 294.965(178) ns^{*}, BR_{$\alpha$} = 100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{208}\text{Pb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
8.95380(12)	8.78486(12)**	100%	0+	0.0		1.52177(18)	0.992(27)

* [2022Be20].

** Value taken from [1991Ry01], based on adjusted values of 8784.90(12) keV [1974Hu15], 8784.37(7) keV [1972RyZX] and 8784.85(31) keV [1971De52].

direct $\alpha$ emission from ²¹²	n1 Po, Ex. =	1.4764(2) MeV*	$J^{\pi} = (8^+), T$	$T_{1/2} = 17.1(2) \text{ ns}^*$	*, $BR_{\alpha} = \approx 42\%$	6***
----------------------------------------------	-------------------	----------------	----------------------	----------------------------------	---------------------------------	------

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{208}\mathrm{Pb})$	coincident γ-rays	R ₀ (fm)	HF
10.376(30)	10.180(30)**	≈42%***	$0^+$	0.0		1.52177(18)	$\approx 124$
* [2020Au03 ** [1978Li14 ** [1984Es0	]. 4]. 1].						

### Table 5

Table 5	
direct $\alpha$ emission from ^{212m2} Po*, Ex. = 2.930(10) MeV**, J ^{$\pi$} = (18 ⁺ ), T ₁	$_{1/2} = 45.1(6) \text{ s}^{***}, BR_{\alpha} = 99.93(2)\%^{@}$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{208}\text{Pb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF		
8.689(8) 9.270(10) 11.884(10)	8.525(8) 9.095(10) 11.660(10)	100% 1.2(2)% 2.1(3)%	96.8% 2.1(3)%	5 ⁻ 1.2(2)%	3.195(13) 3 ⁻ 0 ⁺	0.570, 2.614 2.614(14) 0.0	1.52177 2.614	(18) 3.6(4 1.521 1.521	$) \times 10^{7}$ 177(18) 177(18)	$6.7^{+1.6}_{-1.2}  imes 10^{10}$ $1.9(3)  imes 10^{15}$
* All val ** [2020 *** [196 [@] [1989	lues from [1976F )Au03]. 52Pe15]. Ku08].	rZO], except v	where noted	l.						
Table 6 direct $\alpha$ emis	ssion from ²¹⁶ Rn,	$J^{\pi} = 0^+, T_{1/2}$	$= 45(5) \ \mu s$	$s^*, BR_{\alpha} = 1$	00%.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(ab)$	s) J ²	$f E_{c}$	daughter ( ²¹² P0)	coincident $\gamma$ -rays	R ₀ (fm	) H	F	
8.202(10)	8.050(10)**	100%	0	+ 0.	0	—	1.5658	(59) 1.	.03(12)	
* [1961] ** [1970	Ru06]. )Va13].									
<b>Table 7</b> direct $\alpha$ emis	ssion from ²²⁰ Ra,	$J^{\pi} = 0^+, T_{1/2}$	= 18(2) ms	$s^*, BR_{\alpha} = 1$	00%.					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(a)$	os) J	$f_f^{\pi} = E_{daughter}(^{21})$	⁶ Rn) coinciden	t γ-rays	R ₀ (fm)	HF	
7.03 7.591(7)	6.90 7.453(7)***	1.0(4)% 100%	1.0(4 99%	4)% 2 0	$^+$ 0.461(2) [@] + 0.0	0.4614(2)	@	1.5539(57) 1.5539(57)	$2.6^{+2.3}_{-1.0}\\0.99(1)$	1)

#### * [2000He17].

** In addition to those listed, [2000He17] reported a 5(3)% 7393(15) MeV  $\alpha$  transition to a state at 58(18) keV in ²¹⁶Rn, which would be very unlikely in this nucleus.

*** Weighted average of 7.455(10) MeV [1970Va13] and 7.450(10) MeV [1961Ru06].

@ [2007Wu02].

### Table 8

Table	ð						
direct	$\alpha$ emission	from ²²⁴ T	h, $J^{\pi} = 0^{+}$	$^{+}, T_{1/2} = 1$	1.05(2) s*,	$BR_{\alpha} = \approx 1$	00%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	E _{daughter} ( ²²⁰ Ra) [@]	coincident γ-rays [@]	R ₀ (fm)	HF
6.82	6.70	0.6(4)%	0.5(3)%	$(3^{-})$	0.474(2)	0.1784(2), 0.2957(2)	1.5385(27)	$\begin{array}{c} 3^{+4}_{-1} \\ 1.5^{+1.1}_{-0.5} \\ 0.91^{+0.13}_{-0.10} \\ 0.962(31) \end{array}$
6.89	6.77	1.9(8)%	1.5(6)%	$4^{+}$	0.4101(2)	0.1784(2), 0.2316(2)	1.5385(27)	
7.122(8)	6.995(8)**	24(3)%	19(2)%	$2^{+}$	0.1784(2)	0.1784(2)	1.5385(27)	
7.293(7)	7.163(7)***	100%	79(2)%	$0^{+}$	0.0		1.5385(27)	

* [1978IbZZ].

** Weighted average of 6.984(15) MeV [2000He17] and 7.000(10) MeV [1970Va13].

*** Weighted average of 7.156(10) MeV [2000He17] and 7.170(10) MeV [1970Va13].

@ [2011Br05].

### **Table 9** direct $\alpha$ emission from ²²⁸U, $J^{\pi} = 0^+$ , $T_{1/2} = 9.1(2)$ m*, $BR_{\alpha} = > 95\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{224}\text{Th})^{**}$	coincident γ-rays**	R ₀ (fm)	HF
6.514	6.400	0.7(2)%	0.5(2)%	4 ⁺	0.2841(5)	0.0981(3), 0.1860(3)	1.5237(51)	$\begin{array}{c} 9^{+6}_{-3} \\ 9^{+7}_{-3} \\ 0.94^{+0.21}_{-0.16} \\ 0.98(8) \end{array}$
6.555	6.440	1.0(4)%	0.7(3)%	(1 ⁻ )	0.2510(3)	0.0981(3), 0.1529(3), 0.246(3)	1.5237(51)	
6.708	6.590	41(8)%	29(4)%	2 ⁺	0.0981(3)	0.0981(3)	1.5237(51)	
6.799(10)	6.680(10)	100(6)%	70(4)%	0 ⁺	0.0		1.5237(51)	

* All values from [1961Ru06], except where noted .

** [1991Sc08].

#### Table 10

direct  $\alpha$  emission from ²³²Pu*, J^{$\pi$} = 0⁺, T_{1/2} = 33.7(5) m**, BR_{$\alpha$} =  $\leq$ 20%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{228}\mathrm{U})$	coincident γ-rays	$R_0$ (fm)	HF
6.657(10) 6.716(10)	6.542(10) 6.600(10)	61% 100%	≤7.6% ≤12.4%	$2^+_{0^+}$	0.059(14) 0.0	0.059(14)	1.487(50) 1.487(50)	>0.55 >0.60

* All values from [1973Ja06]. except where noted.

** Weighted average of 33.1(8) m [2000La25] and 34.1(7) m [1973Ja06].

### Table 11

direct  $\alpha$  emission from ²³⁶Cm, J^{$\pi$} = 0⁺, T_{1/2} = 410(50) s*, *BR*_{$\alpha$} = 18(2)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{232}\mathrm{Pu})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.013(5) 7.067(5)	6.894(5)** 6.894(5)**	$\approx 25\%^{***}$ 100%***	$\approx 4\%$ $\approx 14\%$	$2^+_{0^+}$	0.054(7) 0.0	0.054(7)	1.5181(67) 1.5181(67)	$\approx 2.4$ $\approx 1.0$

## * [2010Kh06].

** [2010AsZX].

*** Estimated by evaluator based on Fig 1b in [2010AsZX].

### Table 12

Table	14						
direct	$\alpha$ emission	from ²⁴⁰	Cf, $J^{\pi} =$	$0^+, T_{1/2} =$	= 1.00(12) m	*, $BR_{\alpha} =$	98.5(23)%**

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{236}\mathrm{Cm})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.663(4)	7.535(4)**	$\approx 33\%^{***}$	$\approx 25\%$	2+	0.054(7)	0.046(6)	1.5027(72)	≈1.9
7.709(4)	7.581(4)**	100%***	pprox 75%	$0^{+}$	0.0		1.5027(72)	$\approx 0.9$

* Weighted average of 0.9(2) m [1995La09] and 1.06(15) m [1980Vi04].

** [2010Kh06].

** [2010AsZX].

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Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z = +22$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	$\mathrm{BR}_{\mathcal{E}_F}$	Experimental
²¹⁰ Bi		$1^{-}$	5.013(5) d	-0.064(1)				[1956Ro18]
^{210m} Bi	0.2713(1)	9-	$3.04(6) \times 10^6$ y	0.207(1)	-8.271(6)	4.000(20)		[1976TuZY]
²¹⁴ At		$(2^{-})$	558(10) ns	1.091(4)	-5.436(6)	8.924(4)		[1982Ew01]
^{214m1} At	0.059(9)		265(30) ns	1.150(10)	-5.377(11)	8.983(10)		[1982Ew01]
^{214m2} At	0.233(6)	$(9^{-})$	760(15) ns	1.324(7)	-5.203(8)	9.157(7)		[ <b>1982Ew01</b> ]
²¹⁸ Fr		1-	$1.3^{+0.5}$ ms	1.842(4)	-4 624(6)	9.104(4)		[1982Ew01]
^{218m} Fr	0.088(5)	(8-)	22.0(5) ms	1.930(6)	-4.536(8)	9.192(6)		[1982Ew01]
²²² Ac		1-	4.9(5) s*	2.302(6)	-3.944(7)	8.979(5)		[1958To25, 1952Me13]
222mAc	х		64(2) s**	2.302(6)+x	-3.944(7)+x	8.979(5)+x		[1973Mo07, 1972Es03]
²²⁶ Pa			1.8(2) m	2.836(12)	-2.893(12)	9.288(12)		[1951Me10]
²³⁰ Np			4.6(3) m	3.620(60)	-1.949(55)	9.614(55)		[1968Ha14]
²³⁴ Am			2.32(8) m	4.11(16)#	-0.78(17)#	10.42(16)#	$6.6(18) \times 10^{-3}$	[1990Ha02, 1972SoXX]
²³⁸ Bk			144(5) s	4.77(26)#	0.36(26)#	11.44(26)#	0.048(2)%	[ <b>1994Kr03</b> , 1994La25]
²⁴² Es			16.9(8) s	5.41(26)#	1.53(31)#	12.93(26)#	1.5(4)%	[2024KhXX, 2010An08, 2000Sh10,
				()				1997ShZZ, 1985HiZU]
²⁴⁶ Md***			0.9(2) s	5.92(26)#	2.51(31)#	14.30(26)#		[2010An08]
^{246m} Md	х		4.4(8) s	5.92(26)#+x	2.51(31)#+x	14.30(26)#+x	> 10%	[2010An08]
			× /	/	. ,	/		. ,

* Weighted average of 4.2(5) s [1958To25] and 5.5(5) s [1952Me13].

** Weighted average of 62(3) s [1973Mo07] and 66(3) s [1972Es03].

*** May not be the ground state.

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +22$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	S _{2p}	Qα	$BR_{\alpha}$	Experimental
²¹⁰ Bi*	4 466(1)	12,620(2)	5.036(1)	$1.32(10) \times 10^{-4}\%$	[ <b>1969].a18. 1962Ka27. 1959Wa05</b> [1969].a18 [1969].a7.Y
					1960Wa14, 1958Go891
^{210m} Bi	4,195(1)	12,349(2)	5.307(1)	100%	[ <b>1976TuZY</b> 1975TuZW 1975Sp07 1969La01 1969La18
51		1210 17(2)	0.007(1)	10070	1969LaZY 1968LaZZ 1967Sp07 1962Ko12 1961Ru02
					1960Wa14, 1959Go77, 1954Le60, 1953Hu421
²¹⁴ At	4.015(5)	9.839(4)	8,988(4)	100%	[ <b>1982Ew01</b> , 2009Vi09, 1999Sh03, 1982Bo04, 1981HaZN,
		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			1973BoXW, 1968Ha14, 1964Mc21, 1958To25, 1951Me10.
					1949Me541
^{214m1} At	3.956(10)	9.780(10)	9.047(10)	$\approx 100\%$	[ <b>1982Ew01</b> , 2009Vi09]
214m2 At	3.782(8)	9.606(7)	9.221(7)	$\approx 100\%$	[1982Ew01, 2009Vi09, 1999Sh03, 1981HaZN]
²¹⁸ Fr	3.888(6)	9.775(5)	8.014(1)	100%	[1999Sh03, 1982Ew01, 2014Bu06, 1982Bo04, 1981HaZN,
					1973BoXL, 1972Es03, 1968Ha14, 1964Mc21, 1958To25,
					1951Me10, 1949Me54]
^{218m} Fr	3.800(8)	9.687(7)	8.102(5)	100%	[1999Sh03, 1982Ew01, 2014Bu06, 1981HaZN]
²²² Ac	3.631(6)	9.438(6)	7.137(2)	$\approx 100\%$	[1964Mc21, 1988Hu08, 1973BoXL, 1973BoXW, 1972Es03,
		. ,			1970GhZY, 1968Ha14, 1958To25, 1952Me13, 1949Me54]
$^{222m}Ac$	3.631(6)-x	9.438(6)-x	7.137(2)+x	>97%	[ <b>1972Es03</b> , 1982Bo04, 1973Mo07]
²²⁶ Pa	3.566(12)	8.778(12)	6.987(10)	74%	[1964Mc21, 1991Ga28, 1968Ha14, 1951Me10, 1949Me54]
²³⁰ Np	3.263(55)	8.265(55)	6.778(54)	$\approx 3\%$	[1968Ha14]
²³⁴ Am	2.88(17)#	7.48(19)#	6.80(15)#	0.039(12)%	[ <b>1990Ha02</b> , 2004Sa05, 1974ArYU]
²³⁸ Bk	2.32(27)#	6.40(28)#	7.33(20)#		
²⁴² Es	1.81(32)#	5.44(30)#	8.160(20)	49(3)%**	[2024KhXX, 2010An08, 2000Sh10, 1996Ni09, 1994HoZW,
	、 <i>'</i>			× /	1994La25, 1985HiZU]
²⁴⁶ Md***	1.37(33)#	4.49(32)#	8.889(41)	100%	[2020An08, 1996Ni09, 2003HeZY, 1994HoZW, 1994La25]
^{246m} Md	1.37(33)#-x	4.49(32)#-x	8.889(41)+x	< 23%	[2020An08]

* 100%  $\beta^-$  emitter.

** Weighted average of 41(3)% [2024KhXX] and 57(3)% [2010An08].

*** May not be the ground state.

### Table 3 direct $\alpha$ emission from ²¹⁰Bi, J^{$\pi$} = 1⁻, T_{1/2} = 5.013(5) d*, BR_{$\alpha$} =1.32(10) × 10⁻⁴%**.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi@}$	$E_{daughter}(^{206}\mathrm{Tl})^{@}$	coincident $\gamma$ -rays [@]	R ₀ (fm)	HF
4.750(10) 4.791(10)	4.660(10) 4.700(10)	$\begin{array}{c} 100\% \\ \approx 67\% \end{array}$	$pprox 7.9  imes 10^{-4}\%$ $pprox 5.3  imes 10^{-4}\%$	$1^ 2^-$	0.3049 0.2658	0.3049 0.2658		
* [1956Rc ** [1962K *** [1969 [@] [2008K	018]. Ka27]. La18]. 021].							

#### Table 4

direct	$\alpha$ emission	from ^{210m} B	i*, Ex	. = 271.3(	1) keV**	$J^{\pi} = 9^{-1}$	$, T_{1/2}$	$_{2} = 3.04(6) \times$	10 ⁶ y	$, BR_{\alpha} =$	100%.
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{206}\text{Tl})^{***}$	coincident γ-rays***	$R_0$ (fm)	HF
- 1100	- 4 100	$2.6 \times 10^{-3}$	$2 \times 10^{-3}$	(1-)	1 120/2)	0.2659, 0.9514, 1.120		
≈4.180	$\approx$ 4.100	$3.0 \times 10^{-3}$	$2 \times 10^{-5}$	(1)	1.120(2)	0.2058, 0.8514, 1.120		
≈4.312	$\approx 4.230$	$1.5 \times 10^{-3}$	$8  imes 10^{-4}$	$(2^{-})$	0.9982	0.2658, 0.7323		
4.351(10)	4.268(10)	0.011%	$6  imes 10^{-3}\%$	$(4^{-})$	0.9522	0.2658, 0.6863		
4.506(10)	4.420(10)	0.38%	0.21%	(3 ⁻ )	0.8014	0.2658, 0.5355		
4.657(20)	4.568(20)	7.1%	3.9%	$(1^{-})$	0.6494(1)	0.2658, 0.3049, 0.3445, 0.3840, 0.6494		
4.671(20)	4.582(20)	2.5%	1.4%	$(2^{-})$	0.6350(1)	0.2658, 0.3049, 0.3301, 0.3692, 0.6343		
5.004(10)	4.909(10)	71.8%	39.5%	$(1^{-})$	0.3049	0.3049		
5.042(10)	4.946(10)	100%	55.0%	(2 ⁻ )	0.2658	0.2658		
5.308(10)	5.207(10)	${<}2 imes10^{-4}\%$	${<}1 imes10^{-4}\%$	$(0^{-})$	0.0			

* All values from [1976TuZY], except where noted.

** [2014Ba14].

*** [2008Ko21].

### Table 5

direct  $\alpha$  emission from ²¹⁴At*, J^{$\pi$} = (1⁻), T_{1/2} = 558(10) ns, BR_{$\alpha$} = 100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	E _{daughter} ( ²¹⁰ Bi)**	coincident γ-rays**	R ₀ (fm)***	HF
8.428(5)	8.270(5)	0.32(3)%	0.32(3)%		0.5632(1)	0.0465, 0.5166, 0.5632	1.5438(59)	$21.4^{+3.4}_{-2.2}$
8.642(6)	8.480(6)	0.59(4)%	0.58(4)%	3-	0.3480	0.3480	1.5438(59)	42(6) -5.2
8.669(7)	8.507(7)	0.15(4)%	0.15(4)%	$2^{-}$	0.3197	0.3197	1.5438(59)	$190^{+80}_{-50}$
8.987(4)	8.819(4)	100%	98.95(6)%	$1^{-}$	0.0		1.5438(59)	$1.8(2)^{-50}$

 $\ast$  All values from [1982Ew01], except where noted.

** [2014Ba41].

*** Interpolated between 1.52177(18) (²¹²Po) and 1.5658(59) fm (²¹⁶Rn).

### Table 6

direct $\alpha$ emission from ^{214m1} At*, Ex. = 59(9) keV, T _{1/2}	$_{2} = 265(30)$ ns, $BR_{\alpha} = \approx 100\%$
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{210}\mathrm{Bi})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF
9.046(8)	8.877(8)	$\approx 100\%$	1-	0.0		1.5438(59)	1.14(19)

* All values from [1982Ew01], except where noted. ** Interpolated between 1.52177(18) (²¹²Po) and 1.5658(59) fm (²¹⁶Rn).

Table 7			
direct $\alpha$ emission from ^{214m2} At*, Ex. = 2.	$33(16)$ keV, $J^{\pi} = (9)$	$P^{-}$ ), $T_{1/2} = 760(15)$ ns,	$BR_{\alpha} = \approx 100\%$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{210}\mathrm{Bi})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
8.550(6) 8.784(5)	8.390(6) 8.620(5)	0.18(3)% 0.65(5)%	0.18(3)% 0.64(5)%	10-	0.669(5)** 0.436(4)	0.3977(5)**	1.5438(59) 1.5438(59)	$111^{+29}_{-22} \\ 120^{+19}_{-17} \\ 25$
8.949(5)	8.782(5)	100%	99.18(6)%	9-	0.2713(1)		1.5438(59)	$1.94^{+0.25}_{-0.23}$

* All values from [1982Ew01], except where noted.

*** [2014Ba41]. *** Interpolated between 1.52177(18) (²¹²Po) and 1.5658(59) fm (²¹⁶Rn).

#### Table 8

direct  $\alpha$  emission from ²¹⁸Fr*, J^{$\pi$} = 1⁻, T_{1/2} = 1.3^{+0.5}_{-0.4} ms**, BR_{$\alpha$} = 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{214}\text{At})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
7.519(6)	7.381(6)	1.1(5)%	1.0(0.5)%		0.494(6)		1.5599(82)	$11^{+19}_{-7}$
7.672(8)	7.531(8)	0.5(2)%	0.5(2)%	$(2^{-})$	0.334(8)	0.147, 0.187	1.5599(82)	$70_{-40}^{+90}$
7.710(5)	7.569(5)	5.4(11)%	5(1)%	1(-)	0.303(5)	0.117, 0.187	1.5599(82)	$9^{+7}_{-5}$
7.870(7)	7.726(7)	1.6(5)%	1.5(5)%	$(2)^{-}$	0.143(7)	0.145	1.5599(82)	$90^{+100}_{-5}$
8.013(2)	7.866(2)	100%	92(2)%	0.0		1.5599(82)	3.9(16)	5

* All values from [1999Sh03], except where noted.

** [1982Ew01].

*** Interpolated between 1.5658(59) fm ( 216 Rn) and 1.5539(57) fm ( 220 Ra).

#### Table 9

direct  $\alpha$  emission from ^{218m}Fr*, Ex.= 88(5) keV, J^{$\pi$} = (8⁻), T_{1/2} = 22.0(5) ms, BR_{$\alpha$} = 100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi**}$	$E_{daughter}(^{214}\text{At})$	coincident γ-rays**	R ₀ (fm)***	HF
6.965(7)	6.837(7)	0.10(2)%	0.04(1)%		1.136(7)		1.5599(82)	$55^{+23}_{-16}$
7.085(5)	6.955(5)	1.24(8)%	0.51(3)%		1.016(5)		1.5599(82)	$11.8^{+2.5}_{-2.1}$
7.128(8)	6.997(8)	0.09(4)%	0.040(15)%		0.972(8)		1.5599(82)	$220_{-70}^{-2.1}$
7.219(15)	7.087(15)	0.80(56)%	0.33(23)%		0.881(15)		1.5599(82)	$50_{-30}^{+130}$
7.239(5)	7.106(5)	3.92(55)%	1.61(22)%		0.862(4)		1.5599(82)	$12.9^{+3.5}_{-2.8}$
7.312(6)	7.178(6)	2.17(32)%	0.89(13)%		0.788(5)		1.5599(82)	$42_{-9}^{+12}$
7.375(5)	7.240(5)	23.4(12)%	9.6(4)%	(8-)	0.725(4)	0.046, 0.451, 0.496	1.5599(82)	$6.3^{+1.3}_{-1.1}$
7.469(15)	7.332(15)	1.6(5)%	0.65(20)%		0.631(15)		1.5599(82)	$190_{-60}^{+100}$
7.536(5)	7.398(5)	8.3(6)%	3.4(2)%		0.564(4)	0.083, 0.145, 0.337	1.5599(82)	61(12)
7.597(5)	7.458(5)	3.2(3)%	1.3(1)%		0.503(4)	0.083, 0.145, 0.276	1.5599(82)	250(50)
7.646(6)	7.506(6)	2.3(3)%	0.93(10)%		0.454(5)		1.5599(82)	$500^{+120}_{-100}$
7.690(5)	7.549(5)	1.8(2)%	0.76(9)%		0.411(4)		1.5599(82)	$830^{+210}_{-170}$
7.758(5)	7.616(5)	100.0%	41.1(13)%	(8-)	0.342(4)	0.111	1.5599(82)	25(5)
7.800(7)	7.657(7)	29.0(52)%	11.9(21)%	(6 ⁻ )	0.300(6)	0.074, 0.083, 0.145	1.5599(82)	$120^{+40}_{-30}$
7.825(7)	7.681(7)	39.2(53)%	16.1(21)%	$(7^{-})$	0.276(6)	0.046	1.5599(82)	$102_{-22}^{+27}$
7.869(6)	7.725(6)	10.9(17)%	4.5(7)%	(9-)	0.233(6)		1.5599(82)	$490^{+140}_{-110}$
7.915(5)	7.770(5)	2.8(3)%	1.14(11)%	(3-)	0.185(4)	0.187	1.5599(82)	$2.7(6) \times 10^3$
7.956(5)	7.810(5)	3.9(3)%	1.6(1)%	$(2)^{-}$	0.145(4)	0.145	1.5599(82)	$2.6(5) \times 10^3$
8.022(5)	7.875(5)	3.4(5)%	1.4(2)%	$0^{-}$	0.078(4)	0.078	1.5599(82)	$4.6^{+1.3}_{-1.0}  imes 10^3$
8.101(5)	7.952(5)	5.8(3)%	2.4(1)%	$1^{-}$	0.0		1.5599(82)	$4.5^{+0.9}_{-0.8}  imes 10^3$

* All values from [1982Ew01], except where noted.

** [1999Sh03]. *** Interpolated between 1.5658(59) fm ( 216 Ra) and 1.5539(57) fm ( 220 Th).

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{218}\mathrm{Fr})$	coincident γ-rays	$R_0 \left( fm \right)^@$	HF
7.082(10) 7.128(10)	6.954(10)*** 7.000(10)***	6(1)% 100%	6(1)% 100%	1-	0.047(14) 0.0	_	1.5462(63) 1.5462(63)	$28^{+11}_{-9}$ 2.7(5)

* All values from [1964Mc21], except where noted.

** Weighted average of 4.2(5) s [1958To25] and 5.5(5) s [1952Me13].

*** Value recommended by [1991Ry01]. Original values were 6.952(10) MeV and 6.998(10) MeV respectively. ^(a) Interpolated between 1.5539(57) fm (²²⁰Ra) and 1.5385(27) fm (²²⁴Th).

### Table 11

direct  $\alpha$  emission from ^{222m}Ac*, Ex.= unk., T_{1/2} = 64(2) s**, BR_{$\alpha$} = >97%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{218}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
6.579(20)	6 460(20)	7(5)%	2(1)%		0.550(28) + x		1.5462(63)	< 13 ⁺¹⁵
6.833(20)	6.710(20)	30(18)%	8(4)%		0.295(28)+x		1.5462(63)	$< 30^{+40}_{-20}$
6.874(20)	6.750(20)	56(28)%	15(5)%		0.255(28)+x		1.5462(63)	$<25^{+17}_{-10}$
6.935(20)	6.810(20)	100(37)%	27(10)%		0.193(28)+x		1.5462(63)	$< 24^{+18}_{-10}$
6.966(20)	6.840(20)	37(23)%	10(5)%		0.163(28)+x		1.5462(63)	$< 90^{+100}_{-40}$
7.016(20)	6.890(20)	56(28)%	15(5)%		0.112(28)+x		1.5462(63)	$< 90^{+60}_{-40}$
7.098(20)	6.970(20)	30(16)%	8(3)%		0.031(28)+x		1.5462(63)	$< 330^{+0.50}_{-1.40}$
7.128(20)	7.000(20)	56(28)%	15(5)%		0.0+x		1.5462(63)	$<230^{+140}_{-80}$

* All values from [1972Es03], except where noted.

** Weighted average of 62(3) s [1973Mo07] and 66(3) s [1972Es03].

*** Interpolated between 1.5539(57) fm ( 220 Ra) and 1.5385(27) fm ( 224 Rn).

#### Table 12

direct $\alpha$ emission from ²²⁶ Pa	*, $T_{1/2} =$	1.8(2) m**,	$BR_{\alpha} = 74\%$
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi**}$	$E_{daughter}(^{222}\mathrm{Ac})$	coincident γ-rays**	R ₀ (fm)***	HF
6.844(10) 6.941(10) 6.982(10)	6.723(10) 6.818(10) 6.858(10)	2% 88% 100%	1% 46% 52%	(2-)	0.137 0.041 0.0		1.5311(58) 1.5311(58) 1.5311(58)	80 4.0 5.1

* All values from [1964Mc21], except where noted. Uncertainties for branching ratios was not provided.

** [1951Me10].

*** Interpolated between 1.5385(27) fm ( 224 Th) and 1.5237(51) fm ( 228 U).

#### Table 13

direct  $\alpha$  emission from ²³⁰Np*, T_{1/2} = 4.6(3) m, BR_{$\alpha$} =  $\approx$  3%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	<i>E</i> _{daughter} ( ²²⁶ Pa)	coincident γ-rays	R ₀ (fm)**	HF	
6.778(20)	6.660(20)	100%		0.0?		1.506(50)	$\approx 3$	
* All valu ** Interpo <b>Table 14</b> direct α emiss	tes from [1968Ha1 blated between 1.5	4], except where 237(51) fm ( 228 U T _{1/2} = 2.32(8) m	noted. () and 1.487( ), $BR_{\alpha} = 0.03$	50) fm ( ²³² Pu). 39(12)%.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{226}\mathrm{Pa})$	coincident γ-rays	R ₀ (fm)**	HF	
6.57	6.46	100%		0.0?		1.503(50)	$11^{+26}_{-9}$	

* All values from [1990Ha02], except where noted. ** Interpolated between 1.487(50) fm ( 232 Pu) and 1.5181(67) fm ( 236 Cm).

#### **Table 15** direct *q* emission from 242 Es T₄ = 16.9(8) s* *BR* = -49(3)%**

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{238}\mathrm{Bk})^{***}$	coincident γ-rays***	R ₀ (fm)	HF
8.053(20) 8.160(20)	7.920(20)*** 8.025(20)***	100%*** ≈5%***	$\approx 47\%$ $\approx 2\%$		0.107 0.0	0.0866, 0.1070, 0.1224		
* [2024] ** Weig *** [201	KhXX]. hted average of 41(3) [,] [0An08].	% [2024KhXX]	and 57(3)% [20	010An08].				
Table 16 direct $\alpha$ emis	ssion from ²⁴⁶ Md*, T ₁	$_{1/2} = 0.9(2)$ s, <i>BF</i>	$R_{\alpha} = 100\%.$					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{242}\mathrm{Es})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
8.671(30) 8.886(14)	8.530(30)** 8742(14)***	≈33% 100%	≈25% ≈75%		0.215(33) 0.0?			
* All val ** [1996 *** Wei	lues from [2010An08] 5Ni09]. ghted average of 8.74	l, except where n 4(20) MeV [201	otee. This isom 0An08] and 8.7	ner may not 40(20) Me	be the ground state. V [1996Ni09].			
<b>Fable 17</b> lirect α emis	ssion from ^{246m} Md*, 7	$\Gamma_{1/2} = 4.4(8) \text{ s, } E$	$R_{\alpha} = \langle 23\%.$					
		L.(abs)	$\mathbf{J}_{c}^{\pi}$	Edaught	er( ²⁴² Es) coincid	ent $\gamma$ -rays $R_0$ (fm)	HF	
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	1α(α03)	- f	uuugni				

* All values from [2010An08], except where noted.

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +45/2 nuclei.

Last updated 5/13/2024
Observed and predicted $\beta$ -delayed particle emission from the even-Z, $T_z = +45/2$ nuclei.	Unless otherwise stated, all Q-values are taken from [2021Wa16] or
deduced from values therein, $J^{\pi}$ values for ²⁰⁹ Pb, ²¹³ Po, and ²¹⁷ Rn are taken from ENSDF.	

Nuclide	Fv	Iπ	True	0	0	0	Experimental
	LA.	5	11/2	Qε	$\mathcal{Q}\varepsilon p$	Qεα	Experimental
²⁰⁹ Pb*		9/2+	3.232(5) h	-3.970(6))			[2013Su13]
²¹³ Po		$9/2^{+}$	3.6984(6) µs	-1.422(5)			[2023A122]
²¹⁷ Rn		9/2+	0.59(4) ms**	-0.736(6)			[2018Sa45, 1961Ru06]
²²¹ Ra		$5/2^{+}$	26.20(39) s	-0.313(6)			[2024Ba08]
²²⁵ Th		$(3/2^+)$	8.72(4) m	0.673(7)	-3.805(5)	6.608(7)	[1987Mi10]
²²⁹ U		$(3/2^+)$	58(3) m	1.314(7)	-2.849(6)	7.148(8)	[1951Me10]
²³³ Pu			20.9(4) m	2.100(70)	-1.847(54)	7.730(54)	[ <b>1973Ja06</b> ]
²³⁷ Cm				2.68(10)#	-0.943(74)	8.874(90)#	
²⁴¹ Cf			141(11) s	3.35(24)#	0.31(17)#	10.33(18)#	[2010AsZX]
²⁴⁵ Fm		$(1/2^+)$	5.5(7) s	3.88(26)#	1.43(20)#	11.79(26)#	[2022Te01]
²⁴⁹ No		$(5/2^+)$	38.3(28) ms	4.61(32)#	2.60(28)#	13.05(33)#	[2022Te01, 2021Sv02]
²⁵³ Rf			9.9(12) ms	5.12(44)#	3.48(41)#	14.04(44)#	[2022Lo03]
253mRf	х		52.8(44) µs	5.12(44)#+x	3.48(41)#+x	14.04(44)#+x	[2022Lo03]

* 100%  $\beta^-$  emitter.

** Weighted average of 0.67(6) ms [2018Sa45] and 0.54(5) ms [1961Ru06].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +45/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	BR _{cluster}	type	Experimental
²⁰⁹ Pb	8.153(2)	2.248(4)					
²¹³ Po	5.825(3)	8.536(3)	100%				[ <b>1982Bo04, 1964Va20</b> , 2023A122, 2020Ko06, 2018A132,
							2018Sa45, 2013Su13, 2009In01, 2002Ko06, 2002Mo46,
							2000Gr35, 1998Ar03, 1998Wa25, 1997Ch53, 1997ChZS,
							1997Wa27, 1997VaZV, 1995WaZQ, 1989Ko26, 1986He06,
							1977Vy02, 1973BoXL, 1969LeZW, 1963Uh01, 1960Vo05,
							1958To25, 1955St04, 1951Me10, 1950Ha52, 1949Me54,
							1948Cr12, 1948Je05, 1947Ha02]
²¹⁷ Rn	5.887(5)	7.887(3)	100%				[ <b>1982Bo04</b> , 2018Sa45, 1973BoXL, 1961Ru06, 1960Ru02,
							1951Me10, 1949Me54]
²²¹ Ra	5.807(6)	6.880(2)	100%		$1.15(94) \times 10^{-10}\%^{**}$	$^{14}C$	[1997Li12, 1994Bo28, 2024Ba08, 1994Bo35, 1989Ac01,
							1988Hu08, 1961Ru02, 1961Ru06, 1958To25, 1951Me10,
							1949Me54]
²²⁵ Th	5.213(6)	6.921(2)	100%				[2015Ah04, 1988LiZN, 1961Ru06, 1989Ac01, 1987Mi10,
							1960Ru02, 1949Me54]
²²⁹ U	5.002(7)	6.468(3)*	pprox 20%				[1961Ru06, 1951Me10, 1961Ru02, 1949Me54]
²³³ Pu	4.60(11)#	6.410(20)*	0.12(5)%				[1973Ja10, 1957Th10]
²³⁷ Cm	4.08(14)#	6.770(51)	< 1%				[2006As03, 2002As08, 2002AsZX, 2000TsZX]
²⁴¹ Cf	3.63(23)#	7.502(4)*	15(1)%				[2020Kh10, 2010AsZX, 2022Te01, 1970Si19]
²⁴⁵ Fm	3.12(27)#	8.290(7)*	$88.5^{+6.8}_{-5.0}\%$	< 0.3%			[2022Te01, 2020Kh10, 2021Sv02, 1967Nu01]
²⁴⁹ No	2.45(34)#	9.278(22)*	100%	$<\!0.2\%$			[2022Te01, 2021Sv02, 2022Lo03, 2021Kh07, 2021Te08,
							2013Be18, 2003Ye02]
²⁵³ Rf	2.18(45)#	9.4460(20)*	17(6)%	83(6)%			[2022Lo03, 2022Te01, 2021Kh07, 1997He29]
253mRf	2.18(45)#-x	9.4460(20)*+x		100%			[2022Lo03, 2022Te01, 2021Kh07]

* Deduced from  $\alpha$  energies. Values from [2021Wa16] are 6.476(3) MeV (²²⁹U); 6.416(54) MeV (²³³Pu); 7.66(15)# MeV (²⁴¹Cf); 8.44(10)# MeV (²⁴⁵Fm); 9.17(20)# MeV (²⁴⁹No) and 9.43(30)# MeV (²⁵³Rf).

** [1994Bo28].

$10, J = 3/2, I_{1/2} = 3.0904(0) \mu s^2, D \Lambda_{\alpha} = 100 \pi$	direct $\alpha$ emission	from ²¹³ Po, J	$J^{\pi} = 9/2^+, T_{1/2}$	$_{2} = 3.6984(6)$	$\mu s^*, BR_{\alpha} = 10$	)0%.
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi**}$	Edaughter ( ²⁰⁹ Pb)**	coincident γ-rays**	R ₀ (fm)	HF
7.760(10) 8.536(3)	7.614(10)*** 8.376(3) [@]	0.003(1)%*** 100%	0.003(1)% 99.997(1)%	11/2 ⁺ 9/2 ⁺	0.7789(1) 0.0	0.7789(1)	1.53069(10) 1.53069(10)	$360^{+180}_{-90}$ 1.486(26)
* [2023 ** [201 *** Fro @ [1982	5Al22]. 5Ch30]. om [1964Va20], E. 2Bo04].	$\alpha$ adjusted by -0.5 l	keV in [1991Ry0	01].				

Table 4

direct  $\alpha$  emission from ²¹⁷Rn, J^{$\pi$} = 9/2⁺, T_{1/2} = 0.59(4) ms^{*}, BR_{$\alpha$} = 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{213}\text{Po})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.886(2)	7.741(2)**	100%	9/2+	0.0		1.5632(13)	1.66(16)

* Weighted average of 0.67(6) ms [2018Sa45] and 0.54(5) ms [1961Ru06]. ** Reported as 7.739(2) MeV in [1982Bo04], modified to 7.741(2) MeV by [1991Ry01].

Table	5
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direct  $\alpha$  emission from ²²¹Ra*, J^{$\pi$} = 5/2⁺, T_{1/2} = 26.20(39) s**, BR_{$\alpha$} = 100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{217}\mathrm{Rn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.260	6.147	0.13%	pprox 0.05%	(5/2, 7/2)	0.6189	0.0562, 0.0854, 0.0930, 0.1492, 0.1743, 0.4443, 0.4697, 0.5258	1.5516(38)	≈27
6.309	6.195	0.53%	0.2%	(5/2, 7/2)	0.5896	0.0562, 0.0854, 0.0930, 0.1492, 0.1743, 0.3952, 0.4206, 0.4765	1.5516(38)	9.0
6.403	6.287	0.13%	pprox 0.05%	(7/2, 11/2)	0.4745	0.4745	1.5516(38)	$\approx 113$
6.500	6.382	1.1%	0.4%	(7/2)	0.3822	0.0562, 0.0854, 0.0930, 0.1492, 0.1743, 0.2079, 0.2329, 0.2891, 0.3822	1.5516(38)	34
6.508	6.390	0.26%	pprox 0.1%	(3/2+)	0.3750	0.0562, 0.0860, 0.0930, 0.1400, 0.1492, 0.2257	1.5516(38)	≈150
6.582	6.463	0.13%	pprox 0.05%	$(3/2^+)$	0.2352	0.0562, 0.0860, 0.0930,	1.5516(38)	$pprox 1.1  imes 10^3$
6.646	6.526	0.79%	0.3%	$(7/2^+)$	0.1743	0.0854, 0.0930	1.5516(38)	320
6.700	6.579	14.7%	5.6%	5/2+	0.1492	0.0562, 0.0930, 0.1492	1.5516(38)	22
6.729	6.607	100%	38%	7/2+	0.0930	0.0930	1.5516(38)	5.2
6.785	6.662	60.5%	23%	$(11/2^+)$	0.0889	0.0889	1.5516(38)	9.0
6.878	6.754	84.2%	32%	9/2+	0.0		1.5516(38)	14

* All values from [1997Li12], except where noted. No uncertainties for  $E_{\alpha}$  or  $I_{\alpha}$  were given. ** Weighted average of 26.37(17 st.)(50 sys.)s and 26.00(18 st.)(55 sys.) s [2024Ba08].

# Table 6 direct $\alpha$ emission from ²²⁵Th*, J^{$\pi$} = (3/2⁺), T_{1/2} =8.72(4) m**, BR_{$\alpha$} = 100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi***}$	Edaughter( ²²¹ Ra)***	coincident γ-rays***	R ₀ (fm)	HF
6.421(5)	6.307(5)	5(2)%	2(1)%	5/2-	0.483	0.0503, 0.0531, 0.1265, 0.1468, 0.1641, 0.2120, 0.2178, 0.3058, 0.3213, 0.3589	1.5380(16)	9 ⁺⁹ ₋₃
6.455(5)	6.340(5)	5(2)%	2(1)%	3/2-	0.455	0.0503, 0.0531, 0.0688, 0.1219, 0.1291, 0.1513, 0.1773, 0.2178, 0.2461, 0.2993, 0.3213	1.5380(16)	$11^{+11}_{-4}$
6.552(3)	6.436(3)	35(3)%	15(1)%	7/2+	0.3588	0.0531, 0.1468, 0.2120, 0.3058, 0.3589	1.5380(16)	3.81(29)
6.590(3)	6.473(3)	100(7)%	43(2)%	$(3/2^+, 5/2^+)$	0.3213	0.0503, 0.0531, 0.2178, 0.3213	1.5380(16)	1.91(11)
6.614(3)	6.496(3)	33(3)%	14(1)%	(3/2 ⁺ , 5/2 ⁺ )	0.2998	0.0531, 0.0688, 0.1219, 0.1773, 0.2461, 0.2993	1.5380(16)	7.2(6)
6.742(5)	6.622(5)	7(2)%	3(1)%		0.174		1.5380(16)	$110_{-30}^{+60}$
6.765(5)	6.645(5)	7(2)%	3(1)%	7/2-	0.1468	0.1468	1.5380(16)	$140_{-40}^{+70}$
6.816(5)	6.695(5)	5(2)%	2(1)%	5/2-	0.1034	0.0503, 0.0531	1.5380(16)	$310^{+320}_{-110}$
6.861(5)	6.739(5)	16(2)%	7(1)%	7/2+	0.0531	0.0531	1.5380(16)	$141^{+25}_{-19}$
6.916(5)	6.793(5)	21(3)%	9(1)%	5/2+	0.0	—	1.5380(16)	$177_{-21}^{+25}$

 $\ast$  All values from [1961Ru06], except where noted. ** [1987Mi10].

*** [1988LiZN].

# Table 7

direct $\alpha$ emission from ²²⁹ U*, J ^{$\pi$} = (3/2 ⁺ ), T	$\Gamma_{1/2} = 58(3) \text{ m}^{**}, BR_{\alpha} = \approx 20\%$
---------------------------------------------------------------------------------------------------------	-------------------------------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{225}\mathrm{Th})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6 290(4)	6 180(4)	1 6(8)%	$\approx 0.2\%$		0 178(4)		1 5278(27)	$\approx 15$
6.329(3)	6.218(3)	4.7(16)%	$\approx 0.2\%$ $\approx 0.6\%$		0.139(3)		1.5278(27)	$\approx 15$ $\approx 8$
6.366(3)	6.255(3)	1.6(8)%	pprox 0.2%		0.102(3)		1.5278(27)	$\approx 30$
6.404(2)	6.292(2)	17.2(16)%	$\approx 2.2\%$		0.064(2)		1.5278(27)	$\approx 4.5$
6.439(2)	6.327(2)	31.3(31)%	pprox 4%		0.028(2)		1.5278(27)	$\approx 3.6$
6.468(3)	6.355(3)	100%	$\approx 13\%$	$(3/2^+)$	0.0		1.5278(27)	$\approx 1.5$

* All values from [1961Ru06], except where noted. ** [1951Me10].

# Table 8

direct  $\alpha$  emission from ²³³Pu*, T_{1/2} = 20.9(4) m**, *BR*_{$\alpha$} = 0.12(5)%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{229}\mathrm{U})$	coincident γ-rays	R ₀ (fm)	HF	
6.410(20)	6.300(20)	0.12(5)%	(3/2+)	0.0		1.503(39)	$3^{+4}_{-2}$	
* All val ** [1973] <b>Table 9</b> direct α emis	ues from [1957Th] ja06]. sion from ²³⁷ Cm, J	10], except where $BR_{\alpha} = < 1\%^*$ .	noted.					
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	E _{daughter} ( ²³³ Pu)	coincident γ-rays	R ₀ (fm)	HF	
6.772(7)	6.658(7)	< 1%*		0.0?				

* [2006As03]. ** Weighted average of 6.656(10) MeV [2006As03] and 6.660(10) MeV [2002As08].

direct  $\alpha$  emission from ²⁴¹Cf,  $T_{1/2} = 141(11)$  s,  $BR_{\alpha} = 15(1)\%^{**}$ .

		/						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{237}\mathrm{Cm})$	coincident γ-rays	R ₀ (fm)	HF	
7.452(4)	7.328(4)	15(1)%**		0.050(1)	0.050(1)	1.5007(75)	$1.23^{+0.28}_{-0.24}$	
* All val ** [2020	ues from [2010A )Kh10].	sZX], except who	ere noted.					
<b>Table 11</b> direct $\alpha$ emis	ssion from ²⁴⁵ Fm,	$T_{1/2} = 5.5(7) s^*$	*, $BR_{\alpha} = 88.3$	$5^{+6.8}_{-5.0}\%$ **.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{241}\mathrm{Cf})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
8.290(7)	8.155(7)	100%		0.0		1.506(33)	$1.5^{+1.8}_{-0.9}$	
* All val ** [2022 Table 12 direct $\alpha$ emis	ues from [2020K] 2Te01].	h10], except whe	me noted. $BR_{1} = 10^{-10}$	10%				
	E (l-h)	$I_{1/2} = 36.3(26)$	$\pi^{\pi}$	<i>E</i> (245Em)		D (fra)	UE	
$\frac{E_{\alpha}(\text{c.m.})}{9.278(22)}$	$E_{\alpha}(1ab)$ 9.129(22)	$I_{\alpha}(abs)$ 100%	J _f	0.0		1.504(24)	$1.8^{+1.4}_{-0.8}$	
* All val	ues from [2022Te	e01, 2021Sv02].						
Table 13 direct $\alpha$ emis	ssion from ²⁵³ Rf, '	$T_{1/2} = 9.9(12) \text{ m}$	s, $BR_{\alpha} = 17($	6)%.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi} = E_{daugh}$	_{ter} ( ²⁴⁹ No) coincide	ent γ-rays	R ₀ (fm)	HF
9.358(20) 9.460(20)	9.210(20) 9.310(20)	≈67%** 100%**	≈7% ≈10%	0.102 0.0			1.479(46) 1.479(46)	$\approx 1.5$ $\approx 2$

* All values from [2022Lo03],

** estimated by evaluator from Fig. 2 in [2022Lo03] as  $\approx$ 40/60 % for 9.210(20)/9.310(20) MeV.

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +45/2 nuclei.

Last updated 10/21/2024

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +45/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{arepsilon}$	Q _β -	$Q_{\beta}$ - $\alpha$	Experimental
211 <b>D</b> :(A = <b>C</b> )*		0/2-	2 12(2) m	1 266(5)	0.572(5)	9 249(5)	[1045N02]
BI(ACC)*		912	2.15(2) III	-1.500(5)	0.375(3)	0.540(5)	[1905]NU05]
²¹³ At		9/2-	36.3(9) μs	-0.715(7)	-0.088(9)		[2024Ba08]
²¹⁹ Fr		9/2-	22(2) ms**	-0.212(7)	-0.777(10)		[2018Sa45, 1951Me10]
					$Q_{\varepsilon p}$	Qεα	
²²³ Ac		$(5/2^{-})$	2.2(1) m	0.592(7)	-5.842(10)	6.571(7)	[1987Mi10]
²²⁷ Pa		(5/2)	38.3(3) m	1.026(7)	-4.768(8)	7.172(8)	[1951Me10]
²³¹ Np		$(5/2^{-})$	48.8(2) m	1.820(50)	-3.839(51)	7.394(51)	[1973We08]
²³⁵ Am		$(5/2^{-})$	10.3(6) m	2.440(60)	-2.619(53)	8.394(53)	[2004As12, 2004Sa05]
²³⁹ Bk				3.10(26)#	-1.46(22)#	9.64(21)#	
²⁴³ Es		$(7/2^+)$	24.7(8) s***	3.76(28)#	-0.29(25)#	11.17(26)#	[2019Br06, 2010An08, 2004HeZZ, 1973Es02]
²⁴⁷ Md		7/2-	1.26(8) s [@]	4.26(28)#	0.83(23)#	12.52(28)#	[2022He04, 2010An08]
^{247m} Md	0.153(11)	$1/2^{-}$	240(20) ms@@	4.41(30)#	0.98(25)#	12.67(30)#	[2022He04, 2010An08]
²⁵¹ Lr		$(7/2^{-})$	$42^{+42}_{-14}$ ms	4.98(27)#	2.14(22)#	13.73(27)#	[2022Hu21]
^{251m} Lr	0.117(27)	$(1/2^{-})$	$24.4^{+7.0}_{-4.5}$ ms	5.10(27)#	2.25(22)#	13.85(27)#	[2022Hu21]
²⁵⁵ Db			$2.7^{+0.4}_{-0.3}$ ms	5.27(34)#	2.66(30)#	14.32(34)#	[2024PoXX]

* 0.28(10)%  $\beta^{-}$  emitter.

** Weighted average of 28(3) ms [2018Sa45] and 20(2) ms [1951Me10].

*** Weighted average of 24(3) s [2019Br06], 21(2) s [2010An08], 26(1) s [2004HeZZ] and 21(2) ms [1973Es02].

[@] Weighted average of 1.20(12) s [2022He04] and 1.3(1) s [2010An08].

[@] Weighted average of 230(30) ms [2022He04] and 250(40) s [2010An08].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +45/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	BR _{cluster}	type	Experimental
²¹¹ Bi(AcC)	4.420(5)	6.750(1)	99.72(1)%*				[ <b>1971Gr17, 1967Da10, 1965Nu03, 1962Gi04, 1961Ry02</b> , 1970Mu21, 1966Go13, 1965Va10, 1964Co01, 1964Co22, 1963Uh01, 1962Wa18, 1961Br32, 1961Kn02, 1960Ry01, 1960Wa14, 1957Pi31, 1954Br07, 1949Me54, 1948Gh01, 1934Le01, 1933Ro03, 1931Cu01]
²¹⁵ At	4.076(7)	8.178(4)	100%				[1973BoXL, 1973BoXW, 1966Gr07, 2024Ba08, 2018Sa45,
1944Ka02]							1982Bo04, 1951Me10, 1949Me54, 1948Gh01, 1944Ka01,
²¹⁹ Fr	3.889(7)	7.449(2)	100%				[ <b>1968Ba73</b> , 2018Sa45, 1993Li07, 1973BoXL, 1973BoXW,
223	2 70 ((0)	( 702/1)	000		2.2(10) 10-9	14 Cate	19/0Bo13, 1966Gr07, 1951Me10, 1949Me54, 1948Gh01
²²⁵ Ac	3.784(8)	6.783(1)	99%		$3.2(10) \times 10^{-9}$	14C**	[2010GuZZ, 1991Li19, 1987Mi10, 1969LeZW, 1951Me10,
							1990L133, 1990L12Y, 1968Ba73, 1964Su04, 1963Su03,
227 <b>D</b> o	2656(9)	6 580(2)	~ 9501				$[10005h15, 10625u09, 1958\pi178, 1949Me54, 1948O001]$
Га	3.030(8)	0.380(2)	$\approx 65\%$				1958Hi78 1040Me54 1048Gb011
231 Nn	3 280(51)	6 368(51)	< 1%				[19731a06 1950Ma14 1973We08 1971We7P]
235 Am	3.014(53)	6 576(13)	0.40(5)%				$[20044 \le 12, 20048 \ge 0.5, 20008 \ge 7.5, 7.5, 7.5, 7.5, 7.5, 7.5, 7.5, 7.5,$
²³⁹ Bk	2 49(21)#	7 20(20)#	<1%	<1%			[2010An08]
243 Es	1.93(21)#	8 025(10)***	59 7(25)%	<1%			[2010An08, 2006An13, 2019Br06, 2004HeZZ, 1994HoZW]
20	11/0(21)//	0.020(10)	20)11(20)10	(1)0			1989Ha27, 1989HaZG, 1976GhZU, 1973Es02, 1971EsZZ]
²⁴⁷ Md	1.54(21)#	8.764(10)	99.14(10)%	0.86(10)%			[2022He04, 2010An08, 2006An13, 2005He27, 2004HeZZ,
	. ,			. ,			2003HeZY, 1994HoZW, 1981Mu12]
247m Md	1.39(24)#	8.914(15)	80(2)%	20(2)%			[2022He04, 2010An08, 2006An13]
²⁵¹ Lr	1.03(28)#	9.396(13) [@]	100%				[2022Hu21, 2005LeZN]
$^{251m}Lr$	0.91(28)#	9.513(30)	100%				[2022Hu21]
²⁵⁵ Db	0.900(40)#	9.716(27)@@	8(3)%	92(3)%			[ <b>2024PoXX</b> , 2005LeZN]

* Weighted average from  $BR_{\beta}$  of 0.27(1)% [1965Nu03] and 0.29(1)% [1962Gi04].

*** Deduced from  $\alpha$  energy. 8.072(10) MeV in [2021Wa16].

[@] Deduced from  $\alpha$  energy. 9.47(29)# MeV in [2021Wa16].

^{@@} Deduced from  $\alpha$  energy. 9.33(20)# MeV in [2021Wa16].

^{** [2010}GuZZ].

direct $\alpha$ emission from	$^{211}\text{Bi}, J^{\pi} = 9/2^{-}, \text{T}$	$1/2 = 2.13(2) \text{ m}^*, I$	$3R_{\alpha} = 99.72(1)\%^{**}$
-------------------------------	------------------------------------------------	--------------------------------	---------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^{@}$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{207}\text{Tl})^{@@@}$	coincident γ-rays ^{@@@@}	R ₀ (fm)	HF
6.3995(7) 6.7509(6)	6.2782(7)*** 6.6229(6) ^{@@}	19.66(6)% 100%	16.38(4)% 83.34(4)%	3/2 ⁺ 1/2 ⁺	0.3511(1) 0.0	0.3511(1)	1.485(11) 1.485(11)	$\begin{array}{c} 43^{+11}_{-9} \\ 190^{+50}_{-40} \end{array}$

* [1965Nu03].

** Weighted average from BR_β of 0.27(1)% [1965Nu03] and 0.29(1)% [1962Gi04].

*** From 6.2772(7) MeV [61Ry02] modified to 6.2782(7) MeV in [1991Ry01].

[@] [1967Da10].

[@] From 6.6231(6) MeV [71Gr17] modified to 6.6229(6) MeV in [1991Ry01].

@@@ [2011Ko04].

# Table 4

direct  $\alpha$  emission from ²¹⁵At,  $J^{\pi} = 9/2^{-}$ ,  $T_{1/2} = 36.3(9) \ \mu s^*$ ,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@@}$	$E_{daughter}(^{211}\mathrm{Bi})^{@@}$	coincident γ-rays ^{@@}	R ₀ (fm)	HF
7.771(10) 8.173(4)	7.626(10)** 8.026(4)***	5(2)% [@] 100%	4.8(20)% 95.2(20)%	7/2 ⁻ 9/2 ⁻	0.4049 0.0	0.4049	1.5527(30) 1.5527(30)	$1.7^{+1.3}_{-0.5}\\1.24(9)$

* [2024Ba08].

** Energy raised by 26 keV by the evaluator. [1966Gr07] lists the two peaks as  $E_{\alpha}(lab) = 7.600(10)$  and 8.000(10) MeV. A difference of 407.5 keV in the center of mass frame. The first excited state of ²¹¹Bi is known to be 404.9 keV [2013Si17] based on several different reaction studies.

*** [1973BoXL, 1973BoXW].

[@] [1966Gr07]. [@] [2013Si17].

#### Table 5

Table 5				
direct $\alpha$ emission	from ²¹⁹ Fr, J	$\pi = 9/2^{-}, T_1$	$_{/2} = 22(2) \text{ ms*},$	$BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})^{**}$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi***}$	$E_{daughter}(^{215}\text{At})^{***}$	coincident γ-rays	R ₀ (fm)	HF
6.9295(20)	6.8029(20)	0.26%	0.25%	$(13/2)^{-}$	0.5170	0.517	1.5573(32)	6.6
6.9736(25)	6.8462(25)	0.05%	0.05%	$(7/2^{-})$	0.4723	0.1699, 0.3026, 0.4722	1.5573(32)	48
7.0860(30)	6.9566(30)	0.02%	$\approx 0.02\%$	$(13/2^+)$	0.363		1.5573(32)	$\approx 300$
7.0969(20)	6.9673(20)	0.62%	0.6%	(5/2)-	0.3520	0.3520	1.5573(32)	11
7.2786(20)	7.1457(20)	0.21%	0.2%	$(7/2)^{-}$	0.1699	0.1699	1.5573(32)	140
7.4482(20)	7.3122(20)	100.00%	96.8%	9/2-	0.0		1.5573(32)	1.08(31)

* Weighted average of 28(3) ms [2018Sa45] and 20(2) ms [1951Me10].

** [1968Ba73].

*** [1993Li07].

Table 6			
direct $\alpha$ emission from ²²³ Ac,	$J^{\pi} = (5/2^{-}), T_{1/2}$	$= 2.2(1) \text{ m}^*, BH$	$R_{\alpha} = 99\%.$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi}$	$E_{daughter}(^{219}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.000(15)	5.892(15)	0.02%	0.01%	$(9/2)^+)$	0.779	0.0728, 0.1717, 0.5188	1.5439(23)	15
6.076(15)	5.967(15)	0.07%	0.03%	$(5/2^+)$	0.706	0.1717, 0.5188	1.5439(23)	10.8
6.133(15)	6.023(15)	0.02%	0.01%	11/2-	0.650	,	1.5439(23)	59
6.194(15)	6.083(15)	0.07%	0.03	9/2-	0.589	0.0357, 0.0412, 0.424, 0.0569,	1.5439(23)	37
. ,						0.0783, 0.0824, 0.0836, 0.0927,		
						0.0986, 0.1194, 0.3152, 0.5067		
6.247(15)	6.135(15)	0.22%	0.1%	7/2-	0.5338	0.5188	1.5439(23)	20
6.252(15)	6.140(15)	0.07%	0.03%	$(11/2^+)$	0.530	0.530	1.5439(23)	69
6.276(15)	6.163(15)	0.11%	0.05%	$(9/2^+)$	0.5066	0.0357, 0.0412, 0.424, 0.0569,	1.5439(23)	
						0.0783, 0.0836, 0.0927, 0.0986,		
						0.1194, 0.3152, 0.5067		
6.291(15)	6.178(15)	2%	1%	5/2-	0.4903	0.0357, 0.0412, 0.424, 0.0569,	1.5439(23)	53
						0.0783, 0.0836, 0.0927, 0.0986,		
						0.1194, 0.2160, 0.2791, 0.2991,		
						0.3152, 0.4342, 0.4752, 0.5067,		
						0.5188		
6.319(15)	6.206(15)	0.07%	0.03%	(9/2)	0.4622	0.46221.5439(23)	1.5439(23)	140
6.337(15)	6.223(15)	0.02%	0.01%		0.445		1.5439(23)	490
6.350(15)	6.236(15)	0.22%	0.1%	(9/2)	0.4321	0.1264, 0.2160, 0.2161	1.5439(23)	56
6.396(15)	6.281(15)	0.07%	0.03%	$(5/2^+)$	0.3843	0.2857	1.5439(23)	300
6.408(15)	6.293(15)	1.11%	0.5%	$(7/2^+)$	0.3724	0.0357, 0.0412, 0.424, 0.0783,	1.5439(23)	20
						0.0836, 0.0986, 0.1194, 0.231,		
						0.2740, 0.3574, 0.3724		
6.442(15)	6.326(15)	0.67%	0.3%	$(5/2^+)$	0.3403	0.0357, 0.0412, 0.424, 0.0986,	1.5439(23)	46
						0.1194, 0.1248, 0.2057, 0.2417,		
						0.2842, 0.3253		
6.448(15)	6.332(15)	0.31%	0.14%	$(11/2^{-})$	0.336	0.0357, 0.0412, 0.424, 0.0644,	1.5439(23)	103
						0.0783, 0.0836, 0.0986, 0.1194,		
						0.1346, 0.2692, 0.2544, 0.336		
6.458(15)	6.342(15)	0.11%	0.05%		0.325		1.5439(23)	320
6.476(15)	6.360(15)	0.44%	0.2%	(9/2-)	0.3056	0.0836, 0.0985, 0.0897, 0.1194,	1.5439(23)	97
				- 14		0.2070, 0.2160, 0.3055		
6.514(15)	6.397(15)	0.29%	0.13%	7/2-	0.2692	0.0357, 0.0412, 0.424, 0.0783,	1.5439(23)	210
						0.0836, 0.0986, 0.1194, 0.1346,		
	( 110/15)	0.40	0.00	11/0+	0.01/	0.2692, 0.2544	1.5400(00)	220
6.567(15)	6.449(15)	0.4%	0.2%	11/2+	0.216	0.216	1.5439(23)	230
6.5/3(15)	6.455(15)	0.2%	0.1%	3/2+	0.2104	0.1954	1.5439(23)	490
6.591(15)	6.4/3(15)	6.7%	3%	112	0.1913	0.0357, 0.0412, 0.424, 0.0569,	1.5439(23)	19
						0.0783, 0.0836, 0.0927, 0.0986,		
6 612(15)	6 572(15)	1 201	0.60	$(1/2)^{-}$	0 1208	0.1194, 0.1703, 0.1913	1 5420(22)	160
$\frac{0.042(13)}{6.647(15)}$	6.529(15)	1.5%	0.0%	(1/2)	0.1398	0.1246	1.5459(25)	100
0.047(13)	0.328(13)	0.7%	3%	312	0.1344	0.0836, 0.0986, 0.1194	1.5459(25)	33
6.683(15)	6.563(15)	31%	14%	7/2-	0.0986	0.0412, 0.424, 0.0836	1.5439(23)	9.9
6.727(15)	6.606(15)	$<\!\!2\%$	$<\!1\%$	3/2+	0.0562	0.0412	1.5439(23)	>210
6.767(15)	6.646(15)	100%	45%	5/2-	0.015		1.5439(23)	6.6
6.783(15)	6.661(15)	71%	32%	9/2-	0.0		1.5439(23)	11

* [1987Mi10].
*** [1951Mi10].
*** Deduced from α energies, 8.072(10) MeV in [2021Wa16].
[@] Deduced from α energies, 9.47(29)# MeV in [2021Wa16].
[@]@</sup> Deduced from α energies, 9.34(20)# MeV in [2021Wa16].

Table 7	
direct $\alpha$ emission from ²²⁷ Pa*, $J^{\pi} = (5/2)$	2), $T_{1/2} = 38.3(3) \text{ m}^{**}$ , $BR_{\alpha} = \approx 85\%^{**}$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi*}$	$E_{daughter}(^{223}\mathrm{Ac})^*$	coincident γ-rays*	R ₀ (fm)	HF*
(6.391)***		(9/2)-	≈0.8%	≈0.31%	0.185	0.0205, 0.0211, 0.0223, 0.0384, 0.0424, 0.0455, 0.0466, 0.0543, 0.0595, 0.0605, 0.0646, 0.0749, 0.0800, 0.0891, 0.1100, 0.1307	1.5306(28)	52
6.407(3)	6.294(3) [@]	9/2+	≈1.1%	0.47%	0.1677	0.0223, 0.0424, 0.0455, 0.0483, 0.0575, 0.0605, 0.0646, 0.0770, 0.1100, 0.1251	1.5306(28)	40
6.434(3)	6.321(3) [@]	$(11/2^{-})$	$\approx 0.8\%$	≈0.31%	0.1414	0.0507, 0.0424, 0.0483	1.5306(28)	79
6.445(3)	6.331(3) [@]	(7/2 ⁺ )	≈1.4%	0.65%	0.1307	0.0205, 0.0211, 0.0384, 0.0466, 0.0595, 0.0800, 0.0891, 0.1307	1.5306(28)	50
6.465(3) ^{@@}	6.351(3) [@]	(5/2+)	≈5.5%	$\approx 2.8\%$	0.1102	0.0211, 0.0384, 0.0466, 0.0595, 0.0891	1.5306(28)	≈14
		7/2+	$\approx 9.4\%$	≈3.8%	0.1100	0.0223, 0.0424, 0.0455, 0.0605, 0.0646, 0.1100	1.5306(28)	≈9
6.485(3)@@	6.371(3) [@]	9/2-	≈3.3%	$\approx 1.4\%$	0.0907	0.0424, 0.0483	1.5306(28)	$\approx 30$
		7/2-	$\approx 2.1\%$	$\approx 0.85\%$	0.891	0.0384, 0.0466, 0.0891	1.5306(28)	$\approx 50$
		$(3/2^+)$	$\approx 1.0\%$	$\approx 0.43\%$	0.0889	0.0889	1.5306(28)	$\approx 100$
6.511(3)	6.396(3) [@]	5/2+	$\approx 18.8\%$	≈7.7%	0.0646	0.0223, 0.424, 0.0605, 0.0646	1.5306(28)	7.0
6.525(3)	6.410(3) [@]	5/2-	$\approx 30\%$	$\approx 12\%$	0.0507	0.0507	1.5306(28)	5.1
6.533(3)	6.418(3) [@]	7/2-	$\approx 23\%$	$\approx 9.4\%$	0.0424	0.424	1.5306(28)	7.1
(6.580)***		3/2-	$\approx 11.5\%$	≈4.7% ^{@@@@}	0.0041		1.5306(28)	21@@@
6.576(3)	6.460(3) [@]	5/2-	100%	$\approx 41\%$	0.0		1.5306(28)	2.5

* HF, Level energies and coincident  $\gamma$ 's are taken from [1990Sh05].  $I_{\alpha}$  (rel) values are deduced by the evaluator from the HF values. Note that the values are very close to those of [1963Su10]. ** [1951Me10].

*** Not observed as a individual resolved peak. Deduced by [1990Sh15] from  $\alpha$ - $\gamma$  coincidences.

@ [1963Su10].

@@ Likely an unresolved multiplet.

[@]@[@] Deduced from [1990Sh05] by setting  $I_{\alpha}(tot) = 100\%$ .

#### Table 8

direct  $\alpha$  emission from ²³¹Np,  $J^{\pi} = (5/2)$ ,  $T_{1/2} = 48.8(2)$  m*,  $BR_{\alpha} = <1\%^{**}$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{227}\mathrm{Pa})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.368(8)	6.258(8)***	<1%**	(5/2)	0.0		1.510(25)	>1.5
* [1973We03 ** [1950Ma *** [1973Jat	8]. 14]. 06].						

# Table 9

direct  $\alpha$  emission from ²³⁵Am*,  $J^{\pi} = (5/2^{-})$ ,  $T_{1/2} = 10.3(6)$  m,  $BR_{\alpha} = 0.40(5)\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}^{\pi}_{f}$	$E_{daughter}(^{231}\mathrm{Np})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.569(14)	6.457(14)	0.40(5)%	(5/2 ⁻ )	0.0		1.518(17)	$1.1\substack{+0.6 \\ -0.4}$

# * All values from [2004As12, 2004Sa05].

# Table 10

direct  $\alpha$  emission from ²⁴³Es*,  $J^{\pi} = (7/2^+)$ ,  $T_{1/2} = 10.3(6)$  m,  $BR_{\alpha} = 59.7(25)\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{239}\mathrm{Bk})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.875(20)	7.745(20)	5.4(16)%	x2.5(3)%		0.150(22)	1.502(31)	500	
7.981(20) 8.025(10)	7.850(20) 7.893(10)	20.5(30)% 100(5)%	x9.7(15)% x47.4(24)%		0.044(22) 0.0	1.502(31)	290 1.502(31)	90

* All values from [2010An08], except where noted.

#### **Table 11** direct $\alpha$ emission from ²⁴⁷Md, $J^{\pi} = 7/2^{-}$ , $T_{1/2} = 1.26(8)$ s*, $BR_{\alpha} = 99.14(10)\%^{**}$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	$J_f^{\pi**}$	Edaughter( ²⁴³ Es)**	coincident γ-rays**	R ₀ (fm)	HF
8.474(10)	8.337(10)@	6.5(11)%***	6(1)%		0.304	0.2940	1.511(22)	9+7
8.509(13)	8.371(13)**	0.0(11)/1	-(-)/-	$(7/2^{-})$	0.2714	0.2714		-4
8.549(7)	8.411(7)@@	100%	92(1)%***	$(5/2^{-})$	0.230	0.1381, 0.1640	1.511(22)	$1.0^{+0.7}_{-0.4}$
8.560(10)	8.421(10)**			$(7/2^{-})$	0.219	0.1571, 0.2096, 0.2190		-0.4
8.758(20)	8.616(20)**	2.2(11)%	2(1)%***	$(7/2^+)$	0.0		1.511(22)	$240^{+310}_{-140}$

* Weighted average of 1.20(12) s [2022He04] and 1.3(1) s [2010An08].

** [2022He04]. No Intensities were reported in this work.

*** [2010An08].

[@] Weighted average of 8.334(11) MeV [2022He04] and 8.345(20) MeV [2010An08].

^{@@} Weighted average of 8.406(10) MeV [2022He04] and 8.416(10) MeV [2010An08].

Note that there seems to be considerable disagreement in both isomers between [2022He04] and [2010An08], with different  $\alpha$  transitions reported.

Table 12		
direct $\alpha$ emission from ^{247m} Md, Ex. = 153(11) keV, $J^{\pi} = 1/2^{-}$ , T	$_{1/2} = 240(20) \text{ ms*},$	$BR_{\alpha} = 99.14(10)\%^{**}.$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	$J_f^{\pi**}$	$E_{daughter}(^{243}\text{Es})^{**}$	coincident γ-rays**	R ₀ (fm)	HF
8.540(5)	8.402(5)**				0.391	0.2421		
8.590(11) 8.803(20)	8.451(11)** 8.660(20)***	20(6)%***	14(5)%	(3/2 ⁻ )	0.3421 0.125	0.3421	1.511(22)	$9^{+8}_{-5}$
8.864 8.928(40)	8.720** 8.783(40)***	100%***	66(8)%	$(1/2^{-})$ $(3/2^{-})$	0.068 0.0		1.511(22)	$4.3^{+3.2}_{-2.1}$

* Weighted average of 230(30) s [2022He04] and 250(40) s [2010An08].

** [2022He04]. No Intensities were reported in this work.

*** [2010An08].

[@] Weighted average of 8.334(11) MeV [2022He04] and 8.345(20) MeV [2010An08].

^{@@} Weighted average of 8.406(10) MeV [2022He04] and 8.416(10) MeV [2010An08].

Note that there seems to be considerable disagreement in both isomers between [2022He04] and [2010An08], with different  $\alpha$  transitions reported.

#### Table 13

direct  $\alpha$  emission from ²⁵¹Lr*,  $J^{\pi} = (7/2^{-})$ ,  $T_{1/2} = 42^{+42}_{-14}$  ms,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{247}\mathrm{Md})$	coincident γ-rays	R ₀ (fm)	HF
9.396(19)	9.246(19)	100%	(7/2-)	0.0		1.486(28)	$1.3^{+1.9}_{-0.8}$

* All values taken from [2022Hu21].

# Table 14

direct $\alpha$ emiss	lirect $\alpha$ emission from ^{251m} Lr*, Ex = 117(27), $J^{\pi} = (1/2^{-})$ , $T_{1/2} = 24.4^{+7.0}_{-4.5}$ ms, $BR_{\alpha} = 100\%$ .							
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{m \pi}$	$E_{daughter}(^{247}Md)$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
9.359(19)	9.210(19)	100%	(1/2 ⁻ )	0.153(11)		1.486(28)	$0.6\substack{+0.6 \\ -0.3}$	
* All valu	ues taken from [202	22Hu21].						
Table 15 direct $\alpha$ emiss	sion from ²⁵⁵ Db*, '	$\Gamma_{1/2} = 2.6^{+0.4}_{-0.3} \text{ m}$	as, $BR_{\alpha} = 8(3)\%$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{251}\mathrm{Lr})$	coincident γ-rays	$R_0$ (fm)	HF	
9.439(47)	9.291(47)	8(3)%	(7/2-)	0.0?		1.472(45)	$0.2^{+0.5}_{-0.2}$ ***	

* All values taken from [2024PoXX].

** [2024PoXX] measured three correlated  $\alpha$ s with energies of 9245(47), 9396(47), and 9232(47) keV. The value presented here is a weighted average of the three.

*** The reason for the unphysically low HF is unknown.

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +23 nuclei.

Last updated 6/3/2024

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +23$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{arepsilon}$	Q _β -	$Q_{\beta}$ - $\alpha$	Experimental
210 0 0 0	0+	22.22/12)	5 401 (10)	0.0(4/1)	5 200(2)	
²¹⁰ Pb(RaD)*	$0^+$	22.23(12) y	-5.481(12)	0.064(1)	5.280(2)	[2008ChZV]
214 Po(RaC')	$0^{+}$	163.45(4) µs	-3.269(11)	-1.091(4)		[2015Al10]
²¹⁸ Rn(Em)	$0^+$	33.75(15) ms	-2.883(12)	-1.842(4)		[2012Su11]
²²² Ra	$0^+$	33.17(10) s	-2.058(9)	-2.302(6)		[1995Ko54]
²²⁶ Th	$0^+$	30.70(3) m	-1.112(5)	-2.836(12)		[2012Po13]
²³⁰ U	$0^+$	20.23(2) d	-0.392(2)	-3.620(60)		[2012Po12]
				$Q_{\varepsilon p}$	Qεα	
²³⁴ Pu	$0^+$	8.7(1) h**	0.395(11)	-3.858(7)	5.752(7)	[1973Ja06, 1949Pe04]
²³⁸ Cm	$0^+$	2.2(4) h	1.020(60)	-2.935(12)	7.065(15)	[2006As03]
²⁴² Cf	$0^+$	3.49(10) m***	1.64(14)#	-1.604(13)	8.541(60)#	[1970Si19, 1967Si07, 1967Il01, 1967Fi04]
²⁴⁶ Fm	$0^+$	1.54(4) s	2.370(90)	-0.483(14)	10.015(135)	[2011Ve03]
²⁵⁰ No	$0^+$	4.7(1) µs	3.17(22)#	0.76(20)#	11.32(22)#	[2022Te01]
²⁵⁴ Rf	$0^+$	23.2(11) µs	3.56(30)#	1.55(28)#	12.38(30)#	[2015Da12]
²⁵⁸ Sg	$0^+$	$2.6^{+0.6}_{-0.4}$ ms	3.79(42)#	2.14(41)#	13.23(42)#	[2009Fo02]

*  $\approx 100\% \beta^{-}$  emitter. ** Weighted average of 8.8(1) h [1973Ja06] and 8.5(1) h [1949Pe04]. *** Weighted average of 3.68(44) m [1970Si19], 3.4(2) m [1967Si07], 3.7(3) m [1967II01] and 3.2(5) m [1967Fi04].

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +23$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	$BR_{\alpha}$	BR _{SF}	BR _{cluster}	type	Experimental
²¹⁰ Pb(RaD) ²¹⁴ Po(RaC')	8.373(6) 6.527(5)	3.792(20) 7.834(0)	$\frac{1.9(3) \times 10^{-6}\%*}{100\%}$				[ <b>1964Wo05, 1962Ka27</b> , 1969Ho26] [ <b>1976Ku08, 1971Gr17, 1961Ry02</b> , 2022Be20, 2016Al28, 2015Al10, 2013Al11, 2013Be10, 2012Su11, 2011AlZX, 1993Zh30, 1973BoXL, 1973BoXW, 1971Er02, 1965Le08, 1962Br22, 1961Do02, 1960Og01, 1960Ry01, 1953Ba60, 1950Vo02]
²¹⁸ Rn	6.466(5)	7.262(2)	100%				[1995Ko54, 1973BoXL, 2012Su11, 1971Er02, 1963Di08,
²²² Ra	6.246(6)	6.678(4)	100%		$2.64(31)\times 10^{-8}\%^{**}$	¹⁴ C	1963Le17, 1962Di08, 1961Ru06, 1958To25, 1948St42] [ <b>1995Ko54, 1991Hu02, 1985Ho21, 1985Pr01, 1956As38</b> , 2012Po13, 1991HuZY, 1991LeZV, 1987BaZS, 1976Ka08, 1975VaZD, 1969Pe17, 1964Ba49, 1963Le17, 1961Fo08, 1961Ru06, 1960Be25, 1958To25, 1956Sm88, 1948St42]
²²⁶ Th	5.729(6)	6.453(1)	100%				<b>2012Ma30, 1995Ko54, 1976Ku08</b> , 2012Po13, 1987Mi10, 1975VaZD, 1974KaZM, 1969Br10, 1968GuZU, 1963Le17, 1961Ry06, 1956As38, 1953AsZZ, 1948St42]
²³⁰ U	5.571(5)	5.992(1)	100%		$4.8(20)  imes 10^{-12}\%$	²² Ne	[2012Ma30, 2001Bo11, 1995Ko54, 1976Ku08, 2012Po12, 2000Pa54, 1999Pa22, 1996Tr10, 1974KaZM, 1969Pe17, 1966Ba14, 1963Le17, 1961Ru06, 1956As38, 1953AsZZ, 1948St42]
²³⁴ Pu	4.888(51)	6.310(5)	pprox 6%				[ <b>1964Hy02</b> , 1973Ja06, 1952Or03, 1949Pe04]
²³⁸ Cm ²⁴² Cf	4.413(61)# 3.88(17)#	6.670(10) 7.517(4)	obs*** 61(3)%	$\leq 0.014\%$			[2006As03, 2002As08. 2002AsZX, 1952Hi63] [2011Ve03, 1995La09, 1970Si19, 1985HiZU, 1981Mu12, 1967Fi04, 1967II01, 1967Si07]
²⁴⁶ Fm	3.41(17)#	8.379(5)	93.6(4)% [@]	6.4(4)% [@]			[2022Is05, 2012Pi05, 2011Ve03, 2015Sv02, 2012Sv01, 2011PiZW, 2010An08, 2010Sv01, 2010SvZW, 2010SvZX, 1982Bo21, 1982BoZN, 1980Ho25, 1980Vi04, 1975Og02, 1970Dr05, 1967Fi15, 1967Nu01, 1966Ak01]
²⁵⁰ No	2.90(26)#	8.95(20)#		100%			[2022Kh08, 2022Te01, 2020Ku23, 2020SvZZ, 2006Pe17,
²⁵⁴ Rf	2.61(33)#	9.21(20)#	≤1.5 %	100%			2006PeZ Y, 2003Be18, 2003Po08, 2003 Ye02, 2001Og08] [ <b>2015Da12, 1997He29</b> , 2022IsZZ, 2020Kh01, 2020SuZZ, 2016KhZZ, 2008Dr05, 1999He11, 1996HeZZ] ^{<i>a</i>}
²⁵⁸ Sg	2.15(44)#	9.67(30)#		100%			[1997He29, 2009Fo02, 1999He11, 1996HeZZ]

* Weighted average of  $2.7(6) \times 10^{-6}\%$  [1964Wo05] and  $1.7(3) \times 10^{-6}\%$  [1962Ka27].

** Weighted average of  $2.31(31) \times 10^{-8}\%$  [1991Hu02],  $3.1(10) \times 10^{-8}\%$  [1985Ho21] and  $3.7(6) \times 10^{-8}\%$  [1985Pr01].

*** [1952Hi63] report an  $\varepsilon$ /6.520 MeV  $\alpha$  =240(50). This produces an BR $_{\alpha}$  = 0.54(10)% with a corresponding HF = 6.4 for the 0⁺ to 0⁺ transition. Using an BR $_{\alpha}$  = 3.5% produces a HF = 1.0.

[@] Weighted average of 93.2(6)% [2011Ve03] and 93.9(5)% [2022Is05].

^{*a*} In addition [1976FIZN] and 1975Te01] reported SF from this nuclide with a half-life values of 0.5(2) ms. As this value does not agree with later work, this assignment seems to be in error.

# Table 3

direct $\alpha$ emission	direct $\alpha$ emission from ²¹⁰ Pb, $J^{\pi} = 0^+$ , $T_{1/2} = 22.23(12)$ y*, $BR_{\alpha} = 1.9(3) \times 10^{-6}\%$ **							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{206}\mathrm{Hg})$	coincident $\gamma$ -rays	R ₀ (fm)	HF	
3.792(20)	3.720(20)***	$1.9(3)  imes 10^{-6}\%^{**}$	$0^+$	0.0		1.449(21)	$0.99\substack{+0.19\\-0.14}$	

* [2008ChZV].

** Weighted average of  $2.7(6) \times 10^{-6}\%$  [1964Wo05] and  $1.7(3) \times 10^{-6}\%$  [1962Ka27].

*** [1962Ka27].

direct $\alpha$ emission from ²¹⁴	Po, $J^{\pi} = 0^+$ , $T_{1/2}$	$_2 = 163.45(4) \ \mu s^*, BR_{\alpha} = 100\%$
----------------------------------------------	---------------------------------	-------------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^{**}$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	<i>E</i> _{daughter} ( ²¹⁰ Pb)**	coincident γ-rays**	R ₀ (fm)	HF
6.864 7.1675 7.83324(7)	(6.736)**;@ (7.0335)**;@ 7.68682(7)***	$5(2)  imes 10^{-5}\%$ 0.0104(6)% 100%	$5(2) \times 10^{-5}\%$ 0.0104(6)% 99.99%	$4^+ \\ 2^+ \\ 0^+$	1.098 0.7997 0.0	0.298, 0.7997 0.7997	1.539616(24) 1.539616(24) 1.539616(24)	$470^{+320}_{-140} \\ 27(2) \\ 0.9980(3)$

* [2015Al10].

** [1976Ku08]. *** Weighted average of 7.68709(68) MeV [1971Gr17] (adjusted to 7.68683(68) MeV in [1991Ry01] and 7.68695(75) MeV [1961Ry02] (adjusted to 7.68634(75) MeV in [1991Ry01] [@]  $\alpha$  not observed, inferred from observed  $\gamma$ 's from the  $\alpha$  decay of ²¹⁴Po [1976Ku08].

#### Table 5

direct $\alpha$ emission from ²	18 Rn*, J ^{$\pi$} = 0 ⁺ , 7	$\Gamma_{1/2} = 33.75(15) \text{ ms}^{**},$	$BR_{\alpha} = 100\%$
--------------------------------------------	-----------------------------------------------------------------	---------------------------------------------	-----------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{214}\text{Po})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.963 6.642 7.262(2)	5.854 6.52 7.129(2)	$\begin{array}{l} 9(3)\times 10^{-5}\%\\ 0.127(4)\%\\ 100\% \end{array}$	$9(3)  imes 10^{-5}\%$ 0.127(4)% 99.870(4)%	$(3^+)$ $2^+$ $0^+$	1.2746(2) 0.60931(1) 0.0	0.60931(1), 0.6653(2) 0.60931(1)	1.56062(74) 1.56062(74) 1.56062(74)	$10^{+5}_{-3} \\ 4.79(18) \\ 0.996(5)$

* All values taken from [1995Ko54], except where noted.

** [2012Su11].

#### Table 6

direct  $\alpha$  emission from ²²²Ra*, J^{$\pi$} = 0⁺, T_{1/2} = 33.17(10) s, *BR*_{$\alpha$} = 100%

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi**}$	<i>E</i> _{daughter} ( ²¹⁸ Rn)	coincident $\gamma$ -rays	R ₀ (fm)	HF
5 839(5)	5 734(5)	$444(21) \times 10^{-3}\%$	$43(2) \times 10^{-3}\%$	$(3^{-})$	0 8402	0 3243 0 5158 0 8402	1 5492(18)	4 36(32)
5.882(5)	5.776(5)	$4.56(11) \times 10^{-3}\%$	$4.42(11) \times 10^{-3}\%$	$(3^{-})$	0.7969	0.1449, 0.3243, 0.3289,	1.5492(18)	9.3(6)
						0.4726, 0.6531, 0.7968		
6.026(5)	5.918(5)	$4.51(11) \times 10^{-3}\%$	$4.37  imes 10^{-3}\%$	$(4^{+})$	0.6532	0.3243, 0.3289, 0.6531	1.5492(18)	33.8(20)
6.355(5)	6.241(5)	3.17(9)%	3.07(9)%	$2^{+}$	0.3243	0.3243	1.5492(18)	1.44(8)
6.679(5)	6.559(5)	100(2)%	96.92(10)%	$0^+$	0.0		1.5492(18)	0.9962(32)

* All values taken from [1995Ko54], except where noted.

# ** [2019Si39].

# Table 7

	direct	14 C	c emission	from	²²² Ra, J ²	$\tau = 0^+$	$T_1$	$_{2} = 33.17($	10) s*.	$BR_{14c}$	= 2.64(31)	$) \times 10^{-3}$	8%**
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<i>E</i> _{14<i>C</i>} (c.m.)	$E_{14C}(\text{lab})$	$I_{14C}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{208}\text{Pb})$	coincident $\gamma$ -rays
33.012(90)	30.930(90)	$2.64(31)  imes 10^{-8}\%^{**}$	0+	0.0	

* [1995Ko54].

Table 0				
direct $\alpha$ emission f	rom ²²⁶ Th, J	$\pi = 0^+, T_{1/2}$	= 30.70(3) m*,	$BR_{\alpha} = 100\%$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@}$	E _{daughter} ( ²²² Ra) [@]	coincident γ-rays***	R ₀ (fm)	HF
5.4275(10)***	5.3314(10)	$1.5 \times 10^{-3}\%$	$1.13  imes 10^{-3}\%$ ***	(2+)	1.0249	0.1112, 0.1310, 0.2063, 0.2421, 0.7075, 0.7229, 0.7829, 0.9139	1.53749(45)	0.59
5.5382(10)***	5.4402(10)	$4.2 \times 10^{-3}\%$	$3.2 \times 10^{-3}\%$ ***	(0+)	0.9142	0.1112, 0.1310, 0.2421, 0.6970, 0.8027	1.53749(45)	0.86
5.9785(10)***	5.8727(10)	$4 \times 10^{-4}\%$	$3 \times 10^{-4}\%$ ***	(5 ⁻ )	0.4739	0.1112, 0.1310, 0.1725, 0.1903, 0.2063, 0.2421	1.53749(45)	$1.7 \times 10^{3}$
6.1357(10)	6.0271(10)**	0.305(7)%	0.230(5)%**	(3)-	0.3173		1.53749(45)	12.38(27)
6.1514(10)	6.0425(10)**	0.240(5)%	0.181(4)%**	4+	0.3015	0.1112, 0.1310, 0.1903, 0.2063, 0.2421	1.53749(45)	18.6(4)
6.2101(10)	6.1002(10)**	1.68(1)%	1.27(1)%**	1-	0.2422	0.1112, 0.1310, 0.2421	1.53749(45)	4.98(4)
6.3413(10)	6.2291(10)**	30.42(13)%	22.93(9)%**	$2^{+}$	0.1111	0.1111	1.53749(45)	1.072(4)
6.4524(10)	6.3382(10)**	100.0(19)%	75.39(10)%**	$0^+$	0.0		1.53749(45)	0.9954(17)

* [2012Po13].

** [2022Ma30].

*** [1995Ko54].  $Q_{\alpha}$  values deduced from coincident  $\gamma$ 's.

@ [2023Si22].

#### Table 9

direct  $\alpha$  emission from ²³⁰U, J^{$\pi$} = 0⁺, T_{1/2} = 20.23(2) d*, BR_{$\alpha$} = 100%

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi **}$	$E_{daughter}(^{226}\text{Th})^{**}$	coincident γ-rays**	R ₀ (fm)	HF
5.1354(10)	5.0461(10)	$pprox 7.1  imes 10^{-5}\%$	$pprox 4.8  imes 10^{-5}\%$	(2+)	0.8565(3)	0.07218, 0.08103, 0.15424, 0.23532, 0.54905, 0.62622,	1.53197(29)	$\approx 1.5$
5 1/28(10)	5.05/2(10)	$\sim 1.1 \times 10^{-4}$ %	$\sim 7.5 \times 10^{-4} \% **$	(2+)	0.8481(2)	0.78423, 0.8565	1 52107(20)	$\sim 1.7$
5.1458(10)	5.0545(10)	~1.1 × 10 %	~7.5 × 10 %	(2*)	0.8481(2)	0.23037, 0.23532, 0.54056, 0.61768, 0.7754, 0.8478	1.55197(29)	$\approx 1.7$
5.1870(10)	5.0968(10)	$1.1^{+3.6}_{-0.5} \times 10^{-4}\%$	$7.5^{+2.4}_{-0.4} \times 10^{-4}\%^{**}$	(2 ⁺ )	0.8049(3)	0.07218, 0.23037 0.57457, 0.7328, 0.8049	1.53197(29)	$3.1^{+1.5}_{-0.3}$
5.2237(10)	5.1329(10)	$4.9^{+2.2}_{-0.6} \times 10^{-4}\%$	$3.3  {}^{+1.5}_{-0.4}  imes 10^{-4} \%^{@}$		0.7682(1)	0.07218, 0.6960	1.53197(29)	$12^{+10}_{-2}$
5.5412(10)	5.4448(10)	$\approx 4.9 \times 10^{-4}\%$	$\approx 3.3 \times 10^{-4}\%^{@}$		0.45071(3)	0.07218, 0.15424, 0.22429	1.53197(29)	$\approx 870$
5.5445(10)	5.4481(10)	$pprox 8.9  imes 10^{-6}\%$	$pprox 6.0  imes 10^{-5}\%^{@}$		0.4474(5)	0.07218, 0.15424, 0.2210	1.53197(29)	$pprox 5  imes 10^3$
5.6847(10)	5.5858(10)***	0.0193(15)%	0.013(1)%***	(3 ⁻ )	0.30749(2)	0.07218, 0.08103, 0.15424, 0.23037, 0.23532	1.53197(29)	134(10)
5.7621(10)	5.6619(10)***	0.39(13)%	0.26(9)%***	1-	0.23037(1)	0.07218, 0.15424, 0.23037	1.53197(29)	$17^{+9}_{-5}$
5.7651(10)	5.6648(10)***	0.56(13)%	0.38(9)%***	$4^{+}$	0.22642(2)	0.07218, 0.15424	1.53197(29)	$12_{-2}^{+4}$
5.9197(10)	5.8167(10)***	47.40(36)%	31.95(22)%***	$2^{+}$	0.07218(1)	0.07218	1.53197(29)	0.917(13)
5.9919(10)	5.8877(10)***	100.00(48)%	67.4(23)%***	$0^+$	0.0		1.53197(29)	0.998(34)

* [2012Po13].

** [1995Ko54].  $Q_{\alpha}$  values deduced from coincident  $\gamma$ 's.

*** [2012Ma30].

@ [1976Ku08].

#### Table 10

direct  $\alpha$  emission from ²³⁴Pu*, J^{$\pi$} = 0⁺, T_{1/2} = 8.7(1) h***, BR_{$\alpha$} =  $\approx 6\%$ 

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi***}$	$E_{daughter}(^{230}\mathrm{U})^{***}$	coincident γ-rays***	R ₀ (fm)	HF
6.130 6.252	6.025 6.145	0.6% 47%	$\approx 0.024\%$ $\approx 1.9\%$	$4^+_{2^+}$	0.1693 0.0517	0.0517, 0.1693 0.0517	1.518(27) 1.518(27)	$\approx 25$ $\approx 1.1$
6.304	6.196	100%	$\approx 4.1\%$	$\bar{0}^{+}$	0.0		1.518(27)	$\approx 0.9$

* All values from [1964Hy02] p. 799 (based on unpublished results from R. W. Hoff, F. Asaro, I. Perlman [1960Ho18]), except where noted. ** Weighted average of 8.8(1) h [1973Ja06] and 8.5(1) h [1949Pe04].

*** [2012Br12].

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{234}\mathrm{Pu})$	coincident γ-rays***	R ₀ (fm)	HF
6.614(10) 6.670(10)	6.503(11) 6.558(10)	30(8)% 100(8)%		0+	0.056(7) 0.0		1.4805(90) 1.4805(90)	

* All values from [2006As03], except where noted.

direct  $\alpha$  emission from ²³⁸Cm^{*}, J^{$\pi$} = 0⁺, T_{1/2} = 2.2(4) h, BR_{$\alpha$} = obs^{**}

** [1952Hi63] report an  $\varepsilon/6.520$  MeV  $\alpha$  =240(50). This produces an BR $_{\alpha}$  = 0.54(10)% with a corresponding HF = 6.4 for the 0⁺ to 0⁺ transition. Using an BR $_{\alpha}$  = 3.5% produces a HF = 1.0.

#### Table 12

direct $\alpha$ emission from	242 Cf, J ^{$\pi$} = 0 ⁺	$T_{1/2} = 3.49(10) \text{ m*},$	$BR_\alpha=61(3)\%^{**}$
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{238}\mathrm{Cm})$	coincident γ-rays	R ₀ (fm)	HF
7.482(6) 7.516(4)	7.358(6) 7.392(4)	pprox 20% pprox 100%	$\approx 10\% \\ \approx 51\%$	0+	0.035(7) 0.0		1.4986(78) 1.4986(78)	$\approx 3.5$ $\approx 0.9$

* Weighted average of 3.68(44) m [1970Si19], 3.4(2) m [1967Si07], 3.7(3) m [1967Il01] and 3.2(5) m [1967Fi04]. ** [2011Ve03].

Table 13

direct $\alpha$ emission from ²⁴⁶	Fm, $J^{\pi} = 0^+$ , $T_1$	$_{/2} = 1.54(4) \text{ s*}, BR$	$\alpha = 93.6(4)\%^{**}$
----------------------------------------------	-----------------------------	----------------------------------	---------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{242}\mathrm{Cf})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
8.380(7)	8.244(7)***	93.6(4)%**	$0^+$	0.0		1.506(12)	0.820(22)

* [2011Ve03].

** Weighted average of 93.2(6)% [2011Ve03] and 93.9(5)% [2022Is05].

*** [2012Pi05].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +23 nuclei.

Last updated 10/21/2024

Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +23$ nuclei	. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein. The $J^{\pi}$ value for ²⁰⁸ Tl is taken from ENSDF.	

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	Q _β -	Q _β - α	$BR_{\beta} - \alpha$	$\mathrm{BR}_{\varepsilon F}$	Experimental
²⁰⁸ Tl(ThC")*		$5^{+}$	3.0527(33) m	-3.480(30)	4.998(2)	5.695(2)			[1971Ac02]
$^{212}\text{Bi(ThC)}$		1-	60.600(43) m	-0.569(2)	2.252(2)	11.386(2)			[1961Ap03]
^{212m} Bi	0.239(30)	(9-)	25.0(2) m	-0.340(30)	2.491(30)	11.625(30)	30(1)%		[2013Ch12, 1984Es01, 1980Le27,
									1978Ba44, 1978BaYL, 1978BaZIJ
²¹⁶ At		1-	300(30) µs	0.474(4)	$Q_{\varepsilon p}$ -6.662(7)	$Q_{\varepsilon\alpha}$ 7.381(4)			[1951Me10]
^{216m1} At	0.048(24)	$(4^{-})$	× / <b>·</b>	0.522(24)	-6.614(25)	7.429(24)			[1994Li10, 1971Br13, 1965Br11]
^{216m2} At	0.399(30)	(9-)		0.873(30)	-6.263(31)	7.780(30)			[1994Li10, 1971Br13, 1965Br11]
²²⁰ Fr		$1^{+}$	27.4(3) s	0.870(4)	-6.203(5)	7.275(4)			[1971Br13]
²²⁴ Ac		$0^{-}$	2.78(16) h**	1.408(4)	-5.437(4)	7.197(4)			[1951Me10, 1987Mi10]
²²⁸ Pa		3+	19.5(4) h	2.153(4)	-4.215(5)	7.673(5)			[2021Km01]
²³² Np		$(4^{+})$	14.7(3) m	2.75(10)#	-3.35(10)#	8.16(10)#			[1970Ho27]
²³⁶ Am		$5^{-}$	3.6(2) m	3.14(12)#	-2.29(12)#	9.01(12)#			[2005As01]
²⁴⁰ Bk			4.8(8) m	3.94(15)#	-1.02(15)#	10.34(15)#		$1.3^{+1.8}_{-0.7} \times 10^{-3}\%$	[1983Ga05, 1980Ga07, 1980GaZZ]
²⁴⁴ Es			37(4) s	4.55(18)#	0.05(18)#	11.88(18)#		0.012(4) %	[2002Sh02, 1980Ga07, 1980GaZZ]
²⁴⁸ Md			$13^{+3}_{-2}$ s	5.05(18)#	1.08(19)#	13.05(18)#		< 0.05%	[2024PoXY]
²⁵² Lr			$410^{+70}_{-50}$ ms	5.67(19)#	2.28(19)#	14.21(19)#			[2024PoXY]
²⁵⁶ Db			$1.4_{-0.2}^{+0.3}$ s	6.08(19)#	3.06(19)#	15.00(19)#			[2024PoXY]
²⁶⁰ Bh			$35^{+19}_{-9}$ ms	6.58(20)#	3.84(20)#	16.48(20)#			[2008Ne01]

* 100%  $\beta^-$  emitter. ** Weighted average of 2.9(2) h [1951Me10] and 2.55(28) h [1987Mi10].

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +23$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	Experimental
²⁰⁸ Tl(ThC")	7.552(30)	1.22(20)			
²¹² Bi(ThC)	4.914(3)	6.207	35.94(3) %*		[1971Gr17, 1962Be09, 1960Sc07, 1960Wa14, 1984Es01,
					1969Gr28, 1966Il01, 1966KIZZ, 1963Co28, 1961Ap03,
					1961Ba12, 1961Fe04, 1960Ga15, 1960Gi07, 1960Ha19,
					1958De25, 1956Ho11, 1956Ko60, 1955We10, 1949Me54,
					1948Gh01, 1943Ka05, 1933Ru03]
^{212m} Bi	4.675(30)	6.446(30)	67(1)%		[ <b>1984Es01</b> , 1978Ba44]
²¹⁶ At	4.491(4)	7.950(3)	100%		[1994Li10, 1971Br13, 1965Br11, 1973BoXL, 1973BoXW,
					1964Br16, 1964Mc21, 1962Wa28, 1951Me10, 1949Me54,
					1948Gh01]
^{216m1} At	4.443(24)	7.998(24)	obs		[1994Li10, 1971Br13, 1965Br11]
^{216m2} At	4.092(20)	8.349(30)	obs		[1994Li10, 1971Br13, 1965Br11]
²²⁰ Fr	4.636(4)	6.801(2)	99.65%		[1996Sh05, 1971Br13, 1974Ho27, 1973ChZH, 1970Br29,
					1968Ba73, 1964Br16, 1964Mc21, 1951Me10, 1949Me54,
224					1948Gh01]
²²⁴ Ac	4.288(4)	6.327(1)	10(2)%		[1968Le17, 1992Li31, 1951Me10, 1987Mi10, 1976MiZR,
					1973ChZH, 1970Br31, 1969LeZW, 1968Ba73, 1968Br15,
220					1967Br15, 1964Mc21, 1958Hi78, 1949Me54, 1948Gh01]
²²⁸ Pa	4.170(5)	6.265(1)	2.0(2)%		[ <b>1994Ah03</b> , 1993Sh07, 1964Ge08, 1958Hi78, 1951Me10,
222					1949Me54, 1948Gh01]
²³² Np	3.74(10)#	6.01(10)#			
²³⁰ Am	3.43(12)#	6.256(64)	$4.0(10) \times 10^{-5}\%$		[ <b>2004Sa05, 2002As08</b> , 1989HaZO]
²⁴⁰ Bk	2.77(21)#	7.20(19)#	. 1 2		
²⁴⁴ Es	2.25(26)#	7.696(20)**	$4^{+3}_{-2}\%$		[1973Es02]
²⁴⁸ Md	2.01(26)#	8.785(47) [@]	61(16)-68(22)%		[ <b>2024PoXY</b> , <b>1973Es01</b> , 2008Ne01, 1971EsZY, 1971EsZZ]
²⁵² Lr	1.60(26)#	9.132(47)@@	70-90%		[ <b>2024PoXY</b> , <b>2001He35</b> , 2008Ne01, 1999He07, 1999HeZX]
²⁵⁶ Db	1.32(26)#	9.265(47) ^{@@@@}	90(4)%	10(4)%	[ <b>2024PoXY</b> , <b>2001He35</b> , 2020Ku23, 1999He07, 1999He11,
260-					1999HeZXJ
²⁰⁰ Bh	0.69(27)#	10.400(59)	100%	$<\!18\%$	[ <b>2008Ne01</b> , 1983OgZX]

* Weighted average of 35.81(4) % [1962Be09], 35.96(6) % [1960Sc07] and 36.00(3) % [1962Wa14].

** Deduced from  $\alpha$  energy, 7.94(10) MeV in [2021Wa16].

*** Weighted average of 70(11) % [2008Ne01] and 64(12) % [2001He35]. ^(a) Deduced from  $\alpha$  energy, 8.497(30) MeV in [2021Wa16]. ^(a) Deduced from  $\alpha$  energy, 9.164(17) MeV in [2021Wa16].

[@] Deduced from  $\alpha$  energy, 9.336(30) MeV in [2021Wa16].

Table 3 direct  $\alpha$  emission from ²¹²Bi, J^{$\pi$} = 1⁻, T_{1/2} = 60.600(43) m^{*}, BR_{$\alpha$} = 35.94(3) %^{**}.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\mathrm{rel})^{@@}$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi a}$	$E_{daughter}(^{208}\mathrm{Tl})$	coincident $\gamma$ -rays ^a	$R_0 (fm)^b$	HF
5.399	5.297***	1.6(4)×10 ⁻⁴ %	1.4(4)×10 ⁻⁵ %		0.803	0.0399, 0.0430, 0.1420, 0.1436, 0.2669, 0.2854, 0.2888, 0.3104, 0.4337, 0.4530, 0.4730	1.495(21)	$1.8^{+1.1}_{-0.7}{\times}10^4$
5.443	5.340***	$1.4 \times 10^{-3}\%$	3.6×10 ⁻⁴ %		0.759	0.0399, 0.1420, 0.1436, 0.2669, 0.2854, 0.2888, 0.4337, 0.4530, 0.4730	1.495(21)	$3.4 \times 10^{3}$
5.581	5.476***	0.020%	$5.0  imes 10^{-3}\%$		0.521		1.495(21)	$3.8 \times 10^{3}$
5.710	5.602***	1.7%	0.43%	$(3)^{+}$	0.492	0.0399, 0.4530	1.495(21)	60
5.729	5.621***	0.24%	0.06%	$(4^{+})$	0.473	0.0399, 0.4337, 04730	1.495(21)	540
5.874 6.63291(26) 6.20699(34)	5.763*** 6.50776(26) [@] 6.08988(34) [@]	2.3(2)% 100.0(4)% ^{@@@} 38.5(7)% ^{@@@}	0.59(4)% ^{@@@} 25.2(1)% 9.7(2)%	$5^+$ $4^+$ $5^+$	0.328 0.0398 0.0	0.0399, 0.2882, 0.3280 0.0399	1.495(21) 1.495(21) 1.495(21)	$260^{+150}_{-100} \\ 110^{+70}_{-40} \\ 430^{+250}_{-160}$

* [1961Ap03].

** Weighted average of 35.81(4) % [1962Be09], 35.96(6) % [1960Sc07] and 36.00(3) % [1962Wa14].

*** Values from [1960Wa14], adjusted by -0.7 MeV in [1991Ry01].

@ Values from [1991Ry01], based on measured values from [1971Gr17].

@@ Values from [1960Wa14], except where noted.

@@@ [1982Be09].

^{*a*} [2007Ma45]. ^{*b*} Interpolated between 1.449(21) fm ( 210 Pb) and 1.539616(24) fm ( 214 Po).

# Table 4

direct  $\alpha$  emission from ^{212m}Bi*, Ex. = 239(30) keV**, J^{$\pi$} = (9⁻), T_{1/2} = 25.0(2) m, BR_{$\alpha$} = 67(1) %.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{208}\text{Tl})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
5.861	5.750	1.4(6)%	0.5(2)%	(6+)	0.617	0.0399, 0.1436, 0.2882, 0.2888, 0.3280, 0.4337, 0.4730	1.495(21)	$80_{-40}^{+80}$
6.129	6.013	14(3)%	5(1)%	5+	0.3280	0.0399, 0.2882, 0.3280	1.495(21)	$160^{+100}_{-70}$
6.418 6.458	6.297 6.336	74(4)% 100(3)%	26(1)% 35(1)%	4+ 5+	0.0399 0.0	0.0399	1.495(21) 1.495(21)	$\begin{array}{r} 480\substack{+270\\-180}\\520\substack{+290\\-190}\end{array}$

* All values from [1984Es01], except where noted.

** [2013Ch12].

*** Interpolated between 1.449(21) fm ( 210 Pb) and 1.539616(24) fm ( 214 Po).

# Table 5

 $\beta^-$ -delayed  $\alpha$  emission from ^{212m}Bi*,  $BR_\beta - \alpha = 30(1)$  %**.

$E_{\alpha}$ (c.m.)	$E_{\alpha}$ (lab.)	$I_{\alpha}(\text{rel})\%^{***}$	$I_{\alpha}(abs)\%$	$E_{emitter}$ ( ²¹² Po)	$E_{daughter}(^{208}\text{Pb})$	
10.702(10)	10.500(10)	$\approx 2\%$	$\approx 1.5\%$	1.75	0.0	
10.610(10)	10.410(10)	$\approx 9\%$	$\approx 6\%$	1.655	0.0	
10.565(10)	10.366(10)	$\approx 7\%$	$\approx 4.5\%$	1.610	0.0	
10.531(10)	10.332(10)	$\approx 9\%$	$\approx 6\%$	1.575	0.0	
10.500(10)	10.302(10)	≈11%	$\approx 7.5\%$	1.545	0.0	
10.426(5)	10.229(5)	$\approx 100\%$	$\approx 66$	1.474	0.0	
10.304(5)	10.110(5)	$\approx 95\%$	$\approx 63\%$	1.354	0.0	
10.201(10)	10.009(10)	$\approx 5\%$	$\approx 3\%$	1.247	0.0	
10.086(5)	9.896(5)	$\approx 18\%$	$\approx 12\%$	1.131	0.0	

* All values taken from [1980Le27], except where noted.

** [1984Es01].

*** estimated by the evaluator based on Fig. 1 in [1980Le27].

# Table 6 direct $\alpha$ emission from ²¹⁶At*, J^{$\pi$} = 1⁻, T_{1/2} = 300(30) $\mu$ s**, BR_{$\alpha$} = 100 %.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	E _{daughter} ( ²¹² Bi)	coincident $\gamma$ -rays	$R_0 \; (fm)^{@ \; @ \; @ \; }$	HF
7 457(17)	7 319(17)	≈0.09%	≈0.09%	$(3^{-})$	0 4946(3)	0 1512 0 3793	1 55012(74)	$\approx 77$
7.534(17)	7.394(17)	$\approx 0.28\%^{@}$	$\approx 0.27\%^{\circ}$	$(2^{-})$	0.4179(2)	0.0979, 0.1512, 0.2048, 0.4179	1.55012(74)	$\approx 45$
7.536(17)	7.396(17)	$\approx 0.28\%$ [@]	$\approx 0.27^{@}$	$1^{-}$	0.4153(3)	0.1512, 0.1767, 0.2386, 0.3000	1.55012(74)	$\approx 46$
7.701(17)	7.558(17)	0.07(3)%	0.07(3)%	(4 ⁻ )	0.2507(4)	0.0376, 0.0979, 0.1152	1.55012(74)	$600^{+500}_{-200}$
7.738(17)	7.595(17)	0.16(5)%	0.16(5)%	3-	0.2131(2)	0.0979, 0.1152	1.55012(74)	$330_{-110}^{+200}$
7.836(17)	7.691(17)	1.4(2)%	1.4(2)%	$2^{-}$	0.1152(1)	0.1152	1.55012(74)	$73^{+22}_{-16}$
7.947(10)	7.800(10)	100%	97.5(2)%	$1^{-}$	0.0		1.55012(74)	2.29(28)

* All values taken from [1994Li10], except where noted. This work states that the resolution of the  $\alpha$  detector had a resolution of 17 keV (see Fig. 1 from this Ref.). Note that [1965Br11, 1971Br13] see the same  $\alpha$  transitions without listing uncertainties.

** [1951Me10].

*** [1964Mc21].

^(a) unresolved doublet. The  $I_{\alpha} = 0.27\%$  is shared between them. ^(a) Interpolated between 1.539616(24) fm (²¹⁴Po) and 1.56062(74) fm (²¹⁸Rn).

#### Table 7

direct  $\alpha$  emission from ^{216m1}At*, Ex. = 48(24) keV, J^{$\pi$} = (4⁻), BR_{$\alpha$} = obs.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\boldsymbol{\pi}}$	$E_{daughter}(^{212}\mathrm{Bi})$	coincident γ-rays	$R_0$ (fm)	HF			
7.629(17)	7.488(17)	obs	(6-)	0.381	0.1034					
* All values taken from [1994Li10].										
Table 8 direct $\alpha$ emiss	ion from ^{216m2} At*,	Ex. = 399(30) ke	eV, $J^{\pi} = (9^{-}), I$	$BR_{\alpha} = \text{obs.}$						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{212}\mathrm{Bi})$	coincident $\gamma$ -rays	R ₀ (fm)	HF			
8.110	7.960	obs	(6 ⁻ )	0.239(30)						

* All values taken from [1994Li10].

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irect $\alpha$ emission from ²²⁰ Fr*, J ^{$\pi$} = 1 ⁺ , T _{1/2} = 27.4(3) s**, <i>BR</i> _{$\alpha$} = 99.65%**	*.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi@}$	$E_{daughter}(^{216}\mathrm{At})$	coincident γ-rays [@]	$R_0 (fm)^{@@}$	HF
6.3759	6.260 [@]	<0.008%	<0.005%@		0.423		1.5549(19)	$> 2.6 \times 10^{3}$
6.4198(30)	6.3031(30)	$\approx 0.024\%$	$\approx 0.015\%$		0.3790(36)	0.0446, 0.1421, 0.1545	1.5549(19)	$\approx 1.3 \times 10^3$
						0.2080, 0.3239, 0.3810		
6.4818(25)	6.3639(25)	$\approx 0.02\%$	≈0.01%		0.3171(32)		1.5549(19)	$\approx 3.6 \times 10^3$
6.4963(20)	6.3782(20)	0.57%	0.35%		0.3025(28)	0.0446, 0.0613, 0.0649,	1.5549(19)	119
( 5207(20)	( 4021/20)	2.040	1.050	(4-)	0.0790(09)	0.1969, 0.2582, 0.3028	1.5540(10)	12
6.5207(20)	6.4021(20)	2.04%	1.25%	(4)	0.2782(28)	0.0446, 0.0613, 0.0649,	1.5549(19)	42
						0.1561, 0.2211, 0.2356		
6.5466(20)	6.4276(20)	0.39%	0.24%		0.2522(28)	0.0446, 0.0964, 0.1328	1.5549(19)	280
6.5641(25)	6.4448(25)	< 0.02% [@]	<0.01%@		0.2347(32)	0.0446, 0.0613, 0.0649,	1.5549(19)	$>7.8 \times 10^{3}$
						0.1059, 0.1287		
6.5913(25)	6.4715(25)	2.1%	1.3%	$(1,2)^{-}$	0.2075(32)	0.0446, 0.1634, 0.2080	1.5549(19)	77
6.6001(25)	6.4801(25)	1.0%	0.6%	(3)-	0.1987(32)	0.0446, 0.1421, 0.1545	1.5549(19)	180
6.6291(25)	6.5086(25)	$\approx 1.0\%$	$\approx 0.6\%$	(3 ⁻ )	0.1697(32)	0.0446, 0.1121	1.5549(19)	$\approx 240$
6.6372(25)	6.5165(25)	4.9%	3.0%	(1)-	0.1616(32)	0.0446, 0.0548, 0.0613,	1.5549(19)	51
						0.0649, 0.1059, 0.1162,		
						0.1607		
6.6450(25)	6.5242(25)	4.1%	2.5%	(2)-	0.1538(32)	0.0446, 0,1088, 0.1534	1.5549(19)	66
6.6744	6.5530 [@]	<1.0%	$<\!\!0.6\%^{@}$	$(5^{-})$	0.1245(20)	0.0446, 0.0964	1.5549(19)	> 360
6.6929(20)	6.5712(20)	16.0%	9.8%	$(0)^{-}$	0.1059(28)	0.0446, 0.0613, 0.0649,	1.5549(19)	26
						0.1059		
6.7421(25)	6.6195(25)	10.6%	6.5%	(4-)	0.0567(32)	0.0446	1.5549(19)	61
6.7538(20)	6.6310(20)	19.9%	12.2%	$(2)^{-}$	0.0450(28)	0.0446	1.5549(19)	36
6.7988(20)	6.6752(20)	100%	61.3%	$1^{-}$	0.0		1.5549(19)	10.6

* All values taken from [1968Ba73], except where noted. Energy values are adjusted by +1.5 keV from [1991Ry01] due to changes in calibration energies. ** [1974Ho27]. *** [1971Br13] reported 0.35%  $\beta^+$ . @ [1996Sh05]. @@ Interpolated between 1.56062(74) fm (²¹⁸Rn) and 1.5492(18) fm (²²²Ra).

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi@}$	$E_{daughter}(^{220}\mathrm{Fr})$	coincident $\gamma$ -rays [@]	$R_0 (fm)^{@@}$	HF
5.7469(25)	5.6443(25)	0.23%	0.006%	J	0.5799(26)		1.5433(19)	100
5.8167(20)	5.7128(20)	0.47%	0.012%		0.5101(21)	0.4912	1.5433(19)	120
5.8258(20)	5.7218(20)	0.47%	0.012%		0.5009(21)	0.0486, 0.0555, 0.0791, 0.0819, 0.0973, 0.2013, 0.2253, 0.2277, 0.2613, 0.2631, 0.2738, 0.2876,	1.5433(19)	130
5.9472(25)	5 7409(25)	0.2001	0.0050		0.470(/2/)	0.300	1.5422(10)	400
5.8472(25)	5.7428(25)	≈0.20%	≈0.005%	( <b>-</b> +)	0.4796(26)		1.5433(19)	400
5.8767(20)	5.7718(20)	0.94%	0.024%	(5 ' )	0.4500(21)	0.0484, 0.0555, 0.0791, 0.0819, 0.0973, 0.2631, 0.2876, 0.300	1.5433(19)	120
5.8847(20)	5.7796(20)	0.23%	0.006%		0.4421(21)		1.5433(19)	330
5.9123(25)	5.8067(25)	$\approx 0.08\%$	$\approx 0.002\%$		0.4145(26)		1.5433(19)	210
5.9468(15)	5.8406(15)	1.02%	0.026%		3.800(17)		1.5433(19)	230
5.9508(7)	5.8445(7)	2.2%	0.055%		0.3760(10)	0.1031, 0.3284, 0.3643	1.5433(19)	120
5.9610(25)	5.8546(25)	≈0.27%	≈0.007%	(4 ⁻ )	0.3657(26)	0.016, 0.0204, 0.0246, 0.0484, 0.0498, 0.0531, 0.0543, 0.0607, 0.0730, 0.0923, 0.1042, 0.1289, 0.1633, 0.1648, 0.1869, 0.2715	1.5433(19)	1×10 ³
5.9642(20)	5.8577(20)	0.98%	0.025%	2-	0.3626(21)	0.0484, 0.0875, 0.2253, 0.2613, 0.2738	1.5433(19)	290
5.9706(14)	5.8640(14)	2.9%	0.075%		0.3562(16)	0.0484, 0.0555, 0.0791, 0.0819, 0.2631, 0.2876, 0.300	1.5433(19)	110
5.9777(10)	5.8710(10)	0.39%	0.01%	(3 ⁺ )	0.3490(12)	0.3280	1.5433(19)	90
5.9872(14)	5.8803(14)	6.6%	0.17%	0-	0.3396(16)	0.0246, 0.0404, 0.0484, 0.0531, 0.0607, 0.0666, 0.0923, 0.1284, 0.1407, 0.1995, 0.2253, 0.2613, 0.2738, 0.2876, 0.300	1.5433(19)	56
6.0128(14)	5.9054(14)	0.59%	0.015%	(4 ⁻ )	0.3140(16)		1.5433(19)	80
6.0200(20)	5.9125(20)	0.59%	0.015%		0.3068(21)		1.5433(19)	90
6.0272(14)	5.9196(14)	3.7%	0.094%	$1^{+}$	0.2995(16)	0.0484, 0.2876, 0.300	1.5433(19)	160
6.0537(14)	5.9456(14)	17.2%	0.44%		0.2731(16)	0.0484, 0.2253, 0.2613, 0.2738	1.5433(19)	45
6.0699(20)	5.9615(20)	$\approx 0.16\%$	$\approx 0.004\%$		0.2569(21)		1.5433(19)	$5.8 \times 10^{3}$
6.0801(14) 6.1128(14)	5.9715(14) 6.0036(14)	0.78% 26%	0.02% 0.67%	4-	0.2467(16) 0.2140(16)	0.016, 0.0204, 0.0246, 0.0359, 0.0373, 0.0484, 0.0498, 0.0531, 0.0543, 0.0730, 0.0923, 0.1042, 0.1289, 0.1415, 0.1586, 0.1648, 0.1945, 0.2076	1.5433(19) 1.5433(19)	1.3×10 ³ 55
6.1270(14) 0.0730	6.0176(14)	5.5%	0.14%	5+	0.1998(16)	0.0543, 0.0669, 0.0728,	1.5433(19)	310
6.1700(7)	6.0598(7)	85.6%	2.19%	$2^{-}$	0.1568(10)	0.016, 0.0543, 0.0730, 0.0923	1.5433(19)	31
6.2534(7)	6.1417(7)	100%	2.56%		0.0734((10))	0.0246, 0.0484, 0.0531, 0.0607	1.5433(19)	63
6.2709(7)	6.1589(7)	4.02%	0.103%	5+	0.0559(10)	0.0359	1.5433(19)	$1.9 \times 10^{3}$
6.3199(7)	6.2070(7)	46.5%	1.19%	3+	0.0069(10)		1.5433(19)	280
6.3268(7)	6.2138(7)	79.7%	2.04%	$1^{+}$	0.0		1.5433(19)	170

# Table 10 direct $\alpha$ emission from ²²⁴Ac*, J^{$\pi$} = 0⁻, T_{1/2} = 2.78(16) h**, BR_{$\alpha$} = 10(2)%***.

* All values taken from [1968Le17], except where noted. Energy values are adjusted by +3.8 keV from [1991Ry01] due to changes in calibration energies.

** Weighted average of 2.9(2) h [1951Me10] and 2.55(28) h [1987Mi10]. *** [1951Me10]. @ [1992Li31].

[@] Interpolated between 1.5492(18) fm ( 222 Ra) and 1.53749(45) fm ( 226 Th)

Table 11			
direct $\alpha$ emission from	²²⁸ Pa*, $J^{\pi} = 3^+$ , $T_{1/2}$	$h_2 = 19.5(4) h^{**}$	$BR_{\alpha} = 2.0(2)\%$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{224}\mathrm{Ac})$	coincident γ-rays	R ₀ (fm)***	HF
5.813(2)	5.711(2) [@]	5.1(6)%	0.020(2)%		0.448, 0.451	0.0260, 0.0263, 0.0283, 0.0288, 0.0298, 0.0346, 0.0411, 0.0433, 0.0465, 0.0486, 0.0498, 0.0518, 0.0520, 0.0521, 0.0531, 0.0542, 0.0603, 0.0674, 0.0693, 0.0741, 0.0760, 0.0801, 0.0812, 0.1103, 0.1225, 0.1955, 0.3178, 0.3556	1.53473(54)	$40^{+8}_{-6}$
5 861(2)	5 758(2)	15 4(13)%	0.060(4)%		0.4028	0.0283_0.0433_0.3224	1 53473(54)	23+4
5.868(2)	5 765(2)	13.4(13)%	0.050(4)%		0.3956	0.3172 0.3470	1.53473(54) 1.53473(54)	$29_{-3}$ 29 ⁺⁵
5.883(2)	5.780(2)	6.7(8)%	0.026(3)%		0.3807	0.0263, 0.0283, 0.0288, 0.0298, 0.0346, 0.0433, 0.0486, 0.0498, 0.0518, 0.0521, 0.0212, 0.2505, 2003, 0.2286, 0.2510	1.53473(54)	$70^{+14}_{10}$
5.904(2)	5.800(2)	54.9(37)%	0.214(12)%	(3+)	0.3602	0.0812, 0.2503, .3003, 0.3280, 0.3510 0.0263, 0.0283, 0.0288, 0.0298, 0.0346, 0.0433, 0.0486, 0.0498, 0.0518, 0.0521, 0.0812, 0.2300, 0.2795, 0.3080, 0.3304	1.53473(54)	$10.8^{+1.7}_{-1.3}$
5.910(2)	5.806(2)	35.4(24)%	0.138(8)%		0.3539	0.0603, 0.2375, 0.2447, 0.3168	1.53473(54)	$17.9^{+2.8}_{-2.2}$
5.931(2)	5.827(2)	29.7(37)%	0.116(14)%	(3+)	0.3330	0.0263, 0.0283, 0.0288, 0.0298, 0.0346, 0.0433, 0.0486, 0.0498, 0.0518, 0.0521, 0.0603, 0.0672, 0.0812, 0.2027, 0.2225, 0.2425,0.2526, 0.2801, 0.2840, 0.2959, 0.3032	1.53473(54)	274 ⁺⁶
5.948(2)	5.844(2)	$\approx 2.1\% \approx$	0.008%		0.316		1.53473(54)	$\approx 480$
5.964(2)	5.859(2)	$\approx 1.5\%$	$\approx 0.006\%$		0.301		1.53473(54)	≈760
5.980(2)	5.875(2)	6.7(6)%	0.026(2)%		0.2834	0.2601, 0.2462	1.53473(54)	$210^{+40}_{-30}$
6.010(2)	5.905(2)	5.1(5)%	0.020(2)%		0.2526	0.0260, 0.0263, 0.0283, 0.0288, 0.0298, 0.0346, 0.0411, 0.0433, 0.0465, 0.0486, 0.0498, 0.0518, 0.0520, 0.0521, 0.0531, 0.0542, 0.0603, 0.0674, 0.0693, 0.0741, 0.0760, 0.0801, 0.0812, 0.1103, 0.1225	1.53473(54)	$390^{+80}_{-60}$
6.027(2)	5.921(2)	4.1(5)%	0.016(2)%		0.2365	0.0260, 0.0263, 0.0283, 0.0288, 0.0298, 0.0346, 0.0411, 0.0433, 0.0465, 0.0486, 0.0498, 0.0518, 0.0520, 0.0521, 0.0542, 0.0598, 0.0603, 0.0674, 0.0734, 0.0812	1.53473(54)	590 ⁺¹³⁰ -90
6.046(2)	5.940(2)	2.6(5)%	0.010(2)%		0.218		1.53473(54)	$1.2^{+0.4}_{-0.2} \times 10^3$
6.052(2)	5.946(2)	3.1(5)%	0.012(2)%		0.212		1.53473(54)	$1.0^{+0.3}_{-0.2} \times 10^3$
6.081(2)	5.974(2)	12.8(11)%	0.050(4)%	(5 ⁻ )	0.1833	0.0263, 0.0283, 0.0288, 0.0298, 0.0346, 0.0433, 0.0486, 0.0498, 0.0518, 0.0521, 0.0531, 0.0542, 0.0603, 0.0741, 0.0801, 0.0812	1.53473(54)	$340^{+60}_{-50}$
6.088(2)	5.981(2)	13.3(11)%	0.052(4)%		0.1767	0.0260, 0.0263, 0.0283, 0.0288, 0.0298, 0.0346, 0.0411, 0.0433, 0.0465, 0.0486, 0.0498, 0.0518, 0.0520, 0.0521, 0.0542, 0.0603, 0.0674, 0.0734, 0.0812	1.53473(54)	$350^{+60}_{-50}$
6.095(2)	5.988(2)	5.1(5)%	0.020(2)%		0.169		1.53473(54)	$990^{+150}_{-140}$
6.104(2)	5.997(2)	$\approx 1.5\%$	$\approx 0.006\%$		0.160		1.53473(54)	$\approx 3.6 \times 10^3$
6.117(2)	6.010(2)	4.1(5)%	0.016(2)%		0.147		1.53473(54)	$1.5^{+0.3}_{-0.2} \times 10^3$
6.135(2)	6.027(2)	43.6(26)%	0.170(8)%	(4+)	0.1302	0.0263, 0.0283, 0.0288, 0.0298, 0.0346, 0.0433, 0.0486, 0.0498, 0.0518, 0.0521, 0.0812	1.53473(54)	$178 ^{+24}_{-20}$
6.148(2)	6.040(2)	11.3(16)%	0.044(6)%	(4-)	0.1164	0.0260, 0.0283, 0.0411, 0.0433, 0.0520	1.53473(54)	$800^{+180}_{-130}$
6.155(3)	6.047(3)	$\approx 1.5\%$	$\approx 0.006\%$	(4 ⁻ )	0.1093	0.0603	1.53473(54)	$\approx 6.3 \times 10^3$
6.160(3)	6.052(3)	$\approx 3.6\%$	$\approx 0.014\%$	$(4^{+})$	0.1032	0.0542	1.53473(54)	$\approx 2.9 \times 10^3$
6.173(2)	6.065(2)	5.1(10%	0.020(4)%	+	0.0905	0.0672	1.53473(54)	$2.3^{+0.7}_{-0.5} \times 10^3$
6.185(2)	6.076(2)	100(5)%	0.390(15)%		0.0804	0.0283, 0.0433	1.53473(54)	$133^{+19}_{-15}$
6.198(2)	6.089(2)	11.3(16)%	0.044(6)%	(3 ⁺ )	0.0644	0.0411	1.53473(54)	$1.4^{+0.3}_{-0.2} \times 10^3$
6.213(2)	6.104(2)	57.9(37)%	0.226(12)%	$(2^+)$	0.0521	0.0288, 0.0346, 0.0521	1.53473(54)	$310^{+50}_{-40}$
6.226(2)	6.117(2)	50.8(31)%	0.198(10)%	(2 ⁻ )	0.0371		1.53473(54)	$420^{+00}_{-50}$
6.235(3)	6.126(3)	$\approx 5.1\%$	$\approx 0.020\%$	$(1^{+})$	0.0298	0.0298	1.53473(54)	$\approx$ 4.4 $\times$ 10 ³

* All values taken from [1994Ah03], except where noted.
*** [2021Ku01].
*** Interpolated between 1.53749(45) fm (²²⁶Th) and 1.53197(29) fm (²³⁰U).
@ Unresolved doublet feeding 448 and 451 keV states [1994Ah03].

<ul> <li>≈6.256</li> <li>* All valu</li> <li>** [2005A</li> <li>*** Interp</li> <li>able 13</li> <li>irect α emissi</li> </ul>	$\approx$ 6.150 es taken from [200 As01]. polated between 1.	4.0(10)×10 ⁻³ 02As08, 2004Sa 518(27) fm ( ²³⁴	% (4 ⁺ ) a05], except wh	0.0 ere noted.	_	-	1.499(28) 0.	$9^{+1.0}_{-0.5}$
* All valu ** [2005 *** Interp <b>able 13</b> irect α emissi	es taken from [200 As01]. Polated between 1.	02As08, 2004Sa 518(27) fm ( ²³⁴	a05], except wh	ere noted.				
<b>able 13</b> irect α emissi	ion from ²⁴⁴ Es*, 7		1 u aliu 1.4803(	(90) fm ( ²³⁸ Cm	).			
	,	$\Gamma_{1/2} = 37(4) \text{ s, } E$	$BR_{\alpha} = 4^{+3}_{-2}\%.$					
$C_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{240}\mathrm{B}$	k) coinciden	t $\gamma$ -rays R ₀ (fr	m)** HF	
.696(20)	7.570	(20)	$4^{+3}_{-2}\%$		0.0?		1.502(14)	$5^{+6}_{-3}$
* All value ** Interpo	es taken from [20 lated between 1.4	02As08, 2004Sa 986(78) fm ( ²⁴²	a05], except wh Cf and 1.506(1	ere noted. 2) fm ( ²⁴⁶ Fm).				
<b>able 14</b> irect α emissi	ion from ²⁴⁸ Md*,	$T_{1/2} = 13^{+3}_{-2} s, t$	$BR_{\alpha} = 61(16) - 6$	58(22)%.				
$L_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{244}\mathrm{Es})$	coincident γ-ra	ys R ₀ (fm)	HF
.182(47)	8.050(47)	100%	≈28-31%			1.499(20)	≈1.8-2.0	
.253(47)	8.120(47)	$\approx 44\%$	≈12-13%			1.499(20)	$\approx$ 7-8	
.334-8.741	8.200-8.600	$\approx 66\%$	≈19-20%			1.499(20)	≈9-170	2
* All valu ** Interpo	es taken from [20] lated between 1.5	24PoXY], excep 06(12) fm ( ²⁴⁶ F	ot where noted. Fm) and 1.491(1	6) fm ( ²⁵⁰ No.				
able 15								
irect $\alpha$ emissi	ion from ²⁵² Lr*, 7	$\Gamma_{1/2} = 410^{+70}_{-50} \mathrm{m}$	as, $BR_{\alpha} = 70-90$	)%.				
$Z_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${\sf J}_f^{\pi}$	$E_{daughter}(^{248}Md)$	coincident $\gamma$ -rays	$R_0^{@@@}$ (fm)	HF [@]
.306(20)	8.174(20)**						1.484(53)	6.9**
.027(47)	8.884(47)	$\approx 56\%$	18-23%				1.484(53)	≈5-7
.073(47)	8.929(47)	$\approx 100\%$	32-41%				1.484(53)	$\approx$ 4-5
.132(47)	8.987(47)	$\approx 67\%$	21-27%		0.0?		1.484(53)	≈10-11
* All value ** [2001F *** In add	es taken from [20] He25]. lition to these tran	24PoXY], exceptsions, [2008N	ot where noted. e01] report cor	related $\alpha$ 's of 8	.82 and 9.61 MeV.			
[@] Interpol	lated between 1.49	91(16) fm ( ²⁵⁰ N	o and 1.477(51	) fm ( ²⁵⁴ Rf).				

|--|

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{252}\mathrm{Lr})$	coincident $\gamma$ -rays	R ₀ (fm)	HF [@]
9.032(20)	8.891(20)***	$\approx 16\%$	$\approx 7\%$		0.233			22
9.157(20)	9.014(20)	100%	$\approx 45\%$		0.108			11
9.219(20)	9.075(20)***	$\approx 16\%$	$\approx 7\%$		0.046			86
9.265(20)	9.120(20)***	$\approx 16\%$	$\approx 7\%$		0.0?			114

* All values taken from [2001He25], except where noted.
** [2024PoXY].
*** Tentative assignment [2001He25]. Similar values of 8.890(47) MeV (≈20%), 8.930(47) MeV (≈20%), 8.980(47) MeV (≈30%) and 9.02-9.20 MeV (≈30%) reported in [2024PoXY].
[@] Taken directly from [2001He25].
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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$  = +47/2 nuclei.

Last update 7/17/2024

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +47/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

	-	- 77	-	2	0	0	
Nuclide	Ex.	$J^{\kappa}$	$T_{1/2}$	$Q_{\varepsilon}$	Q _β -	$Q_{\beta} - \alpha$	Experimental
²⁰⁷ Hg*		$(9/2^{+})$	2.9(2) m	-5.85(30)#	4.550(30)	4.411(30)	[ <b>1981.JoZW</b> ]
²¹¹ Pb(AcB)*		9/2+	36.164(13) m	-4.420(40)	1.366(5)	8.296(6)	[2016Ai01]
²¹⁵ Po(AcA)		9/2+	1.780(4) ms**	-2.171(6)	0.715(7)	9.072(5)	[2023Ta02, 1961Vo06]
219 Rn(An)		5/2+	3.96(1) s	-1.567(3)	0.212(7)	7.841(7)	[1966Hu20, 1999Li05]
²²³ Ra(AcX)		3/2+	11.4354(17) d	-1.149(1)	-0.592(7)	6.371(7)	[2015Co02]
²²⁷ Th(RdAc)		$(1/2^+)$	18.681(9) d	-0.045(1)	-1.026(7)	5.735(7)	[2019Ko06]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
²³¹ U		$(5/2^{-})$	4.2(1) d	0.382(2)	-4.346(2)	5.532(3)	[1949Os01]
²³⁵ Pu		$(5/2^+)$	25.8(1) m***	1.139(20)	-3.252(20)	6.333(21)	[1973Jo03, 1971Ke22]
^{235m} Pu	3.00(20)		3.0(5) ns	4.14(20)	-6.25(20)	0.33(20)	[1970Bu02, 1971Br39]
²³⁹ Cm		$(7/2^{-})$	2.7(8) h	1.76(15)	-2.301(15)	7.68(15)	[2008Qi03]
²⁴³ Cf		$(1/2^+)$	10.3(5) m	2.30(18)#	-1.10(18)#	9.17(18)#	[1967Si08]
²⁴⁷ Fm		$(7/2^+)$	31(1) s	3.09(18)#	0.29(18)#	10.56(18)#	[2006He27]
^{247m} Fm	0.047(5)	$(1/2^+)$	5.1(2) s	3.14(18)#	0.35(18)#	10.61(18)#	[2006He27]
²⁵¹ No		$(7/2^+)$	0.80(1) s	3.88(18)#	1.49(18)#	11.85(18)#	[2006He27]
^{251m} No	0.106(6)	$(1/2^+)$	1.02(3) s	3.99(18)#	1.60(18)#	11.96(18)#	[2006He27]
²⁵⁵ Rf		(9/2-)	1.66(7) s@	4.38(18)#	2.32(18)#	12.94(18)#	[2006He27, 2001He35]
²⁵⁹ Sg		$(1/2^+)$	402(56) ms	4.53(19)#	2.89(18)#	14.15(18)#	[2015An05]
^{259m} Sg	0.087(22)	$(11/2^{-})$	226(27) ms	4.64(19)#	2.98(18)#	14.24(18)#	[2015An05]
²⁶³ Hs			$0.74^{+0.48}_{-0.21}$ ms	5.18(36)#	4.02(20)#	15.26(21)#	[2009Dr02]
²⁶⁷ Ds			$4 \mu s^{-0.21}$	6.09(54)#	5.45(21)#	16.96(37)#	[1995Gh05]

* 100%  $\beta^-$  emitter. ** Weighted average of 1.781(5) ms [2023Ta02] and 1.778(5) ms [1961Vo06]. *** Weighted average of 25.6(1) m [1973Jo03] and 25.9(1) m [1971Ke22]. @ Weighted average of 25.6(1) m [1973Jo03] and 25.9(1) m [1971Ke22].

[@] Weighted average of 1.68(9) s [2006He27] and 1.64(11) s [2001He35].

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +47/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BR _α	BR _{SF}	BR _{cluster}	type	Experimental
20711~	0.50(20)#	0 60(20)#					
$211 \text{ Pb}(\Lambda c \mathbf{R})$	9.39(30)#	0.00(20)#					
215 Po(AcA)	6.535(12)	7.526(1)	00,00077(2)%				[1008] ;53 1071C+17 1050Av61 2023T-02 2010M-02
I U(ACA)	0.030(11)	7.520(1)	99.99911(2) <i>1</i> 0				1006Wi27 1070Be58 1076B113 1071Er02 1071Gr17
							$1967D_{2}20$ 1965V ₂ 10 1962W ₂ 18 1961R _v 02 1961V ₀ 06
							1960Rv02, 1950Av61, 1962Wa16, 1961Ry02, 1961V000,
219 Rn(An)	6 560(12)	6 9462(3)	100%				[ <b>1999</b> ] <b>i05</b> 2019Ma02 2015Co07 2015Pi10 1989It01
<b>i</b> iii(i iii)	01000(12)	019 102(0)	10070				1979Be58 1974Bo11 1972NoZZ 1970Da09 1970Kr01
							1970Kr01, 1970Kr08, 1967Le05, 1962Wa18, 1961Ro14,
							1961Ry02, 1960Ry02, 1960Wa16]
²²³ Ra(AcX)	6.434(8)	5.9790(2)	100%		8.9(4)×10 ⁻⁸ %	¹⁴ C	[1998Sh02, 1995Ho11, 1992Ar02, 1962Wa18, 1971Gr17.
							2021Si11, 2019Ma02, 2016Jo02, 2015Be13, 2015Co02,
							2015Co07, 2015Ko06, 2015Pi10, 1991Ho15, 1990Hu02,
							1990Hu07,1990We01, 1989Br34, 1987Mi10, 1985Al28,
							1985Ku24, 1985Pr01, 1984Al34, 1984Ga38, 1984Ro30,
							1976B113, 1974Ri05, 1971Gr17, 1970Da08, 1970Kr01,
							1969Be67, 1968Br37, 1968Be37, 1967JoZX, 1965Ki05,
							1962Gi04, 1961Ry02, 1960Ry02, 1959Ro51, 1957Pi31,
							1954Ha60]
²²⁷ Th(RdAc)	5.793(3)	6.1466(1)	100%				[19s64Ba33, 2019Ma02, 1998Jo08, 1972He18, 2019Ko06,
							2019Co04, 2015Co11, 1990Br23, 1990BrZZ, 1987Mi10,
							1977Ma32, 1972HeYM, 1968Wa07, 1967JoZX, 1965Br23,
							1954Ha60, 1949Pe08]
²³¹ U	5.657(4)	5.576(2)	$4(1) \times 10^{-3}\%$				[ <b>1997Mu08, 1994Li12</b> , 1949Os01]
²⁵⁵ Pu	5.061(22)	5.951(20)	$3.0(6) \times 10^{-5}\%$				[ <b>1957Th10</b> , 1952Or03]
^{235m} Pu	2.06(20)	7.95(20)	2	100%			[ <b>1970Bu02, 1971Br39</b> , 1972Ga42, 1969Me11]
239Cm	4.56(16)	6.54(15)	$< 1 \times 10^{-5}\%$				[2008Qi03]
²⁴³ Cf	4.05(23)#	7.42(10)#	obs				[1967Fi04, 1967Si08]
²⁴⁷ Fm	3.44(20)#	8.258(10)	64%				[2006He27, 2004He2Y, 2004He28]
247 <i>m</i> Fm	3.39(20)#	8.305(11)	88(2)%				[ <b>2006He27</b> , 2004HeZY, 2004He28]
²⁵¹ No	2.84(20)#	8.752(4)	$91^{+9}_{-22}\%$	$0.14^{+0.31}_{-10.12}\%$			[ <b>2006He27</b> , <b>2001He35</b> , 2022Te01, 2009Dr02, 2005KuZZ,
							2005SuZX, 2004He28, 2004HeZY, 1999He07, 1997He29,
251.000	2 74(20) //	0.050(7)	1000				
^{251m} No	2.74(20)#	8.858(7)	100%				[2006He27, 2022Te01, 2005KuZZ, 2005SuZX, 2004He28,
255 5.0	2 (1 (20) //	0.055(4)	1440	5.4.5. St.4			
²⁵⁵ Rf	2.61(20)#	9.055(4)	46(5)%	54(5)%*			[2006He27, 2015An05, 2001He35, 2020Mo11,
							2008Dr05, 199/He29, 1986He06, 1984De0/, 1984Og02,
259 0 -	2 278(20)#	0.7(5(9)	- 070	2(1)0/**			1984UgU3]
255 Sg	2.278(30)#	9.705(8)	~ 91%	5(1)%**			[2015An05, 2015An08, 2009Df02, 2009He20, 1985Mu11,
259m c ~	2 101(20)#	0.852(22)	$\sim 07\%$	2(1)0/**			1904DCU/] [ <b>2015405</b> 2000H_201
26311-	2.191(20)#	9.032(22)	~ 91%	3(1)%*** <9.40/			[2013AH03, 2009FIC20] [2000D-02, 2000K-711, 10840-02
267 D-	1.00(22)#	10.733(78) 11.777(51)	$\sim 100\%$	<0.4%			[2007D102, 2009KaZU, 1964Ug02 [1005Ch05]
Ds	1.08(23)#	11.//(51)	$\approx 100\%$				[1993G1103]

* Weighted average of 58(9)% [2015An05] and 52(6)% [2001He35].

** Combination of ground state and isomer.

#### Table 3 direct $\alpha$ emission from ²¹⁵Po*, $J^{\pi} = 9/2^+$ , $T_{1/2} = 1.780(4)$ ms**, $BR_{\alpha} = 99.99977(2)\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${\rm J}_f^\pi$	$E_{daughter}(^{211}\text{Pb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6 641(20)	6 517(20)	$\approx 3 \times 10^{-4}$ %	$\approx 3 \times 10^{-4}$ %	$(11/2^+)$	0 894	0 894	1 54039(15)	~ 370
6.712(8)	6.587(8)	$2.0(6) \times 10^{-3}\%$	$2.0(6) \times 10^{-3}\%$	$(9/2^+)$	0.815	0.815	1.54039(15)	$110^{+50}_{-30}$
6.760(15)	6.634(15)	$\approx 3 \times 10^{-4} \%$	$\approx 3 \times 10^{-4} \%$	$(3/2^+)$	0.762		1.54039(15)	$\approx 1.2 \times 10^3$
6.795(10)	6.669(10)	8(3)×10 ⁻⁴ %	8(3)×10 ⁻⁴ %	$(13/2^+)$	0.733	0.733	1.54039(15)	$560^{+340}_{-160}$
6.880(10)	6.752(10)	$8(3) \times 10^{-4}\%$	$8(3) \times 10^{-4}\%$	$(11/2^+)$	0.643	0.643	1.54039(15)	$1.2^{+0.7}_{-0.3} \times 10^3$
6.929(8)	6.800(8)	$1.6(5) \times 10^{-3}\%$	$1.6(5) \times 10^{-3}\%$	$(5/2^+)$	0.598	0.598	1.54039(15)	$90_{-20}^{+40}$
6.946(15)	6.817(15)	4(2)×10 ⁻⁴ %	4(2)×10 ⁻⁴ %		0.584	0.584	1.54039(15)	$4^{+4}_{-1} \times 10^3$
7.084(3)	6.952(3)	0.06(2)%	0.06(2)%	$(7/2^+)$	0.4389	0.4389	1.54039(15)	$80_{-20}^{+40}$
7.5261(8)	7.3861(8)	100%	99.93(2)%	5/2+	0.0		1.54039(15)	1.369(10)

* All values from [1998Li53], except where noted.

** Weighted average of 1.781(5) ms [2023Ta02] and 1.778(5) ms [1961Vo06]. *** [1950Av61] report a BR $_{\varepsilon} = 2.3(2) \times 10^{-4} \%$ .

## Table 4

direct  $\alpha$  emission from ²¹⁹Rn*,  $J^{\pi} = 5/2^+$ ,  $T_{1/2} = 3.96(1)$  s**,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{215}\text{Po})$	coincident γ-rays	R ₀ (fm)	HF
5.851(15)	5.744(15)	$< \times 10^{-4}\%$	$<1{\times}10^{-4}\%$		1.094	0.2240, 0.2936, 0.5175 0.5766	1.55805(42)	>250
5.871(8)	5.764(8)	$1 \times 10^{-3} \%$	$1 \times 10^{-3}\%$	(5/2 ⁺ )	1.0737	0.2240, 0.2712, 0.2936, 0.4018, 0.5175, 0.5581, 0.6719, 0.8025, 1.0737	1.55805(42)	31
6.010(15)	5.900(15)***				0.930	0.3218, 0.6083		
6.055(6)	5.944(6)	$3 \times 10^{-3} \%$	$2 \times 10^{-3}\%$		0.8911	0.2240, 0.2712, 0.2936,	1.55805(42)	110
						0.2240, 0.2712, 0.2936,		
						0.3735, 0.4018, 0.4893,		
						0.5175, 0.6199, 0.8911		
6.069(15)	5.958(15)	$1 \times 10^{-4}$ %	$1 \times 10^{-4}\%$		0.8772	0.8772	1.55805(42)	$2.5 \times 10^{3}$
6.112(6)	6.000(6)	$4 \times 10^{-3}\%$	$3 \times 10^{-3}\%$		0.8353	0.2712, 0.5461, 0.8353	1.55805(42)	130
6.213(8)	6.100(8)	$1 \times 10^{-3} \%$	$1 \times 10^{-3}\%$		0.7328	0.1306, 0.2712, 0.3308, 0.4018, 0.4618, 0.7328	1.55805(42)	$1.1 \times 10^{3}$
6.238(8)	6.124(8)	$1 \times 10^{-3}\%$	$1 \times 10^{-3}\%$		0.7081	0.2712, 0.4369, 0.7081	1.55805(42)	$1.4 \times 10^{3}$
6.273(4)	6.158(4)	0.023%	0.018%		0.6767	0.2712, 0.2936, 0.3831, 0.4055, 0.6767	1.55805(42)	78
6.339(6)	6.223(6)	$5 \times 10^{-3}\%$	$4 \times 10^{-3}\%$	$(11/2^+, 13/2^+)$	0.6083	0.6083	1.55805(42)	350
6.428(3)	6.311(3)	0.068%	0.054%	$(7/2^+, 9/2^+)$	0.51755	0.2240, 0.2936, 0.5175	1.55805(42)	170
6.545(1)	6.425(1)	9.5%	7.5%	5/2+	0.40181	0.1306, 0.2712, 0.4018	1.55805(42)	3.5
6.651(2)	6.530(2)	0.15%	0.12%	11/2+	0.29360	0.2936	1.55805(42)	590
6.675(1)	6.553(1)	16%	13%	7/2+	0.27123	0.2712	1.55805(42)	6.7
6.9460(3)	6.8191(3)	100%	79.3%	9/2+	0.0		1.55805(42)	11.4

* All values from [1999Li05], except where noted.

** [1966Hu20].

*** tentative.

			1/2					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	Edaughter( ²¹⁹ Rn)	coincident γ-rays***	R ₀ (fm)	HF
5 1056	5 0140	$\approx 8.4 \times 10^{-4}\%$	$\approx 4.5 \times 10^{-4}\%$		0 8729		1 54569(94)	~121
5 1169	5 0251	$\approx 1.2 \times 10^{-3}\%$	$\approx 6.4 \times 10^{-4}\%$		0.8616		1.54569(94)	$\approx 121$ $\approx 100$
5 1276	5.0251	$\approx 7.4 \times 10^{-4}\%$	$\approx 4.0 \times 10^{-4}\%$		0.8509		1.54569(94)	$\approx 100$ $\approx 190$
5 1479	5.0556	$\approx 4.4 \times 10^{-4}\%$	$\approx 2.0 \times 10^{-4}\%$		0.8305		1.54569(94)	$\approx 490$
5 1787	5.0858	$\approx 5.6 \times 10^{-3}\%$	$\approx 3.0 \times 10^{-3}\%$		0.7997		1.54569(94)	~500
5 2054	5 1120	$\approx 1.1 \times 10^{-3}\%$	$\approx 6.0 \times 10^{-4}\%$		0.7731		1.54569(94)	≈360
5.2282	5.1344	$\approx 3.2 \times 10^{-3}\%$	$\approx 1.7 \times 10^{-3}\%$		0.7503		1.54569(94)	≈170
5.2455	5.1514	0.044%	0.021%		0.7329	0.0345, 0.0695, 0.1040, 0.1085,	1.54569(94)	18
						0.1108, 0.1443, 0.1543, 0.1587,		
						0.1773, 0.1796, 0.2551, 0.2695,		
						0.2860, 0.2881, 0.3284, 0.3383,		
						0.3428, 0.3555, 0.3900, 0.4324,		
						0.5741, 0.7184, 0.7284, 0.7328		
5.2669	5.1724	0.048%	0.026%		0.7116	0.3284, 0.3428, 0.3685, 0.6969, 0.7113	1.54569(94)	19
5.3064	5.2112	0.010%	$5.4 \times 10^{-3}\%$		0.6721	0.1224, 0.5458,	1.54569(94)	150
5.3315	5.2359	0.078%	0.042%		0.6469	0.0345, 0.0695, 0.1040, 0.1108,	1.54569(94)	27
						0.1224, 0.1317, 0.1383, 0.1443,	× /	
						0.1543, 0.1587, 0.1773, 0.1993,		
						0.2493, 0.2551, 0.2695, 0.3284,		
						0.3428, 0.3557, 0.3617, 0.3717,		
						0.3761, 0.3876, 0.4234, 0.4874,		
						0.5000, 0.5100, 0.6417, 0.6461		
5.3544	5.2584	0.080%	0.043%		0.6240	0.2462, 0.0345, 0.3284, 0.3428,	1.54569(94)	36
						0.6091, 0.6191, 0.66235		
5.3789	5.2824	0.18%	0.095%	(3/2,5/2,7/2)	0.5996	0.0345, 0.1443, 0.1543, 0.1587,	1.54569(94)	22
						0.1796, 0.2214, 0.2604, 0.3284,		
5 2925	5 29(0	0.240/	0.120/	(7/2)-	0.5050	0.5383, 0.3428, 0.5843, 0.5987	1.545(0(04)	17
5.3835	5.2809	0.24%	0.13%	(7/2)	0.5950	0.0095, 0.1032, 0.1040, 0.1085, 0.1147, 0.1224, 0.1442, 0.1472	1.54569(94)	17
						0.1147, 0.1224, 0.1443, 0.1472, 0.1543, 0.1587, 0.1773, 0.1796		
						0.2493 0.2512 0.2557 0.2881		
						0.3284, 0.3383, 0.3428, 0.3617		
						0.3717, 0.3761, 0.4324, 0.5796,		
						0.5940		
5.4358	5.3383	0.19%	0.10%	(7/2, 9/2)	0.5426	0.1224, 0.1659, 0.2493, 0.3617,	1.54569(94)	44
						0.3717, 0.3761, 0.5276, 0.5376,		
						0.5420		
5.4632	5.3652	0.20%	0.11	(7/2,9/2)	0.5152	0.1224, 0.1383, 0.1443, 0.1543,	1.54569(94)	56
						0.1587, 0.2493, 0.3557, 0.3617,		
						0.3717, 0.3761, 0.3876, 0.5000,		
	- 1000	1.000	0.000	~ 10	0.11/0	0.5100	1.515(0(0.1)	<u></u>
5.5324	5.4332	4.28%	0.023%	5/2-	0.4460	0.1022, 0.1067, 0.1108, 0.1443,	1.54569(94)	640
						0.1543, 0.1587, 0.1755, 0.1796,		
						0.2551, 0.2095, 0.3239, 0.3284, 0.3230, 0.3282, 0.3428, 0.4206		
						0.3339, 0.3383, 0.3428, 0.4300,		
5 5809	5 4808	~0.023%	≈0.082%	(11/2)	0 3975	0.2703	1 54569(94)	320
5.6017	5.5012	1.5%	0.80%	$9/2^+$	0.3768	0.1224 0.2493 0.3617 0.3717	1.54569(94)	42
010017	010012	110 /0	010070	<i>,,</i>	0.0700	0.3761	110 10 05 (5 1)	
5.6410(10)	5.5398(10)	16.95%	9.1%	5/2+	0.3375	0.1443, 0.1543, 0.1587, 0.1796,	1.54569(94)	6.0
						0.3383	× /	
5.7091(3)	5.6067(3)	48%	26%	3/2+	0.2693	0.1108, 0.1443, 0.1543, 0.1587,	1.54569(94)	4.7
						0.2551, 0.2695		
5.8206(3)	5.7162(3)	100%	53.7%	7/2+	0.1578	0.1443, 0.1543, 0.1587	1.54569(94)	8.2
5.8520(4)	5.7470(4)	17.0%	9.1%	11/2+	0.1265	0.1224	1.54569(94)	69
5.9641	5.8571	0.60%	0.32%	7/2+	0.0144	0.0144	1.54569(94)	$6.8 \times 10^{3}$
5.9784	5.8712	1.6%	0.87%	5/2+	0.0		1.54569(94)	$2.9 \times 10^{3}$

Table 5 direct  $\alpha$  emission from ²²³Ra*,  $J^{\pi} = 3/2^+$ ,  $T_{1/2} = 11.4354(17) d^{**}$ ,  $BR_{\alpha} = 100\%$ .

* All values from [1962Wa18], except where noted. ** [2015Co02]. *** [1998Sh02].

# Table 6 direct ¹⁴C emission from ²²³Ra*, $J^{\pi} = 3/2^+$ , $T_{1/2} = 11.4354(17) d^{**}$ , $Q_{14C} = 31.83 \text{ MeV}$ , $BR_{14C} = 8.9(4) \times 10^{-8} \%^{***}$ .

<i>E</i> _{14<i>C</i>} (c.m.)	$E_{14C}(\text{lab})$	$I_{14C}(\text{rel})$	$I_{14C}(abs)$	$J_f^{\pi@}$	$E_{daughter}(^{209}\text{Pb})^{@}$	coincident $\gamma$ -rays [@]	$R_0$ (fm)	HF
30.43 31.07 31.50	28.52 29.12 29.52	5% ^{@@} 100% ^{@@} 19% ^{@@}	$\begin{array}{c} 3.6\!\times\!10^{-9}\%\\ 7.2\!\times\!10^{-8}\%\\ 1.3\!\times\!10^{-8}\%\end{array}$	15/2 ⁻ 11/2 ⁺ 9/2 ⁺	1.423 0.779 0.0	0.6435, 0.7789, 1.4227 0.7789	1.53069(10) 1.53069(10) 1.53069(10)	4.6 ^{@@} 3.9 ^{@@} 583 ^{@@}

* All values from [1992Ar02], except where noted. ** [2015Co02]. *** [1995Ho11].

⁽¹⁾ [2015Ch30].
 ^(a) [1992Ar02], intensity values reported as 4% (to 1.423 MeV), 81% to (to 0.779 MeV) and 15% (to ground state of ²⁰⁹Pb).

Table 7	
direct $\alpha$ emission from ²²⁷ Th* (1 of 3), $J^{\pi} = (1/2^+)$ , $T_{1/2} = 18.681(9) d^{**}$ , $BR_{\alpha}$	$\alpha = 100\%$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^2$	²³ Ra)	coincident γ-rays	HF***
5.1236(40) 5.1466(40)	5.0333(40) 5.0559(40)	1.3(1)×10 ⁻³ 1.0(2)×10 ⁻³	3.1(2)×10 ⁻⁴ % 2.3(5)×10 ⁻⁴ %		1.025 1.000		1.025 0.0065, 0.0205, 0.0299, 0.0316, 0.0339, 0.0419, 0.0438, 0.0442, 0.0444, 0.0465, 0.0483, 0.0498, 0.0501, 0.0542, 0.0564, 0.0614, 0.0625, 0.0687, 0.0736, 0.0797, 0.0939, 0.0950, 0.0960, 0.0996, 0.1003, 0.1052, 0.1076, 0.1131, 0.1414, 0.1501, 0.1735, 0.1847, 0.2005, 0.2016, 0.2041, 0.2050, 0.2061, 0.2106, 0.2189, 0.2348, 0.2360, 0.2461, 0.2502, 0.2503, 0.2525, 0.2546, 0.2562, 0.2629, 0.2729, 0.2798, 0.2814, 0.2842, 0.2861, 0.2924, 0.2965, 0.3000, 0.3045, 0.3127, 0.3149, 0.3260, 0.3299, 0.3344, 0.3426, 0.3465, 0.3763, 0.6238, 0.9200, 0.9380, 0.9700, 0.9998	$29.8(20) \\ 57^{+16}_{-10}$
5.1745(40)	5.0833(40)	6(1)×10 ⁻³ %	1.5(2)×10 ⁻⁴ %		0.971		0.0205, 0.0299, 0.0316, 0.0438, 0.0442, 0.0498, 0.0501, 0.0614, 0.0625, 0.0736, 0.0797, 0.0939, 0.0950, 0.1735, 0.1847, 0.2050, 0.2061, 0.2348, 0.2503, 0.2798, 0.3000, 0.3299, 0.6410, 0.910, 0.9416	$132^{+21}_{-16}$
5.2020(40) 5.2205(30)	5.1103(40) 5.1285(30)	$\frac{1.2(1)\times10^{-3}\%}{2.6(1)\times10^{-3}\%}$	$\begin{array}{c} 2.8(2) \times 10^{-4}\% \\ 6.2(2) \times 10^{-4}\% \end{array}$	(3/2, 5/2) (3/2, 5/2 ⁻ )	0.943 0.926		0.0205, 0.0299, 0.0501, 0.893 0.0205, 0.0299, 0.0316, 0.0498, 0.0501, 0.0614, 0.0644, 0.0797, 0.1735, 0.1847, 0.2050, 0.2348, 0.2360, 0.2562, 0.2861, 0.3005, 0.3505, 0.5760, 0.6920, 0.8467, 0.8763, 0.0.8961, 0.927	105(8) 59.7(20)
5.2386(20)	5.1463(20)	0.0169(7)%	4.1(8)×10 ⁻³ %		0.908		0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0444, 0.0498, 0.0501, 0.0614, 0.0625, 0.06874, 0.0736, 0.0797, 0.0939, 0.1003, 0.1131, 0.2360, 0.2562, 0.2855, 0.2861, 0.3986, 0.4480, 0.6124, 0.8573, 0.8785, 0.8782, 0.9086	$11.6^{+2.8}_{-1.9}$
5.2635(30)	5.1708(30)	$7.0(7) \times 10^{-3}\%$	$1.70(17) \times 10^{-3}\%$		0.884		0.0299, 0.8543	39(4)
5.2733(40)	5.1804(40)	$5.0(10) \times 10^{-3}\%$	$1.20(24) \times 10^{-3}\%$		0.879		0.0299, 0.8378, 0.8673	$59^{+15}_{-10}$
5.2867(25)	5.1935(25)	0.0157(13)%	3.80(27)×10 ⁻³ %		0.859		0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0444, 0.0483, 0.0498, 0.0501, 0.0542, 0.0564, 0.0614, 0.0625, 0.0687, 0.0736, 0.0797, 0.0939, 0.0996, 0.1003, 0.1052, 0.1076, 0.1131,0.1501, 0.1735, 0.1847, 0.2005, 0.2041, 0.2050, 0.2106, 0.2189, 0.2348, 0.2360, 0.2502, 0.2546, 0.2562, 0.2629, 0.2729, 0.2814, 0.2842, 0.2861, 0.2924, 0.3045, 0.3127, 0.3344, 0.3426, 0.5166, 0.5245, 0.5790, 0.7354, 0.7973, 0.8086, 0.8285, 0.8589	24.3(18)
5.3035(20)	5.2100(20)	0.029(2)%	7(3)×10 ⁻³ %		0.842		0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0444, 0.0483, 0.0498, 0.0501, 0.0542, 0.0614, 0.0625, 0.0687, 0.0736, 0.0797, 0.0939, 0.0996, 0.1003, 0.1052, 0.1131, 0.1501, 0.1735, 0.1847, 0.2041, 0.2005, 0.2050, 0.2106, 0.2189, 0.2348, 0.2360, 0.2502, 0.2546, 0.2562, 0.2729, 0.2842, 0.2861, 0.3045, 0.3344, 0.5075, 0.5561, 0.6077, 0.7185, 0.7622, 0.7810, 0.8126, 0.8425	$17^{+13}_{-5}$
5.3228(20)	5.2290(20)	0.041(2)%	9.8(3)×10 ⁻³ %		0.823		0.0205, 0.0299, 0.0316, 0.0438, 0.0442, 0.0442, 0.0493, 0.0498, 0.0501, 0.0614, 0.0625, 0.7734, 0.0736, 0.0797, 0.0939, 0.0950, 0.1735, 0.1847, 0.2050, 0.2061, 0.2348, 0.2360, 0.2503, 0.2562, 0.2798,0.2861, 0.3000, 0.3299, 0.5369, 0.8234	15.3(5)
5.3422(20)	5.2481(20)	0.0132(8)%	$3.20(1) \times 10^{-3}\%$		0.803		0.0205, 0.0299, 0.0498, 0.0501, 0.7235, 0.7541,	61.3(6)
5.3585(20)	5.2641(20)	0.0107(9)%	2.6(2)×10 ⁻³ %		0.787		0.0797, 0.8039 0.0205, 0.0299, 0.0316, 0.0498, 0.0501, 0.0614, 0.0797, 0.1735, 0.1847, 0.2050, 0.2348, 0.5524, 0.7072, 0.7569, 0.7874	93(7)
5.4171(40)	5.3216(40)	1.0(4)%×10 ⁻³ %	2.4(10)×10 ⁻⁴ %		0.729			$2.2^{+1.6}_{-0.6} \times 10^3$
5.4314(50)	5.3357(50)	$8(4) \times 10^{-3}\%$	$2(1) \times 10^{-3}\%$		0.713		0.0205, 0.0299, 0.0498, 0.0797, 0.6323, 0.6628	$320_{-11}^{+32}$

* All values from [1964Ba33], unless otherwise noted. ** [2019Ko06]. ***  $R_0 = 1.53569(39)$  fm.

Table 8			
direct $\alpha$ emission from ²²⁷ Tl	$n^*$ (2 of 3), $J^{\pi} = (1/2^+)$	), $T_{1/2} = 18.681(9)$	$d^{**}, BR_{\alpha} = 100\%$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{223}\mathrm{Ra})$	coincident γ-rays	HF***
$5.4610(25) 5.5055(30) 5.5563(20) \overline{5.5785(22)} 5.6085(20)$	5.3648(25) 5.4085(30) 5.4584(20) 5.4802(22) 5.5097(20)	$\begin{array}{c} 2.7(2) \times 10^{-3}\% \\ 1.8(3) \times 10^{-3}\% \\ 0.0112(5)\% \\ \overline{5.0(5) \times 10^{-3}\%} \\ 0.0686(28)\% \end{array}$	$\begin{array}{c} 6.6(3) \times 10^{-4}\% \\ 4.4(7) \times 10^{-4}\% \\ 2.7(5) \times 10^{-3}\% \\ 1.2(1) \times 10^{-3}\% \\ 0.0166(3)\% \end{array}$		0.685 0.641 0.590 0.568 0.537	0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0444, 0.0498, 0.0501, 0.0614, 0.0625, 0.06874, 0.0729,	$\begin{array}{c} 1.39(7)\times 10^{3}\\ 3.7^{+0.7}_{-0.5}\times 10^{3}\\ 1.14^{+0.26}_{-0.18}\times 10^{3}\\ 3.37(28)\times 10^{3}\\ 357(7)\end{array}$
5.6307(18)	5.5315(18)	0.0868(89)%	0.021(2)%	(11/2 ⁻ )	0.514	0.0736, 0.0797, 0.0939, 0.1003, 0.1131, 0.1172, 0.1236, 0.2900 0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0444,	380(40)
						0.0498, 0.0501, 0.0542, 0.0614, 0.0625, 0.0687 , 0.0736, 0.0797, 0.0939, 0.1003, 0.1131, 0.2671, 0.2855, 0.3398, 0.3986	
5.6859(16)	5.5857(16)	0.727(37)%	0.176(6)%	(9/2)-	0.460	0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0444, 0.0498, 0.0501, 0.0614, 0.0625, 0.06874, 0.0736, 0.0797, 0.0939, 0.1003, 0.1131, 0.2855, 0.3986	86.3(3)
5.7009(18)	5.6004(18)	0.703(75)%	0.170(17)%	9/2+	0.445	$\begin{array}{c} 0.0065, 0.0205, 0.0209, 0.0299, 0.0316, 0.0339,\\ 0.04020, 0.0419, 0.0438, 0.0442, 0.0444, 0.0465,\\ 0.0483, 0.0498, 0.0501, 0.0542, 0.0564, 0.0614\\ 0.0625, 0.0627, 0.06874, 0.0736, 0.0797, 0.0939,\\ 0.0950, 0.0960, 0.0996, 0.1003, 0.1107, 0.1052,\\ 0.1078, 0.1131, 0.1172, 0.1236, 0.1244, 0.1414,\\ 0.1501, 0.1683, 0.1700, 0.1735, 0.1847, 0.1976,\\ 0.4151, 0.2005, 0.2016, 0.2041, 0.2050, 0.2061,\\ 0.2106, 0.2127, 0.2106, 0.2189, 0.2300, 0.2348,\\ 0.2360, 0.2461, 0.2502, 0.2503, 0.2525, 0.2546,\\ 0.2562, 0.2629, 0.2706, 0.2729, 0.2798, 0.2807,\\ 0.2814, 0.2842, 0.2861, 0.2924, 0.2965, 0.3000,\\ 0.3045, 0.3127, 0.3149, 0.3249, 0.3260, 0.3299,\\ 0.3344, 0.3426, 0.3465, 0.3626, 0.3748, 0.3763,\\ 0.3835\end{array}$	$107^{+12}_{-10}$
5.7138(16)	5.6131(16)	0.893(47)%	0.216(8)%	(5.2 ⁻ )	0.432	$\begin{array}{c} 0.0065, 0.0205, 0.0299, 0.0316, 0.0339, 0.0419,\\ 0.0438, 0.0442, 0.0444, 0.0465, 0.0483, 0.0498,\\ 0.0501, 0.0542, 0.0560, 0.0564, 0.0614, 0.0625,\\ 0.0687, 0.0736, 0.0797, 0.0896, 0.0939, 0.0950,\\ 0.0960, 0.0996, 0.1003, 0.1025, 0.1052, 0.1076,\\ 0.1131, 0.1414, 0.1501, 0.1735, 0.1847, 0.2005,\\ 0.2016, 0.2041, 0.2050, 0.2061, 0.2106, 0.2189,\\ 0.2348, 0.2360, 0.2461, 0.2502, 0.2503, 0.2525,\\ 0.2546, 0.2562, 0.2629, 0.2729, 0.2798, 0.2814,\\ 0.2842, 0.2861, 0.2924, 0.2965, 0.3000, 0.3045,\\ 0.3084, 0.3127, 0.3149, 0.3260, 0.3299, 0.3344,\\ 0.3426, 0.3465, 0.3526, 0.3709, 0.3763, 0.3822,\\ 0.4022, 0.4323\end{array}$	99(4)
5.7226(17) 5.7412(15)	5.6218(17) 5.6400(15)	0.028(2)% 0.0740(68)%	7.0(4)×10 ⁻³ % 0.0179(15)%	(11/2 ⁺ ) (7/2) ⁻	0.424 0.405	0.0299, 0.0316, 0.0614, 0.3626 0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0444, 0.0498, 0.0501, 0.0614, 0.0625, 0.0627, 0.0687, 0.0736, 0.0797, 0.0939, 0.1003, 0.1052, 0.1078, 0.1131, 0.1244, 0.1501, 0.1683, 0.1700, 0.1735, 0.1847, 0.2005, 0.2050, 0.2127, 0.2189, 0.2300, 0.2348, 0.2502, 0.2807, 0.2814, 0.3249, 0.3748	$\frac{3^{+5}_{-1} \times 10^3}{31.64(14) \times 10^3}$
5.7695(15)	5.6678(15)	8.51(59)%	2.06(12)%		0.376	0.0065, 0.0205, 0.0299, 0.0316, 0.0339, 0.0419, 0.0438, 0.0442, 0.0444, 0.0465, 0.0483, 0.0498, 0.0501, 0.0542, 0.0564, 0.0614, 0.0625, 0.0687, 0.0736, 0.0797, 0.0939, 0.0950, 0.0960, 0.0996, 0.1003, 0.1052, 0.1076, 0.1131, 0.1414, 0.1501, 0.1735, 0.1847, 0.2005, 0.2016, 0.2041, 0.2050, 0.2061, 0.2106, 0.2189, 0.2348, 0.2360, 0.2461, 0.2502, 0.2503, 0.2525, 0.2546, 0.2562, 0.2629, 0.2729, 0.2798, 0.2814, 0.2842, 0.2861, 0.2924, 0.2965, 0.3000, 0.3045, 0.3127, 0.3149, 0.3260, 0.3299, 0.3344, 0.3426, 0.3465, 0.3763	20.1(12)

* All values from [1964Ba33], unless otherwise noted. ** [2019Ko06]. ***  $R_0 = 1.53569(39)$  fm.

Table 9				
direct $\alpha$ emission from	²²⁷ Th* (3 of 3), J ⁷	$\tau = (1/2^+), T_{1/2} =$	= 18.681(9) d**,	$BR_{\alpha} = 100\%$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{223}\mathrm{Ra})$	coincident γ-rays	HF***
5.7759(16)	5.6741(16)	0.236(17)%	0.0572(35)%	(5/2)-	0.369	0.0205, 0.0299, 0.0316, 0.0498, 0.0501, 0.0614, 0.0797, 0.1346, 0.1735, 0.1847, 0.2050, 0.2348, 0.2002, 0.2102, 0.2021	790(50)
5.7949(16)	5.6928(16)	6.2(5)%	1.5(1)%	(1/2 ⁻ )	0.351	0.2896, 0.3192, 0.3694 0.0205, 0.0299, 0.0501, 0.0644, 0.2360, 0.253, 0.2861, 0.3005, 0.3505	37.1(25)
5.8029(16)	5.7006(16)	15(1)%	3.63(20)%	3/2+	0.343	0.0205, 0.0299, 0.0316, 0.0498, 0.0501, 0.0564, 0.0614, 0.0797, 0.1076, 0.1735, 0.1847, 0.2050, 0.2348, 0.2360, 0.2562, 0.2629, 0.2814, 0.2861, 0.2924, 0.3127, 0.3426	16.8(10)
5.8110(16)	5.7086(16)	34.3(18)%	8.3(3)%	5/2+	0.334	0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0444, 0.0483, 0.0498, 0.0501, 0.0542, 0.0614, 0.0625, 0.0687, 0.0736, 0.0797, 0.0939, 0.0996, 0.1003, 0.1052, 0.1131, 0.1501, 0.1735, 0.1847, 0.2041, 0.2005, 0.2050, 0.2106, 0.2189, 0.2348, 0.2360, 0.2502, 0.2546, 0.2729, 0.2842, 0.2861, 0.3045, 0.3344	8.18(31)
5.8155(16)	5.7130(16)	20.2(11)%	4.89(20)%	3/2-	0.329	0.0205, 0.0299, 0.0316, 0.0438, 0.0442, 0.0498, 0.0501, 0.0614, 0.0625, 0.0736, 0.0797, 0.0939, 0.0950, 0.1735, 0.1847, 0.2050, 0.2061, 0.2348, 0.2503, 0.2798, 0.3000, 0.3299	14.7(6)
5.8306(16)	5.7279(16)	0.141(12)%	0.0342(25)%	(13/2-)	0.316	0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0498, 0.0501, 0.0614, 0.0625, 0.0687, 0.0736, 0.0797, 0.0939, 0.1003, 0.1414	$2.45(18) \times 10^3$
5.86013(15)	5.75687(15)	84.3(49)%	20.4(9)%	$1/2^{+}$	0.286	0.0205, 0.0299, 0.0501, 0.2360, 0.2562, 0.2861	5.81(26)
5.8655(15)	5.7621(15)	0.942(54)%	0.228(10)%	(7/2)+	0.280	0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0444, 0.0498, 0.0501, 0.0614, 0.0625, 0.0687, 0.0736, 0.0797, 0.0939, 0.1003, 0.1052, 0.1131, 0.1501, 0.2005, 0.2189, 0.2502	557(25)
5.8993(15)	5.7953(15)	1.29(5)%	0.311(5)%	11/2-	0.247	0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0444, 0.0498, 0.0501, 0.0614, 0.0625, 0.0687, 0.0729, 0.0736, 0.0797, 0.0939, 0.1003, 0.1131, 0.1172, 0.1236	596(11)
5.9115(15)	5.8073(15)	5.2(2)%	1.27(2)%	5/2+	0.235	0.0205, 0.0299, 0.0316, 0.0501, 0.0614, 0.1735, 0.1847, 0.2050, 0.2348	167(3)
5.9716(15)	5.8664(15)	10.0(6)%	2.42(10)%	11/2+	0.175	0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0444, 0.0498, 0.0501, 0.0614, 0.0625, 0.0687, 0.0736, 0.0797, 0.0939, 0.1003, 0.1131	173(7)
6.0157(15)	5.9097(15)	0.719(43)%	0.174(8)%	9/2+	0.130	0.0065, 0.0205, 0.0299, 0.0316, 0.0442, 0.0498, 0.0501, 0.0614, 0.0625, 0.0687, 0.0736, 0.0797, 0.0939, 0.1003	$3.97(19) \times 10^3$
6.0219(15)	5.9158(15)	3.20(17)%	0.775(30)%	7/2-	0.124	0.0205, 0.0299, 0.0316, 0.0442, 0.0498, 0.0501, 0.0614, 0.0625, 0.0736, 0.0797, 0.0939	950(40)
6.0664(15)	5.9595(15)	12.40(77)%	3.00(15)%	(5/2)-	0.080	0.0205, 0.0299, 0.0498, 0.0797	398(20)
6.08494(10)	5.97772(10)	97.1(52)%	23.5(9)%	$(7/2^+)$	0.061	0.0299, 0.0316, 0.0614	62.6(6)
6.0966(20)	5.9892(20)	$8.3(13) \times 10^{-3}\%$	$2.0(3) \times 10^{-3}\%$	3/2-	0.050	0.0205, 0.0299, 0.0501	$8.3^{+1.5}_{-1.1}  imes 10^5$
6.1164(15) 6.14632(15)	6.0086(15) 6.03801(15)	11.98(76)% 100(5)%	2.90(15)% 24.2(9)%	5/2+ 3/2+	0.030 0.0	0.0299	710(40) 117(5)

* All values from [1964Ba33], unless otherwise noted. ** [2019Ko06]. ***  $R_0 = 1.53569(39)$  fm.

Table 10
direct $\alpha$ emission from ²³¹ U*, $J^{\pi} = (5/2^{-})$ , $T_{1/2} = 4.2(1) d^{**}$ , $BR_{\alpha} = 4(1) \times 10^{-3} \%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{227}\mathrm{Th})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
5.177	5.087				0.40011	0.00243, 0.0386, 0.0379, 0.0399, 0.0532, 0.0606, 0.0613, 0.0683, 0.0749, 0.0899, 0.0991, 0.1111 0.1507, 0.1899, 0.2042, 0.2114, 0.2196, 0.2647,		
5.258	5.167	0.52%	8.8×10 ⁻⁴ %	(3/2,5/2,7/2)+	0.31889	0.2798, 0.2890 0.00243, 0.0386, 0.0379, 0.0399, 0.0532, 0.0683		
5.288	5.196	1.8%	3.1×10 ⁻³ %	(1/2,3/2,5/2)+	0.28901	0.2426, 0.2943, 0.3097 0.00243, 0.0386, 0.0379, 0.0399, 0.0532, 0.0606, 0.0613, 0.0683, 0.0749, 0.0899, 0.0991, 0.1507, 0.1899, 0.2042, 0.2114, 0.2196, 0.2647, 0.2798, 0.2890		
5.345 5.348	5.252 5.255	0.47% $\approx 0.14\%$	$8.0 \times 10^{-4}\%$ $\approx 2.4 \times 10^{-4}\%$	(-) (3/2,5/2) ⁻	0.23143 0.22864	0.0644, 0.1578 0.00243, 0.0386, 0.0379, 0.0399, 0.0532, 0.0683, 0.1507, 0.2042, 0.2196		
5.356	5.263	0.71%	$1.2 \times 10^{-3}\%$	(-)	0.19999	0.1307, 0.2042, 0.2190 0.0243, 0.0728, 0.1029, 0.1180, 0.1902		
5.392	5.299	0.92%	$1.6 \times 10^{-3}\%$	(1/2,3/2,5/2)-	0.18367	0.0564, 0.1029, 0.1180 0.1594		
5.449	5.355	1.6%	$2.7 \times 10^{-3}\%$	$(3/2.5/2)^+$	0.12726	0.0243, 0.1029, 0.1180		
5.478	5.383	13%	$2.2 \times 10^{-2}\%$	$(1/2,3/2,5/2)^+$	0.09916	0.0243, 0.0386, 0.0379, 0.0613, 0.0749, 0.0899, 0.0991		
5.499	5.404	50%	$8.4 \times 10^{-2}\%$	*3/2,5/2)+	0.07758	0.00243, 0.0386, 0.0379, 0.0399, 0.0532, 0.0683		
5.500	5.405				0.07620	0.00243, 0.0519, 0.0669		
5.503	5.408	< 0.71%	$< 1.2 \times 10^{-3}\%$	$(3/2, 5/2, 7/2)^{-}$	0.07364	0.0644		
5.539	5.443	$\approx 1.4\%$	$\approx 2.4 \times 10^{-3}\%$	3/2-	0.03788	0.0386, 0.0379		
5.552	5.456	100%	$1.7 \times 10^{-1}\%$	3/2+	0.02434	0.0243		
5.567	5.471	66%	$1.1 \times 10^{-1}\%$	5/2+	0.0926			
5.577	5.480	≈1.7%	$\approx 2.8 \times 10^{-3}\%$	$(1/2^+)$	0.0			
* All va ** [194 *** [19	alues from [199 49Os01]. 994Li12].	97Mu08], unle	ess otherwise noted.					
Table 11 directα emis	ssion from ²³⁵ l	$Pu^*, J^{\pi} = (5/2)$	$(t^+), T_{1/2} = 25.8(1) \text{ m}$	**, $BR_{\alpha} = 3.0(6) \times 1$	0 ⁻³ %.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}($	abs)	$\mathbf{J}_f^{\pi} = E_{daughter}$	( ²³¹ U) coincid	ent $\gamma$ -rays R ₀ (fm)	HF	
5.951(20)	5.850(2	0) 3.0	(6)×10 ⁻³ %	x		1.514(14)	$1.1^{+0.6}_{-0.4}$	
* All va ** Wei	alues from [19: ghted average	57Th10], unle of 25.6(1) m [	ss otherwise noted. 1973Jo03] and 25.9(	1) m [1971Ke22].				
Table 12direct $\alpha$ emission	ssion from ²⁴³	Cf*, $J^{\pi} = (1/2)$	⁺ ), $T_{1/2} = 10.3(5)$ m	**, $BR_{\alpha} = \text{obs.}$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}($	(rel) $I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{235}$ Pu)	coincident $\gamma$ -rays	R ₀ (fm)	HF

 $\ast$  All values from [1967Fi04], unless otherwise noted.

 $\approx \! 40\%$ 

100%

7.060(10) 7.170(10)

7.178(10) 7.290(10) 0.112 0.0

(7/2⁻)

direct $\alpha$ emis	sion from ²⁴⁷ Fm*,	$J^{\pi} = (7/2^+), T_1$	$_{1/2} = 31(1) \text{ s}, BR$	$R_{\alpha} = 64\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{m{\pi}}$	$E_{daughter}(^{243})$	Cf) coincident γ-	rays	R ₀ (fm)	HF
7.953(10)	7.824(10)	64%	(7/2 ⁺ )	0.315	0.082, 0.121	8, 0.1418, 0.1666	1.5003(93)	0.84
* All va	lues from [2006He	e27], unless othe	erwise noted.					
<b>Fable 14</b> directα emis	sion from ^{247m} Fm ³	*, Ex. = 47(5) ke	$eV, J^{\pi} = (1/2^+),$	$T_{1/2} = 5.1(2)$ s	$B_{\alpha} = 88(2)\%.$			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\boldsymbol{\pi}}$	E _{daughter} (	coincide	ent $\gamma$ -rays R ₀ (fr	n) HF	
8.307(5)	8.172(5)	88(2)%	$(1/2^+)$	0.0		1.500	3(93) 1.5	$^{+0.4}_{-0.3}$
* All va	lues from [2006He	e27], unless othe	erwise noted.					
<b>Table 15</b> directα emis	sion from ²⁵¹ No*,	$J^{\pi} = (7/2^+), T_1$	$_{/2} = 0.80(1) \text{ s}, H$	$3R_{\alpha} = 91^{+9}_{-22}\%$	кж.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{247}\mathrm{Fm})$	coincident γ-rays	R ₀ (fm)	HF
8.662(8) 8.690(8) 8.701(7)	8.524(8)*** 8.552(8)*** 8.562(7)	$\approx 0.05\%$ $\approx 1.02\%$ $\approx 0.31\%$	$\approx 0.046\%$ $\approx 0.91\%$ $\approx 0.27\%$		0.051		1.485(12) 1.485(12) 1.485(12)	$\approx 80$ $\approx 51$ $\approx 180$ $\approx 120$
3.751(4)	8.612(4)	~0.51% 100.00%	≈0.40 <i>%</i> ≈89.2%	(7/2+)	0.0		1.485(12)	$\approx 120$ $0.81^{+0.28}_{-0.22}$
* All va ** [200 *** Ten	lues from [2006He 1He35]. tative [2006He27]	e27], unless othe	erwise noted.					
<b>Fable 16</b> directα emis	sion from ^{251m} No ³	^k , ex. = 106(6) k	$veV, J^{\pi} = (1/2^+)$	$T_{1/2} = 1.02(3)$	) s, $BR_{\alpha} = 100\%$ .			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{247}\mathrm{Fm})$	coincident γ-rays	R ₀ (fm)	HF
3.765(10) 3.808(4)	8.625(10) 8.668(4)	$\approx 2\%$ 100.00%	pprox 2% pprox 98%	(7/2 ⁺ )	0.043 0.0		1.485(12) 1.485(12)	$\approx 37$ $1.02^{+0.33}_{-0.25}$
* All va	lues from [2006He	27].						
<b>Table 17</b> directα emis	sion from ²⁵⁵ Rf*,	$J^{\pi} = (9/2^{-}), \mathrm{T}_{1/2}$	/ ₂ = 1.66(7) s**	$BR_{\alpha} = 46(5)\%$	ó***.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\boldsymbol{\pi}}$	$E_{daughter}(^{251}\mathrm{No})$	coincident γ-rays	R ₀ (fm)	HF
8.712(5) 8.784(5) 8.816(8)	8.575(5) [@] 8.646(5) [@] 8.678(8) [@]	1.1(5)% 1.6(6)% 3.3(11)%	0.46(24)% 0.69(24)% 1.38(48)%				1.472(38) 1.472(38) 1.472(38)	$\begin{array}{r} 40^{+70}_{-30} \\ 70^{+110}_{-50} \\ 30^{+50}_{-20} \end{array}$
8.855(4) 9.050(8)	8.716(4) 8.908(8) [@]	100(8)% 2.7(11)%	42.3(51)% 1.15(48)%	(9/2-)	0.204	0.1433, 0.2036	1.472(38) 1.472(38)	$1.3^{+2.0}_{-0.8}$ $180^{+310}_{-120}$

* All values from [2006He27], except where noted ** Weighted average of 1.68(9) s [2006He27] and 1.64(11) s [2001He35]. *** Weighted average of 58(9)% [2015An05] and 52(6)% [2001He35]. @ Tentative [2006He27].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{255}\mathrm{Rf})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
0 192(10)	0.040(10)	12(2)0/-	$\sim 10.7\%$		0.592		1 461(20)	$20^{+2.3}$
9.162(10) 9.765(8)	9.040(10)	12(2)% 100(2)%	$\approx 10.7\%$ $\approx 86.3\%$		0.385		1.401(30) 1.461(30)	$11^{+12}$
	9.01 ((0)	100(2)/0	1000.570		0.0		1.101(50)	11-6
* All val	ues from [2015An	)51						
		· • ].						
Table 19								
Table 19 directα emiss	sion from ^{259m} Sg*,	Ex. = 87(22) keV	$J, J^{\pi} = (11/2^{-}), T$	$\Gamma_{1/2} = 226$	(27) ms, $BR_{\alpha} = \approx 97\%$ .			
Table 19 directα emiss	sion from ^{259m} Sg*,	Ex. = 87(22) keV	$J, J^{\pi} = (11/2^{-}), T$	$\Gamma_{1/2} = 226$	(27) ms, $BR_{\alpha} = \approx 97\%$ .			
<b>Table 19</b> direct $\alpha$ emiss $E_{\alpha}(c.m.)$	sion from 259m Sg*, $E_{\alpha}$ (lab)	Ex. = $87(22)$ keV $I_{\alpha}$ (rel)	$J, J^{\pi} = (11/2^{-}), T$ $I_{\alpha}(abs)$	$\Gamma_{1/2} = 2260$ $J_f^{\pi}$	(27) ms, $BR_{\alpha} = \approx 97\%$ . $E_{dauehter}(^{255} \mathrm{Rf})$	coincident γ-rays	R ₀ (fm)	HF
Table 19direct $\alpha$ emiss $E_{\alpha}(c.m.)$	sion from 259m Sg*, $E_{\alpha}$ (lab)	Ex. = $87(22)$ keV $I_{\alpha}$ (rel)	$I_{J}, J^{\pi} = (11/2^{-}), T$ $I_{\alpha}(abs)$	$\Gamma_{1/2} = 2260$ $J_f^{\pi}$	(27) ms, $BR_{\alpha} = \approx 97\%$ . $E_{daughter}(^{255} \text{Rf})$	coincident γ-rays	R ₀ (fm)	HF
Table 19direct $\alpha$ emiss $E_{\alpha}(c.m.)$ 9.344(25)	sion from 259m Sg*, $E_{\alpha}(lab)$ 9.200(25)**	Ex. = $87(22)$ keV $I_{\alpha}$ (rel) 80(10)%	$J, J^{\pi} = (11/2^{-}), T$ $I_{\alpha}(abs)$ $\approx 42\%$	$\Gamma_{1/2} = 2260$ $J_f^{\pi}$	(27) ms, $BR_{\alpha} = \approx 97\%$ . $E_{daughter}(^{255} \text{Rf})$ 0.508	coincident γ-rays	R ₀ (fm) 1.461(30)	HF 0.8 ^{+0.9} _{-0.5}

* All values from [2015An05].

9.700(20)

** Tentative assignment.

#### Table 20

9.852(20)

14010 20			
direct $\alpha$ emission	from 263 Hs, T _{1/}	$_2 = 0.74^{+0.48}_{-0.21}$	ms, $BR_{\alpha} = 100\%$ .

5.6(19)%

direct  $\alpha$  emission from ²⁵⁹Sg*,  $J^{\pi} = (1/2^+)$ ,  $T_{1/2} = 402(56)$  ms,  $BR_{\alpha} = \approx 97\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{259}Sg)$	coincident $\gamma$ -rays	R ₀ (fm)	HF
10.733(60) 10.886(60) 11.058(60)	10.570(60) 10.720(60) 10.890(60)	$\approx 20\%^{**}$ $\approx 40\%^{**}$ $\approx 40\%^{**}$	$(1/2^+)?$	0.0?			

0.0

 $300^{+400}_{-200}$ 

1.461(30)

* All values from [2009Dr02].

** Based on a total of 6 decay chains, with one of the chains containing an escape  $\alpha$  from ²⁶³Hs.

 $\approx 2.9\%$ 

#### Table 21

directa emissi	lirect $\alpha$ emission from ²⁶⁷ Ds, T _{1/2} = 4 $\mu$ s, $BR_{\alpha} = \approx 100\%$ .												
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{263}\mathrm{Hs})$	coincident $\gamma$ -rays	R ₀ (fm)	HF						
11.8	11.6												

* All values from [1995Gh05] based on observation of one event.

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$  = +47/2 nuclei.

Last updated 7/18/24

#### Table 1 Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +47/2$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

NT 111	F	τ	Ŧ	0	0	0	
Nuclide	Ex.	$J^{\pi}$	$I_{1/2}$	$Q_{\varepsilon}$	Q _β -	Q _β - α	Experimental
²⁰⁹ Tl		1/2+	2 161(7) m	-5.04(15)#	3 970(6)	6 398(7)	[1993E108]
²¹³ Bi		9/2-	45.61(4) m**	-2.028(8)	1.422(5)	10.138(5)	[2013Su13, 1973Po16]
²¹⁷ At		9/2-	32.8(3) ms	-1.489(8)	0.736(6)	8.804(6)	[2013Su13]
²²¹ Fr		5/2-	4.806(6) m	-1.194(7)	0.313(6)	7.373(6)	[2017Su13]
²²⁵ Ac		$(3/2^{-})$	9.9176(18) d***	-0.356(5)	-0.356(5)	6.428(7)	[2024Ga01, 2023Br08, 2020Ko06, 2012Po14]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
²²⁹ Pa		$(5/2^+)$	1.50(5) d	0.311(4)	-6.287(4)	5.479(4)	[1987Ah05]
²³³ Np		$(5/2^+)$	36.2(1) m	1.030(50)	-5.287(52)	5.938(51)	[1973We08]
²³⁷ Am		5/2-	73.0(10) m	1.480(60)#	-4.097(78)#	7.226(60)#	[1975Ah05]
²⁴¹ Bk		$(7/2^+)$	4.6(4) m	2.28(17)#	-2.82(17)#	8.46(17)#	[2003As01]
²⁴⁵ Es		$(3/2^{-})$	66(6) s	2.93(17)#	-1.69(17)#	10.19(17)#	[1989Ha27]
²⁴⁹ Md		$(7/2^{-})$	26(1) s	3.66(16)	-0.41(17)#	11.37(16)	[2019Br06]
²⁵³ Lr		$(7/2^{-})$	$520^{+29}_{-32}$ ms	4.16(16)	0.77(19)	12.58(17)	[2017BrXX]
^{253m} Lr	х	$(1/2^{-})$	$2.00_{-0.19}^{+0.16}$ s	4.16(16)+x	0.77(19)+x	12.58(17)+x	[2017BrXX]
²⁵⁷ Db		$(9/2^+)$	1.6(2) s [@]	4.29(16)	1.12(18)	13.37(17)	[2009He20, 2001He35]
^{257m} Db	х	$(1/2^{-})$	670(60) ms	4.29(16)+x	1.12(18)+x	13.37(17)+x	[2009He20]
²⁶¹ Bh		$(5/2^{-})$	$11.8^{+3.9}_{-2.4}$ ms	5.07(18)	2.12(20)#	14.79(18)	[2020He11]
²⁶⁵ Mt		. /	-2.4	5.72(44)#	3.38(47)#	16.20(44)#	

* 100%  $\beta^-$  emitter.

** Weighted average of 45.62(6) m [2013Su13] and 45.59(6) m [1973Po16].
*** Weighted average of 9.914(4) d [2024Ga01], 9.9150(63)) d [2023Br08] 9.9179(30) d [2020Ko06] and 9.920(3) d [2012Po14].
@ Weighted average of 2.3(2) s [2009He20] and 1.50^{+0.19}_{-0.15} s [2001He35].

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +47/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	BR _{cluster}	type	Experimental
²⁰⁹ T1	7.668(31)	2.50(20)#					
²¹³ Bi	4.972(5)	5.988(3)	2.140(10)%				[2013Ma13, 1998Ar03, 1997Ch53, 1997ChZS, 1986He06,
							1967Dz02, 1964Gr11, 1950Ha52]
²¹⁷ At	4.677(5)	7.201(1)	99.32(24) %				[1997Ch19, 1997Ch53, 2013Su13, 1996GrZT, 1969LeZW,
							1967Dz02, 1964Vo05, 1963Di05, 1962Di08, 1960Vo05,
					10	14	1955St04, 1950Ha52, 1949SeZU, 1947Ha02]
221 Fr	4.624(5)	6.458(1)	100%		$1.0(2) \times 10^{-10} \%$	$^{14}C$	[1994Bo35, 2002Gr36, 1968Le07, 1995Sh01, 2020Go11,
							2013Su13, 2002GrZY, 2001GrZU, 1999Gr33, 1999Se17,
							1997/Ch53, 1997/ChZS, 1997/GrZY, 1995Bu17, 1994Ar23,
							1994B028, 1994N1ZZ, 1992L126, 1981D114, 1969DZ06,
							1969Le09, 1969Le2 W, 1967Lo2Z, 1964Va20, 1962Wa28, 1960Va05, 1955St04, 1950Ha52, 1940Sa7U, 1947Ep02
							1900 v005, 19555104, 195011852, 19495020, 1947Ellos, 1947Ha02]
²²⁵ Ac	4.477(5)	5.935(1)	100%		$5.3(10)  imes 10^{-10}\%$	$^{14}C$	[2003Ku44, 2001Ga33, 1993Bo26, 1967Ba51, 1967Dz02,
							2024Ga01, 2023Br08, 2023Mo25, 2012Po14, 2002Ku25,
							2000Ar23, 1999GrZW, 1994Gr20, 1994NiZZ, 1993BoZN,
							1993Bu26, 1993GrZQ, 1992BoZT, 1991Ko12, 1990Ko14,
							1990Li46, 1978AgZX, 1978LiZN, 1977LiYX, 1975PeZO,
							1972Dz14, 1970Dz12, 1969ArZV, 1969Dz06, 1969LeZW,
							1967Dz03, 1966Dz17, 1964Va20, 1962Dz08, 1962Wa28,
							1960Dz16, 1956Hu96, 1950Ha52, 1949SeZU, 1947En03,
229 D-	4.1(2(2)	E 925(4)	0.49(5)0/				194/Ha02]
Pa	4.105(5)	5.855(4)	0.48(5)%				[198/An05, 1903Su10, 1973Ag01, 1904Ge08, 1904Su03, 1058H;78, 1040Hy011
233 Nn	3 950(51)	5 627(51)	<0.003%				[1958] [1949][1901]
²³⁷ Am	3.621(59)	6 1/6(5)**	< 0.003%				[1930L(73] [1075Ab05 1072Po7S 1052Hi63]
²⁴¹ Bk	3.021(3)	6 986(18)#	0.025(5)70				[1975Anos, 19721023, 195211105]
245Es	2 45(17)#	7 909(3)	54(7)%				[2019Br06, 1989Ha27, 1989HaZG, 1986HaZM, 1985He22
10	2.15(17)#	(1.505(5)	51(7)70				1985MaZK, 1973Es01, 1967Mi06, 1964GhZZI
²⁴⁹ Md	2.01(17)#	8.441(18)	75(5)%				[ <b>2019Br06, 2005He27</b> , 2023Ni02, 2021Go26, 2009He20,
							2008Ga25, 2005KuZZ, 2001He35, 1991FuZZ, 1990FuZW,
							1985He22, 1973Es01]
²⁵³ Lr	1.64(17)	8.932(7)***	$98.7^{+1.0}_{-3.0}\%$	$1.3^{+1.0}_{-3.0}\%$			[2017BrXX, 2001He35, 2022Hu21, 2010He11, 2009He20,
252							2005KuZZ, 2000Ho27, 1986He28, 1985He22]
^{235m} Lr	1.64(17)-x	8.932(7)+x***	92(5)%	8(5)%			[ <b>2017BrXX</b> , <b>2001He35</b> , 2022Hu21, 2010He11, 2009He20,
-257	1.04/15	0.00((00))	1000	6.01			2005KuZZ, 2000Ho27, 1986He28, 1985He22]
²³⁷ Db	1.36(17)	9.206(20)	$\approx 100\%$	< 6%			[2010He11, 2009He20, 2005KuZZ, 2001He35, 2023Ni02,
							2021N1ZW, 2008Ga25, 2006F002, 2004HeZZ, 1999He07,
257mp-	1 26(17)	0.206(20) + 7	a 1000	<1201			1999He11, 1999HeZX, 1992An16, 1986He28, 1985He25
Db	1.30(1/)-X	9.200(20)+X	$\approx 100\%$	<13%			[2010He11, 2009He20, 2005KUZZ, 2001He35, 2008Ga25, 2004He77, 1000He07, 1000He11, 1000He77, 1
261 D1-	0.76(19)	10 500(72)	1000	<501			2004ncLL, 1999nc07, 1999nc11, 1999hcLA]
265 M+	0.70(18)	10.300(72) 11.12(40)#	100%	< 3%			[201011011, 2000F002, 1969Mu09, 1966MuZA, 1980MuZA]
1111	0.23(44)#	11.12(40)#					

* Weighted average of  $4.5(14)\times10^{-10}\%$  [2001Ga33] and  $6.0(13)\times10^{-10}\%$  [1993Bo26].

** Deduced from  $\alpha$  energies, 6.196(30) MeV in [2021Wa16].

*** Deduced from  $\alpha$  energies, 8.918(20) MeV in [2021Wa16].

#### Table 3

direct  $\alpha$  emission from ²¹³Bi,  $J^{\pi} = 9/2^{-}$ ,  $T_{1/2} = 45.61(4)$  m**,  $BR_{\alpha} = 2.140(10)$  %.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	$E_{daughter}(^{209}\text{Tl})***$	coincident γ-rays***	$R_0 \; (fm)^@$	HF
5.666(4)	5.560(4)	9.23(12)%	0.181(3)%	3/2 ⁺	0.3238	0.3238	$\approx 1.48$	$\approx 53$
5.990(4)	5.878(4)	100%	1.96(1)%	1/2 ⁺	0.0		$\approx 1.48$	$\approx 155$

* All values from [2013Ma13], except where noted.

** Weighted average of 45.62(6) m [2013Su13] and 45.59(6) m [1973Po16].

*** [2015Ch30].

[@]  $R_0 = 1.485(11)$  fm for ²¹¹Bi,  $\approx 1.48$  fm used for ²¹³Bi

## Table 4 direct $\alpha$ emission from ²¹⁷At, $J^{\pi} = 9/2^{-}$ , $T_{1/2} = 32.8(3)$ ms, $BR_{\alpha} = 99.32(24)$ %**.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	<i>E</i> _{daughter} ( ²¹³ Bi)	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.4407(16)	6.3220(16)	0.005(1)%	0.0050(1)%		0.7589(23)	0.7589	1.55090(15)	$36^{+10}_{-6}$
6.6065(16)	6.4847(16)	0.021(2)%	0.021(2)%		0.5931(23)	0.2579, 0.3355, 0.5931	1.55090(15)	39(4)
6.9418(16)	6.8138(16)	0.036(3)%	0.036(3)%	7/2-	0.2579(23)	0.2579	1.55090(15)	413(35)
7.1996(16)	7.0669(16)	100%	99.94(4)%	9/2-	0.0		1.55090(15)	1.184(17)

* All values from [1997Ch19], except where noted.

** [1997Ch53].

## Table 5

direct  $\alpha$  emission from ²²¹Fr,  $J^{\pi} = 5/2^{-}$ ,  $T_{1/2} = 4.806(6)$  m**,  $BR_{\alpha} = 100$  %.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	$E_{daughter}(^{217}\text{At})^{***}$	coincident γ-rays***	R ₀ (fm)	HF
5.601(25) 5.632(40)	5.500(25) [@] 5.530(40) [@]	$4.0(11) \times 10^{-4}\%$ $1.1(3) \times 10^{-3}\%$	$3.3(9) \times 10^{-4}\%^{@}$ 9(2) ×10^{-4}\%^{@}		$0.857(25)^{@}$ $0.826(40)^{@}$		1.55234(95) 1.55234(95)	$100^{+50}_{-30}$ $52^{+35}_{-32}$
5.794(3)	5.690(3)	0.002(1)%	0.002(1)%	5/2-	0.6644	0.1002, 0.1178, 0.2180 0.2819, 0.3821, 0.4463, 0.5623	1.55234(95)	$150^{+150}_{-50}$
5.803(4)	5.698(4)	$\approx 0.001\%$	$\approx 0.001\%$		0.655		1.55234(95)	$\approx 340$
5.883(3)	5.777(3)	0.07(1)%	0.06(1)%	7/2-	0.5770	0.1002, 0.1178, 0.2180, 0.359, 0.5770	1.55234(95)	$13.5^{+2.7}_{-2.0}$
5.890(4)	5.784(4)	0.006(2)%	0.005(2)%	(7/2,9/2	0.5688	0.1002, 0.4690, 0.5684	1.55234(95)	$180^{+120}_{-50}$
5.9212(25)	5.8140(25)	0.005(2)%	0.004(2)%	(9/2+)	0.5377	0.1002, 0.4378, 0.5375	1.55234(95)	$310^{+310}_{-110}$
6.0352(25)	5.9260(25)	0.04(1)%	0.03(1)%	(5/2,7/2,9/2)-	0.4242	0.1002, 0.3240	1.55234(95)	$140_{-40}^{+70}$
6.049(20)	5.940(20)	0.20(4)%	0.17(3)%	13/2-	0.4104	0.4104	1.55234(95)	$29_{-5}^{+6}$
6.076(25)	5.967(25)	0.10(1)%	0.08(1)%	$(7/2)^{-}$	0.3821	0.1002, 02819, 0.3821	1.55234(95)	$83^{+12}_{-10}$
6.091(20)	5.981(20)	0.59(4)%	0.49(3)%	3/2-	0.3681	0.0538, 0.096, 0.1002, 0.1178, 0.150, 0.2180	1.55234(95)	15.6(10)
6.149(3)	6.038(3)	0.004(2)%	0.003(2)%	$(13/2^+)$	0.3100		1.55234(95)	$5^{+9}_{-2}  imes 10^3$
6.189(20)	6.077(20)	0.18(4)%	0.15(3)%	3/2-	0.2718	0.0538, 0.1002, 0.1178, 0.2180	1.55234(95)	$138^{+35}_{-23}$
6.2399(20)	6.1270(20)	18.1(3)%	15.1(2)%	5/2-	0.2180	0.1002, 0.1178, 0.2180	1.55234(95)	2.36(6)
6.3584(20)	6.2433(20)	1.61(10)%	1.34(10)%	7/2-	0.1002	0.1002	1.55234(95)	86(7)
6.4582(20)	6.3413(20)	100(1)%	83.4(8)%	9/2-	0.0		1.55234(95)	3.62(11)

* All values from [1968Le07], except where noted. Values of  $E_{\alpha}$  are adjusted by +1.5 keV from [1991Ry01]. *** [2017Su13]. *** [1995Sh01]. @ [2002Gr36].

Table 6	
direct $\alpha$ emission from ²²⁵ Ac* (1 of 2), $J^{\pi} = (3/2^{-})$ , T ₁	$_{1/2} = 9.9176(18) \text{ d}^{**}, BR_{\alpha} = 100 \%.$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_{f}^{\pi@}$	$E_{daughter}(^{221}\mathrm{Fr})^{@}$	coincident γ-rays [@]	$\mathrm{HF}^{a}$
4.990(5)	4.901(5)	0.004(1)%	0.0020(5)%		0.945(5)@@@		$1.3^{+0.4}_{-0.3}$
5.158(5)	5.066(5)	0.006(2)%	0.003(1)%		0.777(5)@@@		$9^{+5}_{-3}$
5.183(4)	5.091(4)	0.012(2)%	0.006(1)%		0.7493	0.0106, 0.0367, 0.0462, 0.1199, 0.0629, 0.0735, 0.0996, 0.6035, 0.6495	$6.8^{+1.4}_{-1.0}$
5.223(5)	5.13(5)	0.004(2)%	0.0020(8)%		0.7142	0.0462, 0.1199, 0.5683	$33^{+22}_{-10}$
5.253(5)	5.16(5)	0.004(2)%	0.0020(8)%		0.681(5)@@@		$52^{+35}_{-15}$
5.295(5)	5.201(5)	0.004(1)%	0.0020(5)%		0.6375	0.0106, 0.0367, 0.0629, 0.0643, 0.0714, 0.0735,	$93^{+31}_{-19}$
						0.0746, 0.0996, 0.1008, 0.1084, 0.1262, 0.1336,	
F 205(2)	5 211(2)	0.000((())01	0.002(2).0/	(5/2)	0.(20(	0.1349, 0.1979, 0.4033, 0.691, 0.6371	- (9
5.305(3)	5.211(3)	0.006(6)%	0.003(3)%	(5/2)	0.6306	0.0106, 0.0367, 0.0385, 0.0543, 0.0643, 0.0714, 0.0746, 0.0874, 0.0040, 0.1008, 0.1084, 0.1573	$\approx 68$
						0.0740, 0.0874, 0.0949, 0.1008, 0.1084, 0.1375, 0.1958, 0.435, 0.5221, 0.5297, 0.5312, 0.5914	
						0 5942	
5.333(4)	5.238(4)	0.006(2)%	0.0030(8)%		0.6023	0.0106, 0.0367, 0.5656	$100^{+40}_{-20}$
5.366(4)	5.271(4)	0.017(4)%	0.0090(22)%	$(5/2^+, 7/2)$	0.5708	0.0106, 0.0367, 0.0385, 0.0491, 0.0543, 0.0578,	$50^{+16}_{-10}$
				( ) )		0.0629, 0.0643, 0.0714, 0.0735, 0.0746, 0.0874,	-10
						0.0949, 0.0996, 0.1008, 0.1036, 0.1084, 0.1115,	
						0.1452, 0.1501, 0.1526, 0.1539, 0.1573, 0.1958,	
						0.2169, 0.2282, 0.2535, 0.3174, 0.375, 0.4624,	
5 202(2)	5 29((2)	0.45(0)(	0.02(1)(1)	(210 - 510)	0.5520	0.4695, 0.571	2.50(11)
5.382(3)	5.286(3)	0.45(2)%	0.23(1)%	(3/2 ,5/2)	0.5520	0.0106, 0.0367, 0.0385, 0.0462, 0.0491, 0.0543, 0.0578, 0.0620, 0.0642, 0.0714, 0.0725, 0.0720	2.50(11)
						0.0578, 0.0029, 0.0043, 0.0714, 0.0733, 0.0739, 0.0746, 0.0874, 0.0949, 0.0996, 0.0998, 0.1008	
						0.1036, 0.1084, 0.1115, 0.1199, 0.1452, 0.1501,	
						0.1526, 0.1539, 0.1573, 0.1958, 0.2169, 0.2282,	
						0.2535, 0.2986, 0.3174, 0.3566, 0.4062, 0.4501,	
						0.4524, 0.5125, 0.5153, 0.5261, 0.552	
5.418(3)	5.322(3)	0.13(2)%	0.068(8)%	$(5/2^+)$	0.5177	0.0106, 0.0367, 0.0385, 0.0491, 0.0543, 0.0629,	$13.2^{+1.8}_{-1.4}$
						0.0714, 0.0735, 0.0746, 0.0874, 0.0949, 0.0996,	
						0.1008, 0.1084, 0.1115, 0.1501, 0.1573, 0.1958,	
5 480(4)	5 301(4)	0.002(1)%	0.0010(5)%		0.446(4)@@@	0.5218, 0.5085, 0.4179, 0.4811, 0.4920, 0.5179	$22^{+2.2} \times 10^{3}$
5 509(4)	5.391(4) 5 411(4)	0.002(1)%	0.0010(5)%		0.440(4) $0.426(4)^{@@@}$		$2.2_{-0.8} \times 10^{-10}$ $1.4^{+0.5} \times 10^{-3}$
5.507(4) 5.525(4)	5.477(4)	0.004(1)%	0.0020(3)%		0.4111	0.0106.0.0367.0.1376.0.236	$430^{+260}$
$\frac{5.525(4)}{5.535(4)}$	5 437(4)	0.010(0)%	0.07(2)%	$(7/2^{-})$	0.4007	0.0106, 0.0367, 0.0385, 0.0543, 0.0643, 0.0714	$56^{+23}$
5.555(1)	5.157(1)	0.11(1)//	0.07(2)70	(112)	0.1007	0.0746, 0.0874, 0.0949, 0.1008, 0.1084, 0.1128,	50-13
						0.1573, 0.1798, 0.1872, 0.1958, 0.2047, 0.2496,	
						0.3622	
5.543(3)	5.444(3)	0.25(2)%	0.13(1)%	$(5/2,7/2)^+$	0.3932	0.0106, 0.0367, 0.0385, 0.0462, 0.0491, 0.0543,	33.2(26)
						0.0578, 0.0629, 0.0643, 0.0714, 0.0735, 0.0739,	
						0.0746, 0.0788, 0.0874, 0.0949, 0.0996, 0.0998,	
						0.1008, 0.1036, 0.1084, 0.1115, 0.114, 0.1199,	
						0.1238, 0.1248, 0.1292, 0.1396, 0.1452, 0.1301, 0.1526, 0.1539, 0.1573, 0.1691, 0.1707, 0.1783	
						0.1820, 0.1839, 0.1978, 0.1091, 0.1707, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709, 0.1709,	
						0.2247, 0.2282, 0.2407, 0.2432, 0.248, 0.2535,	
						0.2793, 0.3549	
5.588(4)	5.489(4)	0.004(1)%	0.0020(7)%		0.346(4)@@@		$3.9^{+2.1}_{-1.0}  imes 10^3$
5.596(4)	5.497(4)	0.006(2)%	0.003(1)%		0.338(4)@@@		$2.8^{+1.4}_{-0.7}  imes 10^3$
5.626(5)	5.526(5)	0.019(4)%	0.010(2)%		0.308(5)@@@		$1.2^{+0.3}_{-0.2} \times 10^3$
5.640(5)	5.540(5)	0.08(2)%	0.04(1)%	$(9/2)^+$	0.2946	0.0385, 0.256	$360^{+120}_{-70}$
5.646(4)	5.546(4)***	0.06%	0.03%***	(9/2-)	0.2881	0.0106, 0.0367, 0.0385, 0.0643, 0.0714, 0.0746,	520
ECEEAN	E EE 4 ( 4 ) + + + +	0.0200	0.01501 ***	$(7/2)^+$	0.2702	0.1008, 0.1084, 0.1798, 0.1872, 0.2496	$1.2 \times 10^{-3}$
5.655(4)			· · · · · · · · · · · · · · · · · · ·	1 1 1 1 1 1			1 1 1 11 2
	5.554(4)***	0.030%	0.013%	$(112)^{-1}$	0.2792	0.0746 0 1008 0 1084 0 1115 0 1202 0 1501	$1.2 \times 10$

* All values from [1967Dz02], unless otherwise noted. ** Weighted average of 9.914(4) d [2024Ga01], 9.9150(63)) d [2023Br08] 9.9179(30) d [2020Ko06] and 9.920(3) d [2012Po14].

*** [1967Ba51], values adjusted by +1.3 keV as suggested in [1991Ry01].

^(a) [190/Ba/1], rates as a second of  $\alpha$  (3/2)⁻ 99.6 keV, (3/2)⁺ 99.8 keV and (5/2)⁻ 100.9 keV states ^(a) ^(a) ^(a) ^(b) ^(a) ^(b) ^{(b}

Table 7	
direct $\alpha$ emission from ²²⁵ Ac* (2 of 2), $J^{\pi} = (3/2^{-})$ , $T_{1/2} = 9.9176(18) d^{**}$ , $BR_{\alpha} =$	100 %.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@}$	$E_{daughter}(^{221}\mathrm{Fr})^{@}$	coincident γ-rays [@]	$\mathrm{HF}^{a}$
5.664(2)	5.563(2)***	0.066%	0.034%***	$(7/2, 9/2)^{-}$	0.2735	0.0106, 0.0367, 0.236	550
5.678(3)	5.577(3)	2.3(2)%	1.2(1)%	$(5/2)^+$	0.2535	0.0106, 0.0367, 0.0385, 0.0491, 0.0543, 0.0578,	19.8(17)
						0.0629, 0.0714, 0.0735, 0.0746, 0.0874, 0.0949,	
						0.0996, 0.1008, 0.1036, 0.1084, 0.1115, 0.1452,	
						0.1501, 0.1526, 0.1539, 0.1573, 0.1958, 0.2169,	
						0.2282, 0.2535	
5.700(4)	5.599(4)***	0.1%	0.04%***	$(5/2)^+$	0.2345	0.0106, 0.0367, 0.0629, 0.0643, 0.0714, 0.0735,	740
						0.0746, 0.0996, 0.1008, 0.1084, 0.1262, 0.1336,	
						0.1349, 0.1979	
5.710(3)	5.608(3)	2.1(2)%	1.1(1)%	$(3/2,5/2)^+$	0.2246	0.0106, 0.0367, 0.0385, 0.0462, 0.0643, 0.0739,	30.4(28)
						0.0746, 0.0788, 0.0998, 0.1008, 0.1199, 0.1238,	
						0.1248, 0.1861, 0.1880, 0.1984, 0.2247	
5.739(3)	5.637(3)	8.7(6)%	4.5(3)%	$(5/2, 7/2)^{-}$	0.1958	0.0106, 0.0367, 0.0385, 0.0543, 0.0714, 0.0746,	10.4(7)
						0.0874, 0.0949, 0.1008, 0.1084, 0.1573, 0.1958	
5.784(3)	5.681(3)	2.7(4)%	1.4(2)%	$(7/2)^+$	0.1500	0.0106, 0.0367, 0.0385, 0.0491, 0.0714, 0.1084,	$57^{+10}_{-7}$
						0.1115, 0.1501	,
5.827(3)	5.723(3)	5.6(10)%	2.9(5)%	$(7/2)^{-}$	0.1083	0.0106, 0.0367, 0.0714, 0.1084	$45^{+9}_{-7}$
5.835(3)	5.731(3) ^{@@}	19.4(6)%	10.0(1)%	$(3/2)^{-}$	0.0996	0.0106, 0.0367, 0.0629, 0.0735, 0.0996	14.37(17)
5.897(3)	5.792(3)	51.7(35)%	26.7(10)%	(3/2)-	0.0366	0.0106, 0.0367	11.0(4)
5.910(2)	5.805(2)***	0.6%	0.3%***	$(1/2)^{-}$	0.0259		$1.1 \times 10^3$
5.935(2)	5.829(2)	100(3)%	51.6(15)%	5/2-	0.0	_	8.59(32)

* All values from [1967Dz02], unless otherwise noted.

** Weighted average of 9.914(4) d [2024Ga01], 9.9150(63)) d [2023Br08] 9.9179(30) d [2020Ko06] and 9.920(3) d [2012Po14].

*** [1967Ba51], values adjusted by +1.3 keV as suggested in [1991Ry01] (due to energy changes in calibration sources).

[@] 2003Ku44

^{@@} Likely a multiplet feeding the  $(3/2)^-$  99.6 keV,  $(3/2)^+$  99.8 keV and  $(5/2)^-$  100.9 keV states ^{@@@} Deduced from  $\alpha$  energies.

^{*a*}  $R_0$  (= 1.53983(27) fm.

#### Table 8

direct  $\alpha$  emission from ²²⁹Pa,  $J^{\pi} = (5/2^+)$ ,  $T_{1/2} = 1.50(5) d^*$ ,  $BR_{\alpha} = 0.48(5) \%^*$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi*}$	$E_{daughter}(^{225}\mathrm{Ac})^*$	coincident γ-rays*	R ₀ (fm)	HF
5.415	5.310	0.14%	0.02%		0.422***		1.53293(31)	52
5.509	5.413	0.41%	0.07%		0.328***		1.53293(31)	59
5.518	5.422	0.19%	0.03%		0.319***		1.53293(31)	140
5.576	5.479	4.7%	0.82%	(9/2+)	0.2569	0.0678, 0.0751, 0.1119, 0.1520, 0.1584, 0.1799	1.53293(31)	13
5.599	5.501	1.9%	0.34%	(9/2-)	0.2355	0.1584	1.53293(31)	41
5.615	5.517	1.6%	0.29%		0.222***		1.53293(31)	57
5.634	5.536	24.1%	4.22%	$(7/2^+)$	0.1999	0.0348, 0.0401, 0.0647, 0.0751,	1.53293(31)	5.1
						0.0790, 0.0806, 0.0949, 0.1208,		
						0.1228, 0.1352, 0.1699		
5.664	5.565	10.68%	1.87%	$(7/2^{-})$	0.1708	0.936, 0.1409	1.53293(31)	16
5.679	5.580	100%	17.52%	$(5/2^+)$	0.1557	0.0348, 0.0401, 0.0806, 0.1156,	1.53293(31)	2.1
						0.1208, 0.1557		
5.690	5.591	12.6%	2.21%	$(9/2^+)$	0.1449	0.0678	1.53293(31)	19
5.715	5.615	36.4%	6.38%	$(5/2^{-})$	0.1208	0.0401, 0.0806, 0.1208	1.53293(31)	8.9
5.730	5.630	26.6%	4.66%	$(7/2^{-})$	0.1051	0.0771	1.53293(31)	15
5.771	5.670	50.7%	8.88%	$(5/2^+)$	0.0647	0.0348, 0.0647	1.53293(31)	13
5.796	5.695	4.1%	0.72%	$(3/2^+)$	0.0401	0.0401	1.53293(31)	210
5.837	5.735	1.4%	0.24%	$(3/2^{-})$	0.0		1.53293(31)	1000

* [1987Ah05]. ** [1963Su10].  $E_{\alpha}$  values are adjusted by 5.2 keV as suggested in [1991Ry01] (due to energy changes in calibration sources).

*** Deduced from  $\alpha$  energies.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^2$	³³ Np)	coincide	nt γ-rays	$R_0$ (fm)	HF	
6.146(5)	6.042(5)	0.025(3)%	(5/2+)	0.0				1.4954(46	0.85	+0.17 -0.14
* All val	ues taken from [1	975Ah05].								
Table 10	245									
lirect $\alpha$ emis	sion from ²⁴³ Es*,	$J^{\pi} = (3/2^{-}), T_{1/2}$	$= 66(6) \text{ s}, BR_{\alpha}$	$= 54(7)\%^{**}.$						
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	Edaughter	⁽²⁴¹ Bk)	coincident	γ-rays	R ₀ (fm)	HF
7.781(6)	7.654(6)	4(1)%	2(1)%		0.128				1.502(36)	$30^{+40}_{-20}$
7.827(5)	7.699(5)	16(5)%	7(2)%		0.082				1.502(36)	$2.3_{-1.4}^{+3.2}$
7.858(1)	7.730(1)	100(11)%	43(6)%		0.051				1.502(36)	$18^{+27}_{-12}$
(.909(3)	7.780(3)	6(1)%	3(1)%	$(7/2^+)$	0.0				1.502(36)	$70^{+100}_{-50}$
* All val ** [2019	lues taken from [1 9Br06].	989Ha27], unless	otherwise noted	1.						
<b>Fable 11</b> directα emis	sion from ²⁴⁹ Md*	$J^{\pi} = (7/2^{-}), T_{1/2}$	$_2 = 26(1) \text{ s**}, B$	$R_{\alpha} = 75(5)\%^{**}$	¢.					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{245})$	Es)	coincident j	γ-rays	R ₀ (fm	) HF	1
3.157(10)	8.026(10)	75(5)%**	J.	x		0.2004, 0.22	232, 0.2532	1.493(	14) 1.1	$^{+0.4}_{-0.3}$
* All val ** [2019	lues taken from [1 9Br06].	989Ha27], unless	otherwise noted	1.						
lable 12 lirect $\alpha$ emission	sion from ²⁵³ Lr, J	$T^{\pi} = (7/2^{-})^{*}, T_{1/2}$	$= 520^{+29}_{-32} \text{ ms}^{**}$	$BR_{\alpha} = 98.7^{+1}_{-3}$	.0%***.					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})^*$	$I_{\alpha}(abs)$	$J_f^{\pi*}$	Edaught	$e_{r}(^{217}At)$	coinciden	nt γ-rays	$R_0$ (fm)	HF
3.842(20) 3.932(7)	8.660(20)* 8.791(7) [@]	4(1)% 100%	$4(1)\% \\ 94.6^{+1.0}_{-3.0}$	(11/2 ⁻ ) (7/2 ⁻ )	0.0				1.478(29) 1.478(29)	$16^{+18}_{-9}\\0.7^{+0.8}_{-0.4}$
* [2022] ** [2017 *** [200 [@] Weigh	Hu21]. /BrXX]. )1He35]. hted average of 8.	788(10) MeV [20	17BrXX] and 8.	794(10) MeV [2	2001He35]					
Table 13										
lirect $\alpha$ emis	sion from ^{253m} Lr,	Ex. = unk., $J^{\pi}$ =	$(1/2^{-})^{*}, T_{1/2} = 1$	$2.00^{+0.16}_{-0.19}$ s**, <i>I</i>	$BR_{\alpha} = 92(5)$	)%***.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_{f}^{\pi @}$	$E_{daughter}$	( ²¹⁷ At)	coincid	lent γ-rays	R ₀ (fm)	HF	
3.858(7)	8.718(7) [@]		$94.6^{+1.0}_{-3.0}$	(1/2 ⁻ )				1.478(2	9) 3.0	+3.0
* [2022]	Hu21]. ZBrXX1		5.0							-10

[@] Weighted average of 8.713(10) MeV [2017BrXX] and 8.722(10) MeV [2001He35]

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	$E_{daughter}(^{217}\mathrm{At})^{***}$	coincident γ-rays	$R_0$ (fm)	HF
9.014(20)	8.874(20) [@]		weak [@]	$(9/2^+) 0.201$		1.465(39)		
9.089(15)	8.948(15)		$\approx 50\%^{***}$	$(1/2^{-}) 0.126$	0.102	1.465(39)	$\approx 2.1$	
9.215(10)	9.072(10)		$pprox 50\%^{***}$	(7/2-)	0.0		1.465(39)	$\approx 5$

direct  $\alpha$  emission from ²⁵⁷Db,  $J^{\pi} = (9/2^+)$ ,  $T_{1/2} = 1.6(2)$  s*,  $BR_{\alpha} = \approx 100$  %.

* Weighted average of 2.3(2) s [2009He20] and  $1.50^{+0.19}_{-0.15}$  s [2001He35].

** Weighted average of values from [2010He11], [2009He20], [2005KuZZ] and [2001He35].

*** [2001He35].

[@] [2009He20].

#### Table 15

direct  $\alpha$  emission from ^{257m}Db, E. = unk.,  $J^{\pi} = (1/2^{-})$ ,  $T_{1/2} = 670(60)$  ms*,  $BR_{\alpha} = \approx 100$  %.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	$E_{daughter}(^{217}\text{At})^{***}$	coincident γ-rays	$R_0$ (fm)	HF
9.308(10)	9.163(10)**	$\approx 100\%$	(7/2 ⁻ )	0.0		1.465(39)	$1.9^{+3.1}_{-1.2}$
* [200014-2	01						

** Weighted average of values from [2010He11], [2009He20], [2005KuZZ] and [2001He35].

#### Table 16

|--|

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{257}\text{Db})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
$\approx 10.2$	≈10.0	100%	(5/2 ⁻ )	> 0.350		1.461(22)	≈1.8

* All values from [2010He11].

** [1989Mu09] report three  $\alpha$  transitions with energies of 10.03, 10.10 and 10.40. The later two are shown to be  $\alpha$  peaks summed with conversion electrons in [2010He11].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +24 nuclei.

Last updated 10/21/2024

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +24$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide		$J^{\pi}$	$T_{1/2}$	$Q_{arepsilon}$	Q _β -	$Q_{\beta}$ - $\alpha$	Experimental
208110		0+	125(10) a	7 26(20)#	2 (180(20)	4 70(20)#	[2020Ca25]
212 DL		0+	10.600(7) h	-7.30(30)#	3.460(30)	4.70(20)#	[2020Ca25]
216p		0+	10.622(7) n	-0.00(20)#	0.569(2)	0.785(3)	[2017K010] [10(2D)05]
210 PO		0	145(2) ms	-4.092(11)	-0.474(4)		
²²⁰ Rn		$0^{+}$	55.61(4) s	-3.764(14)	-0.870(4)		[1966Hu20]
²²⁴ Ra		$0^+$	3.6313(14) d	-2.923(11)	-1.408(0)		[2021Be13]
²²⁸ Th		$0^+$	698.3(6) d	-2.124(3)	-2.153(4)		[2014Un01]
²³² U		$0^+$	68.81(38) y	-1.337(7)	-2.75(10)#		[1979Ag04]
²³⁶ Pu		$0^+$	2.862(8) y*	-0.480(50)	-3.14(12)#		[1957Ho66, 1984Na30]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
²⁴⁰ Cm		$0^+$	26.8(3) d	0.214(14)	-4.153(2)	5.921(50)	[1949Se01]
^{240m} Cm	х		55(12) ns	0.214(14)+x	-4.153(2)+x	5.921(50)+x	[1976Si01]
²⁴⁴ Cf		$0^{+}$	19.4(6) m	0.764(15)	-2.993(3)	7.543(14)	[1967Si08]
²⁴⁸ Fm		$0^+$	35.1(8) s	1.600(50)#	-1.501(17)	8.759(17)#	[2011Ga19]
²⁵² No		$0^+$	2.42(6) s	2.400(90)	-0.376(17)	10.148(53)	[2007Su19]
²⁵⁶ Rf		$0^{+}$	6.66(10) ms**	2.480(80)	0.121(23)	11.330(93)	[2023Is03, 2020Ku23, 1997He29, 2012Gr12]
^{256m} Rf	х		$10.4^{+8.4}_{-3.2}$ s	2.480(80)+x	0.121(23)+x	11.330(93)+x	[2009SaZV]
²⁶⁰ Sg		$0^{+}$	4.95(33) ms	2.88(10)#	0.892(75)#	12.376(85)#	[2009He20]
^{260m} Sg	х		$180^{+150}$ ms	2.88(10)#	0.892(75)#	12.376(85)#	[2009SaZV]
²⁶⁴ Hs***			$0.90^{+0.40}$ ms	3 61(18)#	2.079(99)#	13 466(98)#	[2009SaZV]
²⁶⁸ Ds			-0.20 ms	4.50(38)#	3.702(316)#	15.265(350)#	[]

* Weighted average of 2.851(8) y [1957Ho66] and 1046.9(31) d [1984Na30] (365.2424 d = 1 y). ** Weighted average of 6.7(2) ms [2023Is01], 6.90(23) ms [2020Ku23], 6.2(2) ms [1997He29] and 6.9(2) ms [2012Gr12].

*** Possibly an isomer.

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +24$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	BR _{cluster}	type	Experimental
²⁰⁸ Hg ²¹² Pb	9.91(30)# 8.760(42)	1.93(20)# 3.292(31)					
²¹⁶ Po	7.136(6)	6.906(1)	100%				[ <b>1977Ku15, 1971Gr17, 1962Wa28</b> , 2021Az03, 2017Na22, 2003Da24, 1963Di05, 1942Wa04, 1911Mo011
²²⁰ Rn	7.073(3)	6.405	100%				[ <b>1971G17</b> , <b>1962Wa28</b> , 2003Da24, 1989Po03, 1966Hu20, 1963Gi17, 1961Ro14, 1956Ma28, 1955Sc81]
²²⁴ Ra	6.845(2)	5.789	100%		5.6(10)×10 ⁻⁹ %*	¹⁴ C	[ <b>1992Ar02</b> , <b>1991H015</b> , <b>1985Pr01</b> , <b>1977Ku15</b> , <b>1962Ba19</b> , <b>1971Gr17</b> , 2021Be13, 2004Sc04, 1991Ho24, 1991HoZX, 1984Bo15, 1984AIZP, 1982Sa36, 1971Jo14, 1969Pe17, 1962Wa28, 1953As31, 1953AsZZ, 1938Le07]
²²⁸ Th	6.368(2)	5.520	100%		1.13(22)×10 ⁻¹¹ %	²⁰ O	[1993Bo20, 1977Ku15, 1971Gr17, 1993BoZN, 1992BoZT 1990Sa38, 1984Ge07, 1982Sa36, 1972DaYV, 1971Jo14, 1970Ba20, 1957St92, 1954Ne01, 1953As31, 1953AsZZ, 1951Be42]
²³² U	6.104(2)	5.414	100%	2.7(6)×10 ⁻¹² %	8.78(49)×10 ⁻¹⁰ %**	²⁴ Ne	[ <b>2000Bo46</b> , <b>1991Bo20</b> , <b>1990Bo16</b> , <b>1977Ku15</b> , <b>1972Go33</b> , <b>1966Ba49</b> , 1987BaZS, 1985Ba18, 1979Ag04, 1974KaZM, 1971So15, 1968Ba25, 1966Ba15, 1965Be15, 1964Ch05, 1963Le17, 1957Hy90, 1955As28, 1955Go32, 1954Se26, 1953AsZZ
²³⁶ Pu	5.431(2)	5.867	100%	$1.25(3) \times 10^{-7}$	%*** 2.7(7) × $10^{-12}$ % [@]	²⁸ Mg	[ <b>1995Hu21, 1994Ar08, 1988SeZY, 1984Ry02, 1952Gh27</b> 1997De11, 1990Og01, 1989Wa29, 1984Na30, 1957Ho66, 1956Cr69, 1956Hu96, 1952Du04, 1949Ja01]
²⁴⁰ Cm	4.955(2)	6.398(1)	$\approx 100\%$	3.9(8)×10 ⁻⁶ %			[ <b>1971Bb10, 1967Ba42, 1952Gh27</b> , 1960Gl01, 1952Hi11, 1949Se01]
^{240m} Cm ²⁴⁴ Cf	4.955(2)-x 4.501(5)	6.398(1)+x 7.329(2)#	75(6)%	obs			[ <b>1976Sl01</b> ] [ <b>2018Ko05, 1967Si08</b> , 1967Fi04, 1956Ch43]
²⁴⁸ Fm	3.970(21)	7.995(8)	$93^{+7}_{-17}\%$	0.097(48)%			[ <b>1993An10, 1967Nu01</b> , 2024PoXY, 2011Ga19, 2010KeZY, 2006Ni09, 1980Ho25, 1970Dr05, 1966Ak01]
²⁵² No	3.384(21)	8.549(5)	65.3(5)%	33.9(3)%			[ <b>2012Su22, 2007Su19, 1977Be09</b> , 2024PoXY, 2015Sv02, 2015SvZZ, 2012Sv02, 2012SvZZ, 2006Le29, 2003Be18, 2002He01, 1994Wi17, 1967Gh01, 1967Mi03]
²⁵⁶ Rf	3.014(25)	8.926(15)	$0.29^{+0.13}_{-0.10}\%$	$5 99.71^{+0.10}_{-0.13}\%$			[2020Ku23, 1997He29, 2010St14, 1986He28, 2023Is03, 2021Te08, 2020Mo11, 2019MoZV, 2018Mo20, 2016KhZZ, 2016Sv02, 2013Ri07, 2012Gr12, 2011Ro20, 1994Hu18, 1994Wi17, 1985So03, 1984Og03, 1976FIZN, 1975Og01, 1975Og04]
256m Rf	3.014(25)-x	8.926(15)+x	$\approx 100\%$				[2009SaZV]
²⁶⁰ Sg	2.732(60)	9.901(10)	29(3)%	71(3)%			[2009He20, 2009SaZV, 1985Mu11, 1985Ho29, 1984De07, 1984Og03]
$^{260m}Sg$	2.732(60)-x	9.901(10)+x	$\approx 100\%$				[2009SaZV]
²⁶⁴ Hs	2.22(31)#	10.591(20)	$80^{+20}_{-40}\%$	$20^{+46}_{-17}\%$			[ <b>2011Sa41, 2009SaZV</b> , 1987Mu15, 1987MuZX, 1986Mu10, 1984Og03]
²⁶⁸ Ds	1.43(59)#	11.66(30)#					

* Weighted average of  $6.5(10) \times 10^{-9}\%$  [1991Ho15] and  $4.3(12) \times 10^{-9}\%$  [1985Pr01]. ** Weighted average of  $8.88(71) \times 10^{-10}\%$  [1991Bo20] and  $8.68(93) \times 10^{-10}\%$  [1990Bo16]. *** Weighted average of SF partial  $T_{1/2}$  of  $3.5(1) \times 10^9$  y [1952Gh27],  $2.09(6) \times 10^9$  y [1988SeZY] and  $1.13(13) \times 10^9$  y [1995Hu21].

@ [1995Hu21].

## Table 3

direct  $\alpha$  emission from ²¹⁶Po,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 145(2)$  ms*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{212}\text{Pb})$	coincident γ-rays	$R_0$ (fm)	HF	
6.097 6.9062(5)	5.984** 6.7783(5)***	$\frac{1.91(24)\times10^{-3}\%^{@}}{100\%}$	$\begin{array}{c} 1.91(24)\times 10^{-3}\%\\ 99.99809(24)\%\end{array}$	$(2^+)^{@@} 0^+$	0.8049 ^{@@}	0.8049 ^{@@} 1.54117(28)	1.54117(28) 1.006(14)	$35^{+6}_{-4}$

* [1963Di05].

** [1962Wa28]. *** [1971Gr17], modified by 0.2 keV as reccommended by [1991Ry01].

[@] Weighted average of  $1.8(3) \times 10^{-3}\%$  [1977Ku15] and  $2.1(4) \times 10^{-3}\%$  [1962Wa28].

@@ [2020Au03].

direct $\alpha$ emission from	n ²²⁰ Rn, 1	$J^{\pi} = 0^+,$	$T_{1/2} =$	= 55.61(4)s*,	$BR_{\alpha} = 1$	100%.
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{216}\text{Po})$	coincident γ-rays	R ₀ (fm)	HF	
5.853 6.40474(10)	5.747** 6.28829(10)***	0.07(2)%** 100%	0.07(2)% 99.93(2)%	$2^{+@} 0^{+}$	0.5498 [@] 0.0	0.5498 [@]	1.55548(10) 1.55548(10)	$5.2^{+2.1}_{-1.2}$ 1.0018(7)

* [1966Hu20].

** [1962Wa28].

*** [1971Gr17].  $E_{\alpha}$  is reduced by -0.21 keV as recommended in [1991Ry01].

[@] [2007Wu02].

## Table 5

Table	3					
direct	$\alpha$ emission	from ²²⁴ Ra,	$J^{\pi} = 0^+, T_1$	$_{/2} = 3.6313(14)$	$d^{**}, BR_{\alpha} =$	100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{220}\mathrm{Rn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.1257(10) 5.1433(20) 5.2550(10) 5.5477(9) 5.78874(20)	5.0342(10) 5.0515(20) 5.1612(10) 5.4486(9)*** 5.68537(20) [@]	$\begin{array}{l} 3.1(5)\times 10^{-3}\%\\ 7.7(11)\times 10^{-3}\%\\ 7.3(8)\times 10^{-3}\%\\ 5.3(2)\%\\ 100\% \end{array}$	$\begin{array}{l} 2.9(5)\times 10^{-3}\%\\ 7.3(10\times 10^{-3}\%\\ 6.9(8)\times 10^{-3}\%\\ 5.00(16)\%\\ 94.96(16)\% \end{array}$	(1 ⁻ ,2 ⁺ ) 2 ⁺ 0 ⁺	0.6630(10) 0.6454(20) 0.5337(10) 0.24098(1) 0.0	0.2410, 0.4220 0.2410, 0.4042, 0.8456 0.2927 0.2410 —	1.542177(86) 1.542177(86) 1.542177(86) 1.542177(86) 1.542177(86)	$7.7^{+1.6}_{-1.1}$ $3.9^{+0.6}_{-0.5}$ $18.7^{+2.5}_{-2.0}$ $1.088(35)$ $0.9976(17)$

* All values from [1977Ku15], except where noted.  $E_{\alpha}(c. m.)$  values determined from level energies fed by  $\alpha$  decay relative to the value to the ground state. ** [2021Be13].

*** Value of 5.4472(5) MeV reported in [1971Gr17], modified by +1.6 keV in [1991Ry01].

[@] Value of 5.68556(20) MeV reported in [1971Gr17], modified by -0.19 keV in [1991Ry01].

#### Table 6

direct ¹⁴ C emission from ²²⁴ Ra, $J^{\pi} = 0^+$ , $T_{1/2} = 3.6313(14) d^*$ , $BR_{14C} = 5.6(10) \times 10^{-9}\%^{**}$ .									
<i>E</i> _{14<i>C</i>} (c.m.)	$E_{14C}(\text{lab})$	$I_{14C}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{210}\mathrm{Pb})$	coincident $\gamma$ -rays				
30.54	28.63	$5.6(10)  imes 10^{-9}\%^{*}$	$0^+$	0.0					

* [2021Be13].

** Weighted average of  $6.5(10) \times 10^{-9}\%$  [1991Ho15] and  $4.3(12) \times 10^{-9}\%$  [1985Pr01].

*** [1992Ar02].

# Table 7

direct $\alpha$ emission from ²²⁶ Th, $J^{\mu} = 0^+$ , $T_{1/2} = 698.3(6) d^*$ , $BR_{\alpha} = 10^{-1}$
-----------------------------------------------------------------------------------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{224}$ Ra)	coincident $\gamma$ -rays	R ₀ (fm)	HF
4.5271(10)	4.4477(10)	$\approx 4\times 10^{-6}\%$	$\approx 3\times 10^{-6}\%$	(2+)	0.9929(10)	0.08437, 0.16641, 0.7422, 0.9929	1.53389(32)	$\approx 10.8$
4.6036(3)	4.5228(3)	$2.3(4)\%  imes 10^{-5}\%$	$1.7(3) \times 10^{-5}\%$	$0^+$	0.9164(2)	.08437, 0.13161, 0.21598, 0.7006, 0.8320	1.53389(32)	$7.0^{+1.5}_{-1.1}$
5.0407(3)	4.9523(3)	$3.3(6)  imes 10^{-5}\%$	$2.4(4)  imes 10^{-5}\%$	$6^+$	0.4793(2)	0.08437, 0.16641, 0.2285	1.53389(32)	$4.6^{+9}_{-7}  imes 10^3$
5.0872(3)	4.9979(3)	$1.4(3) \times 10^{-5}\%$	$9.80(23) \times 10^{-6}\%$	5-	0.4328(2)	0.08437, 0.1420, 0.16641, 0.1822, 0.20593	1.53389(32)	$2.19(5) \times 10^4$
5.22966(23)	5.13791(23)	0.05(8)%	0.036(6)%	3-	0.29033(5)	0.08437, 0.20593	1.53389(32)	$44^{+9}_{-6}$
5.26921(22)	5.17677(22)	0.290(16)%	0.210(11)%	$4^+$	0.25078(4)	0.08437, 0.16641	1.53389(32)	13.0(7)
5.30401(22) 5.43562(22) 5.51999(22)	5.21096(22) 5.34026(22) 5.42315(22)**	0.55(3)% 37.3(21)% 100.0(19)%	0.395(17)% 27.0(14)% 72.4(1)%	$1^{-}$ $2^{+}$ $0^{+}$	0.21598(5) 0.08437(3) 0.0	0.08437, 0.13161, 0.21598 0.08437	1.53389(32) 1.53389(32) 1.53389(32)	11.1(5) 0.92(5) 1.0117(17)

* [2014Un01].

** Taken from [1971Gr17], modified by -0.18 keV by [1991Ry01].

*** All values from [1977Ku15], except where noted.  $E_{\alpha}$ (c. m.) values determined from level energies fed by  $\alpha$  decay relative to the value to the ground state.
Table 8	
direct $\alpha$ emission from ²³² U*, $J^{\pi} = 0^+$ , $T_{1/2} = 68.81(38)$ y**, B	$R_{\alpha} = 100\%.$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{228}\mathrm{Th})$	coincident γ-rays	R ₀ (fm)	HF
4.539(1)	4.461(1)	$4.7(23) \times 10^{-5}\%$	$3.2(16) \times 10^{-5}\%$	2+	0.874(1)	0.0578, 0.1291, 0.2095, 0.2702, 0.3279, 0.3381, 0.478, 0.547, 0.817	1.52885(29)	$3.3^{+3.4}_{-1.1}$
4.5822(5)	4.5032(5)	$3.1(6)  imes 10^{-5}\%$	$2.1(4) \times 10^{-5}\%$	$0^+$	0.8313(5)	0.0578, 0.2702, 0.3279, 0.5036, 0.7734, 0.831	1.52885(29)	$10.7^{+2.6}_{-1.8}$
4.8944(3)	4.8100(3)	$7.9(4)  imes 10^{-5}\%$	$5.4(3)  imes 10^{-5}\%$	5-	0.5191(3)	0.0578, 0.1291, 0.1410, 0.1910, 0.3323	1.52885(29)	700(40)
5.0176(5)	4.9310(5)	$7.0(3)  imes 10^{-5}\%$	$4.8(2) \times 10^{-5}\%$	3-	0.3959(5)	0.0578, 0.1291, 0.2095, 0.3381	1.52885(29)	$5.2(2) \times 10^3$
5.0356(3)	4.9487(3)	$7.5(6)  imes 10^{-5}\%$	$5.1(4)  imes 10^{-5}\%$	$6^+$	0.3779(2)	0.0578, 0.1291, 0.1910	1.52885(29)	$6.4(5) \times 10^{3}$
5.0856(2)	4.9979(2)	$8.2(25) \times 10^{-3}\%$	$5.6(17) \times 10^{-3}\%$	1-	0.3279(2)	0.0578, 0.2702, 0.3279	1.52885(29)	$80^{+40}_{-20}$
5.2266(2)	5.1364(2)	0.47(2)%	0.32 (1)%	$4^{+}$	0.1869(7)	0.0578, 0.1291	1.52885(29)	16.3(6)
5.35568(15)	5.26334(15)	45.8(6)%	31.3(4)%	$2^{+}$	0.05778(5)	0.0578	1.52885(29)	0.996(14)
5.41346(14)	5.32012(14)***	100%	68.4(4)%	$0^+$	0.0		1.52885(29)	0.993(8)

* All values from [1977Ku15], except where noted.  $E_{\alpha}(lab)$  values are deduced from level energies and the  $E_{\alpha}$  value to the ground state of ²²⁸Th. *** [1979Ag04]. *** Value from [1972Go33], modified by -0.18 keV as recommended by [1991Ry01].

Table 9			
direct $\alpha$ emission from	236 Pu*, $J^{\pi} = 0^+$	$T_{1/2} = 2.862(8) y^*$	**, $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{232}\mathrm{U})$	coincident γ-rays	R ₀ (fm)	HF
4.89917(16)	4.81613(16)	2.12(3)×10 ⁻⁵ %	1.47(2)×10 ⁻⁵ %	(2+)	0.9678(14)	0.0476, 0.1090, 0.3385, 0.4045, 0.4723, 0.5156, 0.5632, 0.5814, 0.8113, 0.9202	1.51022(22)	6.99(19)
4.93948(13)	4.85576(13)	2.02(3)×10 ⁻⁵ %)	$1.40(2) \times 10^{-5}\%$		0.92749(10)	0.0476, 0.3640, 0.5156, 0.5632, 0.8799, 0.9277***	1.51022(22)	13.89(21)
5.00013(13)	4.91538(13)	$1.68(2) \times 10^{-5}\%$	$1.17(1) \times 10^{-5}\%$	$2^+$	0.86684(10)	0.0476, 0.1090, 0.7101, 0.8193, 0.8669	1.51022(22)	42.8(4)
5.03344(22)	4.94813(22)	$1.44(3) \times 10^{-7}\%$	9.96(2)×10 ⁻⁸ %	$4^{+}$	0.83353(20)	0.0476, 0.1090, 0.6770	1.51022(22)	$8.40(3) \times 10^3$
5.12016(13)	5.03136(13)	3.63(5)×10 ⁻⁶ %	$2.52(3) \times 10^{-6}\%$	5-	0.74681(10)	0.0476, 0.1090, 0.166, 0.4239, 0.5903	1.51022(22)	$1.23(2) \times 10^3$
5.13233(13)	5.04534(13)	3.54(6)×10 ⁻⁴ %	2.45(4)×10 ⁻⁴ %	$2^{+}$	0.73464(10)	0.0476, 0.1090, 0.5780, 0.6870, 0.7345	1.51022(22)	15.16(25)
5.17553(9)	5.08781(9)	$3.41(6) \times 10^{-4}\%$	$2.36(3) \times 10^{-4}\%$	$0^+$	0.69144(4)	0.0476, 0.6439	1.51022(22)	29.8(4)
5.30382(8)	5.21392(8)	$3.89(5) \times 10^{-4}\%$	$2.70(3) \times 10^{-4}\%$	1-	0.56315(2)	0.0476, 0.5156, 0.5632	1.51022(22)	164.7(19)
5.32636(14)	5.23608(14)	$1.92(3) \times 10^{-4}\%$	$1.33(2) \times 10^{-4}\%$	8+	0.54061(11)	0.0476, 0.1090, 0.1661, 0.2180	1.51022(22)	459(7)
5.54436(10)	5.45039(10)	$2.55(4) \times 10^{-3}\%$	$1.77(3) \times 10^{-3}\%$	$6^{+}$	0.32261(5)	0.0476, 0.1090, 0.1661	1.51022(22)	668(12)
5.71035(8)	5.61356(8)	0.328(5)%	0.227(3)%	$4^{+}$	0.15662(3)	0.0476, 0.1090	1.51022(22)	44.2(6)
5.81940(8)	5.72077(8)	44.0(7)%	30.51(47)%	$2^{+}$	0.04757(2)	0.0476	1.51022(22)	1.270(20)
5.86697(8)	5.76753(8)	100.0(9)%	69.26(45)%	$0^+$	0.0		1.51022(22)	0.997(7)

* All values from [1994Ar08], except where noted.  $E_{\alpha}(lab)$  values are deduced from level energies and the  $E_{\alpha}$  value to the ground state of ²³²U.  $I_{\alpha}(abs)$  values were deduced from  $\gamma$  intensities. ** Weighted average of 2.851(8) y [1957Ho66] and 1046.9(31) d [1984Na30] (365.2424 d = 1 y).

*** tentative  $\gamma$  transition assignment.

# **Table 10** direct $\alpha$ emission from ²⁴⁰Cm*, $J^{\pi} = 0^+$ , $T_{1/2} = 26.8(3) d^{**}$ , $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@}$	$E_{daughter}(^{236}\mathrm{Pu})^{@}$	coincident γ-rays [@]	R ₀ (fm)	HF
6.091	5.989	0.020%	0.014%	$6^+ 4^+ 2^+ 0^+$	0.3058(1)	0.0446, 0.1028, 0.1584	1.4947(17)	160
6.251	6.147	0.073%	0.052%		0.14745(9)	0.0446, 0.1028	1.4947(17)	270
6.3536	6.2477***	40.6%	28.9%		0.04463(9)	0.0446	1.4947(17)	1.5
6.3971	6.2905***	100%	71.1%		0.0		1.4947(17)	0.98

* All values from [1967Ba42], except where noted.

** [1949Se01].

*** Values from [1971BB10],  $E_{\alpha}(lab)$  values are modified by +0.4 keV as recommended in [1991Ry01].

@ [2022Zh25].

## Table 11

direct  $\alpha$  emission from ²⁴⁴Cf*,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 19.4(6)$  m,  $BR_{\alpha} = 75(6)\%^{**}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{236}\mathrm{Pu})$	coincident γ-rays	R ₀ (fm)	HF
7.296(4) 7.334(4)	7.176(4) 7.214(4)	30(3)% 100%	17(2)% 58(5)%	(2 ⁺ ) 0 ⁺	0.038(6) 0.0		1.498(60) 1.498(60)	$2.4^{+0.6}_{-0.4}$ $1.01(10)$

* All values from [1967Si08], except where noted.  $E_{\alpha}$ (lab) values are adjusted by +1.9 keV as reccommended in [1991Ry01]. ** [2018Ko05].

#### Table 12

## direct $\alpha$ emission from ²⁴⁸Fm*, $J^{\pi} = 0^+$ , $T_{1/2} = 35.1(8) \text{ s**}$ , $BR_{\alpha} = 93^{+7}_{-17}\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{244}\mathrm{Cf})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
7.958(20) 7.999(20)	7.830(20) 7.870(20)	25% 100%	$19^{+1}_{-2} \\ 74^{+6}_{-14}$	0+	0.041(28) 0.0		1.4945(65) 1.4945(65)	3.1 1.07

* All values from [1967Nu01], except where noted.

** [2011Ga19].

*** [1993An10].

#### Table 13

direct $\alpha$ emission from	252 No, $J^{\pi}$	$= 0^+, T_{1/2} =$	= 2.42(6) s*,	$BR_{\alpha} = 65.3$	8(5)%**.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{248}\mathrm{Fm})$	coincident γ-rays	$R_0$ (fm)	HF	
8.507(8) 8.551(6)	8.372(8) 8.415(6)	≈33% 100%	$\approx 16\%$ $\approx 49\%$	$(2^+) \\ 0^+$	0.044(10) 0.0	_	1.4787(75) 1.4787(75)	$\begin{array}{l} \approx 2.3 \\ \approx 1.04 \end{array}$	
* [2007 ** [201 *** [19	Su19]. 2Su22]. 77Be09].								

#### Table 14

Table 14	
direct $\alpha$ emission from ²⁵⁶ Rf, $J^{\pi} = 0^+$ , T	$f_{1/2} = 6.66(10) \text{ ms}^*, BR_{\alpha} = 0.29^{+0.13}_{-0.10}\%^{**}.$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{248}\mathrm{Fm})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
8.930(8)	8.790(8)***	$0.29^{+0.13}_{-0.10}\%^{**}$	$0^+$	0.0	_	1.466(26)	$1.1\substack{+1.0 \\ -0.4}$

* Weighted average of 6.7(2) ms [2023Is01], 6.90(23) ms [2020Ku23], 6.2(2) ms [1997He29] and 6.9(2) ms [2012Gr12].

** [2020Ku23].

*** Weighted average of 8.786(10) MeV [2010St14], 8.790(20) MeV [1997He29] and 8.812(23) MeV [1986He28].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})^{***}$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{248}\mathrm{Fm})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF
8.604(40) 8.919(40)	8.470(40) 8.780(40)	pprox 25%100%	pprox 80% pprox 20%		0.315(57)+x x	1.466(26) 1.466(26)	$\approx 2.5$ $\approx 6$	
* All va	lues from [2009Sa	aZV].						
<b>Table 16</b> direct α emi	ssion from ²⁶⁰ Sg*	$, J^{\pi} = 0^+, T_{1/2} =$	4.95(33) ms, <i>B</i>	$R_{\alpha} = 29(3)\%.$				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}(^{256}\mathbf{R})$	Rf) coincident γ-ray	ys R ₀ (fm)	HF	
9.872(30) 9.900(10)	9.720(30)** 9.748(10)	20(12)%** 100%	5.8(35)% 24.1(16)%	(2 ⁺ ) 0 ⁺	0.028(32) 0.0	1.4562(75)	$\begin{array}{c} 4^{+7}_{-2} \\ 1.4562(75) \end{array}$	$1.0\substack{+0.3 \\ -0.2}$
* All va ** [198	lues from [2009H 5Mu11].	e20], except wher	e noted.					
<b>Table 17</b> direct α emi	ssion from ^{260m} Sg	*, Ex. = unk., T _{1/}	$_2 = 180^{+150}_{-60}$ ms	s, $BR_{\alpha} = \approx 100\%$	ю.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{256}\mathrm{Rt})$	f) coincident $\gamma$ -r	rays R ₀ (fm)	HF	
8.897(80) 9.659(60)	8.760(80) 9.510(60)	25% 100%	pprox 20% pprox 80%	0.76(10)+x x		1.4562(75) 1.4562(75)	$\approx 0.06^{**}$ $\approx 2.5$	
	1 f	ZV].						

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{248}\mathrm{Fm})$	coincident $\gamma$ -rays	$R_0$ (fm)	HF***
10.499(40) 10.773(40) 10.967(40)	10.340(40) 10.610(40) 10.800(40)	50% 100% 17%	24% 48% 13%	0.468(57)+x	0.194(57)+x x	1.485(24)	3.1 1.485(24) 1.485(24)	7 110

* All values from [2011Sa41], except where noted. Based on the HF values, it is doubtful that these transitions are from the  $0^+$  ground state. ** [2009SaZV].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +24 nuclei.

Last updated 8/14/2024

Table 1	
Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +24$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduce	d
from values therein	

NT 1' 1	F	īπ	T	0	0	0	DD	DD	
Nuclide	EX.	J"	$I_{1/2}$	$Q_{\varepsilon}$	$Q_{\beta}$ -	Q _β - α	$BR_{\beta} - \alpha$	$BK_{\varepsilon F}$	Experimental
²¹⁰ Tl*		(5+)	1.30(3) m	-3.95(10)#	5.481(12)	9.274(33)			[1964We06]
²¹⁴ Bi		$1^{-}$	19.71(2) m	-1.018(11)	3.269(11)	11.102(11)	$3.03 imes10^{-3}\%$		[1991Ma68, 1965Le08,
									1975HaZA, 1933RuXX]
²¹⁸ At		(3 ⁻ )	1.27(6) s	-0.256(12)	2.883(12))	6.217(12)			[2019Cu02]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$			
²²² Fr*		$2^{-}$	14.2(3) m	0.0606(8)	-7.694(16)	5.597(8)			[1973AfZV]
²²⁶ Ac		$(1^{-})$	29.37(12) h	0.642(3)	-6.800(12)	5.512(4)			[1987Mi10]
²³⁰ Pa		$2^{-}$	17.4(4) d**	1.311(3)	-5.805(12)	6.081(4)			[1948St42, 1949Os01]
²³⁴ Np		$(0^{+})$	4.4(1) d	1.810(8)	-4.824(8)	6.667(8)			[1955Pr29]
²³⁸ Am		$1^{+}$	98(3) m	2.260(60)	-3.739(59)	7.852(59)			[1972Ah04]
^{238m} Am	х		60(15) µs	2.260(60)+x	-3.739(59)+x	7.852(59)+x			[1967Bo23]
²⁴² Bk			7.0(13) m	2.95(14)#	-2.47(14)#	9.16(13)#			[1979Wi03]
242m1 Bk	х		9.5(20) ns	2.95(14)#+x	-2.47(14)#+x	9.16(13)#+x			[1972Wo07]
^{242m2} Bk	у		600(100) ns	2.95(14)#+y	-2.47(14)#+y	9.16(13)#+y			[1972Wo07]
²⁴⁶ Es			7.7(5) m	3.730(90)	-1.284(90)	10.590(90)		$\approx 3 \times 10^{-3} \%$	[2001Sh09, 1980Ga07,
									1980GaZZ]
²⁵⁰ Md			52(6) s	4.330(90)	-0.065(96)#	11.884(91)		$\approx 0.02\%$	[1973Es01, 1980Ga07,
									1991FuZZ, 1980GaZZ]
²⁵⁴ Lr		$(4^{+})$	18.1(13) s***	4.920(90)	1.184(97)#	13.149(92)			[2008An16, 2008Ga25]
²⁵⁸ Db		$(0^{-})$	2.17(36) s	5.160(90)	1.55(10)#	14.359(92)			[2019Vo03]
^{258m} Db	0.051(14)		4.41(21) s	5.214(91)	1.60(10)#	14.410(93)			[2019Vo03]
²⁶² Bh [@]	у		87(14) ms ^{@@}	5.88(10)+y	2.66(14)#+y	15.483(94)+y			[2009He20, 2006Fo02, 1989Mu09]
262mBh@	X		11(2) ms@@@	5.88(10)+x	2.66(14)#+x	15.483(94)+x			[2009He20, 2006Fo02, 1989Mu09]
²⁶⁶ Mt	у		$0.7^{+0.4}_{-0.2}$ ms	6.53(10)+y	3.99(26)#+y	16.879(99)+y			[1999He11]
²⁶⁶ Mt	X		$1.2^{+1.0}_{-0.4}$ ms	6.53(10)+x	3.99(26)#+x	16.879(99)+x			[1999He11]
			0.4						

* 100%  $\beta^-$  emitter.

* 100%  $\beta^{-}$  emitter. ** Weighted average of 17.0(5) d [1948St42] and 17.7(5) d [1949Os01]. *** Weighted average of 18.4(18) s [2008An16] and 17.8^{+1.9}_{-1.6} s [2008Ga25]. [@] The relative ordering of these states is unclear (i.e. which level is the ground state and which is the excited isomer). [@] Weighted average of 83(14) ms [2009He20], 84⁺²¹₋₁₆ ms [2006Fo02] and 102(26) ms [1989Mu09]. [@] Weighted average of 22(4) ms [2009He20], 9.6^{+3.6}_{-2.4} ms [2006Fo02] and 8.0(21) ms [1989Mu09].

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +24$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	S _p	Qα	BRα	BR _{SF}	Experimental
210 <b>T</b> 1	7 93(15)#	2 52(30)#			
²¹⁴ Bi	5 286(13)	5 621(3)	0.0210(13)%		[1960Wa14, 1948Ch22, 1934Le011992Po07, 1939Du01]
218 At	5.200(13) 5.072(13)	6.876(3)	99.9%		[2019Cu02 1964Hv02 1949Wa05 1990Mo08 1989Bu09
1 II	5.072(15)	0.070(5)	<i>,,,,,</i> ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		1958Wa16 1952Hi60
²²² Fr	5.382(9)	5.853(14)			1550 (110, 15521100)
²²⁶ Ac	4.973(4)	5.506(8)	$6(2) \times 10^{-3}\%$		[ <b>1975VaZD</b> , 1987Mi10
²³⁰ Pa	4.701(4)	5.439(1)	$3.2(1) \times 10^{-3}\%$		[ <b>1966Ba14</b> , 1965Br32, 1964Mc21]
²³⁴ Np	4.253(9)	5.356(9)	. ,		
²³⁸ Am	3.959(59)	6.042(58)	$1.0(4) \times 10^{-4}\%$		[ <b>1972Ah04</b> , 1972AhZS]
^{238m} Am	3.959(59)-x	6.042(58)+x		$\approx 100\%$	[1967Bo23]
²⁴² Bk	3.24(14)	6.91(15)	<1%	< 0.03%	[1979Wi03
242m1 Bk	3.24(14)-x	6.91(15)+x		100%	[1972Wo07]
^{242m2} Bk	3.24(14)-y	6.91(15)+y		100%	[ <b>1972Wo07</b> , 1972Ga42]
²⁴⁶ Es	2.855(90)	7.64(10)	9.9(18)%		[1989Ha27, 1967Mi06, 1986HaZM, 1973Es01]
²⁵⁰ Md	2.409(91)	8.155(28)	7(1)%		[2008An16, 1985He22, 1973Es01, 2009Ne02, 2008Ga25]
²⁵⁴ Lr	2.002(92)	8.822(8)	72(2)%		[2019Vo13, 2008An16, 2022Ka45, 2009Ne22, 2008Ga25,
					2006Fo02, 2001Ga20, 1986He28, 1985He22, 1982HeZL]
²⁵⁸ Db	1.648(92)	9.437(10)	$\approx 96\%$		[2019Vo03, 2022Ka45, 2016He15, 2009He20, 2006Fo02,
					1999He11, 1985He22]
^{258m} Db	1.597(93)	9.488(17)	$\approx$ 57%		[2019Vo03, 2016He15, 2009He20, 2008Ga25, 2006Fo02,
					2001Ga20, 1985He22]
²⁶² Bh	1.042(95)-y	10.319(15)+y	100%		[2009He20, 2006Fo02, 1989Mu09, 2008Ne08, 1997Ho14,
					1988Mu15, 1988MuZX, 1986MuZX, 1984Og03, 1983OgZX,
					1981Mu06]
^{262m} Bh	1.042(95)-x	10.319(15)+x	100%		[2009He20, 2006Fo02, 1989Mu09, 2008Ne08, 1997Ho14,
					1988Mu15, 1988MuZX, 1986MuZX, 1984Og03, 1983OgZX,
					1981Mu06]
²⁶⁶ Mt*	0.517(99)-y	10.996(25)+y	100%*	<25%	[2009Ne02, 1999He11, 1997Ho14, 1989Mu16, 1989MuZY,
					1988Mu15, 1984Mu07, 1984Og03, 1982Mu15]
^{266m} Mt*	0.517(99)-x	10.996(25)+x	100%*	<25%	[2009Ne02, 1999He11, 1997Ho14, 1989Mu16, 1989MuZY,
					1988Mu15, 1984Mu07, 1984Og03, 1982Mu15]

* ²⁶⁶Mt has a very complex  $\alpha$ -decay scheme with  $\alpha$ - $\alpha$  correlations to known ²⁶²Bh and ^{262m}Bh  $\alpha$ 's. The observed  $E_{\alpha}$  are a broad distribution from 10.5 to 11.7 MeV.

#### Table 3

direct  $\alpha$  emission from ²¹⁴Bi*,  $J^{\pi} = 1^{-}$ ,  $T_{1/2} = 19.71(2)$  m**,  $BR_{\alpha} = 0.0210(13)\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{210}\text{Tl})$	coincident γ-rays	R ₀ (fm)***	HF
5 020(2)	4.045(2)	0.46(0)%	$5.2(11) \times 10^{-5}\%$		0.582(4)		1 405(21)	49+32
5.059(5)	4.943(3) 5 027(3)	0.40(9)%	$3.3(11) \times 10^{-5}\%$ $4.41(88) \times 10^{-5}\%$		0.382(4) 0.498(4)		1.495(21)	$48_{-20}$ $180^{+110}$
5.287(3)	5.027(3) 5.188(3)	1.13(11)%	$1.28(15) \times 10^{-4}\%$		0.334(4)		1.495(21)	$490^{+300}_{-100}$
5.372(3)	5.272(3)	10.76(19)%	1.22(8)×10 ⁻³ %		0.249(4)		1.495(21)	$\frac{-190}{150+90}$
5.556(3)	5.452(3)	100%	$1.13(7) \times 10^{-2}\%$		0.065(4)		1.495(21)	$140_{-50}^{+80}$
5.621(3)	5.516(3)	72.73(69)%	$8.23(51) \times 10^{-3}\%$	(5 ⁺ )	0.0		1.495(21)	$400^{+230}_{-150}$

* All values from [1960Wa14], except where noted.  $E_{\alpha}$  (lab) values have been adjusted by +3.8 keV as recommended by [1991Ry01].

** [1991Ma68].

*** Interpolated between 1.449(21) fm ( 210 Pb) and 1.54117(28) fm ( 216 Po).

#### Table 4 $\beta^-$ -delayed $\alpha$ emission from ²¹⁴Bi*, $J^{\pi} = 1^-$ , $T_{1/2} = 19.71(2)$ m**, $BR_{\beta} - \alpha = 3.03 \times 10^{-3}\%$ .

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$E_{\alpha}$ (c.m.)	$E_{\alpha}$ (lab.)	$I_{\alpha}(\text{rel})\%^{***}$	$I_{\alpha}(abs)\%$	$E_{emitter}$ ( ²¹² Po)	$E_{daughter}(^{208}\text{Pb})$	
8.445(6)	8.287(6)	5.5%	$1.20 \times 10^{-4}\%$	0.610	0.0	
8.591(6)	8.430(6)	2.7%	$6.00 \times 10^{-5}\%$	1.536	0.0	
9.120(8)	8.950(8)	0.9%	$2.00 \times 10^{-5}\%$	1.286	0.780	
9.253(6)	9.080(6)	100.0%	$2.20 \times 10^{-3}$	1.419	0.0	
9.498(6)	9.320(6)	2.3%	$5.10 \times 10^{-5}\%$	1.663	0.0	
9.557(8)	9.378(8)	0.9%	$2.00 \times 10^{-5}\%$	1.722	0.0	
9.681(6)	9.500(6)	4.5%	$1.00 \times 10^{-4}\%$	1.847	0.0	
9.854(8)	9.670(8)	0.5%	$1.00 \times 10^{-5}\%$	2.020	0.0	
9.989(6)	9.802(6)	5.5%	$1.20 \times 10^{-4}\%$	2.154	0.0	
10.096(6)	9.907(6)	3.2%	$7.00 \times 10^{-5}\%$	2.261	0.0	
10.274(6)	10.082(6)	6.4%	$1.40 \times 10^{-4}\%$	2.440	0.0	
10.343(8)	10.150(8)	1.0%	$2.10 \times 10^{-5}\%$	2.509	0.0	
10.529(6)	10.332(6)	3.6%	$8.00 \times 10^{-5}\%$	2.694	0.0	
10.705(10)	10.505(10)	0.9%	$2.00 \times 10^{-5}\%$	2.871	0.0	

* All values taken from [1965Le08], except where noted.

# ** [1991Ma68].

## Table 5

direct  $\alpha$  emission from ²¹⁸At*,  $J^{\pi} = (3^{-})$ ,  $T_{1/2} = 1.27(6)$  s**,  $BR_{\alpha} = 99.9\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{214}\mathrm{Bi})$	coincident γ-rays	$R_0 (fm)^{@@}$	HF
6.779(7)	6.655(7)	7.5%	6.9(1)%	(4 ⁻ )	0.102(9)	0.010, 0.0522	1.54833(30)	21.2(11)
6.819(5) 6.882(5)	6.694(5) 6.756(5) [@]	100% 1.0%	92.2% ≤0.9%	(3) $1^{-}$	0.063	0.010, 0.0533	1.54833(30) 1.54833(30)	$2.2(2) \ge 390$

* All values from [1960Wa14], except where noted.

** [2019Cu02].

*** [1949Wa05].

^(a) Va;ue from [1964Hy02], adjusted by -1.2 keV as recommended in [1991Ry01]. ^(a) ^(a) Interpolated between 1.54117(28) fm (²¹⁶Po) and 1.55548(10) fm (²²⁰Rn).

#### Table 6

direct  $\alpha$  emission from ²²⁶Ac*,  $J^{\pi} = (1^{-})$ ,  $T_{1/2} = 29.37(12)$  h**,  $BR_{\alpha} = 6(2) \times 10^{-3} \%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{222}\mathrm{Fr})$	coincident $\gamma$ -rays	R ₀ (fm)***	HF
5.496(5)	5.399(5)	$6(2) \times 10^{-3}\%$	2-	0.0		1.53803(33)	$51^{+26}_{-13}$

* All values from [1975VaZD], except where noted.

** [1987Mi10].

*** Interpolated between 1.542177(86) fm (²²⁴Ra) and 1.53389(32) fm (²²⁸Th).

Table 7				
direct $\alpha$ emission from	230 Pa*, $J^{\pi} = 2^{-1}$	$T_{1/2} = 17.4(4) d^*$	*, $BR_{\alpha} = 3.2(1) \times 10^{-3}$	3%

					226			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi}$	$E_{daughter}(^{220}\mathrm{Ac})$	coincident $\gamma$ -rays	$R_0 (fm)^{***}$	HF
4 850(2)	1766(2)	0.0(5)%	$2.8(14) \times 10^{-5}$		0.580(2)		1 53137(43)	7+8
4.833(5)	4.700(2) 4.798(5) [@]	0.09-0.22%	$2.8(14) \times 10^{-6}$ 2.8-7.0×10 ⁻⁶		0.565(2)		1.53137(43) 1 53137(43)	$\frac{7-3}{47-118}$
5.021(3)	4.934(3)	1.7(9)%	$5.6(29) \times 10^{-5}$		0.418(3)		1.53137(43)	$50^{+0.5}$
5.061(2)	4.973(2)	3.0(10)%	$9.7(31) \times 10^{-5}$		0.378(2)		1.53137(43)	$49^{+22}_{-12}$
5.150(3)	5.060(3)	1.7(9)%	$5.6(29) \times 10^{-5}$		0.290(3)		1.53137(43)	$310^{+320}_{-110}$
5.174(2)	5.084(2)	3.04%0.96%	$9.7(31) \times 10^{-5}$		0.265(2)		1.53137(43)	$250^{+110}_{-60}$
5.210(3)	5.119(3)	2.6(9)%	$8.3(30) \times 10^{-5}$		0.230(3)		1.53137(43)	$480^{+260}_{-130}$
5.244(2)	5.153(2)	1.7(5)%	$5.6(16) \times 10^{-5}$		0.195(2)		1.53137(43)	$1.2(4) \times 10^{3}$
5.275(3)	5.183(3)	2.2(9)%	$7.0(3) \times 10^{-5}$		0.165(3)		1.53137(43)	$1.4^{+1.0}_{-0.4} \times 10^3$
5.3089(15)	5.2166(15)	2.17%0.52%	$7.0(2) \times 10^{-5}$		0.1304(17)		1.53137(43)	$2.3^{+0.7}_{-0.4} \times 10^3$
5.3616(7)	5.2684(7)	15.2(29)%	$4.9(9) \times 10^{-4}$		0.0777(10)		1.53137(43)	$660^{+110}_{-100}$
5.3690(7)	5.2756(7)	13.0(28)%	$41.2(9) \times 10^{-4}$		0.0703(10)		1.53137(43)	$850^{+200}_{-140}$
5.3810(15)	5.2874(15)	13.0(39)%	$4.2(12) \times 10^{-4}$		0.058317		1.53137(43)	$1.0^{+0.4}_{-0.3} \times 10^3$
5.3943(7)	5.3005(7)	74(16)%	$2.4(5) \times 10^{-3}$		0.0450(10)		1.53137(43)	$210_{-40}^{+50}$
5.4060(7)	5.3120(7)	57(15)%	$1.8(5) \times 10^{-3}$		0.0333(10)		1.53137(43)	$320^{+110}_{-70}$
5.4205(7)	5.3262(7)	78(17)%	$2.5(5) \times 10^{-3}$		0.0188(10)		1.53137(43)	$280_{-50}^{+70}$
5.4342(10)	5.3397(10)	65(23)%	$2.1(7) \times 10^{-3}$		0.005112		1.53137(43)	$410_{-110}^{+220}$
5.4393(7)	5.3447(7)	100(13)%	0.0032(4)		0.0		1.53137(43)	$280_{-40}^{+50}$

* All values from [1966Ba14], except where noted. ** Weighted average of 17.0(5) d [1948St42] and 17.7(5) d [1949Os01]. *** Interpolated between 1.53389(32) fm (²²⁸Th) and 1.52885(29) fm (²³²U).

[@] Tentative assignment.

#### Table 8

direct  $\alpha$  emission from ²³⁸Am*,  $J^{\pi} = 1^+$ ,  $T_{1/2} = 98(3)$  m,  $BR_{\alpha} = 1.0(4) \times 10^{-4}$ %.

$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{234}Np)$	coincident $\gamma$ -rays	$R_0 (fm)^{***}$	HF	
≈5.94	1.0(4)×10 ⁻⁴ %	(0 ⁺ )			1.5024(17)	$110^{+80}_{-30}$	
ues from [1972Ah olated between 1. sion from ²⁴⁶ Es*,	104], 51022(22) fm ( ²³⁶ Pu) $T_{1/2} = 7.7(5)$ m, <i>BR</i> _o	and 1.4947 y = 9.9(18)%	(17) fm ( ²⁴⁰ Cm).				
$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	<i>E</i> _{daughter} ( ²⁴² Bk)	coincident $\gamma$ -rays	R ₀ (fm)***	HF	
7.370(4)**	9.9(18)%				1.496(60)	$4^{+12}_{-3}$	
	$\frac{E_{\alpha}(\text{lab})}{\approx 5.94}$ ues from [1972Ab olated between 1. sion from ²⁴⁶ Es*, $\frac{E_{\alpha}(\text{lab})}{7.370(4)^{**}}$	$E_{\alpha}(lab)$ $I_{\alpha}(abs)$ $\approx 5.94$ $1.0(4) \times 10^{-4}$ %         ues from [1972Ah04], olated between $1.51022(22)$ fm ( ²³⁶ Pu)         sion from ²⁴⁶ Es*, $T_{1/2} = 7.7(5)$ m, $BR_{\alpha}$ $E_{\alpha}(lab)$ $I_{\alpha}(abs)$ 7.370(4)**       9.9(18)%	$E_{\alpha}(lab)$ $I_{\alpha}(abs)$ $J_{f}^{\pi}$ $\approx 5.94$ $1.0(4) \times 10^{-4}\%$ $(0^{+})$ ues from [1972Ah04],       0lated between $1.51022(22)$ fm ( ²³⁶ Pu) and $1.4947$ sion from ²⁴⁶ Es*, $T_{1/2} = 7.7(5)$ m, $BR_{\alpha} = 9.9(18)\%$ $E_{\alpha}(lab)$ $I_{\alpha}(abs)$ $J_{f}^{\pi}$ $7.370(4)^{**}$ $9.9(18)\%$	$E_{\alpha}(lab)$ $I_{\alpha}(abs)$ $J_{f}^{\pi}$ $E_{daughter}(^{234}Np)$ $\approx 5.94$ $1.0(4) \times 10^{-4}\%$ $(0^{+})$ ues from [1972Ah04], olated between $1.51022(22)$ fm ( $^{236}Pu$ ) and $1.4947(17)$ fm ( $^{240}Cm$ ).         sion from $^{246}Es^*$ , $T_{1/2} = 7.7(5)$ m, $BR_{\alpha} = 9.9(18)\%$ . $E_{\alpha}(lab)$ $I_{\alpha}(abs)$ $J_{f}^{\pi}$ $E_{daughter}(^{242}Bk)$ 7.370(4)**       9.9(18)\%	$E_{\alpha}(lab)$ $I_{\alpha}(abs)$ $J_{f}^{\pi}$ $E_{daughter}(^{234}Np)$ coincident $\gamma$ -rays $\approx 5.94$ $1.0(4) \times 10^{-4}$ % $(0^{+})$ ues from [1972Ah04], olated between $1.51022(22)$ fm ( $^{236}Pu$ ) and $1.4947(17)$ fm ( $^{240}Cm$ ).       sion from $^{246}Es^{*}$ , $T_{1/2} = 7.7(5)$ m, $BR_{\alpha} = 9.9(18)$ %.         E_{\alpha}(lab) $I_{\alpha}(abs)$ $J_{f}^{\pi}$ $E_{daughter}(^{242}Bk)$ coincident $\gamma$ -rays         7.370(4)**       9.9(18)% $P_{\alpha}(abs)$ $P$	$E_{\alpha}(lab)$ $I_{\alpha}(abs)$ $J_{f}^{\pi}$ $E_{daughter}(^{234}Np)$ coincident $\gamma$ -rays $R_{0}$ (fm)*** $\approx 5.94$ $1.0(4) \times 10^{-4}\%$ $(0^{+})$ $1.5024(17)$ ues from [1972Ah04], olated between $1.51022(22)$ fm ( $^{236}Pu$ ) and $1.4947(17)$ fm ( $^{240}Cm$ ). $sion from ^{246}Es^*, T_{1/2} = 7.7(5)$ m, $BR_{\alpha} = 9.9(18)\%$ .         E_{\alpha}(lab) $I_{\alpha}(abs)$ $J_{f}^{\pi}$ $E_{daughter}(^{242}Bk)$ coincident $\gamma$ -rays $R_{0}$ (fm)***         7.370(4)**       9.9(18)\%       1.496(60)	$E_{\alpha}(lab)$ $I_{\alpha}(abs)$ $J_{f}^{\pi}$ $E_{daughter}(^{234}Np)$ coincident $\gamma$ -rays $R_{0}$ (fm)***       HF $\approx 5.94$ $1.0(4) \times 10^{-4}$ % $(0^{+})$ $1.5024(17)$ $110^{+80}_{-30}$ ues from [1972Ah04], olated between $1.51022(22)$ fm ( 236 Pu) and $1.4947(17)$ fm ( 240 Cm). $sion from ^{246}Es^*, T_{1/2} = 7.7(5)$ m, $BR_{\alpha} = 9.9(18)$ %.       HF $E_{\alpha}(lab)$ $I_{\alpha}(abs)$ $J_{f}^{\pi}$ $E_{daughter}(^{242}Bk)$ coincident $\gamma$ -rays $R_{0}$ (fm)***       HF $7.370(4)^{**}$ $9.9(18)$ % $1.496(60)$ $4^{+12}_{-3}$ $4^{+12}_{-3}$

* All values from [1967Mi08], except where noted.

** [1989Ha27].

*** Interpolated between 1.498(60) fm ( 244 Cf) and 1.4945(65) fm ( 248 Fm).

#### Table 10

direct  $\alpha$  emission from ²⁵⁰Md, T_{1/2} = 52(6) s*, *BR*_{$\alpha$} = 7(1)%**.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{246}\mathrm{Es})$	coincident γ-rays	$R_0 \left( fm \right)^@$	HF
7.877(20) 7.964(20)	7.751(20)*** 7.837(20)***	$100\%^{@} \approx 33\%^{@}$	≈5.3% ≈1.8%			0.1523**	1.4866(99) 1.4866(99)	≈3.1 ≈19

* [1973Es01].

** [2008An16].

*** [1985He22].

⁽¹⁾ Average of 7.751(20) MeV  $\approx$ 80%, 7.837(20) MeV  $\approx$ 20% [1985He22] and 7.751(20) MeV  $\approx$ 70%, 7.837(20) MeV  $\approx$ 30% [1973Es01]. Interpolated between 1.4945(65) fm (²⁴⁸Fm) and 1.4787(75) fm (²⁵²No).

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{250}\mathrm{Md})$	coincident $\gamma$ -rays	$R_0 (fm)^@$	HF
8.520(10)	8.386(10)	100(29)%	24(7)%		0.307	0.0963, 0.2091, 0.3068	1.472(27)	$1.8^{+1.9}_{-1.0}$
8.539(15)	8.405(15)	38(12)%	9(1)%		0.284	0.0753, 0.2091	1.472(27)	$5^{+5}_{-3}$
8.572(15)	8.437(15)	88(49)%	21(10)%		0.252	0.0428, 0.2091	1.472(27)	$3^{+4}_{-2}$
8.616(15)	8.480(15)	42(28)%	10(6)%		0.209	0.2091	1.472(27)	$9^{+16}_{-6}$
8.641(10)	8.505(10)	33(23)%	8(5)%		0.184	0.1633	1.472(27)	$13_{-9}^{+29}$

direct  $\alpha$  emission from ²⁵⁴Lr*, T_{1/2} = 18.1(13) s**, BR_{$\alpha$} = 72(2)%***.

* All values from [2019Vo03], except where noted.

** Weighted average of 18.4(18) s [2008An16] and  $17.8^{+1.9}_{-1.6}$  s [2008Ga25].

*** [2008An16].

[@] Interpolated between 1.4787(75) fm ( 252 No) and 1.466(26) fm ( 256 Rf).

#### Table 12

direct  $\alpha$  emission from ²⁵⁸Db*, T_{1/2} = 2.17(36) s, BR_{$\alpha$} =  $\approx$ 96%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{254}\mathrm{Lr})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF
0.202(15)	0.0(0(15)	- 100/	- 7 401		0.225		1 4(1/27)	- 10
9.203(15)	9.060(15)	$\approx 10\%$	$\approx$ 7.4%		0.235		1.461(27)	$\approx 40$
9.217(10)	9.074(10)	$\approx 11\%$	$\approx 8\%$		0.221	0.221	1.461(27)	$\approx 40$
9.236(10)	9.093(10)	$\approx 11\%$	$\approx 8\%$		0.199	0.043, 0.156, 0.199	1.461(27)	$\approx 50$
9.330(15)	9.185(15)	$\approx 100\%$	$\approx 73\%$		0.108		1.461(27)	$\approx 10$

* All values from [2019Vo03], except where noted.

** Interpolated between 1.466(26) fm ( 256 Rf) and 1.4562(75) fm ( 260 Sg).

#### Table 13

direct $\alpha$ emission from ²	^{58m} Db*, Ex.	= 51(14) keV, T _{1/}	$_2 = 4.41(21)$ s,	$BR_{\alpha} = \approx 57\%$
--------------------------------------------	-------------------------	-------------------------------	--------------------	------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{254}\mathrm{Lr})$	coincident $\gamma$ -rays	R ₀ (fm)**	HF
9.149(15)	9.007(15)	$\approx 38\%$	$\approx 6\%$		0.338		1.461(27)	$\approx 120$
9.182(15)	9.040(15)	$\approx 44\%$	$\approx 7\%$		0.304		1.461(27)	$\approx 130$
9.213(10)	9.070(10)	$\approx 75\%$	$\approx 12\%$		0.274	0.043, 0.096, 0.134	1.461(27)	$\approx 90$
9.265(15)	9.121(15)	$\approx 56\%$	$\approx 9\%$		0.221	0.221	1.461(27)	$\approx 180$
9.288(10)	9.144(10)	$\approx 100\%$	$\approx 16\%$		0.199	0.043, 0.156, 0.199	1.461(27)	$\approx 110$
9.309(15)	9.165(15)	$\approx 42\%$	$\approx 6.7\%$		0.178	0.043, 0.134	1.461(27)	≈310

* All values from [2019Vo03], except where noted.

** Interpolated between 1.466(26) fm (²⁵⁶Rf) and 1.4562(75) fm (²⁶⁰Sg).

#### Table 14

Table 14				
direct $\alpha$ emission from	²⁶² Bh*, Ex. =	y, $T_{1/2} = 87(14)$	ms**, $BR_{\alpha} =$	100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\mathrm{rel})^{@}$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{258}\text{Db})$	coincident $\gamma$ -rays	$R_0 (fm)^{@@}$	HF
9.843(15)	9.693(15)	$\approx 82\%$	≈31%		v+0.345		1.471(25)	≈7
9.878(25)	9.727(25)@@@	≈14%	≈5%		y+0.311		1.471(25)	≈50
9.961(25)	9.809(25)@@@	$\approx 5\%$	$\approx 2\%$		y+0.227		1.471(25)	$\approx 220$
10.089(15)	9.935(15)	$\approx 64\%$	$\approx 24\%$		y+0.100		1.471(25)	$\approx 40$
10.189(15)	10.033(15)	$\approx 100\%$	$\approx 38\%$		y+0.0		1.471(25)	$\approx 40$

* Which level is the ground state and which is the excited isomer is unknown.

** Weighted average of 83(14) ms [2009He20],  $84^{+21}_{-16}$  ms [2006Fo02] and 102(26) ms [1989Mu09].

*** Weighted average of values from [1989Mu09] (9.740(25) MeV; 4 counts, 9.910(25) MeV; 4 counts, 10.060(25) MeV; 7 counts), [2006Fo02] (9.657(25) MeV; 2 counts, 9.727(25) MeV; 1 count, 9.809(25) MeV; 3 counts, 9.936(25) MeV; 4 counts, 10.075(25) MeV; 5 counts) and [2009He20] (9.689(15) MeV; 12 counts, 9.943(15) MeV; 6 counts, 10.008(15) MeV; 10 counts).

[@] Counts from [2009He20, 2006Fo02, 1989Mu09] summed to determine relative intensities.

[@] [@] Interpolated between 1.4562(75) fm ( 260 Sg) and 1.485(24) fm ( 264 Hs).

@@@ Only observed in [2006Fo02].

# Table 15 direct $\alpha$ emission from ^{262m}Bh*, Ex. = x, T_{1/2} = 11(2) ms, BR_{$\alpha$} = 100%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{@}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{258}\text{Db})$	coincident γ-rays	$R_0 (fm)^{@@}$	HF
9.978(15) 10.371(15) 10.528(15)	9.826(15) ^{@@@} 10.213(15) 10.367(15)	$\begin{array}{l} \approx 24\% \\ \approx 60\% \\ \approx 100\% \end{array}$	≈13% ≈33% ≈54%		x+0.549 x+0.156 x+0.0		1.471(25) 1.471(25) 1.471(25)	$\approx 5$ $\approx 18$ $\approx 27$

* Which level is the ground state and which is the excited isomer is unknown.

** Weighted average of 22(4) ms [2009He20],  $9.6^{+3.6}_{-2.4}$  ms [2006Fo02] and 8.0(21) ms [1989Mu09].

*** Weighted average of values from [1989Mu09] 10.240(25) MeV; 6 counts, 10.370(25) MeV; 8 counts), [2006Fo02] (10.231(25) MeV; 1 count, 10.348(25) MeV; 7 counts) and [2009He20] (9.86215) MeV; 6 counts, 10.197(15) MeV; 8 counts, 10.373(15) MeV; 10 counts).

[@] Counts from [2009He20, 2006Fo02, 1989Mu09] summed to determine relative intensities.

[@] Interpolated between 1.4562(75) fm ( 260 Sg) and 1.485(24) fm ( 264 Hs).

@@@ Only observed in [2009He20].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +49/2 nuclei.

Last updated 10/21/2024

Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +49/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values for ²⁰⁹Hg, ²¹³Pb, ²¹⁷Po, ²²¹Rn, ²²⁵Ra, ²³⁷Pu, ²⁴¹Cm, ²⁴⁵Cf, and ²⁴⁹Fm are taken from ENSDF.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	Q _β -	$Q_{\beta}$ - $\alpha$	Experimental
²⁰⁹ Hg*		$(9/2^{+})$	$35^{+9}_{-6}$ s	-6.38(43)#	5.040(150)#	7.72(26)#	[1998Zh19]
²¹³ Pb*		$(9/2^+)$	10.2(3) m	-4.987(28)	2.028(8)	8.196(9)	[1964Bu05]
²¹⁷ Po		$(9/2^+)$	1.52(3) s**	-2.847(19)	1.489(8)	8.870(9)	[2003Ku25, 2004Li28]
²²¹ Rn		$(7/2^+)$	25(2) m	-2.311(15)	1.194(7)	7.831(8)	[1956Mo15]
²²⁵ Ra		1/2+	14.8(2) d	-1.828(12)	0.356(5)	6.471(6)	[1950Ha52]
²²⁹ Th		5/2+	7894(40) y***	-1.104(12)	-0.311(4)		[1989Go19, 2014Va04, 2018Es07]
²³³ U		$5/2^{+}$	$1.5903(13) \times 10^5 y$	-0.570(2)	-1.030(5)		[2009Po15]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
²³⁷ Pu		$7/2^{-}$	45.31(3) d [@]	0.220(1)	-4.642(1)	5.177(2)	[1994Ta25, 1981Ba15]
^{237m1} Pu	2.90(20)@@		94.8 ns ^{@@@}	2.92(20)	-1.74(20)	8.08(20)	[1971Ru03, 1974Ba82]
^{237m2} Pu	$3.20(25)^a$		1.12(8) µs	3.40(25)	-1.44(25)	8.38(25)	[1971Ru03]
²⁴¹ Cm		$(1/2^+)$	32.8(2) d	0.767(1)	-3.713(1)	6.405(2)	[1974Po08]
^{241m} Cm	$2.45(20)^{b}$		15.3(10) ns	3.22(20)	-1.26(20)	8.86(20)	[1972Vy07, 1971Br39, 1971Re11]
²⁴⁵ Cf		$(1/2^+)$	46.4(3) m	1.571(3)	-2.356(2)	8.026(3)	[1996Ma72]
²⁴⁹ Fm		$(7/2^+)$	99(6) s ^c	2.340(30)#	-1.008(8)	9.280(6)#	[2004He28, 2006Ni09]
²⁵³ No		(9/2-)	1.56(2) m	3.190(30)#	0.253(9)	10.759(31)#	[2009He23]
²⁵⁷ Rf		$(1/2^+)$	5.5(4) s	3.200(50)#	0.754(13)	12.268(33)#	[2010St14]
^{257m} Rf	0.074(16)	$(11/2^{-})$	4.9(7) s	3.274(52)#	0.828(21)	12.342(37)#	[2010St14]
²⁶¹ Sg		$(3/2^+)$	184(5) ms	3.700(11)#	1.567(20)#	12.915(48)#	[2010St14]
²⁶⁵ Hs			1.9(2) ms	4.51(24)#	2.83(28)#	14.17(11)#	[2009He20]
265mHs	$\mathbf{x}^d$		$300^{+200}_{-100} \mu s$	4.51(24)#+x	2.83(28)#+x	14.17(11)#+x	[2009He20]
²⁶⁹ Ds			$170_{70}^{-100} \mu s$	5.54(31)#	4.58(30)#	16.02(24)#	[1999He07]

* 100%  $\beta^-$  emitter.

** Weighted average of 1.53(3) s [2003Ku25] and 1.48(5) s [2004Li28].

*** Weighted average of 7880(120) y [1989Go19], 7917(48) y [2014Va04] and 7825(87) y [2018Es07].

[@] Weighted average of 45.66(4) d [1994Ta25], and 45.12(3) d [1981Ba15].

Weighted average of 45.00(1) a [1971Ru03], and 110(9) ns [1974Ba82].
^a [1973Va16] reports 300(150) keV above ^{237m1}Pu.
^b Weighted average of 2.30(20) MeV [1971Br39], and 2.60(20) MeV [1972Vy07].

^d The ordering of the two isomers is uncertain.

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +49/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	S _p	Qα	BRα	BR _{SF}	BR _{cluster}	type	Experimental
²⁰⁹ Hg	9.99(34)#	1.79(34)#					
²¹³ 1977Vv02Pb	8.94(20)#	2.98(15)					
²¹⁷ Po	7.280(13)	6.662(2)	$\approx 100\%$				[2004Li28, 2003Ku25, 1997Li23, 1977Vv02, 1956Mo15]
²²¹ Rn	7.193(15)	6.148(2)*	22(1)%				[2004Li28, 1997Li23, 1977Vv02, 1956Mo15]
²²⁵ Ra	7.045(11)	5.097(5)	$2.6(8) \times 10^{-3}\%$	[2000Li37]			
²²⁹ Th	6.598(3)	5.168(1)	100%	[]			[2000Ga52, 1987He28, 1970Ba20, 2018Es07, 2014Va04,
							1998Ga48, 1995Vo07, 1987AhZV, 1986He06, 1986He12,
							1983Ra01, 1981Di14, 1971Bb10, 1970BaZZ, 1969Ba57,
							1968Ba46, 1964Hv02, 1961Ko11, 1961Tr08, 1959Go87,
							1950Ha52, 1949SeZU, 1947Ha02]
²³³ U	6.316(8)	4.909(1)	100%		$7.2(12) \times 10^{-11}\%$	²⁴ Ne	[2003Ba78, 1991Pr01, 1967Ba43, 2024Gr01, 2020Si22,
							2009Po15, 1998Ya17, 1992El01, 1986Ba65, 1985AlZQ,
							1984Re05, 1979Ce04, 1977Ca04, 1976Kr03, 1976Va02,
							1968 Ba25, 1968Ke15, 1967Ga15, 1967Mo28, 1967Tr07,
							1966Ba43, 1964Ba42, 1961An08, 1961Po10, 1960Dz07,
							1959Do63, 1958Cl49, 1953AsZZ, 1950Ha52, 1949SeZU,
							1947Ha02]
²³⁷ Pu	5.575(50)	5.748(2)	$4.2(4) \times 10^{-3}\%$				[1979El05, 1957Ho68, 1957Th10]
^{237m1} Pu	2.38(21)	8.65(20)		obs			[1978De07, 1974Ba82, 1971Br39, 1971Ru03, 1982Ra04
							1979Gu03, 1973Va16, 1972Vi10, 1971Te07, 1970Bu02,
							1970Po01, 1970RuZS, 1969Me11, 1979VaZX]
^{237m2} Pu	2.38(26)	8.95(25)		obs			[ <b>1973Va16</b> , 1979Gu03, 1974Ba82, 1972Vi10, 1971Ru03,
							1971Te07, 1970Po01]
²⁴¹ Cm	5.097(14)	6.185(1)	1.0(1)%				[1975Ah05, 1974Po08, 1971Bb10, 1969Ba57, 1967Ba42,
							1965Ba51, 1952Hi11]
241m Cm	2.65(20)	8.64(20)		obs			[1972Vy07, 1971Br39, 1971Re11, 1974SpZS, 1972Ga42,
							1970Po01]
²⁴⁵ Cf	4.618(15)	7.258(2)	36.0(26)%				[ <b>1996Ma72</b> , 2004He28, 1968Ku12, 1967Fi04, 1956Ch43]
²⁴⁹ Fm	4.069(53)	7.709(6)	15.6(1)%				[2012He09, 2011Lo06, 2006Ni09, 2004He28, 1967Mi03,
							1966Ak01, 1959Pe27]
²⁵³ No	3.397(92)	8.415(4)	55(3)%				[2012He09, 2011An13, 2011Lo06, 2006Lo12, 2015KaZX,
							2008DoZZ, 2006Po10, 2004He04, 2004He28, 1997He29,
257							1971GhZV, 1967Gh01, 1967Mi03]
²⁵⁷ Rf	3.169(84)	9.083(8)	79.3(17)%	1.3(3)%			[ <b>2022Ha04, 2010St14, 1997He29</b> , 2016He08, 2009He20,
							2008Dr05, 2002HeZS, 2001He35, 1985He06, 1985So03,
257							1974BeYN, 1969Gh01]
$^{25/m}$ Rf	3.095(86)	9.157(18)	81.0(25)%	14(9)%			[2022Ha04, 2010St14, 1997He29, 1985So03, 2016He08,
							2009He20, 2008Dr05, 2002HeZS, 2001He35, 1985He06,
261 ~							1974BeYN, 1969Gh01]
²⁰¹ Sg	2.957(95)#	9.714(15)	98.1(5)%	0.6(2)%			[ <b>2010St14</b> , 2010Be16, 2007St12, 2004He23, 1985Mu11,
265++		10.170/17	1000	. ~			1984De07, 1984Mu17, 1984Og03, 1983DeZHJ
²⁰⁵ Hs	2.35(18)#	10.470(15)	$\approx 100\%$	<1%			[2009He20, 2000HoZZ, 2011Sa41, 1999He11, 1987Mu15,
265m++	2.25(10) //	10.470(15)	1000				1984DeZO, 1984Mu17J
^{205m} Hs	2.35(18)#-x	10.470(15)+x	$\approx 100\%$				[2009He20, 2011Sa41, 1999He11, 1984DeZO,
²⁰⁹ Ds	1.61(24)#	11.510(30)	100%				[ <b>199Heu</b> 7, 2002Ho11, 1995Ho03]
* Deduced f	rom α energy	( 6 163(3) in [2	021Wa161				
Deduced I	ioni a chergy	, 0.105( <i>3</i> ) III [20	021 Wal0J.				
Table 2							

Table 3

direct  $\alpha$  emission from ²¹⁷Po,  $J^{\pi} = (9/2^+)$ ,  $T_{1/2} = 1.52(3)$  s*,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{213}\text{Pb})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
6.664(3)	6.541(3)**	$\approx 100\%$	(9/2+)	0.0		1.53953(24)	1.63(5)

* Weighted average of 1.53(3) s [2003Ku25] and 1.48(5) s [2004Li28]. ** Weighted average of 6.543(4) MeV [2003Ku25] and 6.539(4) MeV (adjusted to 6.537(4) MeV in [1991Ry01]) [1977Vy02].

## Table 4 direct $\alpha$ emission from ²²¹Rn*, $J^{\pi} = (7/2^+)$ , $T_{1/2} = 25(2)$ m**, $BR_{\alpha} = 22(1)\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_{f}^{\pi***}$	$E_{daughter}(^{217}\text{Po})^{***}$	coincident γ-rays***	R ₀ (fm)	HF
5.882(2)	5.776(2)	9%	1.5%	$(11/2^+)$	0.265	0.265	1.55206(14)	12
5.893(2)	5.786(2)	15%	2.6%	$(7/2^+)$	0.254	0.254	1.55206(14)	8.1
6.148(2)	6.037(2)	100%	17.6%	$(9/2^+)$	0.0		1.55206(14)	17

* All values from [1977Vy02], except where noted.  $E_{\alpha}(lab)$  values are adjusted by -1.7 keV in [1991Ry01]. [1977Vy02] lists uncertainties as 3 keV, which was reduced to 2 keV in [1997Li23].

** [1956Mo15]. *** [2018Ko01].

#### Table 5

direct $\alpha$ emission from ²²⁵ Ra*, $J^{\pi}$ =	$1/2^+, T_1$	$_{/2} = 14.2(8) \text{ d}^{**}, BR_{\alpha} = 2.6(8) \times 10^{-3}\%.$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{221}\mathrm{Rn})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
5.066(5) 5.097(5)	4.976(5) 5.006(5)	30(17)% 100(25)%	$6(3) \times 10^{-4}\%$ 2.0(5)×10 ⁻³ %7/2 ⁺	(3/2 ⁺ ) 0.0	0.030(10)			

* All values from [2000Li37], except where noted.

** [1950Ha52].

## Table 6

## direct $\alpha$ emission from ²²⁹Th, $J^{\pi} = 5/2^+$ , $T_{1/2} = 7894(40)$ y*, $BR_{\alpha} = 100\%$ (1 of 3).

$E_{\alpha}(\text{c.m.})^{**}$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@@}$	E _{daughter} ( ²²⁵ Ra) ^{@@}	coincident $\gamma$ -rays (keV) ^{@@}	HF ^{@@@}
4.5044(10)	4.426**	0.011%	0.006%	(5/2+,7/2+)	0.6632	<b>11.1, 17.3, 23.6, 25.4</b> , 28.7, 29.9, <b>31.4, 37.8</b> , 42.4, <b>42.8, 44.0</b> , 49.7, 51.0, <b>53.8</b> , 55.2, 56.5, 59.3, 63.7, <b>65.0</b> , 68.1, <b>68.8</b> , 75.2, 77.6, <b>78.5</b> , <b>86.3</b> , 89.1, 94.7, 94.8, 98.9, 100.8, 107.1, 109.1, 110.3, 115.9, 118.1, 120.1, 123.2, 124.6, 126.1, 126.5, <b>131.9</b> , 134.2, 137.0, 139.8, 142.0, <b>142.9</b> , 147.7, 148.2, 149.9, 151.6, 154.3, <b>156.4</b> , 166.9, 167.5, 171.2, 174.1, 179.8, 185.6, 190.6, 193.5, 194.9, 200.8, 204.7, <b>210.3</b> , 210.9, 217.4, 218.2, 221.2, 225.3, 228.6, 234.8, 236.3, 242.6, <b>252.4</b> , 296.2, 303.8, 310.1, 313.3, 317.8, 349.4, 327.9, <b>341.1</b> , 414.6, 419.9, 483.7, 513.5, 543.0, 551.7, 594.4	16
4.5587(10)	4.478 [@]	0.016%	0.0091%		0.6089	11.1, <b>17.3</b> , <b>23.6</b> , <b>25.4</b> , <b>31.4</b> , 37.8, 42.4, <b>42.8</b> , 44.0, 55.2, 68.8, <b>75.2</b> , 86.3, 94.7, <b>102.5</b> , <b>107.1</b> , 118.1, <b>124.6</b> , 149.9, <b>169.2</b> , 182.1, 193.5, <b>216.0</b> , <b>225.3</b> , <i>281.3</i> , 327.9, <b>459.1</b> , <b>565.7</b>	26
4.5631(10)	4.484(2)	0.070%	0.0396%	(5/2+)	0.6045	11.2, <b>17.3</b> , 22.0, <b>23.6</b> , <b>25.4</b> , 29.9, <b>31.4</b> , 33.1, 37.8, 42.4, <b>42.8</b> , 44.0, 51.0, 55.2, 59.3, 63.7, <b>65.0</b> , 68.1, <b>68.8</b> , 75.2, 77.6, <b>86.3</b> , 89.1, 94.7, 94.8, 102.5, <b>107.1</b> , 109.1, 110.3, <b>114.8</b> , 115.9, 118.1, 120.1, 123.2, <b>124.6</b> , 126.1, <b>131.9</b> , 134.2, <b>137.0</b> , 139.8, <b>142.9</b> , 147.7, 148.2, 149.9, 151.6, 154.3, 156.4, 166.9, 154.3, 167.5, 169.2, 171.2, 174.1, 179.8, 182.1, 183.0, <b>185.6</b> , <b>189.3</b> , 190.6, <b>193.5</b> , 194.9, 200.8, 204.7, 210.9, 216.0, 217.4, 218.2, 225.3, 228.6, 234.8, 236.3, 242.6, 250.1, 267.4, <b>276.9</b> , 298.7, 320.8, 327.9, 349.4, 328.2, 336.7, <b>344.4</b> , 358.0, 361.0, 366.5, <b>368.1</b> , 377.4, <b>379.4</b> , 403.3, 408.5, <b>424.8</b> , 452.6, 453.3, <b>454.8</b> , 478.0, <b>492.9</b> , 503.6, 523.5, <b>535.1</b> , 549.8, <b>561.8</b> , <b>573.0</b> , 579.2, 592.5	6.5
4.5748(10)	4.4949**	0.048%	0.027%	(3/2 ⁻ ,5/2 ⁻ )	0.5928	<b>11.1</b> , <b>17.3</b> , 22.0, 23.6, <b>25.4</b> , 29.9, <b>31.4</b> , <b>33.1</b> , <b>37.8</b> , <b>42.4</b> , 42.8, <b>44.0</b> , 51.0, 55.2, 59.3, 63.7, <b>65.0</b> , 68.1, <b>68.8</b> , 75.2, 77.6, 86.3, <b>89.1</b> , 94.7, 94.8, <b>110.3</b> , <b>107.1</b> , 109.1, <i>114.8</i> , 118.1, 120.1, 123.2, <b>124.6</b> , 126.1, <b>131.9</b> , 134.2, 137.0, <b>139.8</b> , <b>142.9</b> , 148.2, 149.9, 151.6, 154.3, 171.2, 174.1, 179.8, 183.0, <b>185.6</b> , <b>189.3</b> , 190.6, 194.9, 200.8, <b>217.4</b> , 218.2, 228.6, <b>234.8</b> , 250.1, 267.4, 298.7, 320.8, 349.4, 328.2, 358.0, 366.5, 377.4, 403.3, 408.5, 453.3, 452.6, 478.0, 523.5, 549.8, 592.5	11.6
4.6323(10)	4.5514**	0.026%	0.0145%	(5/2 ⁺ )	0.5353	<b>11.1</b> , <b>17.3</b> , <b>23.6</b> , <b>25.4</b> , 28.7, 29.9, <b>31.4</b> , 37.8, 42.4, <b>42.8</b> , 44.0, 49.7, <b>53.8</b> , 55.2, 56.5, 59.3, 63.7, <b>65.0</b> , 68.1, <b>68.8</b> , 75.2, 77.6, <b>78.5</b> , <b>86.3</b> , 51.0, 89.1, 94.7, 94.8, 98.9, 100.8, 110.3, 107.1, 109.1, 115.9, 118.1, 120.1, 123.2, 124.6, 126.1, 126.5, <b>131.9</b> , 134.2, 137.0, 142.0, <b>142.9</b> , 147.7, 148.2, 149.9, 151.6, 154.3, <b>156.4</b> , 166.9, 167.5, 171.2, 174.1, 179.8, 193.5, 194.9, 200.8, 204.7, 210.3, 210.9, <b>213.5</b> , 218.2, 221.2, 225.3, 236.3, 242.6, 252.4, 296.2, 465, 503.6, 535.1	57

Fable 7	
lirect $\alpha$ emission from ²²⁹ Th, $J^{\pi} = 5/2^+$ , $T_{1/2} = 7894(40)$ y*, $BR_{\alpha} = 100\%$ (continued, 2 of .	3).

$E_{\alpha}(\text{c.m.})^{**}$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi@@}$	E _{daughter} ( ²²⁵ Ra) ^{@@}	coincident $\gamma$ -rays (keV) ^{@@}	HF ^{@@@}
4.6804(10)	4.5986**	0.092%	0.0519%		0.4872	11.1, 17.3, 23.6, <b>25.4</b> , 28.7, 29.9, 31.4, 37.8, 42.4, 42.8, 44.0, 49.7, 51.0, 53.8, 55.2, 56.5, 59.3, 63.7, 65.0, 68.1, 68.2, 68.8, <b>75.2</b> , 77.6, 78.5, 86.3, 89.1, 94.7, 94.8, <b>97.0</b> , 98.9, 100.8, 110.3, 107.1, 109.1, <b>115.9</b> , 118.1, 120.1, 123.2, 124.6, 126.1, <b>126.5</b> , 131.9, 134.2, 137.0, 142.0, 142.9, 147.7, 148.2, 149.9, 151.6, 154.3, 156.4, <b>163.2</b> , 166.9, 1 67.5, 169.2, 171.2, <b>174.1</b> , 179.8, 193.5, 194.9, 200.8, 204.7, 210.3, 210.9, 218.2, 221.2, 225.3, 236.3, 242.6, 252.4, 278.7, <b>289.6</b> , 296.2	35
4.6808(10)	4.600(2)	0.037%	0.021%	(5/2 ⁺ )	0.4868	<b>11.1</b> , <b>17.3</b> , 23.6, <b>25.4</b> , 29.9, 31.4, 37.8, 42.4, <b>42.8</b> , 44.0, 51.0, 55.2, 59.3, 65.0, 68.1, 68.8, 77.6, 86.3, 89.1, 94.7, 94.8, 110.3, 107.1, 118.1, 124.6, <b>137.0</b> , 148.2, 149.9, <b>154.3</b> , 179.8, <b>307.3</b> , 336.7, 366.5, 375.1, 386.4, 417.4, 444.1, <b>461.4</b> , 487.3	87
4.6895(10)	4.608(2)	0.089%	0.05%	(5/2+)	0.4781	<b>11.1</b> , <b>17.3</b> , 22.0, 23.6, <b>25.4</b> , 29.9, <b>31.4</b> , <b>33.0</b> , <b>37.8</b> , 42.4, <b>42.8</b> , <b>44.0</b> , 51.0, 55.2, 59.3, 63.7, 65.0, 68.1, <b>68.8</b> , <b>75.2</b> , 77.6, <b>86.3</b> , 89.1, 94.7, 94.8, 110.3, 107.1, 118.1, 123.2, 124.6, <b>131.9</b> , 137.0, <b>139.8</b> , <b>142.9</b> , 148.2, 149.9, 154.3, 174.1, 179.8, <i>185.6</i> , 190.6, 200.8, <b>217.4</b> , 218.2, 228.6, 234.8, 250.1, 267.4, <b>298.7</b> , 328.2, 358.0, 366.5, 377.4, 408.5, 453.3,452.6, 478.0	42
4.7211(10)	4.639**	0.082%	0.046%	(7/2 ⁺ ,9/2 ⁻ )	0.4465	11.1, 17.3, 22.0, <b>23.6</b> , <b>25.4</b> , <b>28.7</b> , 29.9, <b>31.4</b> , <b>37.8</b> , 42.4, 42.8, <b>44.0</b> , 51.0, 59.3, 63.7, <b>65.0</b> , 68.1, 68.8, <b>75.2</b> , 77.6, 86.3, 89.1, 94.7, 94.8, 107.1, 110.3, 118.1, 123.2, 124.6, <b>131.9</b> , 137.0, <b>139.8</b> , <b>142.9</b> , 148.2, 149.9, 154.3, 174.1, <b>174.7</b> , 179.8, <b>186.1</b> , <b>190.6</b> , 200.8, 218.2, 217.4, <b>219.8</b> , 228.6, 234.8, 250.1, 267.4, 334.7, 345.8	76
4.7508(10)	≈4.667 [@]	0.002%	0.00113%		0.4168	11.1, 17.3, 23.6, <b>25.4</b> , <b>31.4</b> , <b>37.8</b> , 42.4, 42.8, <b>44.0</b> , 55.2, 68.8, <b>75.2</b> , 86.3, <b>89.1</b> , 94.7, <b>102.5</b> , <b>107.1</b> , 118.1, <b>124.6</b> , 149.9, <b>169.2</b> , 182.1, 193.5, <b>216.0</b> , <b>225.3</b> , 327.9, <b>347.4</b>	5×10 ³
4.7641(10)	4.681**	0.021%	0.012%	(3/2 ⁺ ,5/2 ⁺ )	0.4035	<b>11.1, 17.3, 25.4</b> , 31.4, 37.8, 42.4, <b>42.8</b> , 44.0, <b>49.7</b> , <b>68.8</b> , <b>75.2</b> , <b>86.3</b> , <b>109, 1, 120, 1, 126, 1, 151, 6</b> , <i>183, 0</i> , 194, 9, 403, 3,	580
4.7681(10)	4.685**	0.008%	0.0046%	(3/2-)	0.3995	<b>11.1</b> , <b>17.3</b> , 23.6, <b>25.4</b> , 29.9, <b>31.4</b> , <b>37.8</b> , 42.4, <b>42.8</b> , <b>44.0</b> , 51.0, 55.2, 59.3, 65.0, 68.1, 68.8, 77.6, 86.3, 89.1, 94.7, 94.8, 110.3, 107.1, 118.1, 124.6, <b>137.0</b> , 148.2, 149.9, 154.3, 179.8, <b>219.8</b> , <b>329.9</b> , 344.4, 399.9	1.6×10 ³
4.7731(10)	4.690(2)	0.80%	0.45%	(5/2)+	0.3945	<b>11.1</b> , <b>17.3</b> , 23.6, <b>25.4</b> , 28.7, 29.9, <b>31.4</b> , 37.8, 42.4, <b>42.8</b> , 44.0, 49.7, 51.0, <b>53.8</b> , 55.2, <b>56.5</b> , 59.3, 63.7, 65.0, 68.1, <b>68.8</b> , <b>72.8</b> , 75.2, 77.6, <b>78.5</b> , <b>86.3</b> , 89.1, 94.7, 94.8, 98.9, 100.8, 110.3, <b>107.1</b> , 109.1, 115.9, 118.1, 120.1, 123.2, <b>124.6</b> , 126.1, 126.5, <b>131.9</b> , 134.2, <b>137.0</b> , 142.0, <b>142.9</b> , 147.7, 148.2, 149.9, <b>151.6</b> , 154.3, <b>156.4</b> , <i>158.4</i> , 166.9, 167.5, 171.2, 174.1, 179.8, 193.5, 194.9, 200.8, 204.7, <b>210.3</b> , <b>210.9</b> , 218.2, 225.3, 236.3, 242.6, 252.4, 282.6, 293.8, 296.2, 351.7, 395.3	18
4.7734(10)	4.690(2)	0.019%	0.0104%	(3/2 ⁻ ,5/2 ⁻ )	0.3942	<b>17.3</b> , 22.0, <b>23.6</b> , <b>25.4</b> , 31.4, <b>33.0</b> , <b>37.8</b> , <b>42.8</b> , <b>44.0</b> , <b>51.0</b> , 55.2, <b>65.0</b> , 75.2, 77.6, 89.1, 94.7, 94.8, 101.6, 107.1, 10.3, 118.1, <b>124.6</b> , <b>134.2</b> , <b>139.8</b> , 149.9, <i>16</i> 9.2, <b>182.1</b> , <b>190.6</b> , 193.5, 217.4, 225.3, 228.6, 234.8, <b>244.4</b> , 250.1, 267.4, 324.6, <b>368.9</b>	780
4.7774(10)	4.695(2)	0.21%	0.12%	(11/2 ⁺ )	0.3902	<b>11.1</b> , 17.3, 23.6, <b>25.4</b> , 28.7, 29.9, <b>31.4</b> , <b>37.8</b> , 42.4, 42.8, 44.0, 49.7, 51.0, 53.8, 55.2, 56.5, 59.3, 63.7, 65.0, 68.1, 68.2, <b>68.8</b> , <b>75.2</b> , 77.6, 78.5, 86.3, 89.1, 94.7, 94.8, 98.9, 100.8, 110.3, 107.1, 109.1, <b>115.9</b> , 118.1, 120.1, 123.2, 124.6, 126.1, <b>126.5</b> , 131.9, 134.2, 137.0, 142.0, 142.9, 147.7, 148.2, 149.9, 151.6, 154.3, 156.4, <i>163.2</i> , 166.9, 167.5, <b>169.2</b> , 171.2, <b>174.1</b> , 179.8, 193.5, 194.9, 200.8, 204.7, 210.3, 210.9, 218.2, 221.2, 225.3, 236.3, 242.6, 252.4, 278.7, <b>289.6</b> , 296.2	72
4.8182(10)	≈4.737 [@]	0.019%	0.0107%	(3/2,5/2 ⁺ )	0.3494	<b>11.1</b> , <b>17.3</b> , 23.6, <b>25.4</b> , 31.4, 37.8, <b>42.8</b> , 44.0, 51.0, 55.2, 65.0, <b>68.8</b> 77.6, <b>89.1</b> , <b>86.3</b> , 94.7, 94.8, <b>107.1</b> , <b>110.3</b> , 118.1, 124.6, <b>139.8</b> , 149.9, <b>190.6</b> , 217.4, 228.6, 234.8, 317.8, 349.4	860
4.8322(10)	≈4.748 [@]	0.010%	0.0054%	(1/2 ⁺ ,3/2,5/2)	0.3354	17.3, 23.6, <b>125.4</b> , 31.4, 37.8, 42.8, 44.0, 51.0, 55.2, 65.0, 77.6, 89.1, 94.7, 94.8, 107.1, 110.3, 118.1, 124.6, 139.8, 149.9, <b>1185.6</b> , 90.6, 217.4, 228.6, 234.8, 303.8, <b>310.1</b>	3.8×10 ³
4.8404(10)	≈4.754 [@]	0.23%	0.13%	(3/2 ⁺ ,5/2 ⁺ )	0.3277	<b>11.1, 17.3, 23.6, 25.4, 31.4</b> , 37.8, 42.4, <b>42.8</b> , 44.0, 55.2, <b>68.8</b> , <b>75.2</b> , <b>86.3</b> , 94.7, <i>102.5</i> , <b>107.1</b> , 118.1, 124.6, 149.9, <b>169.2</b> , <b>182.1</b> , <b>193.5</b> , <b>216.0</b> , <b>225.3</b> , <b>327.9</b>	180

Table 8	
direct $\alpha$ emission from ²²⁹ Th, $J^{\pi} = 5/2^+$ , $T_{1/2} = 7894(40)$ y*, $BR_{\alpha} = 100\%$	(continued, 3 of 3).

$E_{\alpha}(\text{c.m.})^{**}$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@@}$	E _{daughter} ( ²²⁵ Ra) ^{@@}	coincident $\gamma$ -rays (keV) ^{@@}	HF ^{@@@}
4.8458(10)	4.760(2)	3.19%	1.79%	(9/2+)	0.3218	<b>11.1</b> , <b>17.3</b> , 23.6, <b>25.4</b> , 28.7, 29.9, <b>31.4</b> , 37.8, 42.4, <b>42.8</b> , 44.0, 49.7, 51.0, <b>53.8</b> , 55.2, 56.5, 59.3, 63.7, 65.0, <b>68.1</b> , <b>68.8</b> , <b>75.2</b> , 77.6, <b>78.5</b> , <b>86.3</b> , 89.1, <b>94.7</b> , 94.8, 98.9, <b>100.8</b> , 107.1, 109.1, 110.3, 115.9, 118.1, 120.1, 123.2, 124.6, 126.1, <b>126.5</b> , <b>131.9</b> , 134.2, 137.0, 142.0, <b>142.9</b> , 147.7, 148.2, 149.9, 151.6, 154.3, <b>156.4</b> , 166.9, 167.5, 171.2, 174.1, 179.8, 193.5, 194.9, 200.8, 204.7, <b>210.3</b> , 210.9, 218.2, 221.2, 225.3, 236.3, 242.6, <b>252.4</b> , 296.2	14
4.8833(10)	4.798(2)	2.67%	1.5%	7/2+	0.2843	11.1, 17.3, 23.6, <b>25.4</b> , 29.9, <b>31.4</b> , 37.8, 42.4, <b>42.8</b> , <b>44.0</b> , 51.0, 55.2, 59.3, <b>63.7</b> , 65.0, 68.1, 68.8, 75.2, 77.6, 86.3, 89.1, 94.7, 94.8, <b>104.3</b> , 110.3, 107.1, <b>109.1</b> , 118.1, <b>120.1</b> , 124.6, 126.1, 134.2, <b>137.0</b> , 148.2, 149.9, 151.6, <b>154.3</b> , <i>172.9</i> , 179.8, <b>183.9</b> , 194.9, <b>215.1</b> , 259.1	30
4.8954(10)	≈4.809 [@]	0.75%	0.42%	(7/2 ⁻ ,9/2 ⁻ )	0.2722	<b>11.1</b> , 17.3, 23.6, <b>25.4</b> , <b>28.7</b> , <b>11.1</b> , 29.9, <b>31.4</b> , <b>37.8</b> , 42.4, 42.8, <b>44.0</b> , 51.0, 55.2, 59.3, 63.7, 65.0, 68.1, <b>68.8</b> , <b>75.2</b> , 77.6, <b>86.3</b> , 89.1, 94.7, 94.8, 98.9, 110.3, 118.1, 123.2, 124.6, <b>124.9</b> , <b>131.9</b> , 134.2, 137.0, 148.2, 149.9, 154.3, <b>171.8</b> , 174.1, 179.8, 200.8, 218.2	129
4.8997(10)	4.815(2)	16.55%	9.3%	7/2+	0.2679	11.1, <b>17.3</b> , 23.6, <b>25.4</b> , 29.9, <b>31.4</b> , 37.8, 42.4, <b>42.8</b> , 44.0, 51.0, 55.2, 56.5, 59.3, 65.0, 68.1, <b>68.8</b> , 75.2, 77.6, <b>86.3</b> , 89.1, 94.7, 94.8, 107.1, 110.3, 115.9, 118.1, <b>124.6</b> , 137.0, 147.7, 148.2, 149.9, 154.3, <b>156.4</b> , 166.9, 167.5, 179.8, 193.5, 204.7, 210.9, 225.3, 236.3, 242.6	6.2
4.9074(10)	4.822**	0.05%	0.026%	(5/2) ⁻	0.2602	<b>11.1. 17.3, 23.6, 25.4, 31.4, 37.8, 42.8, 44.0,</b> 51.0, 55.2, <b>65.0</b> , 77.6, 89.1, 94.7, 94.8, 107.1, <b>110.3</b> , 118.1, <b>124.6, 139.8</b> , 149.9, <b>190.6</b> , <b>217.4, 228.6, 234.8</b>	$2.5 \times 10^{3}$
4.919(10)	≈4.833 [@]	0.45%	0.253%	(3/2 ⁺ ,5/2,7/2 ⁺ )	0.2486	11.1, <b>17.3</b> , 23.6, <b>25.4</b> , 29.9, 31.4, 37.8, 42.4, <b>42.8</b> , 44.0, 51.0, 55.2, 59.3, 65.0, 68.1, <b>68.8</b> , 77.6, 86.3, 89.1, 94.7, 94.8, <b>98.9</b> , 110.3, <b>107.1</b> , 118.1, <b>124.6</b> , <b>137.0</b> , 148.2, 149.9, <b>154.3</b> , 179.8	310
4.9241(10)	4.838(2)	8.90%	5%	7/2+	0.2435	<b>11.1</b> , <b>17.3</b> , 23.6, <b>25.4</b> , 29.9, <b>31.4</b> , <b>37.8</b> , 42.4, <b>42.8</b> , <b>44.0</b> , 51.0, 55.2, 59.3, 63.7, 65.0, 68.1, <b>68.8</b> , <b>75.2</b> , 77.6, 86.3, 89.1, 94.7, 94.8, 110.3, 107.1, 118.1, 123.2, 124.6, <i>131.9</i> , 137.0, <b>142.9</b> , 148.2, 149.9, 154.3, 174.1, 179.8, 200.8, <b>218.2</b>	17
4.9313(10)	4.845(2)	100.00%	56.2%	5/2+	0.2363	11.1, <b>17.3</b> , 23.6, <b>25.4</b> , 29.9, <b>31.4</b> , <b>37.8</b> , 42.4, <b>42.8</b> , <b>44.0</b> , 51.0, 55.2, <b>56.5</b> , 59.3, 65.0, 68.1, 68.8, 77.6, <b>86.3</b> , 89.1, 94.7, 94.8, 110.3, <b>107.1</b> , 115.9, 118.1, <b>124.6</b> , <b>137.0</b> , 148.2, 149.9, <b>154.3</b> , 166.9, 179.8, <b>193.5</b> , 204.7, <b>210.9</b> , 236.3	1.7
4.9407(10)	≈4.852 [@]	0.053%	0.03%	$(11/2^+)$	0.2269	<b>25.4</b> , <b>31.4</b> , 37.8, 44.0, <b>75.2</b> , <b>126.5</b>	3.6×10 ³
4.9425(10)	4.856**	0.023%	0.013%	3/2-	0.2251	<b>17.3</b> , <b>23.6</b> , <b>25.4</b> , <b>31.4</b> , <b>42.8</b> , <b>55.2</b> , <b>75.2</b> , 94.7, <b>107.1</b> , 118.1, <b>124.6</b> , 149.9, <b>169.2</b> , <i>182.1</i> , <b>193.5</b> , <b>225.3</b>	8.5×10 ³
4.947(10)	4.860(2)	0.50%	0.28%	$(7/2^+, 9/2^+)$	0.2206	11.1, <b>17.3</b> , <b>25.4</b> , <b>31.4</b> , <b>37.8</b> , 42.4, <b>42.8</b> , <b>44.0</b> , <b>49.7</b> , <i>68.8</i> , <b>75.2</b> , <b>86.3</b> , <b>101,6</b> , <b>109.1</b> , <b>120.1</b> , <b>126.1</b> , 151.6, <b>194.9</b>	420
4.9513(10)	≈4.865 [@]	0.073%	0.041%	$(13/2^+)$	0.2163	25.4, 31.4, 37.8, 44.0, 75.2, 115.9	$3.1 \times 10^{3}$
4.9641(10)	$\approx 4.878^{@}$	0.14%	0.077%	(9/2 ⁻ )	0.2035	<b>25.4</b> , <b>31.4</b> , <b>37.8</b> , <b>44.0</b> , <i>134.2</i>	$2.0 \times 10^{3}$
4.9879(10)	4.901(2)	18.15%	10.2%	5/2+	0.1797	<b>11.1</b> , <b>17.3</b> , 23.6, <b>25.4</b> , 29.9, <b>31.4</b> , <b>37.8</b> , 42.4, <b>42.8</b> , <b>44.0</b> , 51.0, 55.2,	21
						59.3, 65.0, <b>68.1</b> , 68.8, 7 <b>5.2</b> , 77.6, <b>86.3</b> , 89.1, 94.7, 94.8, 110.3, 107.1, 118.1, 124.6, <i>137.0</i> , <b>148.2</b> , 149.9, <b>154.3</b> , 179.8	
5.0182(10)	4.930(2)	0.28%	0.16%	3/2+	0.1499	<b>17.3</b> , 23.6, <b>25.4</b> , 31.4, <b>42.8</b> , 55.2, 94.7, <i>107.1</i> , 118.1, <b>124.6</b> , 149.9	$2.1 \times 10^{3}$
5.056(10)	4.968(2)	10.62%	5.97%	7/2+	0.1116	11.1, 17.3, 25.4, 31.4, 37.8, 44.0, 42.4, 42.8, 68.8, 75.2, 86.3	99
5.0671(10)	4.979(2)	5.64%	3.17%	$(9/2)^+$	0.1005	25.4, 31.4, 37.8, 44.0, 75.2	220
5.0982(10)	5.009(2)	0.16%	0.09%	(1/2)-	0.0694	25.4, 31.4, 37.8, 44.0	1.2×10 ⁴
5.1124(10) 5.1240(10)	5.023(2)	0.02%	0.009%	$(1/2^{-})$ $2/2^{+}$	0.0552	<i>23.0, 31.4, 55.2</i> <i>17 3, 25 4, 42 8</i>	$1.5 \times 10^{3}$
5.1249(10) 5.136(10)	5.050(2) 5.046**	0.45%	0.24%	3/2-	0.0427	17.3, 43.4, 44.0 31 A	$0.0 \times 10^{\circ}$ 0.1 × 10 ³
5.1422(10)	5.053(2)	11.74%	6.6%	5/2+	0.254	25.4	310
5.1676(10)	5.077(2)	0.089%	0.05%	1/2+	0.0		$5.8 \times 10^4$

* Weighted average of 7880(120) y [1989Go19], 7917(48) y [2014Va04] and 7825(87) y [2018Es07]. ** Deduced from  $\gamma$  energies [2000Ga52] and  $Q_{\alpha} = 5167.6(10)$  keV [2021Wa16].

*** [1987He28]

*** [198/He28] @ [1970Ba20]. @@ [2000Ga52]. The 100% peak decaying from  $E_{daughter}$  (i.e. the state that the  $\alpha$  populated) is marked in **bolditalic**, and peaks 10% or larger of the aforementioned peak are marked in **bold**. @@@  $R_0$  (fm) = 1.53355(71) fm

Table 9		
direct $\alpha$ emission from ²³³ U, $J^{\pi} = 5/2^+$ , $T_{1/2} = 1.5903(13) \times 10^5$ y	$y^*, BR_{\alpha} = 100\% (1)$	of 2).

$E_{\alpha}(\text{c.m.})^{**}$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_{f}^{\pi @}$	E _{daughter} @ ( ²²⁹ Th)	coincident $\gamma$ -rays (keV) ^{@@}	HF ^{@@@}
4.1596	4.0882	$1.7 \times 10^{-5}\%$	$1.44{ imes}10^{-5}\%$	(5/2 ⁺ ,7/2,9/2 ⁺ )	0.7491	25.3, 29.2, <b>42.4</b> , 42.6, <b>54.7</b> , 67.9, 71.8, 74.6, 76.3, 86.3, 88.7, 97.1, 117.2, 119.0, 146.3, 148.2, 514.7, 652.8, <b>707.4</b> , 740.6, 749.8	13.5
4.2437	4.1708	$1.1{\times}10^{-6}\%$	$9.3 \times 10^{-7}\%$	(1/2,3/2)-	0.6650	29.2, 135.3, 164.5, 500.4, 665.0	$1.1 \times 10^3$
4.2518	4.1788	7.0×10 ⁻⁶ %	6.1×10 ⁻⁶ %	(5/2+,7/2,9/2+)	0.6569	25.3, <b>29.2</b> , 37.8, 42.4, <b>42.6</b> , <b>53.6</b> , 54.7, 66.1, 67.9, 71.8, 83.0, 96.2, 97.1, 120.8, 125.4, 177.9, 315.9, 381.5, 406.6, 436.2, 494.5, 478.6, <b>531.5</b> , <b>559.9</b> , 584.9, <i>614.6</i> , <b>627.7</b> , <b>657.3</b>	200
4.2713	4.1979	1.2×10 ⁻⁵ %	1.03×10 ⁻⁵ %	(5/2 ⁺ ,7/2,9/2 ⁺ )	0.6375	25.3, <b>29.2</b> , 42.4, 42.6, 54.7 67.9, 71.8, 74.6, 76.3, 86.3, 87.3, <b>88.7</b> , 97.1, <b>117.2</b> , 119.0, <b>146.3</b> , 148.2, 212.3, <i>402.4</i> , <b>425.3</b> , 480.7, <b>540.7</b> , 608.2, 637.3	$1.7 \times 10^{3}$
4.2879	42143	8.4×10 ⁻⁶ %	7.3×10 ⁻⁶ %	(5/2 ⁺ ,7/2)	0.6208	<b>25.3</b> , <b>29.2</b> , <b>42.4</b> , 42.6, <b>54.7</b> , 67.9, 71.8, 74.6, 97.1, 117.2, <b>146.3</b> , <b>474.4</b> , <b>523.6</b> , 578.6, <b>591.6</b> , <b>620.6</b>	330
4.3035	4.2296	$1.0 \times 10^{-5}\%$	$8.7 \times 10^{-6}\%$	5/2+,7/2+	0.6052	<b>29.2</b> , <b>42.4</b> , <b>42.6</b> , <b>71.8</b> , 76.3, 119.0, 148.2, 456.9, <b>533.5</b> , <b>563.0</b> , <b>576.1</b> , <i>605.2</i>	370
4.3236	4.2494	9.5×10 ⁻⁶ %	8.3×10 ⁻⁶ %	(5/2 ⁺ ,7/2,9/2 ⁺ )	0.5851	<b>29.2</b> , 42.4, <b>42.6</b> , <b>53.6</b> , <b>71.8</b> , 76.3, 119.0, 148.2, <b>459.7</b> , 513.2, 542.4, 584.9	570
4.3394	4.2649	1.8×10 ⁻⁵ %	1.58×10 ⁻⁵ %	3/2+,5/2+	0.5693	<b>25.3</b> , <b>29.2</b> , 32.7, <b>42.4</b> , <b>42.6</b> , <b>43.7</b> , 51.0, 52.6, 53.6, <b>54.7</b> , 63.8, 67.9, 68.9, <b>71.8</b> , 74.6, 76.3, 83.0, 85.2, 86.3, <b>87.3</b> , 88.7, 89.4, 91.0, 96.2, 97.1, <b>97.4</b> , 101.7, 103.8, 111.9, 114.2, 117.2, 119.0, 125.4, 131.2, <b>135.3</b> , 139.7, 146.3, 148.2, 156.2, 162.5, 164.5, 165.6, 172.3, 174.2, 188.0, 208.2, 212.3, 216.1, 217.1, 223.4, 226.2, 248.7, 255.9, 261.9, 278.1, 291.4, <b>307.3</b> , <i>313,5</i> , 320.6, <b>404.3</b> , 423.1, <b>569.3</b>	350
4.3724 4.384	4.2973 4.309***	$\frac{3.0 \times 10^{-6}\%}{9.2 \times 10^{-4}\%}$	$\frac{2.6 \times 10^{-6}\%}{8.0 \times 10^{-4}\%}$	(1/2 ⁻ ) (5/2,7/2) ⁻	0.5363 05265	<b>29.2</b> , <b>135.3</b> , <b>164.5</b> , <i>371.3</i> , <b>536.4</b> <b>29.2</b> , <b>42.4</b> , <b>42.6</b> , 52.6, 68.9, <b>71.8</b> , <b>74.6</b> , 76.3, 86.3, 88.7, 97.4, <b>117.2</b> , 119.0, 135.3, 142.7, 145.3, <b>146.3</b> , 148.2, 164.5, <b>167.1</b> , 188.0, 217.1, 261.9, <b>291.5</b> , <b>309.6</b> , <b>317.2</b> , 359.4, 455.1, 484.8	4.5×10 ³ 18
4.3953	4.3198	5.6×10 ⁻⁵ %	4.9×10 ⁻⁵ %	(5/2+,7/2,9/2+)	0.5134	<b>25.3, 29.2, 42.4, 42.6</b> , 53.6, <b>54.7</b> , 67.9, 71.8, 83.0, 96.2, 97.1, 125.4, 387.6 <b>416.2</b> , 441.5, 471.1, <b>513.2</b>	370
4.4301	4.3540	$5.7 \times 10^{-5}\%$	$5.0 \times 10^{-5}\%$	(7/2 ⁺ ,9/2 ⁺ )	0.4787	25.3, <b>29.2, 37.8, 42.4, 42.6, 53.6, 54.7, 66.1,</b> 67.9, 71.8, 83.0, 96.2, 97 1 <b>120 8</b> 125 <b>4 315 9 381 5 406 6</b> 436 2 <b>494 5 478 6</b>	680
4.4433	4.3670	$1.4 \times 10^{-4}\%$	1.19×10 ⁻⁴ %	(5/2 ⁻ ,7/3,9/2 ⁺ )	0.4654	<b>25.3</b> , <b>29.2</b> , 42.4, <b>42.6</b> , 53.6, 54.7, 63.8, 65.6, 67.9, 71.8, 74.6, 76.3 83.0, 89.4, 91.0, 96.2, 97.1, 101.7, 111.9, 117.2, <b>119.0</b> , 125.4, 131.2, 146.3, 148.2, 154.8, 162.5, 165.6, 177.9, 205.9, 208.2, 260.5, 273.7, <b>291.9</b> , 303.0, 393.6, 423.1, 465.4	360
4.4719	4.3952	8.3×10 ⁻⁴ %	7.2×10 ⁻⁴ %	(7/2 ⁻ )	0.4368	<b>25.3,29.2,</b> 32.7, <b>42.4</b> , 42.6, 51.0, 52.6, 53.6, 54.7, 63.8, 67.9, 68.9, 71.8, 74.6, 76.3, <b>77.1</b> , 83.0, 85.2, 86.3, 87.3, 88.7, 89.4, 91.0, 96.2, 97.1, 97.4, 101.7, 103.8, 111.9, 114.2, <b>116.3</b> , 117.2, 119.0, 125.4, 131.2, 135.3, 139.7, 142.7, 146.3, 148.2, 156.2, 162.5, 164.5, 165.6, 172.3, 174.2, 188.0, 208.2, 212.3, 216.1, 217.1, 223.4, 224.4, 248.7, 261.9, 272.4, 278.1, <b>291.4</b> , 311.9, <b>317.2</b> , 320.6, 339.2, <b>359.4</b>	101
4.481	4.404***	3.3×10 ⁻⁴ %	2.90×10 ⁻⁴ %	(5/2+	0.4280	25.3, <b>29.2</b> , 32.6, 42.4, <b>42.6</b> , <b>43.7</b> , <b>53.6</b> , 54.7, 63.8, 65.6, 67.9, 71.8, 74.6, 76.3, 83.0, <b>87.3</b> , 89.4, 91.0, 96.2, 97.1, 101.7, 111.9, 117.2, 119.0, 125.0, <b>125.4</b> , 131.2, <i>139.3</i> , 142.0, 146.3, 148.2, 154.8, 165.6, 177.9, 205.9, 208.2, 212.3, 226.2, 255.9, 259.3, 260.5, 273.7, 288.5, 303.0	290
4.4828	4.4059	6.2×10 ⁻⁴ %	5.40×10 ⁻⁴ %	(9/2+)	0.4259	25.3, 29.2, 37.8, 42.4, 42.6, 53.6, 54.7, 63.8, 66.1, 67.9, 70.3, 71.8, 74.6, 76.3, <b>78.2</b> , 83.0, 89.4, 91.0, 96.2, 97.1, 101.7, 111.9, 116.3, 117.2, 119.0, 120.8, 123.9, 125.4, 131.2, <b>144.4</b> , 146.3, 148.2, 153.1, 165.6, <b>184.1</b> , 188.7, 208.2, <b>230.1</b> , <b>328.5</b> , <b>354.1</b> , <b>383.5</b> , 390.6	160
4.488	4.411***	$4.6 \times 10^{-4}\%$	4.0×10 ⁻⁴ %***		0.421***		240
4.5262	4.4485	6.6×10 ⁻⁵ %	5.70×10 ⁻⁵ %	(7/2 ⁻ ,9/2,11/2 ⁺ )	0.3825	<b>25.3</b> , 29.2, <b>42.4</b> , 42.6, <b>71.8</b> , 76.3, 101.7, <b>119.0</b> , 131.2, 148.2, <b>209.1</b> , <i>310.7</i>	$3.3 \times 10^{3}$
4.535	4.457***	3.1×10 ⁻³ %	2.70×10 ⁻³ %	(7/2+)	0.3748	25.3, <b>29.2</b> , <b>32.6</b> , 42.4, <b>42.6</b> , 43.7, <b>53.6</b> , 54.7, 67.9, 71.8, 74.6, 76.3, <b>86.3</b> , <b>87.3</b> , 88.7, 97.1, 117.2, 119.0, 139.3, 142.0, 146.3, 148.2, 212.3, 226.2, 259.3, 288.5, 255.9, 303.0, 374.7	81
4.543	4.465***	5.2×10 ⁻³ %	$4.50 \times 10^{-3}\%$	7/2+	0.3658	<b>25.3, 29.2, 42.4, 42.6, 53.6, 54.7</b> , 67.9, <b>71.8</b> , 74.6, 76.3, 83.0, <b>96.2</b> , 97.1, 101.7, 117.2, 119.0, 125.4, 131.2, 146.3, 148.2, 192.3, <b>219.4</b> , <b>240.4, 268.7, 294.0, 323.3, 336.6, 365.8</b>	66
4.5491	4.4710	$6.9 \times 10^{-4}\%$	$6.00 \times 10^{-4}\%$	(7/2+)	0.3596	29.2, <b>42.4</b> , 97.4, 135.3, 164.5, 261.9, 142.7, <b><i>317.2</i></b> , 359.4	470
4.561	4.483***	1.6×10 ⁻³ %	1.40×10 ⁻³ %	(5/2+)	0.3478	25.3, 29.2, <b>42.4</b> , 42.6, <b>43.7</b> , <b>44.8</b> , 53.6, 54.7, 63.8, 65.6, 67.9, 71.8, 74.6, 76.3, 83.0, <b>87.3</b> , 89.4, 91.0, <b>92.2</b> , 96.2, 97.1, 101.7, 111.9, 117.2, <b>119.0</b> , 125.4, 131.2, 146.3, 148.2, <b>154.8</b> , 165.6, 177.9, 205.9, 208.2, 212.3, 226.2, 255.9, <b>260.5</b> , 273.7, <b>303.0</b>	250

Table 10	
direct $\alpha$ emission from ²³³ U, $J^{\pi} = 5/2^+$ , $T_{1/2} = 1.5903(13) \times 10^{-10}$	$10^5 \text{ y*}, BR_{\alpha} = 100\% \text{ (continued, 2 of 2)}$

$E_{\alpha}(\text{c.m.})^{**}$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi @}$	E _{daughter} [@] ( ²²⁹ Th)	coincident $\gamma$ -rays (keV) ^{@@}	HF ^{@@@}
4.582	4.503***	$01.2 \times 10^{-3}\%$	$1.02 \times 10^{-3}\%$	(15/2+)	0.3278	<b>29.2, 37.8, 42.4, 42.6, 53.6, 54.7, 66.1</b> , 71.8, <b>78.2</b> , 83.0, 96.2, <b>120.8</b> ,	480
4.586	4.507***	0.024%	0.0205%	(5/2)+	0.3205	125.4, <b>144.4</b> , <i>164.5</i> <b>25.3</b> , <b>29.2</b> , <b>32.7</b> , <b>42.4</b> , <b>42.6</b> , <b>51.0</b> , 52.6, 53.6, 54.7, 63.8, 67.9, 68.9, 71.8, 74.6, 76.3, 83.0, 85.2, 86.3, 88.7, 89.4, 91.0, 96.2, 97.1, 101.7, 103.8, 111.9, <b>114.2</b> , 117.2, <b>119.0</b> , 125.4, 131.2, 135.3, 139.7, 146.3, 148.2, 156.2, 162.5, 164.5, 165.6, 172.3, 174.2, 188.0, <b>208.2</b> , 216.1, 217.1, 223.4, <b>248.7</b> , <b>278.1</b> , <b>291.4</b> , <b>320.6</b>	27
4.592	4.513***	0.023%	0.020%	(5/2)+	0.3172	<b>29.2</b> , <b>42.6</b> , 52.6, 68.9, 71.8, 74.6, 76.3, 100.0, 117.2, 119.0, 135.3, 145.3, 146.3, 148.2, 152.6, 164.5, 169.1, 170.8, 188.0, 217.1, <b>245.3</b> , 274.7, <b>288.0</b> , 317.2	30
4.6057	4.5267	$5.7 \times 10^{-3}\%$	5.0×10 ⁻³ %	(7/2 ⁺ )	0.3030	<b>25.3</b> , <b>29.2</b> , <b>42.4</b> , <b>42.6</b> , <b>53.6</b> , 54.7, 63.8, <b>65.6</b> , 67.9, 71.8, 74.6, 76.3, 83.0, 89.4, <b>91.0</b> , 96.2, 97.1, 101.7, 111.9, 117.2, <b>119.0</b> , 125.4, <b>129.3</b> , 131.2, <b>146.3</b> , 148.2, <b>154.8</b> , 165.6, <b>177.9</b> , <b>205.9</b> , <b>208.2</b> , <i>260.5</i> , <b>273.7</b> , <b>303.0</b>	150
4.617	1 538***	$4.6 \times 10^{-3}$ %	$4.0 \times 10^{-3}$ %***		0 202***	505.0	230
4.017	4.530	$4.0 \times 10^{-4}$	<b>2</b> 00 × 10 ^{−4} 0⁄-		0.292	25 2 20 2 22 6 42 4 42 6 42 7 54 7 67 0 71 8 74 6 87 2 07 1	$\frac{230}{1.2 \times 10^3}$
4.0202	4.5409	9.2×10 %	8.00×10 %		0.2883	25.5, <b>25.2</b> , <b>25.0</b> , <b>42.4</b> , <b>42.0</b> , <b>43.7</b> , <b>34.7</b> , <b>34.7</b> , <b>07.9</b> , <b>71.0</b> , <b>74.0</b> , <b>87.9</b> , <b>71.1</b> , 117.2, <b>135.3</b> , 142.0, 146.3, <b>164.5</b> , 212.3, 226.2, <b>259.3</b> , 255.9, <b>261.9</b> , 288.5	1.2×10
4.6208	4.5415	$1.1 \times 10^{-3}\%$	$1.0 \times 10^{-3}\%$	(7/2 ⁻ )	0.2879	<b>25.3</b> , <b>29.2</b> , 42.4, <b>42.6</b> , <b>51.0</b> , 53.6, 54.7, 63.8, 67.9, 71.8, 74.6, 76.3, 83.0, 89.4, 91.0, 96.2, 97.1, 101.7, 111.9, <b>114.2</b> , 117.2, <b>119.0</b> , 125.4, 131.2, <b>139.7, 146.3</b> , 148.2, 162.5, 165.6, <b>208.2</b> , <b>216.1</b>	980
4.645	4.565***	$3.3 \times 10^{-3}\%$	$2.9 \times 10^{-3}\%$	$(1/2^+)$	0.2619	29.2, 97.4, 135.3, 164.5, 261.9	530
4.652	4.572***	$1.1 \times 10^{-3}\%$	$1.0 \times 10^{-3}\%$	(3/2,5/2+,7/2+)	0.2560	<b>29.2</b> , 42.4, <b>42.6</b> , 43.6, <b>53.6</b> , 71.8, 83.0, <b>87.3</b> , <b>96.2</b> , 125.4, <b>212.1</b> , <b>226.2</b> , 255.9	$1.7 \times 10^{3}$
4.6671	4.5870	1.8×10 ⁻³ %	1.57×10 ⁻³ %	13/2+	0.2416	<b>25.3</b> , <b>29.2</b> , <b>37.8</b> , <b>42.4</b> , <b>42.6</b> , <b>53.6</b> , <b>54.7</b> , <b>66.1</b> , 67.9, 71.8, 78.2, 83.0, 96.2, <b>97.1</b> , 116.3, <b>120.8</b> , 125.4, <i>144.4</i>	$1.4 \times 10^{3}$
4.670	4.590	$\approx 3.4 \times 10^{-3}\%$	$\approx 3.0 \times 10^{-3}\%$	(7/2 ⁻ )	0.2374	<b>25.0</b> , <b>25.3</b> , <b>29.2</b> , 42.4, 42.6, <b>53.6</b> , <b>63.8</b> , 71.8, <b>74.6</b> , 76.3, 83.0, <b>87.3</b> , <b>89.4</b> , <b>91.0</b> , 96.2, 101.7, 111.9, <b>117.2</b> , <b>119.0</b> , 125.4, 131.2, <b>146.3</b> , 148.2, 165.6, <b>208.2</b>	≈770
4.6734	4.5931	$8.0 \times 10^{-4}\%$	$7.00 \times 10^{-4}\%$	$(5/2^{-},7/2^{-})$	0.2351	<b>29.2, 42.6</b> , 71.8, <b>74.6</b> , 76.3, 86.3, <b>88.7</b> , <b>117.2</b> , 119.0, <b>146.3</b> , 148.2	$3.4 \times 10^{3}$
4.692	4.611***	0.013%	0.0115%	(5/2 ⁻ )	0.2172	<b>29.2</b> , <b>42.6</b> , <b>52.6</b> , <b>68.9</b> , 71.8, 76.3, <b>119.0</b> , <b>135.3</b> , <b>145.3</b> , 148.2, <b>164.5</b> , <b>188.0</b> , <i>217.1</i>	280
4.696	4.615***	$5.7 \times 10^{-4}\%$	$5.00 \times 10^{-4}\%$	$(5/2^+)$	0.2123	25.3, <b>29.2</b> , 42.4, <b>42.6</b> , 53.6, 54.7, 67.9, 71.8, <b>87.3</b> , <b>96.2</b> , <b>212.3</b>	$7.0 \times 10^{3}$
4.707	4.626***	$<4.6\times10^{-3}\%$	$<4 \times 10^{-3}$ ***	11/2-	0.2024		$>1.0 \times 10^{3}$
4.715	4.634***	0.016%	0.0137%	$(11/2^+)$	0.1957	25.3, <b>29.2</b> , 42.4, <b>42.6</b> , <b>53.6</b> , 54.7, 67.9, <b>70.3</b> , 71.8, <b>97.1</b> , <b>123.9</b> , 153.1	340
4.722	4.641***	$3.4 \times 10^{-3}\%$	$3 \times 10^{-3}\%$ ***		0.1870***	25.3, <b>29.2</b> , <b>42.4</b> , <b>42.6</b> , <b>54.7</b> , <b>67.9</b> , 71.8, <b>92.9</b> , <b>97.1</b>	$1.8 \times 10^{3}$
4.7352	4.6539	$8.0  imes 10^{-4}\%$	$7.00 \times 10^{-4}\%$	(9/2 ⁻ )	0.1735	<b>25.3</b> , <b>29.2</b> , 42.4, 42.6, 71.8, 76.3, 101.7, <b>119.0</b> , 131.2, 148.2	$9.5 \times 10^{3}$
4.737	4.656***	$\approx 6 \times 10^{-3}\%$	$\approx 5 \times 10^{-3} \% * * *$		0.171***		$\approx 1.4 \times 10^3$
4.7442	4.6627	$4.8 \times 10^{-3}\%$	$4.2 \times 10^{-3}\%$	$(3/2^{-})$	0.1645	29.2, 135.3, 164.5	$1.8 \times 10^{3}$
4.745	4.664***	0.074%	0.064%***	11/2+	0.1633	<b>25.3</b> , <b>29.2</b> , <b>37.8</b> , <b>42.4</b> , <b>42.6</b> , <b>53.6</b> , <b>54.7</b> , <b><i>66.1</i></b> , 71.8, 83.0, <b>96.2</b> , <b>97.1</b> , 120.8, 125.4	123
4.7606	4.6788	$1.0 \times 10^{-3}\%$	$9.00 \times 10^{-4}\%$	$(7/2^{-})$	0.1482	<b>29.2</b> , 42.6, 71.8, 76.3, <b>119.0</b> , 148.2	$1.1 \times 10^{4}$
4.763	4.681***	$7.5 \times 10^{-3}\%$	$6.50 \times 10^{-3}\%$	$(5/2^{-})$	0.1464	<b>29.2, 42.6</b> , 71.8, 74.6, 117.2, <i>146.3</i>	$1.6 \times 10^{3}$
4.769	4.687***	$3.2 \times 10^{-3}\%$	$2.8 \times 10^{-3}\%$ ***		0.140***	25.3, 29.2, 42.4, 42.6, 43.7, 54.7, 65.6, 67.9, 71.8, 97.1, 120.8	$4.1 \times 10^{3}$
4.783	4.701***	0.12%	0.107%	$(9/2)^+$	0.1254	<b>29.2</b> , 42.4, <b>42.6</b> , <b>53.6</b> , <b>71.8</b> , 83.0, <b>96.2</b> , 125.4	136
4.812	4.729***	1.94%	1.69%	9/2+	0.0971	25.3, 29.2, 42.4, 42.6, 54.7, 67.9, 71.8, 97.1	13.6
4.834	4.751***	0.011%	0.01%***		0.075***	54.7	$3.3 \times 10^{3}$
4.837	4.754***	0.47%	0.41%	$(7/2^+)$	0.0718	29.2, 42.6, 71.8	84
4.841	4.758***	0.018%	0.016%***		0.067***	25.3, 42.4, 67.9	$2.3 \times 10^{3}$
4.867	4.783***	11.49%	10%	7/2+	0.0424	42.4	5.5
4.880	4.796***	0.57%	0.5.%	$(5/2^+)$	0.0292	29.2	135
4.888	4.804***	0.059%	0.051%***		0.0204***		$1.5 \times 10^{3}$
4.9087	4.8244	100.00%	87%	5/2+	0.0		1.22

* [2009Po15].

** Deduced from  $\gamma$  energies [2003Ba78] and  $Q_{\alpha} = 4908.7(12)$  keV [2021Wa16], except where noted. *** Measured  $\alpha$  energies from[1967Ba43].  $I_{\alpha}(abs)$  indicates the transition was not observed in [2000Ga52].

*** Measured  $\alpha$  energies from [150/Da+5].  $r_{\alpha}(\alpha\sigma)$ , measured  $\alpha$ [@] [2008Br17]. [@]  $\alpha$   $\gamma$ 's from [2003Ba78]. The 100% peak decaying from  $E_{daughter}$  (i.e. the state that the  $\alpha$  populated) is marked in **bolditalic**, and peaks 10% or larger of the aforementioned peak are marked in **bold**. [@]  $\alpha$   $\alpha$   $R_0$  (fm) = 1.52555(39) fm

## Table 11 direct $\alpha$ emission from ²³⁷Pu*, $J^{\pi} = 7/2^{-}$ , $T_{1/2} = 45.31(3) d^{**}$ , $BR_{\alpha} = 4.2(4) \times 10^{-3} \%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{233}\mathrm{U}^{***})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
5.186(3)	5.099(3)	≈1.1%	$\approx 2.1 \times 10^{-3}\%$		0.5615(20)	40.4, 51.5, 92.0, 228.6, 241, 280.4, 320.8, 521.1	1.50884(18)	≈17
5.244(2)	5.155(2)	14.7%	0.027%		0.50362(10)	40.4, 51.5, 92.0, 181.8, 205.0, 228.6, 258.5, 280.4, 298.9, 320.8, 411.1, 463.1, 503.9	1.50884(18)	3.1
5.350(2)	5.260(2)	≈1.6%	≈2.9×10 ⁻³ %		0.39755(21)	32.9, 40.4, 43.7, 51.5, 54.8, 63.1, 76.7, 92.0, 114.7, 198.6, 228.6, 258.5, 261.7, 280.4, 298.9, 305.4, 313.3, 320.8	1.50884(18)	≈130
5.394(2)	5.303(2)	28.0%	0.051%		0.35378(12)	32.9, 40.4, 51.5, 54.8, 63.1, 92.0, 114.7, 198.6, 228.6, 258.5, 261.7, 280.4, 298.9, 313.3, 320.8	1.50884(18)	14
5.427(2)	5.335(2)	100%	0.18%	5/2-	0.32077(5)	40.4, 51.5, 92.0, 228.6, 280.4, 320.8	1.50884(18)	5.9
5.449(2)	5.357(2)	39.5%	0.072%	5/2-	0.29882(1)	40.4, 258.5, 298.9	1.50884(18)	20
5.592(2) 5.656(2) 5.707(2) 5.748(2)	5.498(2) 5.560(2) 5.611(2) 5.651(2)	≈16.3% 16.6% 8.3% 4.8%	$\approx 0.030\%$ 0.030% 0.015% $8.8 \times 10^{-3}\%$	(11/2 ⁺ ) 9/2 ⁺ 7/2 ⁺ 5/2 ⁺	0.15523(8) 0.09215(4) 0.04035(1) 0.0	40.4, 51.5, 63.1, 114.7 40.4, 51.5, 92.0 40.4	1.50884(18) 1.50884(18) 1.50884(18) 1.50884(18)	$\approx 330$ 730 $2.8 \times 10^{3}$ $8.0 \times 10^{3}$

* All values from [1979El05], except where noted. ** Weighted average of 45.66(4) d [1994Ta25], and 45.12(3) d [1981Ba15]. *** [2020Si28].

## Table 12

direct $\alpha$ emission from ²⁴¹ Cm*, J ^{$\pi$} = (1/2 ⁺ ), T _{1/2} = 32.8(2) d**, BR _{$\alpha$} = 1.0(1)%*
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{237}\mathrm{Pu}^{***})$	coincident γ-rays (keV)***	R ₀ (fm)	HF
5.783(3)	5.687(3)	0.32(8)%	2.2(5)×10 ⁻³ %	5/2+	0.4042	9.9, 45.7, 55.6, 68.8, 79.1, 123.8, 124.7, 179.9, 203.0, 248.7, 280.2	1.49798(88)	33 ⁺¹¹ -7
5.816(3)	5.719(3)	0.12(6)%	8(4)×10 ⁻⁴ %	3/2+	0.3704	9.9, 214.9, 224.9	1.49798(88)	$140^{+150}_{-50}$
5.882(3)	5.784(3)	$\approx 0.10\%$	$\approx 7 \times 10^{-4}$	9/2+	0.304		1.49798(88)	≈360
5.962(3)	5.863(3)	0.20(8)%	$1.4(5) \times 10^{-3}\%$	$7/2^{+}$	0.2243	9.9, 68.8	1.49798(88)	$480^{+290}_{-130}$
5.984(3)	5.885(3)	17(2)%	0.118(13)%	5/2+	0.2012	9.9, 45.7, 55.6	1.49798(88)	$7.5^{+1.0}_{-0.8}$
6.014(3)	5.914(3)	0.17(7)%	$1.2(5) \times 10^{-3}\%$	$13/2^{-}$	0.175		1.49798(88)	$1.0^{+0.8}_{-0.3} \times 10^3$
6.029(3)	5.929(3)	26.3(27)%	0.0181(19)%	3/2+	0.1555	9.9	1.49798(88)	$8.4^{+1.5}_{-1.1}$
6.039(3)	5.939(3)	100(10)%	0.689(70)%	$1/2^{+}$	0.1455		1.49798(88)	2.5(3)
6.079(3)	5.978(3)	0.41(11)%	$2.8(8) \times 10^{-3}\%$	$112^{-}$	0.106		1.49798(88)	$1.0^{+0.4}_{-0.2} \times 10^3$
6.138(3)	6.036(3)	0.17(6)%	$1.2(4) \times 10^{-3}\%$	9/2-	0.0477	47.7	1.49798(88)	$4.5^{+2.4}_{-1.2} \times 10^{3}$
6.185(3)	6.082(3)	0.22(8)%	$1.5(5) \times 10^{-3}\%$	$7/2^{-}$	0.0		1.49798(88)	$6.2^{+3.4}_{-1.7} \times 10^3$

* All values from [1975Ah05], except where noted. ** [1974Po08].

*** [2006Ba41].

Table 13				
direct $\alpha$ emission from ²	$^{45}Cf^*, J^{\pi} = (1/2)$	$2^+$ ), $T_{1/2} = 46.4(3)$	m, $BR_{\alpha} = 36.0(26)\%$	

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{241}\mathrm{Cm})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
7.101	6.985	0.34%	0.11%	9/2+	0.160		1.497(31)	150
7.140	7.023	0.34%	0.11%	7/2+	0.122		1.497(31)	220
7.182	7.065	0.74%	0.24%	$5/2^{+}$	0.080		1.497(31)	150
7.208 7.261(2)	7.090 7.142(5)**	7.6% 100%	2.5% 33.0%	5/2 ⁺ 1/2 ⁺	0.0561 0.0	50.6, 56.1	1.497(31) 1.497(31)	$\frac{18}{2.2^{2.4}_{1.2}}$

 $\ast$  All values from [1996Ma72], except where noted.

** [2004He28].

direct $\alpha$ emissio	n from ²⁴⁹ Fm*	$, J^{\pi} = (7/2^+)$	$T_{1/2} = 99(6)$	5) s**, $BR_{\alpha}$ =	= 15.6(1)%.
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{245}\mathrm{Cf})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
7.652	7.529	15.6(1)%	(1/2+)	0.047	0.047	1.4867(57)	$0.73^{+12}_{-10}$

* All values from [2012He09], except where noted.

** Weighted average of 96(9) s [2004He28], and 117(15) s [2006Ni09].

## Table 15

direct $\alpha$ emission from ²⁵³ No*, J ^{$\pi$} = (9/2 ⁻ ), T _{1/2} =	$= 1.56(2) \text{ m}, BR_{\alpha} = 55(3)\%^{***}$
---------------------------------------------------------------------------------------------------------------------------	----------------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{249}\mathrm{Fm})$	coincident γ-rays (keV)***	$R_{0}\left(fm\right)$	HF
								9
7.742(15)	7.620(15)**	0.26(6)%**	$0.14(3)\%^{**}$	$(7/2^{-})$	0.6695**	669.5**	1.4730(54)	$22^{+\circ}_{-6}$
8.132(5)	8.003(5)	100(1)%	53(3)%	(9/2-)	0.279	58, 71, 129, 150, 221, 279	1.4730(54)	1.4(2)
8.200(10)	8.070(10)	4.4(6)%	2.3(4)%	$(5/2^{-}+)$	0.211	211	1.4730(54)	$56^{+14}_{-11}$
8.281(20)	8.150(20)		obs	$(11/2^+)$	0.129	58, 71, 129	1.4730(54)	
8.352(20)	8.220(20)		obs	$(9/2^+)$	0.058	58	1.4730(54)	
8.413(20)	8.280(20)		obs	$(7/2^+)$	0.0		1.4730(54)	

* All values from [2006Lo12], except where noted.

** [2012He09].

*** [2011An13].

#### Table 16

direct  $\alpha$  emission from ²⁵⁷Rf*, J^{$\pi$} = (1/2⁺), T_{1/2} = 5.5(4) s, *BR*_{$\alpha$} = 79.3(17)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{253}\text{No})$	coincident γ-rays (keV)	R ₀ (fm)	HF
9 594(15)	9 450(15)				0.510		1 468(22)	
8.637(11)	8.503(11)***				0.450	0.167, 0.283	1.468(22)	
8.823(15)	8.686(15)				0.258	0.091, 0.167	1.468(22)	
8.923(5)	8.784(5)**			$(5/2^+)$	0.167	0.167	1.468(22)	
9.092(15)	8.950(15)			(9/2 ⁻ )	0.0		1.468(22)	

 $\ast$  All values from [2010St14], except where noted.

** Weighted average of 8.778(10) MeV [2010St14] and 8.785(5) MeV [2022Ha04].

*** Weighted average of 8.510(15) MeV [2010St14] and 8.497(15) MeV [2022Ha04].

#### Table 17

Tuble 17		
direct $\alpha$ emission from ²⁵⁷	m Rf*, Ex. = 74(16) keV, J ^{$\pi$} = (11/2 ⁻ ), T _{1/2} = 4.9(7) s**, BR _{$\alpha$} = 81.0(2	25)%

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{253}\text{No})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
8.417(5) 9.107(5) 9.166(5)	8.286(5) 8.965(5) 9.023(5)	3.1(9)% 100(36)% 8.1(27)%	1.8(2)% 58(15)% 4.7(11)%	(9/2-)	0.750 0.063 0.0		1.468(22) 1.468(22) 1.468(22)	$\begin{array}{c} 3.5^{+2.8}_{-1.7} \\ 15^{+13}_{-8} \\ 280^{+240}_{-150} \end{array}$

* All values from [2022Ha04], except where noted.

** [2010St14].

#### Table 18

direct  $\alpha$  emission from ²⁶¹Sg*, J^{$\pi$} = (3/2⁺), T_{1/2} = 184(5) ms, *BR*_{$\alpha$} = 98.1(5)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{257}\mathrm{Rf})$	coincident $\gamma$ -rays	R ₀ (fm)	HF
9.556(10)	9.410(10)	98.1(5)%	(1/2 ⁺ )	0.157	0.107, 0.157	1.459(22)	$1.2^{+0.9}_{-0.5}$

* All values from [2010St14].

direct $\alpha$ emission from ²⁶⁵ H	$s^*, T_{1/2} =$	1.9(2) ms, B	$R_{\alpha} = \approx 100\%$
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{253}\text{No})$	coincident γ-rays (keV)	R ₀ (fm)	HF
10 440(15)	10.282(15)							
10.470(15)	10.312(15)							
10.588(15)	10.428(15)							
10.735(15)	10.573(15)							

* All values from [2009He20], From the text of this reference: " $\alpha$  lines were modified by energy summing with conversion electrons; therefore line intensities could not be deduced unambiguously."

#### Table 20

Table 20			
direct $\alpha$ emission fr	om 265 Hs*, Ex. = unk	$T_{1/2} = 300^{+200}_{-100} \mu$	s, $BR_{\alpha} = \approx 100\%$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{253}\text{No})$	coincident $\gamma$ -rays (keV)	$R_0$ (fm)	HF	
10.700(15)	10.538(15)	$\approx 100\%$				1.483(18)	$0.7\substack{+0.6 \\ -0.4}$	
* All values from [2009He20].								
<b>Table 21</b> direct $\alpha$ emission from ²⁶⁹ Ds*, T _{1/2} = 170 ¹⁶⁰ ₇₀ $\mu$ s, <i>BR</i> _{$\alpha$} = 100%.								
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{217}\text{Po})^{***}$	coincident γ-rays***	R ₀ (fm)	HF	
11.280(20)	11.112(20)	100%		0.0?		1.450(27)	$1.1^{+1.5}_{-1.2}$	

* All values from [1999He07].

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$  = +49/2 nuclei.

Last updated 10/21/2024
Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +49/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

		-					
Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\varepsilon}$	Q _β -	Q _β - α	Experimental
211							
²¹¹ TI*			76.5(178) s	-5.69#	4.420(40)	8.162(50)	[2017Ca12]
²¹⁵ Bi*		$(9/2^{-})$	7.7(2) m	-2.710(50)	2.171(6)	9.877(6)	[1990Ru02]
²¹⁹ At		(9/2-)	56(3) s	-2.285(16)	1.567(2.9)	8.693(4)	[2015Fi07]
²²³ Fr		3/2-	22.00(7) m	-2.007(8)	1.149(0)	7.308(3)	[1993Ab01]
²²⁷ Ac		3/2-	$21.778^{+29}_{-32}$ y	-1.328(2)	0.045(1)	6.382(3)	[1967JoZX]
²³¹ Pa		3/2-	$3.257(13) \times 10^4$ y	-0.392(2)	-0.382(2)		[2020Je01]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
²³⁵ Np		5/2+	396.1(12) d	0.124(1)	-6.585(4)	4.802(2)	[1970La08]
²³⁹ Am		$(5/2^{-})$	11.9(1) h	0.802(2)	-5.353(2)	6.047(2)	[1972Po04]
^{239m} Am	2.5(2)		163(12) ns	3.3(2)	-2.8(2)	8.5(2)	[1972Br35]
²⁴³ Bk		$(3/2^{-})$	4.5(1) h	1.508(5)	-4.067(4)	7.676(5)	[1953Hu60]
²⁴⁷ Es	х	$(7/2^+)$	4.55(26) m	2.469(24)	-2.677(63)	8.972(19)	[1989Ha27]
²⁵¹ Md		$(7/2^{-})$	4.28(12) m	3.008(24)	-1.55(10)#	10.432(24)	[2021Go26]
²⁵⁵ Lr		$(1/2^{-})$	31.1(13) s	3.135(23)	-0.79(10)#	11.564(23)	[2006Ch52]
^{255m} Lr	0.037(10)	$(7/2^{-})$	2.53(5) s	3.172(25)	-0.42(14)#	11.601(25)	[2008An16]
²⁵⁹ Db			510(160) ms	3.620(90)#	-0.08(12)#	12.754(58)#	[2001Ga20]
²⁶³ Bh				4.30(32)#	0.95(34)#	13.70(31)#	-
²⁶⁷ Mt				5.13(51)#	2.40(53)#	15.17(51)#	

* 100%  $\beta^-$  emitter.

** Unclear if this is the ground state.

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +49/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	BR _{cluster}	type	Experimental
211-							
²¹¹ Tl	8.07(21)#	2.14(30)#					
²¹³ Bi	5.477(6)	5.282(42)					
²¹⁹ At	5.250(4)	6.342(5)	93.6(10)%				[ <b>2015Fi07</b> , 1989Bu09, 1953Hy83]
²²³ Fr	5.279(2)	5.561(3)	0.02(1)%				[ <b>2001Li44</b> , 1982AlZL, 1956Pe27, 1955Ad10, 1953Hy83,
207							1950WaZZ]
²²⁷ Ac	5.107(2)	5.042(0)	1.3800(36)%				[1995Sh03, 1986Ry04, 1970Ki12, 1966Ba19, 1959No41,
							1995Ma82, 1981Va28, 1974Mo05, 1972GaZR, 1972HeYM,
				10	0	24	1950WaZZ, 1949Pe03]
²³¹ Pa	4.727(1)	5.150(1)	100%	$\leq 3 \times 10^{-10}\%$	$1.34(17) \times 10^{-9}\%$	²⁴ Ne	2019Ga34, 1992Pr05, 1983Ba77, 1968Ba25, 1961Ba42,
					$1.0^{+4.8}_{-0.7} \times 10^{-12}\%$	23 F	<b>1961Ba42</b> , 2020Je01, 2020Km01, 2009Mo37, 1995Ar33,
							1986BaYK, 1986Tr10, 1985Sa40, 1979Te02, 1974De11,
							1971Le10, 1970De19, 1970Le11, 1969Ba20, 1969La04,
							1969Ro33, 1968Ha22, 1966Ba14, 1960Fo05, 1956Hu96,
							1955Hu37]
²⁵⁵ Np	4.391(1)	5.194(1)	$2.60(13) \times 10^{-3}\%$				[ <b>1986AgZV</b> , <b>1973Br12</b> , 1987Ha07, 1984Wh02, 1970BrZX,
220							1970La08, 1957Th37, 1956Ho46]
²⁵⁹ Am	4.062(2)	5.922(1)	0.010(1)%				[ <b>1971Go01</b> , 1972Po04, 1960Gl01, 1952Hi63]
^{239m} Am	1.5(2)	8.4(2)		obs			[ <b>1972Br35</b> , 1983Ra36, 1971Br39, 1971Fe09, 1970Vi05,
- 242							1969La14]
²⁴³ Bk	3.403(4)	6.874(4)	0.15%				[ <b>1966Ah02, 1953Hu60</b> , 1956Ch77]
²⁴ /Es	2.801(19)#	7.464(20)	obs				[ <b>1989Ha27</b> , 1989HaZG, 1986HaZM, 1985MaZK, 1973Es01,
251							1967Mi06]
251 Md	2.394(20)	7.963(4)	10(1)%				[2006Ch52, 2021Go26, 2006An13, 2005ChZQ, 2005He27,
							2005He27, 1973Es01, 1971EsZZ, 1971EsZY]
²⁵⁵ Lr	2.065(20)	8.556(7)	99.7(5)%				[2008An16, 2008Ha31, 2006Ch52, 2006An13, 2005ChZQ,
							2004HeZZ, 2002Gu33, 2001Ga20, 1976BeYM, 1976BeZY,
255							1971Es01]
^{255m} Lr	2.028(22)	8.593(12)	$\approx 40\%$				[2008Ha31, 2006Ch52, 2008An16, 2005ChZQ, 2004HeZZ]
²⁵⁹ Db	1.642(59)#	9.619(54)	$\approx 100\%$				[ <b>2001Ga20</b> , 2002Gu33]
²⁶³ Bh	1.16(31)#	10.08(30)#					
²⁶⁷ Mt	0.64(50)#	10.87(40)					

# Table 3 direct $\alpha$ emission from ²¹⁹At*, $J^{\pi} = (9/2^{-})$ , $T_{1/2} = 56(3)$ s, $BR_{\alpha} = 93.6(10)\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	<i>E</i> _{daughter} ( ²¹⁵ Bi)	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
6.343(5)	6.228(5)	93.6(10)%	(9/2 ⁻ )	0.0		1.54668(15)	1.33(10)

* All values from [2015Fi07].

Table 4

direct  $\alpha$  emission from ²²³Fr*,  $J^{\pi} = 3/2^{-}$ ,  $T_{1/2} = 22.00(7)$  m**,  $BR_{\alpha} = 0.02(1)\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{219}\text{At})$	coincident γ-rays (keV)	R ₀ (fm)	HF
5.266(5)	5.172(5)	$\approx 14\%$	$\approx 1 \times 10^{-3}\%$	$(3/2^{-})$	0.296	0.1453, 0.1509	1.54540(11)	≈2.7
5.388(4)	5.291(4)	100(66)%	$7(3) \times 10^{-3}\%$	$(3/2^{-})$	$\approx 0.174$	150.9	1.54540(11)	$1.7^{+3.4}_{-0.7}$
5.411(4)	5.314(4)	86(55)%	$6(3) \times 10^{-3}\%$	$(5/2^{-})$	0.1509	0.1509	1.54540(11)	$3^{+7}_{-1}$
5.502(3)	5.403(3)	71(46)%	$5(2) \times 10^{-3}\%$	$(7/2^{-})$	0.0589	0.0589	1.54540(11)	$10^{+18}_{-4}$
5.562(3)	5.462(3)	57(29)%	$4(2) \times 10^{-3}\%$	(9/2-)	0.0		1.54540(11)	$30_{-10}^{+70}$

* All values from [2001Li44], except where noted. ** [1993Ab01].

Table 5		
direct $\alpha$ emission from ²²⁷ Ac, $J^{\pi} = 3/2^{-}$ , T ₁	$_{/2} = 21.778^{+29}_{-32} \text{ y*}, BR_{\alpha}$	= 1.3800(36)%**

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi@}$	$E_{daughter}(^{223}\mathrm{Fr})^{@}$	coincident γ-rays (keV) [@]	R ₀ (fm)	HF
4.441(7)	4.363(7)	$\approx 6 \times 10^{-3} \%^{@@}$	$\approx 4.1 \times 10^{-5}\%$	7/2-	0.601@@		1.53667(29)	≈7.8
4.502(5)	4.423(5)	0.021%	$.4 \times 10^{-4}\%$	(5/2-)	0.5407	44.7, 55.0, 86.7, 69.3, 88.1, 82.2, 99.6, 101.0, 106.8, 176.1 351.7, 441.0	1.53667(29)	6.6
4.525(4)	4.445(4)	0.11%	$6.9 \times 10^{-4}\%$	3/2-	0.5152	44.7, 55.0, 86.7, 99.6, 415.6, 460.2	1.53667(29)	2.1
4.539(7)	4.459(7)	0.011%	$6.9 \times 10^{-5}\%$		0.503		1.53667(29)	25
4.593(5)	4.512(5)	$\approx 6 \times 10^{-3} \%^{@@}$	$\approx 4.1 \times 10^{-5}\%$		0.449@@		1.53667(29)	$\approx 110$
4.663(7)	4.581(7)	$\approx 6 \times 10^{-3} \%^{@@}$	$\approx 4.1 \times 10^{-5}\%$		0.379@@		1.53667(29)	≈330
4.671(4)	4.589(4)	$0.021\%^{@@}$	$1.4 \times 10^{-4}\%$		0.371@@		1.53667(29)	112
4.676(4)	4.594(4)	0.064%	4.1×10 ⁻⁴ %	(9/2+)	0.3655	33.5, 35.0, 44.7, 53.7, 55.0, 69.3, 70.6, 72.5, 79.5, 86.7, 88.1, 82.2, 90.0, 99.6, 101.0, 106.8, 108.0, 118.7, 121.6, 121.8, 134.5, 137.4, 142.6, 143.0, 147.6, 172.0, 176.1, 176.5, 206.8, 229.7, 242.5, 283.4	1.53667(29)	41
4.744 [@]	4.660 [@]	0.043%	$2.8 \times 10^{-4}\%$	(9/2-)	0.2988	69.3, 82.2, 216.6	1.53667(29)	180
4.797 [@]	4.712 [@]	0.085%	5.5×10 ⁻⁴ %	(9/2+)	0.2448	44.7, 55.0, 69.3, 72.5, 72.8, 82.2, 86.7, 90.0, 99.6, 147.6, 162.6, 172.0	1.53667(29)	210
4.799 [@]	4.714 [@]	0.15%	$9.7 \times 10^{-4}\%$	$(7/2^{-})$	0.2437	69.3, 82.2, 161.4, 230.9, 243.8	1.53667(29)	121
4.800(4)	4.715(4)	0.43%	2.8×10 ⁻³ %	(7/2 ⁻ )	0.2426	33.5, 35.0, 44.7, 53.7, 55.0, 69.3, 70.6, 72.5, 79.5, 86.7, 88.1, 82.2, 90.0, 99.6, 101.0, 106.8, 108.0, 121.6, 134.5, 143.0, 147.6, 172.0, 176.1, 229.7, 242.5	1.53667(29)	43
4.819@	4.734 [@]	0.064%	$4.1 \times 10^{-4}\%$	$(7/2^+)$	0.223	69.3, 82.2, 140.9	1.53667(29)	390
4.823(4)	4.738(4)	0.13%	8.3×10 ⁻⁴ %	7/2+	0.2196	69.3, 88.1, 82.2,101.0, 118.7, 137.4, 206.8	1.53667(29)	210
4.854(3)	4.768(3)	2.3%	0.015%	7/2-	0.189	69.3, 88.1, 82.2, 101.0, 106.8, 176.1	1.53667(29)	1.1
4.856@	4.770 [@]	0.64%	$4.1 \times 10^{-3}\%$		0.1872	69.3, 82.2, 105.0, 174.3	1.53667(29)	67
4.871(4)	4.785(4)	0.17%	$1.1 \times 10^{-3}\%$	5/2+	0.172	44.7, 55.0, 69.3, 72.5, 82.2, 86.7, 90.0, 99.6, 147.6, 172.0	1.53667(29)	320
4.882(3)	4.796(3)	1.72%	0.011%	3/2+	0.1605	44.7, 55.0, 59.4, 60.6, 86.7, 88.1, 99.6, 101.0, 147.6, 160.5	1.53667(29)	37
4.908(4)	4.822(4)	0.15%	$9.7 \times 10^{-4}\%$	3/2+	0.1345	33.5, 35.0, 44.7, 55.0, 79.5, 86.7, 88.1, 99.6, 101.0, 121.6, 134.5	1.53667(29)	640
4.941 [@]	4.854 [@]	1.5%	$9.7 \times 10^{-3}\%$	$5/2^{-}$	0.101	88.1, 101.0	1.53667(29)	106
4.942(2)	4.855(2)	6.4%	0.04.1%	3/2-	0.0996	44.7, 55.0, 86.7, 99.6	1.53667(29)	25
4.960(2)	4.873(2)	13%	0.08.4%	$7/2^{-}$	0.0822	69.3, 82.2	1.53667(29)	16
4.988 [@]	4.900 [@]	0.23%	$1.5 \times 10^{-3}\%$	$1/2^{-}$	0.055	55.0	1.53667(29)	$1.3 \times 10^{3}$
5.0293(8)	4.9407(8)	85%	0.55%	5/2-	0.0129		1.53667(29)	6.8
5.04211(14)	4.95326(14)	100%	0.65%	$3/2^{-}$	0.0		1.53667(29)	6.9

* [1967JoZX]. ** [1970Ki12]. *** [1966Ba19], except where noted. [@] [1995Sh03], except where noted. [@] [1959No41].

direct $\alpha$ emission from ²³¹ Pa, $J^{\pi} = 3/2^{-}$ , $T_{1/2}$	$= 3.257(13) \times 10^4 \text{ y*}, BR_{\alpha} =$	100%
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@@}$	$E_{daughter}$ ^{@@} ( ²²⁷ Ac)	coincident $\gamma$ -rays (keV) ^{@@}	R ₀ (fm)	HF
4.493	4.4156***	0.0052(8)%	0.0013(2)%	(7/2 ⁺ )	0.6564(4)	16.5, 25.5, 27.4, 30.0, 35.8, 38.2, 40.2, 44.1, 54.6, 57.2, 63.6, 546.5, 546.5, 571.6, 583, 609	1.53103(70)	$64^{+12}_{-9}$
4.5878(30)	4.5084(30)	0.012(1)%	0.0030(3)%	(3/2 ⁺ ,5/2)	0.5628(1)	16.5, 27.4, 30.0, 38.2, 40.2, 44.1, 54.6, 57.2, 478.4, 486.8, 516.2, 535.6	1.53103(70)	$141^{+17}_{-14}$
4.6474(30)	4.5669(30)	0.075(4)%	0.0189(11)%	(3/2-,5/2-)	0.5013(1)	16.5, 24.5, 27.4, 30.0, 38.2, 44.1, 54.6, 57.2, 146.9, 198.9, 226.6, 228.0, 243.1, 245.6, 246.0, 255.8, 273.2, 283.7, 300.1, 302.7, 327.1, 330.1, 354.5, 427.0, 471.3, 501.4	1.53103(70)	63(4)
4.6807(30))	4.5996(30)	0.10(1)%	0.0258(30)%	9/2+	0.4693(1)	16.5, 25.5, 27.4, 30.0, 35.8, 38.2, 40.2, 44.1, 54.6, 57.2, 63.6, 359.3, 384.7	1.53103(70)	$79^{+11}_{-9}$
4.7139(30) 4.7256(25)	4.6323(30) 4.6438(25)	0.58(2)% 0.53(1)%	0.145(4)% 0.1335(13)%	1/2 ⁺ 5/2 ⁺	0.4352 0.4256	16.5, 30.0, 390.4, 407.8, 435.2 16.5, 27.4, 30.0, 38.2, 40.2, 44.1, 54.6, 57.2 341.1, 351.5, 379.4, 395.5, 398.1	1.53103(70) 1.53103(70)	24.6(8) 31.2(6)
4.7636(24)	4.6811(24)	6.27(3)%	1.572(4)%	7/2-	0.3872	16.5, 25.5, 27.4, 30.0, 35.8, 38.2, 40.2, 44.1, 54.6, 57.2, 63.6, 96.8, 198.9, 226.6, 243.1, 245.6, 246.0, 255.8, 260.2, 273.2, 277.2, 283.7, 300.1, 302.7, 312.9, 330.1, 340.7, 357.1, 387.0	1.53103(70)	4.94(9)
4.7964(24)	4.7133(24)	4.15(7)%	1.041(18)%	1/2-	0.3545	16.5, 24.5, 27.4, 30.0, 38.2, 40.2, 44.1, 54.6, 57.2, 198.9, 226.6, 243.1, 245.6, 246.0, 255.8, 273.2, 283.7, 300.1, 302.7, 327.1, 330.1, 354.5	1.53103(70)	12.6(3)
4.8195(8)	4.7360(8) [@]	34.37(13)%	8.613(10)%	3/2-	0.3304	16.5, 27.4, 30.0, 38.2, 40.2, 44.1, 54.6, 57.2, 198.9, 226.6, 243.1, 245.6, 246.0, 255.8, 273.2, 283.7, 300.1, 302.7, 330.1	1.53103(70)	2.23(4)
4.8451	4.7612***	0.20(9)%	0.051(22)%	(5/2 ⁺ )	0.3047(1)	16.5, 27.4, 30.0, 38.2, 40.2, 44.1, 54.6, 57.2, 219.9, 230.0, 258.4, 277.4	1.53103(70)	$600^{+400}_{-200}$
4.8798(22)	4.7953(22)	6.00(9)%	1.503(22)%	(5/2)-	0.2732	16.5, 27.4, 30.0, 40.2, 44.1, 198.9, 226.6, 243.1, 246.0, 273.2	1.53103(70)	31.3(7)
4.9385(21)	4.8530(21)	5.6(6)%	1.40(15)%	13/2+	0.2108(1)	16.5, 25.5, 27.4, 30.0, 35.8, 38.2, 40 2, 44 1, 54 6, 57 2, 63 6, 100 9	1.53103(70)	$88^{+11}_{-9}$
4.9870(21)	4.9006(21)	13.09(9)%	3.281(18)%		0.160(2)		1.53103(70)	80.7(14)
5.0212(21)	4.9343(21)	11.6(12)%	2.9(3)%	9/2-	0.1268	30.0, 40.2, 44.1, 52.7, 96.8	1.53103(70)	$150^{+18}_{-15}$
5.0385(14)	4.9513(14)@	89.1(3)%	22.32(2)%	9/2+	0.1100	16.5, 25.5, 27.4, 30.0, 35.8, 38.2, 40.2, 44.1, 54.6, 57.2, 63.6	1.53103(70)	25.0(4)
5.0628(20)	4.9751(20)	2.19(10)%	0.550(25)%	7/2+	0.0845	27.4, 30.0, 38.2, 54.6, 57.2	1.53103(70)	$1.47(7) \times 10^3$
5.0737(10)	4.9858(10)	6.87(7)%	1.721(16)%	7/2-	0.0741	30.0, 40.2, 44.1	1.53103(70)	548(11)
5.1021(14)	5.0138(14)@	100.0(4)%	25.06(9)%	5/2+	0.0464	16.5, 30.0	1.53103(70)	56.3(10)
5.1170(10)	5.0284(10)@	92.1(4)%	23.09(6)%	5/2-	0.0300	30.0	1.53103(70)	77.4(13)
5.1186(14)	5.0300(14)@	11.2(12)%	2.8(3)%	3/2+	0.0274	27.4	1.53103(70)	$660^{+80}_{-70}$
5.1477(15)	5.0586(15)@	43.24(18)%	10.837(25)%	3/2-	0.0	—	1.53103(70)	254(7)

* [2020Je01].
** Values from [1961Ba42], except where noted. Values are adjusted by [1991Ry01] to match newer calibration energies.
*** [2019Ga34].
@ Recommended values from [1991Ry01].
@@ [2016Ko07].

# **Table 7** direct $\alpha$ emission from ²³⁵Np*, $J^{\pi} = 5/2^+$ , $T_{1/2} = 396.1(12) \text{ d**}$ , $BR_{\alpha} = 2.60(13) \times 10^{-3} \%^{***}$ .

					221			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{231}\mathrm{Pa})$	coincident $\gamma$ -rays (keV) [@]	$R_0$ (fm)	HF
			6					
4.892(7)	4.809(7)	$\approx 0.2\%$	$\approx 2.6 \times 10^{-6}\%$	$(9/2^+)$	0.304		1.51623(36)	$\approx$ 53
4.946(3)	4.862(3)	1.3(3)%	$1.8(3) \times 10^{-5}\%$	$7/2^{+}$	0.250		1.51623(36)	$17.6^{+3.2}_{-2.4}$
5.010(2)	4.925(2)	22(3)%	$3.0(2) \times 10^{-4}\%$	5/2+	0.1834	58.5, 61.2, 102.2, 125, 185	1.51623(36)	2.9(2)
5.026(6)	4.940(6)	$\approx 1.1\%$	$\approx 1.6 \times 10^{-5}\%$	$(11/2^{-})$	0.1693	58.5, 110.8	1.51623(36)	pprox 70
5.084(4)	4.997(4)	11(4)%	1.6(3)×10 ⁻⁴ %	9/2+	0.113		1.51623(36)	$17^{+9}_{-4}$
5.094(4)	5.007(4)	45(13)%	$6.2(16) \times 10^{-4}\%$	7/2+	0.103		1.51623(36)	$4.8^{+1.7}_{-1.0}$
5.112(2)	5.025(2)	100(15)%	$1.4)2) \times 10^{-3}\%$	$5/2^{+}$	0.0842	84.2	1.51623(36)	$2.9_{-0.4}^{+0.6}$
5.138(2)	5.051(2)	3.4(8)%	4.7(8)×10 ⁻⁵ %	7/2-	0.0585	58.5	1.51623(36)	$124_{-19}^{+27}$
5.188(3)	5.100(3)	$\approx 0.4\%$	pprox5 $ imes$ 10 ⁻⁶ %	$1/2^{-}$	0.008		1.51623(36)	$\approx 2.3 \times 10^3$
5.196(4)	5.108(4)	2.8(6)%	$3.9(5) \times 10^{-5}\%$	3/2-	0.0		1.51623(36)	$350^{+60}_{-50}$

* All values from [1973Br12], except where noted.

** 1970La08

*** [1986AgZV].

# Table 8

direct  $\alpha$  emission from ²³⁹Am*,  $J^{\pi} = (5/2^{-})$ ,  $T_{1/2} = 11.9(1)$  h**,  $BR_{\alpha} = 0.010(1)\%$ **.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{235}\text{Np})$	coincident $\gamma$ -rays (keV)	$R_0$ (fm)	HF
5.777(2) 5.832(2) 5.874(2) 5.924(4)	5.680(2) 5.734(2) 5.776(2) 5.825(4)	2.37(4)% 16.43(11)% 100.0(5)% 0.39(2)%	$\begin{array}{c} 1.98(20) \times 10^{-4}\% \\ 1.38(14) \times 10^{-3}\% \\ 8.37(84) \times 10^{-3}\% \\ 3.30(39) \times 10^{-5}\% \end{array}$	(9/2 ⁻ ) (7/2 ⁻ ) (5/2 ⁻ ) (5/2 ⁺ )	0.1468(7) 0.0916(3) 0.0490(1) 0.0		1.50108(92) 1.50108(92) 1.50108(92) 1.50108(92)	$16(2) \\ 4.7^{+0.5}_{-0.5} \\ 1.30^{+0.17}_{-0.15} \\ 600^{+90}_{-70}$

* All values from [1971Go01], except where noted.

** [1972Po04].

#### Table 9

direct  $\alpha$  emission from ²⁴³Bk*,  $J^{\pi} = (5/2^{-})$ ,  $T_{1/2} = 4.5(1)$  h**,  $BR_{\alpha} = 0.15\%$ **.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi***}$	$E_{daughter}(^{239}\text{Am})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
6.289(4)	6.185(4)	15(2)%	$\approx$ 5.9 $\times$ 10 ⁻³	$(5/2^{-})$	0.587(6)		1.500(30)	11
6.317(4)	6.213(4)	53.13%4.84%	$\approx 0.020$	$(3/2^{-})$	0.558(6)		1.500(30)	4
≈6.504	≈6.397	$\approx 0.78\%$	$\approx 3 \times 10^{-4}$	$(13/2^+)$	≈0.370		1.500(30)	$\approx 2.3 \times 10^3$
6.557(5)	6.449(5)	2.73%0.80%	$\approx 1.1 \times 10^{-3}$	$(11/2^+)$	0.317(6)		1.500(30)	$21.2 \times 10^{3}$
6.614(4)	6.505(4)	26.95%3.21%	≈0.010	$(9/2^+)$	0.260(6)		1.500(30)	210
6.655(4)	6.545(4)	75.78%6.94%	$\approx 0.029$	$(7/2^+)$	0.220(6)		1.500(30)	110
6.687(4)	6.577(4)	100.00%8.84%	$\approx 0.038$	$(5/2^+)$	0.187(6)	146.4, 187.1	1.500(30)	120
6.719(5)	6.608(5)	≈2.73%	$\approx 1.1 \times 10^{-3}$	$(11/2^{-})$	0.156(6)		1.500(30)	$\approx 6 \times 10^3$
6.781(4)	6.669(4)	$\approx 4.69\%$	$\approx 1.8 \times 10^{-3}$	$(9/2^{-})$	0.094(6)		1.500(30)	$\approx 7 \times 10^3$
6.833(4)	6.721(4)	48.83%4.66%	$\approx 0.019$	$(7/2^{-})$	0.041(6)		1.500(30)	$1.1 \times 10^{3}$
6.874(4)	6.761(4)	60.16%5.42%	≈0.023	$(5/2^{-})$	0.0		1.500(30)	$1.3 \times 10^{3}$

* All values from [1966Ah02], except where noted.  $E_{\alpha}$ (lab) is adjusted by +3.0 keV by [1991Ry01].

** [1953Hu60].

*** [2014Br18].

# **Table 10** direct $\alpha$ emission from ²⁴⁷Es*, T_{1/2} = 4.55(26) m, *BR*_{$\alpha$} = obs.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{243}\mathrm{Bk})$	coincident $\gamma$ -rays (keV)
7 332(5)	7 213(5)	2 3(8)%				

7.395(3)	7.275(3)	14(2)%
7.444(1)	7.323(1)	100(7)%

* All values from [1989Ha27].

 $R_0$  (fm)

HF

Table 11		
direct $\alpha$ emission from ²⁵¹ Md, $J^{\pi}$	$=(7/2^{-}), T_{1/2} = 4.28(12) \text{ m}^{**}$	$BR_{\alpha} = 10(1)\%$ .

					*					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{247}\mathrm{E}$	s)	coincident $\gamma$	rays (keV)	$R_0$ (fm)	HF	
7.672(1)	7.550(1)	10(1)%		0.293+x		243, 293		1.4788(62)	$74^{+16}_{-14}$	
* All val ** [2021	ues from [20060 Go26].	Ch52], except wh	nere noted.							
$\frac{\text{Table 12}}{\text{direct } \alpha \text{ emis}}$	sion from ²⁵⁵ Lr [,]	*, $J^{\pi} = (1/2^{-}), T$	$f_{1/2} = 31.1(13) \text{ s}^3$	**, $BR_{\alpha} = 99.7($	(5)%**.					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	Edaughter	( ²⁵¹ Md)	coincident $\gamma$ -rays	(keV)	R ₀ (fm)	HF
8.422(5) 8.498(2) 8.554(10)	8.290(5) 8.365(2) 8.420(10)	1.8(6)% 100(3)% 5.4(8)%	0.7(2)% 37.3(8)% 2.0(3)%	(11/2 ⁻ ) 1/2 ⁻ (7/2 ⁻ )	0.135 0.055 0.0				1.467(15) 1.467(15) 1.467(15)	$50^{+40}_{-20}\\1.7^{+0.8}_{-0.5}\\48^{+23}_{-17}$
* All val ** [1200 Table 13	ues from [20060 8Ha31].	Ch52], except wh	here noted.							
direct $\alpha$ emis	sion from ^{255m} L	r*, Ex. = 37(10)	keV, $J^{\pi} = (1/2^{-1})^{-1}$	), $T_{1/2} = 2.53(5$	5) s**, <i>BR</i>	$\alpha = \approx 40\%.$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	Edaugh	ter ⁽²⁵¹ Md)	coincident γ-ra	ys (keV)	$R_0$ (fm)	HF
8.455(10) 8.592(2)	8.322(10) 8.457(2)	8.1(19)% 100(3)%	$\approx 7.5(18)\%$ $\approx 92(3)\%$	(11/2 ⁻ ) (7/2 ⁻ )	0.135 0.0				1.467(15) 1.467(15)	$\approx 3.2$ $\approx 0.7$
* All val ** [2008	ues from [20060 An16].	Ch52], except wh	here noted.							
Table 14direct $\alpha$ emis	sion from ²⁵⁹ Db	$T_{1/2} = 510(160)$	)) ms, $BR_{\alpha} = \approx$	100%.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{255}I$	Lr)	coincident	γ-rays (keV)	R ₀ (fm)	HF	
9.623	9.474	$\approx 100\%$		0.0?				1.463(13)	$11^{+6}_{-5}$	

* All values from [2001Ga20].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +25 nuclei.

Last updated 11/18/24

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +25$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values for XX are taken from ENSDF.

		_					
Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	Q _β -	Q _β - α	Experimental
206-							
²⁰⁶ Pt*		$0^+$	obs		4.950(42)#	5.16(42)#	[2012Ku26]
²¹⁰ Hg*		$0^{+}$	63.7(116) s	-7.98(45)#	3.95(20)#	6.65(36)#	[2017Ca12]
²¹⁴ Pb(RaB)*		$0^+$	27.06(7) m	-6.65(20)#	1.018(11)	6.809(23)	[2011Vo01]
²¹⁸ Po(RaA)		$0^+$	3.062(8) m**	-4.859(27)	0.256(12)	7.313(11)	[1989Ma67, 1986Po17, 1982Va09]
²²² Rn		$0^+$	3.82146(16) d	-4.581(16)	-0.006(8)		[2015Be07]
²²⁶ Ra		$0^+$	1600(5) y***	-3.853(7)	-0.642(3)		[1966Ra13, 1959Ma12]
²³⁰ Th(Io)		$0^+$	75584(110) y	-2.976(16)	-1.311(3)		[2013Ch53]
$^{234}U(U_{II})$		$0^+$	245526(260) y@	-2.194(4)	-1.810(8)		[2013Ch53, 2016Va13]
²³⁸ Pu		$0^+$	87.71(3) y	-1.291(1)	-2.260(20)		[1977Di04]
^{238m1} Pu	2.40(20)		0.60(14) ns ^{@@}	1.11(20)	-0.14(20)	-4.12(20)	[1974MeYP, 1973Li01]
^{238m2} Pu	3.70(20)		5.9(12) ns ^{@@@}	2.41(20)	1.44(20)	-2.82(20)	[1973Li01, 1970Bu02]
²⁴² Cm		$0^+$	162.80(11) d ^a	-0.664(1)	-2.95(14)#		[1982Ag02, 1981Us03]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
²⁴⁶ Cf		$0^+$	35.7(5) h	0.120(60)	-4.203(1)	6.197(2)	[1951Hu39]
^{246m} Cf	$\approx 2.5$	$0^{+}$	45(10) ns	$\approx 2.6$	$\approx$ -1.8	pprox 8.7	[1968Ga04, 1966Ga26]
²⁵⁰ Fm		$0^{+}$	30.4(15) m	0.85(10)#	-2.940(8)	7.680(61)#	[2006Ba09]
^{250m} Fm	х		1.8(1) s	0.85(10)#+x	-2.940(8)+x	7.680(61)#+x	
²⁵⁴ No		$0^{+}$	51.2(4) s	1.27(10)#	-1.911(10)	9.07(10)#	[2006He19]
^{254m} No	1.295(2)	8-	275(7) ms	2.57(10)#	-0.616(10)	10.37(10)#	[2010He10]
²⁵⁸ Rf		$0^{+}$	11.5(12) ms ^b	1.56(10)#	-1.192(17)	10.47(10)#	[2020Mo11, 2008Ga08]
²⁶² Sg		$0^+$	$6.9^{+3.8}_{-1.8}$ ms	2.12(15)#	-0.238(69)	11.16(10)#	[2001Ho06]
²⁶⁶ Hs		$0^{+}$	$2.97^{+0.78}_{-0.51}$ ms	3.04(17)#	1.06(14)#	12.46(15)#	[2012Ac04]
^{266m} Hs	≈1.2		$74^{+354}_{24}$ ms	≈4.2#	≈2.3#	12.46(15)#	[2015Ac04, 2012Ac04]
²⁷⁰ Ds		$0^+$	$200^{+70}$ µs	3.97(20)#	2.90(14)#	14.15(17)#	[2012Ac04]
^{270m} Ds	≈1.13	910-	$3.9^{+1.3}$ ms	≈5.10#	≈4.03#	≈15.28#	[2015Ac04, 2012Ac04]
20			-0.8				

* 100%  $\beta^-$  emitter.

** Weighted average of 3.040(8) m [1989Ma67], 3.093(12) m [1986Po17] and 3.11(2) m [1982Va09].

*** Weighted average of 1599(7) y [1966Ra13] and 1602(8) y [1959Ma12].

[@] Weighted average of 245620(260) y [2013Ch53] and 244900(670) [2016Va13]. [@] Weighted average of 0.7(2) ns [1974MeYP] and 0.5(2) ns [1973Li01].

^{@@@} Weighted average of 5(2) ns [1973Li01] and 6.5(15) ns [1970Bu02].

^a Weighted average of 163.00(11) d [1982Ag02] and 161.35(30) d [1981Us03].

^b Weighted average of 8.8(11) ms [2020Mo11] and  $4.7^{+1.2}_{-1.0}$  ms [2008Ga08].

#### Table 2

(1 of 2). Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +25$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	BR _{cluster}	type	Experimental
206 <b>D</b> t	10.03(58)#	0.87(50)#					
210	10.95(50)#	1.52(36)#					
214ph (D-D)	10.50(45)#	1.32(30)#					
218 PD(RaB)	9.256(27)	2.69(20)#					
218 Po(RaA)	7.662(18)	6.115	99.978(3)%				[1971Gr17, 1958Wa16, 1952Hi60, 2023Ch30, 1989Ma67,
							1986Po17, 1982Va09, 1949Wa05, 1944Ka01, 1943Ka04,
							1933Ro03, 1911Ru02, 1904Ru05]
²²² Rn	7.700(14)	5.590	100%				[1971Gr17, 1958Wa16, 1998Mo14, 1996Wi27, 1989Po03,
							1987Er06, 1968Bi08, 1963Ba62, 1956Ma28, 1953Ba29,
							1936Br05]
²²⁶ Ra	7.442(12)	4.871	100%		2.6(6)×10 ⁻⁹ %	¹⁴ C	2017Ma22, 1990We01, 1986Ba26, 1985Ho21, 1971Lo19,
							1963Ba62, 2001La14, 1986HoZU, 1985Al28, 1984AlZP,
							1971DiZI, 1971Gr17, 1969Gr33, 1968Bi08, 1967Ma51,
							1966Ra13, 1959Ma12, 1958Wa16, 1953AsZZ, 1953Ba29,
							1949Ko01, 1931Cu01, 1949Ro08, 1912Fa01, 1911Cu01]

(20f 2). Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +25$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	BR _{cluster}	type	Experimental
²³⁰ Th(Io)	7.116(12)	4.770(2)	100%		5.6×10 ⁻¹¹ %	²⁴ Ne	[ <b>1985TrZY</b> , <b>1966Ba14</b> , <b>1954Ro12</b> , 2013Ch53, 2000Ch56] 1980Me10, 1977Ku25, 1962At01, 1957Cl17, 1956Hu96, 1955St97, 1953Ra13, 1953Va01, 1949Hy03, 1948RoXX, 1931So01, 1930Cu02, 1912Fa01]
²³⁴ U(U _{II} )	6.633(1)	4.858(1)	100%	1.64(17)×10 ⁻⁹ %	9.06(660)×10 ⁻¹² 1.64(17)×10 ⁻¹¹	²⁴ Ne ²⁸ Mg	[2000Ho27, 1991Bo20, 1984Va41, 1967Ba43, 1963Bj03, 2016Va13, 2013Ch53, 1989Ho24, 1989Mo07, 1989Tr11, 1987Sh27, 1986LoZT, 1981Vo02, 1980Ge13, 1980VaZP, 1978ReZX, 1973JaYS, 1973Ta25, 1971Cl03, 1971DeYN, 1971LoZL, 1970Cl11, 1970DeZM, 1970LoZZ, 1970MeZN, 1961Ko11, 1957Ha08, 1955Go57, 1953As40, 1953AsZZ, 1953Va03, 1952Fl20, 1952Gh27, 1952Ki19, 1952Se67, 1949Ba41, 1949Go18, 1940Fl02, 1939Ni03]
²³⁸ Pu ^{238m1} Pu	5.997	5.593	100%	1.86(10)×10 ⁻⁷ % ≈100%	$\approx 5.5 \times 10^{-15} \%$ $\approx 1.5 \times 10^{-14} \%$	³⁰ Mg ³² Si	<b>1999Ka70, 1998Ya17, 1989Wa10, 1984Bo41, 1971Gr17,</b> <b>1970Ba72</b> , 1996Sa24, 1992Sc15, 1989Wa29, 1988SeZY, 1986LoZT, 1984Ah06, 1984He19, 1984Ov01, 1983OvZZ, 1981Ag06, 1980VaZO, 1977Di04, 1976JaZG, 1976Po08, 1972Ha11, 1971Ma68, 1971So15, 1970Cl11, 1969LeZX, 1968Ba25, 1968Jo15, 1963Ei09, 1962Le11, 1961Dr04, 1957Ho71, 1957Ko33, 1956Hi33, 1954As07, 1953AsZZ, 1949JaZX, 1949JaZZ, 1947Ch01, 1946FaZZ, 1943ChZZ] <b>[1973Li01</b> , 1974MeYP]
^{238m2} Pu	2.30(20)	9.29(20)		$\approx 100\%$			[ <b>1973Li01</b> , 1971Br39, 1970Bu02]
²⁴² Cm	5.420	6.216	100%	6.07(4)×10 ⁻⁶ %*	$1.0^{+0.4}_{-0.2} \times 10^{-14}$	³⁴ Si	[2000Og01, 1989Us04, 1982Ra33, 1981Le15, 1979Ch41, 1971Gr17,1967Ar09, 1966Ba07, 1951Ha87, 1998Ya17, 1989Fo10, 1984Zh01, 1982Ag02, 1982UmZZ, 1981Us03, 1981Zh06, 1980Ha28, 1977Di04, 1975Ke02, 1971Bb10, 1971Re11, 1970BaZZ, 1963Bj03, 1963Dz07, 1963Le17, 1962Iv01, 1956Cr69, 1954G137, 1954St95, 1953As14, 1953AsZZ, 1952As40, 1950Ha14, 1949MaZZ]
²⁴⁶ Cf	5.013(2)	6.862(1)	100%	3.0(3)×10 ⁻⁴ %**			[ <b>1977Ba69, 1968Sk01, 1963Fr04, 1956Ch77, 1953Hu85</b> , 1973Da16, 1968Ga02, 1968Ga04, 1966Ma72, 1955Hu31, 1951Hu39]
^{246m} Cf ²⁵⁰ Fm	≈2.5 4.392(31)#	≈9.3 7.557(8)	≈75%***	$\approx 100\%$ 6.9(10)×10 ⁻³ %			[ <b>1968Ga04</b> , 1966Ga26] [ <b>2006Fo02, 1989La07, 1981Mu06</b> , 2018Mi11, 2006Ba09, 2006Ni09, 1970Dr05, 1966Ak01, 1957Am47, 1954At35]
^{250m} Fm	4.392(31)#-x	7.557(8)+x		obs			[1980Ga07,1970Dr05]
²⁵⁴ No	3.738(33)#	8.226(8)	90(4)%	0.17(2)%			[ <b>2010He10</b> , <b>1994Wi17</b> , <b>1988Tu07</b> , <b>1985He22</b> , 2020Ku23, 2009Ne02, 2008Ga08, 2006Fo02, 1989TuZZ, 1973Gh03, 1970KoZM, 1967GH01, 1967Mi03, 1966Do04, 1966Za04, 1958Gh40]
^{254m} No	2.443(33)#	9.521(8)	$\leq 0.01\%$	0.020(12)%			[2010He10, 2022Br08, 2021Is09, 2021Te08]
²⁵⁸ Rf ²⁶² Sg ²⁶⁶ Hs	3.610(47)# 3.23(11)# 2.54(24)#	9.196(13) 9.600(15) 10.346(16)	4.9(16)% 6(4)% 76(9)%	95.1(16)% 94(4)% 24(9)%			[2016He15, 2008Ga08, 2019MoZV, 2018Mo20, 1994Hu18, 1994Ni17, 1984Og03, 1969Gh01] [2012Ac04, 2011Ac01, 2006Gr24, 2001Ho06] [2012Ac04, 2015Ac04, 2011Ac01, 2001Ho06]
200mHs	$\approx 3.7 \#$	≈11.5	$\approx 100\%$				[2012Ac04, 2015Ac04] [2012Ac04, 2001Hc06, 2017Ac02, 2015Ac04, 2011Ac01
²⁷⁰ Ds	1.91(31)# ≈0.78#	≈12.24	≈70%				[2012Ac04, 2001H006, 2017Ac02, 2015Ac04, 2011Ac01, 1990Sc11] [2012Ac04, 2001H006, 2017Ac02, 2015Ac04, 2011Ac01]

* Weighted average of  $6.96(18) \times 10^6$  y [1989Us04),  $7.15(15) \times 10^6$  y [1982Ra33],  $7.46(6) \times 10^6$  y [1979Ch41] and  $7.1(2) \times 10^6$  y [1960Ar09] and  $7.2(2) \times 10^6$  y [1951Ha87].

** Weighted average of  $2.0(2) \times 10^3$  y [1968Sk01],  $1.34(16) \times 10^3$  y [1963Fr04] and  $2.1(3) \times 10^3$  y [1953Hu85].

*** The BR for  $\alpha$ -decay has not been measured. A 0⁺ even-even to a 0⁺ even-even  $\alpha$ -decay is expected to be unhindered. Setting the BR to 75% gives a HF = 1.0. A 100% BR would result in HF = 0.76.

direct $\alpha$ emission from ²¹⁸ Po, $J^{\pi} = 0$	$^{+}, T_{1/2} = 3.062(8) \text{ m}^{*}, L$	$BR_{\alpha} = 99.978(3)\%^{**}$
----------------------------------------------------------------	---------------------------------------------	----------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@}$	$E_{daughter}(^{214}\mathrm{Pb})^{@}$	coincident $\gamma$ -rays (keV) [@]	R ₀ (fm)	HF
5.278(2) 6.11454(10)	5.181(2)** 6.00235(10)***	1.1×10 ⁻³ %** 100%	1.1×10 ⁻³ % 99.978(3)%	$(2^+) \\ 0^+$	0.835(1) 0.0	835	1.53788(19) 1.53788(19)	11.7 0.9867(26)

* Weighted average of 3.040(8) m [1989Ma67], 3.093(12) m [1986Po17] and 3.11(2) m [1982Va09].

** [1952Hi60].

*** Value from [1971Gr17] modified by -0.20 keV in [1991Ry01].

@ [2021Zh35].

# Table 5

direct  $\alpha$  emission from ²²²Rn,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 3.82146(16) d^*$ ,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{218}\text{Po})$	coincident $\gamma$ -rays (keV)	$R_0$ (fm)	HF
4.915(4) 5.077(1) 5.59020(30)	4.826(4)** 4.986(1)** 5.48948(30)***	$\approx 5 \times 10^{-4}\%$ 0.078% 100%	$\approx 5 \times 10^{-4}\%$ 0.078% 99.9%	$2^{+@}_{0^{+}}$	0.676 0.5097 [@] 0.0	509.7	1.54863(17) 1.54863(17) 1.54863(17)	$\approx 30$ 2.0 0.99798(4)

* [2015Be07].

** [1958Wa16], modified by -1.2 keV in [1991Ry01].

*** [1971Gr17], modified by -0.18 keV in [1991Ry01].

@ [2019Si39].

#### Table 6

direct  $\alpha$  emission from ²²⁶Ra,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 1600(5)$  y*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@}$	$E_{daughter}(^{222}\mathrm{Rn})^{@@}$	coincident $\gamma$ -rays (keV) ^{@@}	R ₀ (fm)	HF
		4	4					120
4.238(2)	4.163(2)	$2.9(5) \times 10^{-4}\%$	$2.7(5) \times 10^{-4}$	3-	0.6363	186.0, 449.4	1.53945(26)	$8.5^{+2.0}_{-1.4}$
4.270(1)	4.194(1)	$1.1(1) \times 10^{-3}\%$	$1.0(1) \times 10^{-3}\%$	$1^{-}$	0.6007	186.0, 414.6, 600.7	1.53945(26)	$4.4_{-0.4}^{+0.5}$
4.421(1)	4.343(1)	$6.3(16) \times 10^{-3}\%$	$5.9(15) \times 10^{-3}\%\%$	$4^+$	0.4482	186.0, 262.3	1.53945(26)	$11^{+4}_{-2}$
4.684(1)	4.601(1)	6.30(1)%	5.93(1)%	$2^{+}$	0.1860	186.0	1.53945(26)	0.893(15)
4.87054(25)	4.78434(25)***	100%	94.07(1)%	$0^+$	0.0		1.53945(26)	0.9979(31)

* Weighted average of 1599(7) y [1966Ra13] and 1602(8) y [1959Ma12].

**  $E_{\alpha}$  values from [1963Ba62], adjusted by +3.3 keV as recommended in [1991Ry01].

*** From [1971Gr17], adjusted by -0.16 keV as recommended in [1991Ry01].

[@] [2023Si22]. [@] [1971Lo19].

# Table 7

direct $\alpha$ emission from	230 Th, $J^{\pi} = 0^+$ , T ₁	$_{/2} = 75584(110) \text{ y*}, BR_{0}$	x = 100%

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$J_f^{\pi@}$	E _{daughter} ( ²²⁶ Ra) [@]	coincident $\gamma$ -rays (keV) [@]	R ₀ (fm)	HF
4.324	4.249	$\approx 6.6 \times 10^{-6}$	$\approx 5 \times 10^{-6}$	5-	0.4463	67.7, 110.0, 124.8, 143.9, 186.1, 234.8, 253.7, 253.9	1.5332(11)	$7.4 \times 10^{3}$
4.353	4.277	$\approx 6.6 \times 10^{-6}$	$\approx 5 \times 10^{-6}$	$6^+$	0.4165	67.7, 143.9, 204.9	1.5332(11)	$1.3 \times 10^{4}$
4.449	4.372	$1.3 \times 10^{-3}\%$	$1 \times 10^{-3}$	3-	0.3215	67.7, 110.0, 143.9, 186.1, 253.7, 253.9	1.5332(11)	350
4.520	4.441	0.039%	0.03%	1-	0.2537	67.7, 186.1, 253.7	1.5332(11)	38
4.554	4.475	0.16%	0.12%	$4^{+}$	0.2115	67.7, 143.9	1.5332(11)	20
4.7023(15)	4.6205(15)	31.8%	24.3%	$2^{+}$	0.0677	67.7	1.5332(11)	1.07
4.7700(15)	4.6870(15)	100%	76.3%	$0^+$	0.0		1.5332(11)	1.01

* [2013Ch53].

** [1954Ro12].  $\alpha$ 's at 4.249, 4.277 and 4.372 were not observed, their energies were deduced from  $\gamma$ -rays following the  $\alpha$  decay of ²³⁰Th. Energy values are adjusted by +3.9 keV as recommended in [1991Ry01].

*** [1966Ba14]. Energy values are adjusted by +3.0 keV as recommended in [1991Ry01].

@ [1996Ak02].

Fable 8	
lirect $\alpha$ emission from ²³⁴ U, $J^{\pi} = 0^+$ , $T_{1/2} = 245526(260)$ y*, $BR_{\alpha} = 100$	0%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_{f}^{\pi@@}$	$E_{daughter}(^{230}\mathrm{Th})^{@@}$	coincident $\gamma$ -rays (keV) ^{@@}	R ₀ (fm)	HF
4.079**	4.009	$2.8 \times 10^{-5}\%$	2×10 ⁻⁵ %**	$2^{+}$	0.7814	53.2, 120.9, 607.4, 728.1, 781.4	1.52224(19)	2.8
4.225**	4.153	$1.7 \times 10^{-5}\%$	$1.2 \times 10^{-5}\% **$	$0^+$	0.6349	53.2, 581.7, 634.9	1.52224(19)	90
4.352**	4.278	$5.6 \times 10^{-5}\%$	$4 \times 10^{-5}\%$ **	$1^{-}$	0.5081	53.2, 454.9, 508.2	1.52224(19)	300
4.686**	4.605	0.29(1)%	0.206(4)%***	$4^{+}$	0.1741	53.2, 120.9	1.52224(19)	21.5(4)
4.8067(20)	4.7245(20) [@]	39.82(8)%	28.42(5)%***	$2^{+}$	0.0532	53.2	1.52224(19)	1.1260(23)
4.8603(20)	4.7772(20)@	100%	71.38(5)%***	$0^+$	0.0		1.52224(19)	1.0454(13)

* Weighted average of 245620(260) y [2013Ch53] and 244900(670) [2016Va13].

**  $\alpha$  not observed, inferred from observation of  $\gamma$ 's in [1963Bj03].  $E_{\alpha}$  deduced from level energy and the 4.8603(20) MeV ground state  $\alpha$  transition.  $I_{\alpha}$  values from [1963Bj03].

*** [1984Va41].

^(a) Values from [1967Ba43].  $E_{\alpha}$  values adjusted by +0.4 keV as recommended in [1991Ry01]. ^(a) [2024Mo17].

#### Table 9

direct  $\alpha$  emission from ²³⁸Pu,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 87.71(3)$  y*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{234}\mathrm{U})^{@@}$	coincident $\gamma$ -rays (keV) ^{@@}	$R_0$ (fm)	HF
~1 656	~1 578**	$2.8 \times 10^{-5}$	$2.0 \times 10^{-5}$ **			13 5 99 9 801 1 901 1		~24
≈4.668	$\approx 4.590 **$	$1.7 \times 10^{-5}$	$1.2 \times 10^{-5} **$	$2^{+}$	0.9267	43.5, 99.9, 783.4, 883.4, 926.7		≈2. <del>4</del> ≈5.7
4.7411(20)	4.6614(20)**	$<\!\!2.8\! imes\!10^{-6}$	$<2.0 \times 10^{-6} **$	$2^{+}$	0.8517	43.5, 99.9, 708.3	1.50745(13)	> 123
4.7848(20)	4.7044(20)**	$7 \times 10^{-5}$	$5 \times 10^{-5**}$	$0^+$	0.8099	43.5, 766.4, 810.0	1.50745(13)	9.9
4.8052(20)	4.7244(20)**	$3.1 \times 10^{-5}$	$2.2 \times 10^{-5**}$	1-	0.7863	43.5, 742.8, 786.3	1.50745(13)	33
≈5.101	≈5.015**	$\approx$ 5.6 $\times$ 10 ⁻⁶	$\approx 4.00 \times 10^{-6**}$	$8^+$	0.4970	43.5, 99.9, 152.7, 201.0		$\approx 1.7 \times 10^4$
5.2946(20)	5.2056(20)**	$2.5 \times 10^{-3}$	$1.80 \times 10^{-3} **$	$6^{+}$	0.2961	43.5, 99.9, 152.7	1.50745(13)	710
5.4493(20)	5.3577(20)**	0.151(10)%	0.107(7)%@	$4^{+}$	0.1434	43.5, 99.9	1.50745(13)	99(7)
5.54955(40)	5.45628(40)***	40.63(15)%	28.86(10)%@	$2^{+}$	0.0435	43.5	1.50745(13)	1.387(5)
5.59303(20)	5.49903(20)***	100%	71.03(7)%@	$0^+$	0.0		1.50745(13)	0.9954(10)

* [1977Di04]. ** [1970Ba72].  $E_{\alpha}$  values are adjusted by +0.4 keV as recommended in [1991Ry01]. *** [1971Gr17].  $E_{\alpha}$  values are adjusted by -0.18 keV as recommended in [1991Ry01].

^(a) Weighted average of values from [1998Ya17] and [1984Bo41]. ^(a) @ [2007Br04].

#### **Table 10** direct $\alpha$ emission from ²⁴²Cm, $J^{\pi} = 0^+$ , $T_{1/2} = 162.80(11)$ d*, $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$J_f^{\pi}$	$E_{daughter}$ ( ²³⁸ Pu)***	coincident γ-rays (keV)***	R ₀ (fm)	HF
	,	,	,	J		• • •	,	
4.930	4.849	$6.5 \times 10^{-7}\%$	$4.80 \times 10^{-5}\%$	$2^{+}$	1.2643	44.1, 101.9, 1118.3, 1.2202	1.501258(57)	6.4
4.966	4.884	$6.9 \times 10^{-7}\%$	$5.10 \times 10^{-5}\%$	$0^+$	1.2287	44.1, 1184.6	1.501258(57)	10.7
5.071	4.987	$4.6 \times 10^{-7}\%$	$3.40 \times 10^{-5}\%$	$4^{+}$	1.1258	44.1, 101.9, 979.8, 1081.7	1.501258(57)	80
5.170	5.084	$4.6 \times 10^{-6}\%$	$3.40 \times 10^{-4}\%$	$2^{+}$	1.0285	44.1, 984.5, 1028.5	1.501258(57)	35
5.216	5.130	$2.2 \times 10^{-6}\%$	$1.60 \times 10^{-4}\%$	$2^{+}$	0.9831	44.1, 101.9, 837.0, 938.9,	1.501258(57)	150
						983.0		
5.2367	5.150	$1.5  imes 10^{-6}\%$	$1.10 \times 10^{-4}\%$	$1^{-}$	0.9628	44.1, 918.7, 982.8	1.501258(57)	290
5.258	5.172	$7.0 \times 10^{-5}\%$	$5.20 \times 10^{-3}\%$	$0^+$	0.9414	44.1, 561.0, 605.4, 336.4,	1.501258(57)	8.2
						897.3, 941.5		
5.440	5.350	$2.7 \times 10^{-7}\%$	$2.00 \times 10^{-5}\%$	5-	0.7633	44.1, 101.9, 157.4, 459.8, 617.2	1.501258(57)	$2.7 \times 10^{4}$
5.543	5.451	$1.6 \times 10^{-5}\%$	$1.20 \times 10^{-3}\%$	3-	0.6615	44.1, 101.9, 561.0, 605.4	1.501258(57)	$1.8 \times 10^{3}$
5.600	5.508	$3.2 \times 10^{-4}\%$	2.40E-04%	$1^{-}$	0.6052	44.1, 561.0, 605.4	1.501258(57)	190
5.693	5.599	$2.7 \times 10^{-5}\%$	$2.00 \times 10^{-3}\%$	$8^+$	0.514		1.501258(57)	$7.5 \times 10^{3}$
5.906(2)	5.809(2) [@]	$6.2 \times 10^{-3}\%$	0.0046%	6+	0.3034	44.1, 101.9, 157.4	1.501258(57)	460
6.067(2)	5.967(2) [@]	0.047%	0.035%	$4^+$	0.1460	44.1, 101.9	1.501258(57)	400
6.17164(12)	6.06963(12)@@	35%	26%	$2^{+}$	0.0441	44.1	1.501258(57)	1.7
6.215656(12)	6.112918(12)@@	100%	74%	$0^+$	0.0		1.501258(57)	1.00

* Weighted average of 163.00(11) d [1982Ag02] and 161.35(30) d [1981Us03].

**  $E_{\alpha}$  (lab) deduced from  $Q_{\alpha}$  (determined by the ground state to ground state decay) and  $E_{daughter}$  from [1981Le15], except where noted. Note that the  $\alpha$ 's were not measured in [1981Le15].

*** [1981Le15].

[@] [1958Ko87].

@@ [1971Gr17].

#### Table 11

direct  $\alpha$  emission from ²⁴⁶Cf,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 35.7(5)$  h*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{242}\mathrm{Cm})$	coincident γ-rays (keV)***	$R_0$ (fm)	HF
6.576(5)	6.469(5)**	≈0.06%	≈0.05%**	. 1	0.286	146(5)	1.49528(88)	≈ 85
6.7249(10)	6.6156(10)	≈0.19%	≈0.15%	4+	0.1366	96(3)	1.49528(88)	≈130
6.8191(10) 6.8616(10)	6.7082(10) 6.7500(10)	26.0(13)% 100%	20.6(10)% 79.3(10)%	$2^+_{0^+}$	0.0425 0.0	4293)	1.49528(88) 1.49528(88)	2.53(13) 1.000(19)

* [1951Hu39].

** Value from [1963Fr04],  $E_{\alpha}$  (lab) modified by +4.4 keV as recommended in [1991ry01].  $I_{\alpha}$  estimated by evaluator from Fig. 2 in [1963Fr04]. *** [1956Ch77].

#### Table 12

direct  $\alpha$  emission from ²⁵⁰Fm,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 30.4(15)$  m*,  $BR_{\alpha} = \approx 75\%^{***}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{250}\mathrm{Fm})$	coincident $\gamma$ -rays (keV)	$R_0$ (fm)	HF
7.551(25)	7.430(25)**	$\approx 100\%$	$0^{+}$	0.0		1.4789(48)	1.0***

* [2006Ba09].

** Weighted average of 7.424(35) MeV and 7.435(35) MeV [1981Mu06].

*** The BR for  $\alpha$ -decay has not been measured. A 0⁺ even-even to a 0⁺ even-even  $\alpha$ -decay is expected to be unhindered. Setting the BR to 75% gives a HF = 1.0. A 100% BR would result in HF = 0.76.

#### Table 13

direct  $\alpha$  emission from ²⁵⁴No,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 51.2(4)$  s*,  $BR_{\alpha} = 90(4)\%^{**}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{250}\mathrm{Fm})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
8.215(20)	8.086(20)	90(4)%**	0.0		1.4672(33)	0.79(4)	

* [2006He19].

** [1988Tu07].

*** [1985He22].

[@] This HF is < 1, indicating that the  $BR_{\alpha}$  is too high. A value of 70% gives a HF = 1.0.

direct $\alpha$ emiss	sion from 258 Rf, $J^{\pi}$	$= 0^+, T_{1/2} = 11.5$	5(12) ms*,	$BR_{\alpha} = 4.9(16)\%^{**}.$					
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(ab)$	s) $J_f^{\pi} E$	daughter ( ²⁵⁴ No)	coincident γ-1	rays (keV)	R ₀ (fm)	HF
.101(30) .197(16)	8.960(30)*** 9.054(16)**	≈33%*** 100%***	≈1.29 ≈3.79		.096(34) .0				$\approx 0.6$ $\approx 1.2$
* Weight ** [2016] *** [2003	ed average of 8.8(1 He15]. 8Ga08], $I_{\alpha}$ (rel) dete	1) ms [2020Mo11 ermined from 3 ev	] and 4.7 ⁺ vents at 9.0	^{1.2} ms [2008Ga08]. 5 MeV and 1 event at	t 8.96 MeV.				
able 15 rect $\alpha$ emiss	sion from ²⁶² Sg*, J	$\pi = 0^+, T_{1/2} = 6.9$	9 ^{+3.8} _{-1.8} ms**	$BR_{\alpha} = 6(4)\%.$					
$G_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{262}Sg)$	coincident $\gamma$	-rays (keV)	R ₀ (fm)	HF	
.60	9.45	94(4)%	$0^+$	0.0			1.462(37)	$1.1\substack{+4.1 \\ -0.8}$	
* All valu ** [2001]	ues from [2012Ac04 Ho06].	4], except where r	noted.						
able 16 irect α emiss	sion from 266 Hs, $J^{\pi}$	$T = 0^+, T_{1/2} = 2.9^{\circ}$	$7^{+0.78}_{-0.51}$ ms*.	$BR_{\alpha} = 76(9)\%^*.$					
$G_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi}$	$E_{daughter}(^{262}\mathbf{S})$	g) coincide	nt γ-rays (keV)	$R_0$ (fm)	HF	
0.335(20)	10.180(20)**	76(9)%*	$0^+$	0.0			1.481(12)	$1.3\substack{+0.6 \\ -0.4}$	
* [2012A ** [2001]	.c04]. Ho06].								
<b>able 17</b>	sion from ^{270m} Hs. F	$F_{X} = \approx 1.2 \text{ MeV}^*$	• T _{1/2} = 74	$^{+354}$ ms**, $BR_{\alpha} = \approx$	: 100%				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_{f}^{\pi}$	$E_{daughter}(^{262}Sg)$	coincident $\gamma$ -	rays (keV)	R ₀ (fm)	HF	
0.60	10.44	$\approx 100\%$	<u> </u>		332**	• • •	1.481(12)	100(50)	
* [2015A ** [2012. *** [200	.c04]. Ac04]. 1Ho06].								
<b>able 18</b> irect $\alpha$ emission	sion from ²⁷⁰ Ds, $J^{\pi}$	$T = 0^+, T_{1/2} = 200$	$D_{-40}^{+70} \ \mu s^*, B$	$R_{\alpha} = 100\%.$					
$G_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{266}\mathrm{H}$	s) coincide	nt γ-rays (keV)	R ₀ (fm)	HF	
1.196(50)	11.030(50)**	100%	$0^+$	0.0			1.472(12)	1.5(5)	
* [2012A ** [2001]	.c04]. Ho06[.								
able 19 irect $\alpha$ emiss	sion from ^{270m} Ds, E	Ex. = $\approx 1.2 \text{ MeV}^*$	$J^{\pi} = 9^{-}, 1$	$0^{-*}, T_{1/2} = 3.9^{+1.3}_{-0.8}$	ms**, $BR_{\alpha} = \approx 70$	%***.			
$C_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi}$ E	E _{daughter} ( ²⁶⁶ Hs)	coincident γ-	-rays (keV)	R ₀ (fm)	HF
1.115(20) 1.318(20) 2.333(50)	10.950(20) 11.150(20) 12.150(50)			$\approx 1.21 \\ \approx 1.01 \\ \approx 0.01$					
* [2015A ** [2012. *** [200	.c04]. Ac04]. 1Ho06].								

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Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +25$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein, $J^{\pi}$ values for ²⁰⁸ Au, ²¹² Tl, ²²⁰ At, ²²⁴ Fr, ²²⁸ Ac, ²³² Pa, and ²³⁶ N are taken from ENSDF.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\varepsilon}$	Q _β -	Qβ- α	$BR_{\varepsilon F}$	Experimental
²⁰⁸ Au*			obs	-5.41(50)#	7.360(30)#	1.42(50)#		[2010Al24]
²¹² Tl*		$(5^{+})$	30.9(80) s	-4.57(36)#	6.00(20)#	3.476(30)		[2016Ca25]
²¹⁶ Bi*		$(6^{-},7^{-})$	135(5) s	-1.640(20)#	4.092(11)	11.178(11)		[2000Ku06]
²²⁰ At		(6 ⁻ )	3.7(4) m	-0.888(23)	3.764(14)	10.349(14)		[1989Li04]
²²⁴ Fr*		1(-)	3.33(10) m	-0.696(15)	2.923(11)	8.892(11)		[1981Ku02]
²²⁸ Ac(MsTh)		3+	6.15(2) h	-0.046(1)	2.124(3)	7.824(3)		[1985Sk02]
²³² Pa*			31.4(2) h**	0.500(8)	-1.337(7)	6.931(8)		[1950Ja51]
					$Q_{\varepsilon p}$	Qεα		
²³⁶ Np			$1.55(1) \times 10^5$ y	0.930(50)	-6.200(52)	5.506(50)		[1981Li30]
²⁴⁰ Am			50.8(3) h	1.385(14)	-5.090(14)	6.641(14)		[1972Ah07]
^{240m} Am	3.0(2)		940(40) μs	4.4(2)	-2.1(2)	9.6(2)		[1979Be46, 1971Br39]
²⁴⁴ Bk			5.02(3) h	2.262(14)	-3.750(14)	8.164(14)		[2014So17]
^{244m} Bk	х		820(60) ns	2.262(14)+x	-3.750(14)+x	8.164(14)+x		[1972Wo07]
²⁴⁸ Es			24.5(23) m***	3.060(50)#	-2.479(53)#	9.422(52)#	$3.5(18) \times 10^{-4}\%$	[2001Sh09, 1989Ha27, 1956Ch67,
								1980Ga07, 1980GaZZ]
²⁵² Md			2.3(8) m	3.650(90)	-1.333(91)	10.804(91)		[1973Es01]
²⁵⁶ Lr			28(1) s	3.920(80)	-0.384(83)	12.505(83)		[2014Sa21]
²⁶⁰ Db			1.52(13) s	4.53(22)#	0.53(12)#	13.425(93)#		[1977Be36]
²⁶⁴ Bh			$0.9^{+0.3}$ s	5.18(33)#	1.56(24)#	14.39(27)#		[2004Mo26, 2004Mo27]
²⁶⁸ Mt			$21^{+8}$ ms	6.18(38)#	3.10(35)#	15.94(37)#		[2004Mo26, 2004Mo27]
272 R g			$38^{+1.4}$ ms	6 69(48)#	4 38(40)#	17 38(38)#		[2004Mo26, 2004Mo27]
Rg			5.0 _{-0.8} ms	0.07(40)#	1.50(10)#	17.50(50)#		[200411020, 200411027]

* 100%  $\beta^-$  emitter.

** Weighted average of 32.3(4) h and 31.2(2) h [1950Ja51].

** Weighted average of 23(3) m [2001Sh09], 28(5) m [1989Ha27] and 25(5) m [1956Ch67].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +25$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	$BR_{\alpha}$	BR _{SF}	Experimental
²⁰⁸ Au ²¹² TI	9.06(50)#	1.24(50)#			
216 <b>p</b> ;	8.45(28)# 5.757(54)	1.93(30)#			
220 A t	5.757(54)	5.00(20)#	8(2)%		[1080B100 1080] ;0/]
224 Er	5.930(14)	4.948(18)	0(2)70		[1909Du09, 1909Di04]
228 Ac(MsTh)	5 572(2)	4 721(11)			
232Pa	5.158(8)	4 627(8)			
²³⁶ Np	4.830(50)	5.007(51)	0.16(6)%*		[1981Li30]
²⁴⁰ Am	4.367(14)	5.707(52)	$1.9 \times 10^{-4}\%$		[1970Go42]
^{240m} Am	1.4(2)	8.7(2)		100%	[2015Ba55, 1985Be58, 1979Be46, 1971Br39, 1981Lu06,
					1976BeZM, 1973Be04, 1972Wo07]
²⁴⁴ Bk	3.757(14)	6.779(4)	$6(3) \times 10^{-3}\%$		[1966Ah02, 1956Ch77, 1950Th55]
^{244m} Bk	3.757(14)-x	6.779(4)+x		$\approx 100\%$	[1972Wo07, 1972Ga42, 1972WoZP]
²⁴⁸ Es	3.099(54)#	7.160(50)#	$\approx 0.25\%$		[1989Ha27, 1956Ch67, 2001Sh09, 1970Ah01]
²⁵² Md	2.781(92)	7.74(11)#			
²⁵⁶ Lr	2.354(84)	8.86(12)	>80%		[2014Sa21, 1971Es01, 2010SaZV, 2008An16, 2004Fo08,
					2004Mo14, 2004Mo26, 2002Ho11, 2001HoZY, 1976BeYM,
					1976BeZY, 1970Dr08, 1968Do19, 1968Fl08, 1967Fl06]
²⁶⁰ Db	1.98(12)#	9.501(42)#	90.4(5)%	9.6(6)%	[1977Be36, 2004Fo08, 2004Mo14, 2004Mo26, 2004Mo27,
					2002Ho11, 2001HoZY, 1995Ho04, 1976DiZY, 1970FlZY,
244					1970ZvZZ, 1968Fl09]
²⁶⁴ Bh	1.53(20)#	9.86(15)#	86(6)%	14(6)%	[2004Mo027, 1995Ho04, 2004Fo08, 2004Mo26, 2004Mo14,
					2002Ho11, 2001HoZY]
²⁶⁸ Mt	0.80(25)#	10.77(15)#	$\approx 100\%$		[2004Mo027, 1995Ho04, 2004Fo08, 2004Mo26, 2004Mo14,
272					2002Ho11, 2001HoZY]
272 Rg	0.47(25)#	11.197(13)	$\approx 100\%$		

*  $\alpha$  decay was not observed. It was inferred to have happened from the observation of the  $\alpha$  daughter ²³²Pa arising from ²³⁶Np [1981Li30].

$\frac{\text{direct } \alpha \text{ emis}}{\alpha}$	irect $\alpha$ emission from ²²⁰ At*, T _{1/2} = 3.7(4) m**, BR _{$\alpha$} = 8(2)%.												
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${ m J}_f^{m \pi}$	$E_{daughter}(^{216}\mathrm{Bi})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)**	HF						
6.053(6)	5.943(6)	8(2)%	(6 ⁻ ,7 ⁻ )	0.0		1.5433(25)	$3.8^{+18}_{-11}$						
* All va ** [1989 *** Inte	lues from [19Bu( 9Li04]. rpolated between	09], except when 1.53788(19) fn	re noted. n ( ²¹⁸ Po) and 1.5	4863(17) fm ( ²²² Rn).									
<b>Table 4</b> direct $\alpha$ emis	ssion from ²⁴⁰ An	$1^*, T_{1/2} = 50.8($	3) h**, $BR_{\alpha} = 1$ .	$9 \times 10^{-4}$ %.									

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{236}Np)$	coincident $\gamma$ -rays (keV)	$R_0 (fm)^{***}$	HF
5 276(2)	5 296(2)	1 42(12)07	$2.2 \times 10^{-4}$				1 50426(14)	111
3.370(3)	5.280(5)	1.42(12)%	2.5×10 %				1.30430(14)	111
5.427(2)	5.337(2)	13.8(5)%	$2.3 \times 10^{-3}\%$				1.50436(14)	23
5.469(1)	5.378(1)	100(1)%	0.017%				1.50436(14)	5.5

* All values from [1970Go42], except where noted.

** [1972Ah07].

*** Interpolated between 1.50745(13) fm (²³⁸Pu) and 1.501258(57) fm (²⁴²Cm).

#### Table 5

direct $\alpha$ emission from ²⁴⁴ Bk*, T _{1/2} = 5.0	$D2(3)$ h**, $BR_{\alpha} = 6(3) \times 10^{-3} \%$ ***.
--------------------------------------------------------------------------	----------------------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{240}\mathrm{Am})$	coincident $\gamma$ -rays (keV)	$R_0 \; (fm)^@$	HF
6.736(4) 6.779(4)	6.626(4) 6.668(4)	$\approx 50\%$ $\approx 50\%$	$ \substack{\approx 3 \times 10^{-3} \% \\ \approx 3 \times 10^{-3} \% } $		0.0?		1.49827(10) 1.49827(10)	$\substack{\approx 3 \times 10^3 \\ \approx 4 \times 10^3}$

* All values from [1966Ah02], except where noted.  $E_{\alpha}(lab)$  are modified by +1.5 keV as reccommended int [1991Ry01].

** [2014So17].

*** [1956Ch77].

[@] Interpolated between 1.501258(57) fm (²⁴²Cm) and 1.49528(88) fm (²⁴⁶Cf).

# Table 6

direct  $\alpha$  emission from ²⁴⁸Es*, T_{1/2} = 24.5(23) m**, BR_{$\alpha$} =  $\approx 0.25\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{244}\mathrm{Bk})$	coincident $\gamma$ -rays (keV)	$R_0 (fm)^@$	HF
6.960(14) 6.992(5) 7.020(5)	6.848(14) 6.879(5) 6.907(5)	14(13)% 100(22)% 44(21)%	$\approx 0.02\%$ $\approx 0.16\%$ $\approx 0.07\%$				1.4871(39) 1.4871(39) 1.4871(39)	$\approx 40$ $\approx 7$ $\approx 20$

* All values from [1989Ha27], except where noted.

** Weighted average of 23(3) m [2001Sh09], 28(5) m [1989Ha27] and 25(5) m [1956Ch67].

*** [1956Ch67].

[@] Interpolated between 1.49528(88) fm ( 246 Cf) and 1.4789(38) fm ( 250 Fm).

#### Table 7

direct  $\alpha$  emission from ²⁵⁶Lr*, T_{1/2} = 28(1) s, *BR*_{$\alpha$} = >80%**.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{252}Md)$	coincident γ-rays (keV)	$R_0 (fm)^@$	HF
8.462(10)	8.330(10)	17(4)%	>4.8%				1.469(18)	< 25
8.523(10)	8.390(10)	71(13)%	>20%				1.469(18)	< 10
8.564(10)	8.430(10)	100(20)%	>28%				1.469(18)	< 9
8.604(10)	8.470(10)	23(7)%	>6.4%				1.469(18)	< 50
8.645(10)	8.510(10)	57(10)%	>16%				1.469(18)	< 29
8.737(10)	8.600(10)	11(3)%	>3.2%				1.469(18)	< 280
8.767(10)	8.630(10)	9(3)%	>2.4%				1.469(18)	< 460

* All values from [2014Sa21], except where noted.

** [1971Es01].

[@] Interpolated between 1.4672(33) fm ( 254 No) and 1.470(18) fm ( 258 Rf).

#### Table 8

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{256}\mathrm{Lr})$	coincident γ-rays (keV)	R ₀ (fm)**	HF
9.182(14) 9.216(14) 9.263(17)	9.041(14) 9.074(14) 9.120(17)	100(10)% 52(8)% 35(7)%	43(5) % 23(3)% 15(3)%				1.466(41) 1.466(41) 1.466(41)	$5^{+18}_{-4}\\12^{+21}_{-8}\\20^{+40}_{-20}$

direct  $\alpha$  emission from ²⁶⁰Db*, T_{1/2} = 1.52(13) s, *BR*_{$\alpha$} = 90.4(6)%.

* All values from [1977Be36].

** Interpolated between 1.470(18) fm (258Rf), and 1.462(37) fm (²⁶²Sg).

#### Table 9

direct $\alpha$ emission from ²⁶⁴ Bh, 7	$\Gamma_{1/2} = 0.9^{+0.3}_{-0.2}$	$s^*, BR_{\alpha} = 86(6)\%$
----------------------------------------------------	------------------------------------	------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})^{**}$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{260}\text{Db})$	coincident γ-rays (keV)	R ₀ (fm)***	HF
9.621(20) 9.767(20)	9.475(20) 9.619(20)	$\approx 50\%$ 100%	≈28% ≈57%				1.472(39) 1.472(39)	$\approx 30$ $\approx 30$

* [2004Mo27, 2004Mo26].

** Values are taken from [1995Ho04], which reported 2 events at 9.619(20) MeV and 1 event at 9.475(20) MeV. [2004Mo27] report 12 events from the  $\alpha$  decay of ²⁶⁴Bh, and 2 fission events. They report: "Observed decay energy ranges from 8.86 to 9.83 MeV showing broad distribution, although the 'peak' is located at 9.7 MeV." Figure 2a from this reference roughly supports the assignment of the two peaks reported in [1995Ho04].

*** Interpolated between 1.462(37) fm ( 262 Sg) and 1.481(12) fm ( 266 Hs).

#### Table 10

direct  $\alpha$  emission from ²⁶⁸Mt,  $T_{1/2} = 21^{+8}_{-5}$  ms*,  $BR_{\alpha} = \approx 100\%$ **.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})^{**}$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{264}\mathrm{Bh})$	coincident $\gamma$ -rays (keV)	$R_0 (fm)^@$	HF
10.250(20) 10.395(20)	10.097(20) 10.240(20)	$\approx 50\%$ 100%	≈33% ≈67%				1.477(17) 1.477(17)	$\approx 6 \approx 7$

* [2004Mo27, 2004Mo26].

** Only  $\alpha$ -decay has been observed.

*** Values are taken from [1995H004], which reported 2 events at 10.240(20) MeV and 1 event at 10.097(20) MeV. [2004M027] report 14 events from the  $\alpha$  decay of ²⁶⁸Mt, and 2 fission events. They report: "Observed decay energy ranges from 9..40 to 10.77 MeV showing broad distribution, although the ' peak' is located at 10.4 MeV." Figure 2a from this reference shows a peak with 7 counts at roughly 10.3 MeV, 1 count at roughly 19,1 MeV and three counts from 10.5-10.8 MeV.

[@] Interpolated between 1.481(12) fm (²⁶⁶Hs) and 1.472(12) fm (²⁷⁰Ds).

# Table 11 direct of emission from 272 Box T

direct $\alpha$ emission from ²⁷² Rg, $T_{1/2} = 3.8^{+1.4}_{-0.8}$ ms*, $BR_{\alpha} = \approx 100\%$ **.										
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(abs)^{**}$	$J_f^{\pi}$	$E_{daughter}(^{268}\mathrm{Mt})$	coincident $\gamma$ -rays (keV)	$R_0 \left( fm \right)^@$	HF			
10.981(20)	10.820(20)	$\approx 100\%$				1.47	≈5			

* [2004Mo27, 2004Mo26].

** Only  $\alpha$ -decay has been observed.

*** Values are taken from [1995Ho04], which reported 2 events at 10.240(20) MeV and 1 event at 10.097(20) MeV. [2004Mo27] report 14 events from the  $\alpha$  decay of ²⁶⁴Bh, and 2 fission events. They report: "Observed decay energy ranges from 10.20 to 11.56 MeV showing broad distribution, although the ' peak' is located at 11.0 MeV." Figure 2a from this reference shows a peak with 7 counts at roughly 11 MeV.

[@] 1.47 fm is used to calculate HF.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +51/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values for all nuclei are taken from ENSDF.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	Q _β -	Q _β - α	Experimental
²⁰⁷ Pt*					6.50(50)#	7.99(57)#	[2012Ku26]
²¹¹ Hg*				26.4(81) s	5.69(21)#	8.01(36)#	[2017Ca12]
²¹⁵ Pb*		$(9/2^+)$	147(12) s	-5.69(31)#	2.710(50)#	8.175(64)	[2013De20]
²¹⁹ Po		$(9/2^+)$	620(59) s	-3.64(20)#	2.285(16)#	8.807(17)	[2015Fi07]
²²³ Rn*		7/2	24.3(3) m**	-3.038(16)	2.007(8)	7.749(9)	[1992Ku03, 1986Bo35]
²²⁷ Ra*		3/2+	41.2(2) m	-2.505(6)	1.328(2)	6.550(3)	[1953Bu63]
²³¹ Th*		$5/2^{+}$	25.52(10 h	-1.947(13)	0.392(2)	5.721(2)	[1958Ca19]
²³⁵ U		$7/2^{-}$	7.04(1)×10 ⁸ y	-1.370(14)	-0.124(1)		[2004Sc03]
^{235m} U	2.5(3)		3.6(18) ms	1.1(3)	2.4(3)	7.8(3)	[2007Ob02]
²³⁹ Pu		$1/2^{+}$	24085(13) y***	-0.773(1)	-0.802(2)		[1975Al15, 1978Ja20, 1978Se12, 1978Pr07]
^{239m} Pu	2.5(10)		$7.0(4) \ \mu s^{@}$	1.7(10)	1.7(10)	7.8(10)	[1970Po01, 1972Wo07, 1977GoYZ, 1980Gu20]
212					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
²⁴³ Cm		5/2+	29.20(14) y	0.007(2)	-4.824(1)	5.446(2)	[1986Ti03, 1958Ch38]
^{243m} Cm	1.50(30)		42(6) ns	0.151(30)	-3.32(30)	6.75(30)	[1973Br04, 1972Wo07]
²⁴ /Cf		$(7/2^{+})$	3.11(3) h	0.620(15)	-3.796(14)	6.509(14)	[1984Ah02]
²⁵¹ Fm		(9/2-)	5.30(8) h	1.447(15)	-2.500(14)	8.044(15)	[1973Ah02]
²⁵⁵ No		$(1/2^{+})$	3.52(18) m	1.970(015)	-1.380(14)	9.875(15)	[2011As02]
²⁵⁹ Rf			2.4(4) s ^{@@}	2.52(10)#	-0.40(12)#	11.100(73)#	[1973Dr10, 1981Be03, 1985So03,
262 ~							[1994Gr08, 2004Fo08, 2006Gr24]
²⁰³ Sg			0.9(2) s	3.09(19)#	0.51(24)#	11.92(12)#	[1974Gh04
^{203m} Sg	х		$560^{+100}_{-100}$ ms	3.09(19)#+x	0.51(24)#+x	11.92(12)#+x	[2006Ni10]
²⁰ /Hs ^{@@@}			$0.80^{+5.80}_{-0.37}$ s	3.89(28)#	1.75(26)#	13.12(19)#	[2004Mo40]
²⁶ / ^m Hs ^{@@@}	Х		$52^{+13}_{-8}$ ms	3.89(28)#+x	1.75(26)#+x	13.12(19)#+x	[2004Mo40]
²⁷¹ Ds ^{@@@}			$1.63^{+0.44}_{-0.29}$ ms	4.85(34)#	3.55(27)#	14.76(28)#	[2015Mo25]
^{271m} Ds ^{@@@}	Х		$69^{+56}_{-21}$ ms	4.85(34)#+x	3.55(27)#+x	14.76(28)#+x	[2015Mo25]

* 100%  $\beta^-$  emitter.

** Weighted average of 25.3(4) m [1992Ku03] and 23.2(4) m [1986Bo35].

*** Weighted average of 24060(16) y [1975A115], 24131(16) y [1978Ja20], 24101(20) y [1978Se12], 24089(13) y and 24019(21) [1978Pr07].

[@] Weighted average of 3.2(8) s [1970Po01], 8.1(8)  $\mu$ s [1972Wo07], 7.5(10)  $\mu$ s [1977GoYZ], and 6.5(4)  $\mu$ s [1980Gu20]. [@] Weighted average of 3.2(8) s [1973Dr10], 3.0(1.3) s [1981Be03], 3.4(17) s [1985So03], $1.7^{+0.8}_{-0.5}$  s [1994Gr08],  $2.2^{+17}_{-0.8}$  s [2004Fo08] and  $1.9^{+1.3}_{-0.5}$  s [2006Gr24]. @@@ Unclear which is the ground state.

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +51/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	BR _{cluster}	type	Experimental
²⁰⁷ Pt ²¹¹ Hg ²¹⁵ Pb ²¹⁹ Po	10.36(45)# 9.41(20)# 7.824(31)	0.71(57)# 1.32(45)# 2.31(21) 5.914(5)	28.2(20)%				[2015Fj07]
²²³ Rn ²²⁷ Ra	7.852(18) 7.632(7)	5.283(18) 4.363(8)					
²³¹ Th ²³⁵ U	7.312(16) 6.709(4)	4.213(2) 4.678(1)	100%	7.2(21)×10 ⁻⁹ %	8.06(432)×10 ⁻¹² %	Ne*	<b>2005Ga36</b> , <b>2004Da24</b> , <b>1991Bo20</b> , <b>1981Vo02</b> , <b>1975Va11</b> , 2020FoZZ, 2018Ma03, 2017Le03, 2006Al28, 2005Ga36, 2004Sc03, 1999Yu01, 1997Tr17, 1989Tr11, 1986BaYK, 1986He12, 1984He12, 1983Ba77, 1983Ol01, 1982Va04, 1982VaZP, 1981VaZV, 1977Ba72, 1974De19, 1974GrZA, 1974Te03, 1973GrYU, 1971Cl03, 1971Ja07, 1971KrZH, 1966Al23, 1966Ba58, 1966Ga03, 1966Ga27, 1965De06, 1965Wh05, 1964Sc27, 1962De15, 1960Ba44, 1960Vo07, 1958Fi10, 1957Cl16, 1957Wu39, 1955St04, 1953Fr37, 1952Fl20, 1952Se67, 1951Gh22, 1951Sa30, 1944ChZX, 1940Fl02]
235m U	4.2(3)	7.2(3)		obs			[2007Ob02]
²³⁹ Pu	6.1553(4)	5.2455(2)	100%	3.1(6)×10 ⁻¹⁰ %			[2000Ho27, 1993Ga28, 1976GuZN, 1968Ba25, 1966Ah02, 2020Yo01, 2016Di11, 1992B113, 1986LoZT, 1985Dr09, 1984Iw02, 1982He02, 1981AhZV, 1980RyZX, 1979Ce04, 1978Ja20, 1978Lu10, 1978Ma45, 1978Pr07, 1978Se12, 1977Ja08, 1977MeYY, 1977VaYQ, 1977VaZW, 1976BaZZ, 1975A115, 1971GuZY, 1970Cl11, 1968Cl02, 1966He11, 1965Ho04, 1965Tr03, 1963Ba09, 1963Le17, 1963Bj03, 1962Ba52, 1962Le11, 1961Dz05, 1959Do64, 1959Ma25, 1957No15, 1955Go57, 1953AsZZ, 1952As28, 1952Se67, 1950Ro09, 1949GaZZ, 1949SeZY, 1949Se7X, 1948Le02, 1945RoZZI
^{239m} Pu	3.7(10)	7.7(10)		$\approx 100\%$			[ <b>1980Gu20</b> , <b>1977GoYZ</b> , <b>1973Na03</b> , <b>1972Wo07</b> , 1974Be52, 1974BeYO, 1973Na35, 1972GaZW, 1971Ta17, 1969Me11, 1969VaZX]
²⁴³ Cm	5.575(1)	6.169(1)	99.71(3)%	5.3(9)×10 ⁻⁹			[ <b>1987Po19</b> , <b>1966Ba07</b> , <b>1963Dz07</b> , <b>1958Ch38</b> , <b>1957As70</b> , 1989Ho24, 1986Ti03, 1976BaZZ, 1971Bb10, 1970BaZZ, 1970By01, 1969Ba57, 1963La07, 1963La07, 1963La07, 1953As14, 1953As7Z, 1951Hu30]
^{243m} Cm	4.08(30)	7.67(30)		100%			[ <b>1973Br04</b> , <b>1972Wo07</b> , 1974GaZD, 1971Re11, 1970Po01]
²⁴⁷ Cf	5.146(62)	6.503(14)	0.035(5)%				[1984Ah02]
²⁵¹ Fm	4.56(10)#	7.424(1)	1.80(13)%				[1978Ah02, 1973Ah02, 1973AhZZ, 1967Ch17, 1957Am47]
²⁵⁵ No	3.93(10)#	8.428(3)	30(5)%				[ <b>2011As02</b> , 2015Mo25, 2007AsZU, 2006AsZY, 2006Gr24, 2006He20, 2006Ni10, 2005HeZU, 2004Fo08, 2004Mo27, 2004Mo40, 2004Mo43, 1976SiZS, 1971BeYR, 1971BeZZ, 1970Es02, 1970GhZY, 1968FI08, 1967Dr02, 1967Gh01]
²⁵⁹ Rf	3.70(13)#	9.130(71)#	92.1(23)%	7.9(23)%**			[ <b>1981Be03</b> , <b>1985S003</b> , 2015Mo25, 2006Gr24, 2006Ni10, 2004Fo08, 1994Gr08, 1983SoZZ, 1976GhZX, 1976GhZV, 1976GhZW, 1974DiZI, 1973Dr10, 1973DrZZ, 1970GhZY, 1970Og05]
²⁶³ Sg	3.35(17)#	9.403(61)#	87(8)%	13(8)%			[2006Ni10, 2006Gr24, 2015Mo25, 2010Ni14, 1997Ho03, 1997Ho13,
^{263m} Sg	3.35(17)#-x	9.403(61)#+x	pprox 100%				1996LaZY, 1994Gr08, 1976GhZV, 1976GhZW] [ <b>2006Ni10</b> , 2015Mo25, 2010Ni14, 2004Fo08, 1997Ho03, 1997Ho13, 1996LaZY]
²⁶⁷ Hs	2.74(19)#	10.038(13)#	100%				[2015Mo15, 2004Mo40, 2011Ho10, 2010Ni14, 2004Fo08, 2004Mo14, 2004Mo27, 2004Mo43, 2003Gi05, 2003MoZT, 1998Ho13, 1997Ho03, 1997Ho13, 1995La20. 1995LaZX, 1995Og02, 1994HoZQ]
2077 Hs	2.74(19)#-x	10.038(13)#+x	100%				[2015)v1015, 2004M1040, 2011H010, 2004M014, 2004M027, 2004M043, 2003MoZT, 1998H013 1997H003]
²⁷¹ Ds	2.05(21)#	10.870(18)#	100%				[2015Mo15, 2004Mo40, 2011Ho10, 2004Fo08, 2004Mo14, 2004Mo27, 2004Mo43, 2003Gi05, 2003MoZT, 1998Ho13 1997Ho03, 1997Ho13, 1995Og02, 1994HoZO]
^{271m} Ds	2.05(21)#-x	10.870(18)#+x	100%				[ <b>2015Mo15</b> , <b>2012Zh04</b> , <b>2004Mo40</b> , 2011Ho10, 2004Mo14, 2004Mo27, 2004Mo43, 2003MoZT, 1998Ho13]

* Unclear which isotope of Ne [1991Bo20]. ** Weighted average of 6.3(37)% [1981Be03] and 9(3)% [1985So03].
| direct $\alpha$ emission | n from ²¹⁹ Po*, | $J^{\pi} = (9/2^+), T_1$ | $_{/2} = 620(59)$ s, | $BR_{\alpha} = 28.2(20)\%$ |
|--------------------------|----------------------------|--------------------------|----------------------|----------------------------|
|--------------------------|----------------------------|--------------------------|----------------------|----------------------------|

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{215}\text{Pb})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
5.914(5)	5.806(5)	28.2(20)%	(9/2+)	0.0		1.5434(12)	1.78(24)

* All values from [2015Fi07].

Table 4

direct  $\alpha$  emission from ²³⁵U,  $J^{\pi} = 7/2^{-}$ ,  $T_{1/2} = 7.04(1) \times 10^{8}$  y*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$J_f^{\pi@}$	$E_{daughter}(^{231}\mathrm{Th})^{@}$	coincident $\gamma$ -rays (keV) [@]	R ₀ (fm)	HF
4.045(5) 4.112(5)	3.976(5)*** 4.042(5)***	≈0.12% ≈0.12% %	$\approx 0.07\%^{***}$ $\approx 0.07\%^{***}$	(7/2 ⁻ )	0.6324 0.5658	1.52410(58) 1.52410(58)	$\approx 1.3$ $\approx 4.9$	
4.1513(4)	4.0806(4)***	0.04(2)%	0.026(12)%***	(11/2 ⁻ )	0.5302	19.5, 31.6, 42.0, 51.2, 54.3, 74.9, 96.1,109.2, 120.4, 142.4, 143.8, 144.5, 147.0, 150.9, 163.4, 185.7, 192.5, 202.1, 205.4, 291.7, 345.9, 387.8	1.52410(58)	$27^{+24}_{-9}$
4.224(2)	4.152(2)	0.52(2)%	0.298(13)%	9.2-	0.4521	19.5, 31.6, 42.0, 51.2, 54.3, 74.9, 96.1, 109.2, 120.4, 143.8, 163.4, 185.7, 205.4, 215.3, 246.8, 266.5, 291.2, 356.0, 410.3	1.52410(58)	11.3(5)
4.2888(48)	4.2158(48)	13.9(1)%	8.02(6)%	7/2-	0.3878	19.5, 31.6, 42.0, 51.2, 54.3, 74.9, 96.1,109.2, 120.4, 143.8, 144.5, 147.0, 150.9, 163.4, 185.7, 192.5, 202.1, 205.4, 291.7, 345.9, 387.8	1.52410(58)	1.45(2)
4.322(5)	4.248(5)***	0.12(1)%	0.07(1)%***	7/2+	0.3515	42.0, 54.3, 96.1, 255.4, 309.6, 351.5	1.52410(58)	$330^{+60}_{-40}$
4.340(2)	4.266(2)	0.39(2)%	0.223(12)%	$(13/2^{-})$	0.337	1.52410(58)	136(8)	
4.3571(24)	4.2829(24)	0.19(1)%	0.112(8)%	5/2+	0.3171	42.0, 76.2, 95.7, 144.5, 221.4, 275.1, 317.1	1.52410(58)	394(29)
4.3979(6)	4.3230(6)	6.1(1)%	3.5(5)%	(11/2 ⁻ )	0.2776	19.5, 31.6, 41.1, 42.0, 51.2, 54.3, 72.7, 74.9, 96.1, 109.2, 115.5, 120.4, 143.8, 163.4, 182.1, 185.7, 205.4	1.52410(58)	$26^{+5}_{-3}$
4.4399(4)	4.3643(4)	34.5(2)%	19.94(11)%	9/2-	0.23691	19.5, 31.6, 42.0, 51.2, 54.3, 74.9, 96.1, 109.2, 120.4, 143.8, 163.4, 185.7, 205.4	1.52410(58)	9.67(15)
4.4715(4)	4.3954(4)	100.0(3)%	57.79(19)%	(7/2-)	0.2053	19.5, 42.0, 54.3, 96.1, 109.2, 143.8, 163.4, 185.7, 205.4	1.52410(58)	5.90(9)
4.4913(5)	4.4149(5)	5.3(1)%	3.09(5)%	$5/2^{-}$	0.1857	42.0, 143.8, 185.7	1.52410(58)	157(3)
4.516(2)	4.439(2)	0.40(2)%	0.230(12)%	$11/2^{+}$	0.1621	42.0, 120.4	1.52410(58)	$3.2(2) \times 10^3$
4.5805(7)	4.5025(7)	2.2(1)%	1.28(3)%	$9/2^{+}$	0.0961	42.0, 54.3, 96.1	1.52410(58)	$1.82(5) \times 10^3$
4.6349(4)	4.5560(4)	6.6(1)%	3.84(4)%	$7/2^{+}$	0.0419	42.0	1.52410(58)	$1.54(3) \times 10^3$
4.6770(4)	4.5974(4)	8.3(1)%	4.78(6)%	$5/2^{+}$	0.0		1.52410(58)	$2.50(5) \times 10^3$

* [2004Sc03].

** weighted average of [2005Ga36] and [2004Da24] except where noted. In addition to those listed, several  $\alpha$  transitions were reported by [1966Ga03] (4.579, 4.559, 4.537, 4.552, 4.510, 4.478, 4.424, 4.368, 4.339, 4.184, 4.164, 4.131, 4.091, 3.945, 3.892, 3.825, and 3.769 MeV) and [1960Ba44] (4.578, 4.522, 4.426, 4.368 and 4.339). None of these lines were observed in [2005Ga36] or [2004Da24] despite having much more statistics.

*** [2004Da24]. @ [2022Si29].

Table 5 direct  $\alpha$  emission from ²³⁹Pu,  $J^{\pi} = 1/2^+$ ,  $T_{1/2} = 24085(13)$  y*,  $BR_{\alpha} = 100\%$ . (1 of 3)

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$J_f^{\pi@@@}$	$E_{daughter}(^{235}\mathrm{U})^{@@@}$	coincident γ-rays (keV) ^{@@@}	HF
4.1282(2) ^b	4.0591(2)	4.8(2)×10 ⁻⁸	$3.4(2) \times 10^{-8} b$	(5/2 ⁻ )	1.1162(1)	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 69.0, 77.6, 89.6, 116.3, 119.7, 123.2, 129.3, 158.1, 171.4, 994.9, 986.9, 1102.9, 1115.6	25.3(15)
4.1870(4) ^b	4.1170(4)	1.81(4)×10 ⁻⁷	1.28(7)×10 ^{-7 b}		1.0574(3)	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 54.0, 69.0, 77.6, 89.6, 96.1, 116.3, 119.7, 129.3, 123.2, 143.4, 158.1, 171.4, 173.7, 179.2, 225.4, 832.5, 886.0, 927.8, 1005.7, 1057.3	22.5(13)
4.2518(4) ^b	4.1807(4)	5.1(2)×10 ⁻⁸	$3.6(2) \times 10^{-8} b$	(5/2+)	0.9926(3)	13.0, 978.9, 992.6	293(17)
$\frac{4.2760(2)^{p}}{1.2760(2)^{p}}$	4.2045(2)	$8.95(14) \times 10^{-8}$	$6.3(1) \times 10^{-8} b$	(3/2)+	0.9684	13.0, 38.7, 51.6, 916.8, 955.4, 968.4	270(5)
4.3525(2) ^b	4.2797(2)	2.6(6)×10 ⁻⁷	1.8(4)×10 ⁻⁷	5/2+	0.8919	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 69.0, 77.6, 89.6, 116.3, 119.7, 123.2, 129.3, 158.1, 171.4, 720.6, 762.6, 840.3, 879.2, 891.0	42(1)
4.3792(2) ^b	4.3059(2)	1.4(6)×10 ⁻⁷	9.9(4)×10 ⁻⁸ b	3/2+	0.8652	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 69.0, 77.6, 89.6, 116.3, 119.7, 123.2, 129.3, 158.1, 171.4, 693.8, 735.9, 783.4, 813.5	1.26(5)×10 ³
$4.3991(2)^{b}$	4.3255(2)	$4.6(7) \times 10^{-8}$	$3.2(5) \times 10^{-8} b$	$(7/2^+)$	0.8454	3.0, 30.0, 38.7, 51.6, 69.0, 763.6	$5.7^{+1.1}_{-0.8} \times 10^3$
4.4005(2) ^b	4.3269(2)	3.00(9)×10 ⁻⁷	2.13(6)×10 ⁻⁷ b	(1/2)+	0.8439	13.0, 30.0, 38.7, 47.6, 51.6, 69.0 77.6, 116.3, 129.3, 714.7, 843.8	1.83(3)×10 ³
4.4232(2) ^b	4.3492(2)	3.74(9)×10 ⁻⁷	2.64(6)×10 ^{-7 b}	5/2+	0.8212	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 54.0, 68.7, 69.0, 77.6, 89.6, 96.1, 98.8, 116.3, 119.7, 129.3, 123.2, 143.4, 158.1, 171.4, 173.7, 179.2, 225.4, 264.0, 341.5, 380.2, 393.1, 428.0, 596.0, 670.8, 769.6, 808.2, 821.3	1.08(3)×10 ³
4.4387(2) ^b	4.3644(2)	1.24(6)×10 ⁻⁷	8.8(4)×10 ⁻⁸ b	3/2-	0.8057(1)	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 69.0, 77.6, 89.6, 116.3, 119.7, 129.3, 123.2, 158.1, 171.4, 172.6, 255.4, 264.0, 297.5, 345.0, 341.5, 375.1, 378.8, 380.2, 393.1, 412.3, 413.7, 426.7, 633.2, 792.6, 805.7	4.3(2)×10 ³
$\overline{4.4649(2)^b}$	4.3902(2)	8.6(3)×10 ⁻⁷	$6.1(2) \times 10^{-7} b$	3/2+	0.7795	13.0, 30.0, 38.7, 51.6, 69.0, 697.8 727.9, 766.5, 779.4	$1.01(3) \times 10^3$
4.4660(3) ^b	4.3913(3)	9.0(2)×10 ⁻⁷	6.4(1)×10 ⁻⁷ b	(11/2)-	0.7784(2)	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 57.8, 69.0, 77.6, 89.6, 103.1, 116.3, 119.7, 123.2, 129.3, 158.1, 171.4, 606.9, 674.4	1.01(2)×10 ³
4.4751(2) ^b	4.4002(2)	3.23(6)×10 ⁻⁵	2.29(4)×10 ⁻⁵ b	1/2+	0.7693(1)	13.0, 30.0, 38.7, 47.6, 51.6, 69.0 77.6, 116.3, 129.3, 640.0, 756.4, 769.2	35.8(7)
4.4942(2) ^b	4.4190(2)	4.6(3)×10 ⁻⁷	$3.2(2) \times 10^{-7} b$	(9/2 ⁻ )	0.7502	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 68.7, 69.0, 77.6, 89.6, 98.8, 116.3, 119.7, 129.3, 123.2, 158.1, 171.4	3.3(2)×10 ³
$4.5242(2)^{b}$	4.4485(2)	$2.62(8) \times 10^{-6}$	$1.86(5) \times 10^{-6} b$	(9/2)-	0.7202	46.2, 57.8, 103.1, 617.1, 674.1	$1.0^{+0.4}_{-0.2} \times 10^3$
$4.5406(2)^{b}$	4.4646(2)	$1.56(2) \times 10^{-5}$	$1.11(1) \times 10^{-5 b}$	3/2-	0.7038	13.0, 38.7, 51.6, 652.1, 690.8, 703.6	219(2)

* Weighted average of 24060(16) y [1975A115], 24131(16) y [1978Ja20], 24101(20) y [1978Se12], 24089(13) y and 24019(21) [1978Pr07].

** Values from[1993Ga28], except where noted.

*** Value from [1980RyZX], adjusted by -0.11 keV as recommended by [1991Ry01].

[@] Value from [1968Ba25], adjusted by +1.0 keV as recommended by [1991Ry01].

@@ [1966Ah02]. @@@ [2014Br18].

^{*a*}  $R_0$  (fm) = 1.51188(12).

^b Deduced from  $\gamma$  energies [1976GuZN] and  $Q_{\alpha}$  = 5244.43(14) keV, using the levels and transitions from [2014Br18]. Conversion electron strength and strength from unobserved  $\gamma$ 's (in [1976GuZN]) decaying from a given level are taken into account.

Table 6		
direct $\alpha$ emission from ²³⁹ Pu, $J^{\pi} = 1/2^+$ , T ₁	$_{1/2} = 24085(13) \text{ y}^*, BR_{\alpha} = 100\%.$ (	2 of 3)

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$J_f^{\pi@@@}$	$E_{daughter}(^{235}\mathrm{U})^{@@@}$	coincident $\gamma$ -rays (keV) ^{@@@}	HF
4.5433(2) ^b	4.4673(2)	9.6(2)×10 ⁻⁶	6.8(1)×10 ⁻⁶ ^b	(7/2)-	0.7011	13.0, 30.0, 38.7, 46.2, 51.6, 57.8, 68.7, 69.0, 98.8, 103.1, 550.5, 598.0, 619.2, 649.3, 654.9, 701.0	376(6)
$4.5735(2)^{b}$	4.4970(2)	$6.6(8) \times 10^{-7}$	$4.7(5) \times 10^{-7 b}$	$(7/2)^{-}$	0.6709	46.2, 624.8, 671.0	$9.3^{+1.1}_{-0.9} \times 10^3$
4.5799(2) ^b	4.5033(2)	8.66(8)×10 ⁻⁶	6.13(6)×10 ⁻⁶ ^b	(5/2)-	0.6645	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 69.0, 77.6, 89.6, 116.3, 119.7, 129.3, 123.2, 158.1, 171.4, 493.0, 582.9, 612.8, 618.3, 664.6	800(8)
4.5854(2) ^b	4.5087(2)	3.70(4)×10 ⁻⁵	$2.62(3) \times 10^{-5} b$	1/2-	0.659.0	13.0, 30.0, 38.7, 47.6, 51.6, 69.0 77.6, 116.3, 129.3, 264.0, 265.7, 341.5, 380.2, 393.1, 645.9, 658.9	206(3)
4.6066(2) ^b	4.5295(2)	4.56(4)×10 ⁻⁶	3.23(3)×10 ⁻⁶ ^b	3/2-	0.6378	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 69.0, 77.6, 89.6, 116.3, 119.7, 129.3, 123.2, 158.1, 171.4, 211.1, 244.6, 255.4, 264.0, 297.5, 341.5, 345.0, 375.1, 380.2, 393.1, 413.7, 426.7, 586.3, 624.8, 637.8	2429(24)
4.6362(2) ^b	4.5586(2)	$1.7(1) \times 10^{-5}$	$1.17(7) \times 10^{-5 b}$	11/2+	0.6082	13.0, 30.0, 38.7, 51.6, 68.7, 69.0, 115.3, 411.2, 457.6, 526.4	$1.1(1) \times 10^3$
4.709(3)	4.630(3) ^{@@}	1.0(3)×10 ⁻³ %	7(2)×10 ⁻⁴ %	9/2+	0.5332	13.0, 30.0, 38.7, 51.6, 65.7, 68.7, 69.0, 98.1, 115.3, 119.0, 188.2, 242.1, 244.9, 307.9, 336.1, 361.9, 382.8, 430.1, 451.5, 481.7, 487.1	$68^{+27}_{-15}$
$4.7339(2)^{b}$	4.6547(2)	$1.29(7) \times 10^{-6}$	9.1(5)×10 ⁻⁷ b	$(9/2^+)$	0.5105	46.2, 57.8, 103.1, 406.8, 463.9	$7.7(4) \times 10^4$
4.769(3)	4.689(3) ^{@@}	7(3)×10 ⁻⁴ %	5(2)×10 ⁻⁴ %	7/2+	0.4738	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 54.0, 68.7, 69.0, 77.6, 89.6, 96.1, 98.8, 116.3, 119.7, 123.2, 129.3, 143.4, 158.1, 171.4, 173.7, 179.2, 225.4, 249.0, 302.9, 323.8, 341.0, 392.5, 422.6, 428.4, 461.3, 473.9	$260^{+1/0}_{-70}$
4.7988(2) ^b	4.7185(2)	7.2(1)×10 ⁻⁵ %	5.11(8)×10 ⁻⁵ % ^b	7/2+	0.4456	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 69.0, 77.6, 89.6, 116.3, 119.7, 129.3, 123.2, 158.1, 171.4, 274.4, 336.4, 399.5, 445.7	$4.0(1) \times 10^3$
4.807(9)	4.727(9)	7.2(11)×10 ⁻³ %	5.1(8)×10 ⁻³ %	5/2+	0.4267	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 69.0, 77.6, 89.6, 116.3, 119.7, 129.3, 123.2, 158.1, 171.4, 255.4, 297.5, 345.0, 375.1, 413.7, 426.7	$55^{+10}_{-8}$
4.830(5)	4.749(5) ^{@@}	$\approx 8 \times 10^{-4} \%$	$\approx 6 \times 10^{-4}$ %	9/2+	0.4148	13.0, 30.0, 38.7, 51.6, 65.7, 69.0, 115.3, 119.0, 123.6, 188.2, 189.4, 218.0, 244.9, 311.8, 368.6	≈570
4.851(9)	4.770(9)	2.1(8)×10 ⁻³ %	1.5(6)×10 ⁻³ %	3/2+	0.3932	13.0, 30.0, 38.7, 47.6, 51.6, 69.0 77.6, 116.3, 129.3, 264.0, 341.5, 380.2, 393.1	$320^{+220}_{-90}$
4.877(9)	4.795(9)	1.7(8)×10 ⁻³ %	1.2(6)×10 ⁻³ %	7/2+	0.3670	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 54.0, 69.0, 77.6, 89.6, 96.1, 116.3, 119.7, 129.3, 123.2, 143.4, 141.7, 158.1, 171.4, 173.7, 179.2, 195.7, 225.4, 237.8, 285.3, 320.9, 354.0, 367.1	$600^{+60}_{-20}$
4.910(9)	4.828(9)	03.4(10)×10 ⁻³ %	2.4(7)×10 ⁻³ %	5/2+	0.3328	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 69.0, 77.6, 89.6, 116.3, 119.7, 129.3, 123.2, 158.1, 161.5, 171.4, 203.6, 281.2, 319.7, 332.8	$530^{+220}_{-120}$

* Weighted average of 24060(16) y [1975A115], 24131(16) y [1978Ja20], 24101(20) y [1978Se12], 24089(13) y and 24019(21) [1978Pr07].

** Values from[1993Ga28], except where noted.

*** Value from [1980RyZX], adjusted by -0.11 keV as recommended by [1991Ry01].

[@] Value from [1968Ba25], adjusted by +1.0 keV as recommended by [1991Ry01].

^{@@} [1966Ah02]. ^{@@@} [2014Br18].

^{*a*}  $R_0$  (fm) = 1.51188(12).

^b Deduced from  $\gamma$  energies [1976GuZN] and  $Q_{\alpha} = 5244.43(14)$  keV, using the levels and transitions from [2014Br18]. Conversion electron strength and strength from unobserved  $\gamma$ 's (in [1976GuZN]) decaying from a given level are taken into account.

Table 7 direct  $\alpha$  emission from ²³⁹Pu,  $J^{\pi} = 1/2^+$ ,  $T_{1/2} = 24085(13)$  y*,  $BR_{\alpha} = 100\%$ . (3 of 3)

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$J_{f}^{\pi@@@}$	$E_{daughter}(^{235}\mathrm{U})^{@@@}$	coincident γ-rays (keV) ^{@@@}	HF
4.950(9)	4.867(9)	$2.7(10) \times 10^{-3}\%$	$1.9(7) \times 10^{-3}\%$	13/2+	0.2946	13.0, 30.0, 38.7, 51.6, 68.7, 69.0, 97.6, 98.8, 115.3, 144.2	$1.2^{+0.7}_{-0.3}{\times}10^3$
4.995(9)	4.911(9)	3.4(13)×10 ⁻³ %	2.4(9)×10 ⁻³ %	15/2-	0.2500	3.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 57.8, 69.0, 77.6, 78.8, 89.6, 103.1, 116.3, 116.3, 119.7, 129.3, 123.2, 146.3, 158.1, 171.4	$1.9^{+1.2}_{-0.5} \times 10^3$
5.018(9)	4.934(9)	8.5(14)×10 ⁻³ %	6(1)×10 ⁻³ %	9/2+	0.2254	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 54.0, 69.0, 77.6, 89.6, 96.1, 116.3, 119.7, 129.3, 123.2, 143.4, 158.1, 171.4, 173.7, 179.2, 225.4	$1.14^{+0.23}_{-0.16} \times 10^3$
5.046(9)	4.962(9)	0.010(1)%	$7(1) \times 10^{-3}\%\%$	$11/2^{+}$	0.1971	13.0, 30.0, 38.7, 51.6, 69.0, 115.3	$1.5^{+3}_{-2} \times 10^3$
5.074(9)	4.989(9)	0.018(3)%	0.013(2)%	7/2+	0.1714	13.0, 30.0, 38.7, 41.9, 46.2, 47.6, 51.6, 69.0, 77.6, 89.6, 116.3, 119.7, 123.2, 129.3, 158.1, 171.4	1.2(2)×10 ³
5.094(9)	5.009(9)	0.024(3)%	0.017(2)%	9/2+	0.1504	13.0, 30.0, 38.7, 51.6, 68.7, 69.0 98.8	$1.25^{+0.17}_{-0133} \times 10^3$
5.117(9)	5.031(9)	0.013(42%)	$9.4(3) \times 10^{-3}\%$	5/2+	0.1293	13.0, 30.0, 38.7, 47.6, 51.6, 69.0 77.6, 116.3, 129.3	$3.1(1) \times 10^3$
5.141(9)	5.055(9)	0.066(18)%	0.047(13)%	$11/2^{-}$	0.1039	46.2, 57.8, 103.1	$910^{+350}_{-200}$
5.162(9)	5.076(9)	0.11(1)%	0.078(8)%	7/2+	0.0817	13.0, 30.0, 38.7, 51.6, 69.0	$760_{-70}^{+90}$
5.1927(8)	5.1058(8)@	16.87(10)%	11.94(7)%	$5/2^{+}$	0.0517	13.0, 38.7, 51.6	7.68(5)
5.2319(8) 5.24436(14)	5.1443(8) [@] 5.15659(14)***	24.18(20)% 100.0(2)%	17.11(14)% 70.77(14)%	3/2 ⁺ 1/2 ⁺	0.0130 0.000076	13.0	9.40(8) 2.74(1)

* Weighted average of 24060(16) y [1975A115], 24131(16) y [1978Ja20], 24101(20) y [1978Se12], 24089(13) y and 24019(21) [1978Pr07].

** Values from[1993Ga28], except where noted.

*** Value from [1980RyZX], adjusted by -0.11 keV as recommended by [1991Ry01].

[@] Value from [1968Ba25], adjusted by +1.0 keV as recommended by [1991Ry01].

@@ [1966Ah02]. @@@ [2014Br18].

^{*a*}  $R_0$  (fm) = 1.51188(12).

^b Deduced from  $\gamma$  energies [1976GuZN] and  $Q_{\alpha} = 5244.43(14)$  keV, using the levels and transitions from [2014Br18]. Conversion electron strength and strength from unobserved  $\gamma$ 's (in [1976GuZN]) decaying from a given level are taken into account.

Table 8			
direct $\alpha$ emission from	243 Cm, $J^{\pi} = 5/2^+$	$T_{1/2} = 29.20(14) \text{ y}$	*, $BR_{\alpha} = 99.97(3)\%$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^{\pi}$	$E_{daughter}(^{239}\mathrm{Pu})$	coincident $\gamma$ -rays (keV) ^{@@}	HF ^a
5.355(3)	5.267(3)***	0.002%	0.0015%***		0.813(3)		60
5.405(3)	5.316(3)***	0.001%	0.001%***		0.763(3)		180
5.412(3)	5.323(3)***	0.004%	0.003%***		0.756(3)		67
5.421(3)	5.332(3)***	0.004%	0.003%***		0.747(3)		76
5.615(3)	5.523(3)***	0.003%	0.002%***		0.552(3)		$1.6 \times 10^{3}$
5.625(3)	5.532(3)***	0.008%	0.006%***		0.543(3)		610
5.630(3)	5.537(3)***	0.003%	0.002%***		0.538(3)		$2.0 \times 10^{3}$
5.661(3)	5.568(3)***	0.010%	0.007%***	$(5/2^{-})$	0.5056(2)@@	49.4, 57.3, 67.8, 430.0, 448.3, 505.6	850
5.668(3)	5.575(3)***	0.010%	0.007%***		0.499(3)		930
5.675(3)	5.582(3)***	$\approx 0.012\%$	$\approx 0.009\%^{***}$	3/2-	0.4921(3)@@	49.4, 57.3, 434.7, 484.3, 492.3	$\approx 790$
5.681(3)	5.587(3)***	$\approx 0.027\%$	$\approx 0.02\%$	$(11/2^{-})$	0.487(3)		≈380
5.687(2)	5.593(2) [@]	0.041(10)%	0.03(1)%@		0.481(3)		$270^{+140}_{-70}$
5.703(3)	5.609(3)***	0.014%	0.01%***		0.465(3)		$1.0 \times 10^{3}$
5.706(3)	5.612(3)***	$\approx 0.055\%$	$\approx 0.04\%^{***}$	$(11/2^+)$	0.462(3)		$\approx 260$
5.716(3)	5.622(3)***	0.082%	0.06%***		0.452(3)		200
5.780(2)	5.685(2) ^{@ @}	2.25(28)%	1.65(20)%@	9/2+	0.3874 ^{@@}	44.7, 49.4, 57.3, 67.8, 88.1, 102.0, 106.5, 166.3, 209.8, 228.1, 254.4, 272.9, 277.6, 322.3, 285.5, 311.7	$16.5^{+2.4}_{-1.9}$
5.8382(9)	5.7421(9)	16.80(97)%	12.3(6)%	7/2+	0.3301@@	44.7, 49.4, 57.3, 67.8, 88.1, 106.5, 166.3, 209.8, 228.1, 254.4, 272.9, 277.6, 322.3, 285.5	4.53(24)
5.8820(9)	5.7852(9)	100.0(44)%	73.2(23)%	5/2+	0.2855@@	49.4, 57.3, 67.8, 209.8, 228.1, 277.6, 285.5	1.32(4)
6.0921(15)	5.9918(15)	7.79(37)%	5.7(2)%	$7/2^{+}$	0.0757@@	67.8	209(8)
6.158	6.057	6.83%	5%	$3/2^{+}$	$0.0078^{@@}$		570
6.1677(17)	6.0662(17)	2.05(28)%	1.5(2)%	$1/2^{+}$	0.00		$1.9^{+3.1}_{-2.4} \times 10^3$

* [1986Ti03].

** [1958Ch38].

*** From [1966Ba07],  $E_{\alpha}$ (lab) is adjusted by +0.4 keV as recommended by [1991Ry01]. ^(a) Weighted average of values from [1963Dz07] (adjusted by -1.5 keV [1991Ry01]) and [1966Ba07] (adjusted by +0.4 keV [1991Ry01]).  $I_{\alpha}$ (abs) taken from [1963Dz07]. @@ [2014Br13]. @@@ Recommended by [1991Ry01] based on the adjusted values of [1957As70], [1963Dz07] and [19Ba07].

# Table 9

direct  $\alpha$  emission from ²⁴⁷Cf*,  $J^{\pi} = (7/2^+)$ ,  $T_{1/2} = 3.11(3)$  h,  $BR_{\alpha} = 0.035(5)\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{243}\mathrm{Cm})$	coincident γ-rays (keV)	R ₀ (fm)	HF
6.341(6) 6.400(5)	6.238(6) 6.296(5)	5(1)% 100%	5(1)% 95(3)%				1.4903(17) 1.4903(17)	$16^{+5}_{-3} \\ 1.56^{+0.31}_{-0.24}$

* All values from [1984Ah02].

# **Table 10** direct $\alpha$ emission from ²⁵¹Fm*, $J^{\pi} = (7/2^+)$ , $T_{1/2} = 5.30(8)$ h, $BR_{\alpha} = 1.80(13)\%^{**}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{247}\mathrm{Cf})$	coincident γ-rays (keV)	$R_0$ (fm)	HF
6.687(3)	6.58(3)	0.30(5)%	$4.7(8) \times 10^{-3}\%$	$(9/2^{-})$	0.738	55.0, 683	1.4730(28)	$39^{+9}_{-7}$
6.747(3)	6.639(3)	0.64(7)%	0.010(1)%	$(7/2^{-}+)$	0.678	55.0, 623.0, 678.0	1.4730(28)	$34^{+6}_{-5}$
6.790(4)	6.682(4)	0.08(3)%	$1.3(5) \times 10^{-3}\%$	$(13/2^+)$	0.634		1.4730(28)	$430^{+340}_{-140}$
6.830(3)	6.721(3)	0.51(5)%	$7.9(9) \times 10^{-3}\%$	$(13/2^{-})$	0.594		1.4730(28)	$103_{-15}^{+180}$
6.873(3)	6.763(3)	0.44(7)%	6.68(12)×10 ⁻³ %	$(11/2^+)$	0.552	55.0, 496	1.4730(28)	$180^{+50}_{-30}$
6.893(2)	6.783(2)	5.52(24)%	0.086(7)%	$(11/2^{-})$	0.5320	55.0, 67.1, 122.1, 331.0, 410.0, 477.0	1.4730(28)	17.7(21)
6.945(2)	6.834(2)	100%	1.6(1)%	$(9/2^{-})$	0.4804	55.0, 67.1, 122.1, 358.3, 425.4, 480.4	1.4730(28)	1.63(18)
6.998(2)	6.886(2)	1.95(12)%	0.031(3)%	$(7/2^+)$	0.4272	55.0, 372.2	1.4730(28)	141(17)
7.041(2)	6.929(2)	2.07(12)%	0.0320(3)%	$(5/2^+)$	0.383	383.2	1.4730(28)	205(24)
7.222(5)	7.107(5)	$\approx 0.06$	$\approx 9 \times 10^{-4} \%$	$(13/2^+)$	0.202		1.4730(28)	$\approx$ 4.2 $\times$ 10 ⁴
7.301(3)	7.185(3)	0.33(3)%	$5.2(7) \times 10^{-3}\%$	$(11/2^+)$	0.1221	55.0, 67.1, 122.1	1.4730(28)	$1.5^{+0.3}_{-0.2} \times 10^4$
7.369(3)	7.252(3)	1.07(9)%	0.017(2)%	$(9/2^+)$	0.0550	55.0	1.4730(28)	$8.6^{+1.4}_{-1.1} \times 10^3$
7.424(3)	7.306(3)	1.7(2)%	0.027(3)%	$(7/2^+)$	0.0		1.4730(28)	$8.7(11) \times 10^3$

* All values from [1973Ah02], except where noted.

** [1978Ah02].

#### Table 11

direct  $\alpha$  emission from ²⁵⁵No*,  $J^{\pi} = (1/2^+)$ ,  $T_{1/2} = 3.52(18)$  m,  $BR_{\alpha} = 30(5)\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{251}\mathrm{Fm})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
7.825(5)	7.702(5)	9(2)%	0.81(22)%	$(5/2^+)$	0.604(4)		1.4717(26)	$18^{+9}_{-5}$
7.849(6)	7.726(6)	9.1(29)%	0.81(29)%	$(3/2^+)$	0.579(5)		1.4717(26)	$22_{-7}^{+14}$
7.871(3)	7.748(3)	62(5)%	5.5(10)%	$(1/2^+)$	0.5887	163.3, 166.7, 191.9, 195.3, 200.1, 358.5	1.4717(26)	$3.0_{-0.6}^{+0.9}$
7.967(4)	7.842(4)	14.4(22)%	1.29(29)%	$(5/2^+)$	0.461(3)		1.4717(26)	$37^{+10}_{-8}$
8.035(3)	7.909(3)	56(4)%	5.1(9)%	$(3/2^+)$	0.3954	191.9, 195.3, 200.1	1.4717(26)	$16^{+5}_{-3}$
8.129(4)	8.001(4)	22.8(26)%	2.04(41)%	(9/2+)	0.301(3)		1.4717(26)	$84_{-19}^{+28}$
8.185(4)	8.057(4)	34.7(31)%	3.11(59)%	$(7/2^+)$	0.243(3)		1.4717(26)	$87^{+27}_{-19}$
8.229(3)	8.100(3)	100(5)%	9.0(16)%	$(5/2^+)$	0.2001	200.1	1.4717(26)	$42_{-9}^{+12}$
8.364(4)	8.233(4)	23.1(26)%	2.07(42)%	$(11/2^{-})$	0.0639	63.9	1.4717(26)	$520_{-110}^{+170}$
8.428(6)	8.296(6)	4.0(12)%	0.36(12)%	(9/2 ⁻ )	0.0		1.4717(26)	$4.9^{+3.0}_{-1.5} \times 10^3$

* All values from [2011As02].

#### Table 12

direct  $\alpha$  emission from ²⁵⁹Rf*,  $J^{\pi} = (1/2^+)$ ,  $T_{1/2} = 2.4(4) \text{ s**}$ ,  $BR_{\alpha} = 92.1(23)\%^{***}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$ $J_{f}^{\pi}$	$E_{daughter}(^{255}No)$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
8.908(10)	8.770(10)	100%	55%	x + 101 keV		1.481(16)	3.1
9.009(10)	8.870(10)	67%	37%	x		1.481(16)	9

* All values from [1981Be03], except where noted.

** Weighted average of 3.2(8) s [1973Dr10], 3.0(1.3) s [1981Be03], 3.4(17) s [1985So03],  $1.7^{+0.8}_{-0.5}$  s [1994Gr08],  $2.2^{+17}_{-0.8}$  s [2004Fo08] and  $1.9^{+1.3}_{-0.5}$  s [2006Gr24]. *** Weighted average of 6.3(37)% [1981Be03] and 9(3)% [1985So03] for BR_{SF}.  $\alpha$ -decay is expected to be the rest of the decay strength.

Table 13direct $\alpha$ emission	able 13 irrect $\alpha$ emission from ²⁶³ Sg*, T _{1/2} = 0.9(2) s, $BR_{\alpha}$ = 87(8)%**.									
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{259}\mathrm{Rf})$	coincident γ-rays (keV)	R ₀ (fm)	HF			

1.466(30)

 $0.9^{+1.0}_{-0.5}$ 

9.200(40) 9.060(40)

* All values from [1974Gh04], except where noted.

** [2006Gr24].

uneet a enns	sion nom – Sg	$^{\circ}$ , EX. = ulik., 1	$1/2 = 500_{-100}$	Ins, $BR_{\alpha} = \sim 100 \ \%$ .				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{259}\mathrm{Rf})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF	
9.393	9.250					1.466(30)	1.7	
* All value	ues from [2006N	i10].						
<b>Table 15</b> direct $\alpha$ emiss	sion from ²⁶⁷ Hs*	, $T_{1/2} = 0.80^{+3.0}_{-0.0}$	$^{80}_{37}$ s, $BR_{\alpha} = 10$	0%.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{263}Sg)$	coincident $\gamma$ -rays (keV)	$R_0$ (fm)	HF	
10.00	9.85					1.470(30)	28	
* All valu	ues from [2004M	[040].						
Table 16 direct $\alpha$ emiss	sion from ^{267m} Hs	*, Ex. = unk., T	$_{1/2} = 52^{+13}_{-8}$ m	s, $BR_{\alpha} = 100\%$ .				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{263}\mathrm{Sg})$	coincident $\gamma$ -rays (keV)	$R_0$ (fm)	HF	
9.88	9.73					1.470(30)	0.9	
* All valu	ues from [2004M	[040].						
<b>Table 17</b> direct $\alpha$ emiss	sion from ²⁷¹ Ds*	, $T_{1/2} = 1.63^{+0.0}_{-0.0}$	$^{44}_{29} \text{ ms}, BR_{\alpha} = 1$	00%.				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{267}\text{Hs})$	coincident γ-rays (keV)	R ₀ (fm)	HF	
10.87	10.71							
* All valu	ues from [2015M	[025].						
<b>Table 18</b> direct $\alpha$ emiss	sion from ^{271m} Ds	*, Ex. = unk., T	$_{1/2} = 69^{+56}_{-21} \text{ ms}$	s, $BR_{\alpha} = 100\%$ .				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi} = E_{daughter}$	$r(^{267}\text{Hs})$ coincident $\gamma$ -rays	s (keV) R	R ₀ (fm)	HF
10.06 10.61 10.89	9.91 10.45 10.73	13% 63% 100%	7% 36% 57%					

direct  $\alpha$  emission from ^{263m}Sg*, Ex. = unk., T_{1/2} = 560⁺¹⁶⁰₋₁₀₀ ms, BR_{$\alpha$} =  $\approx$  100%.

* All values from [2015Mo25].  $I_{\alpha}$  is based on the 14 events reported therein.

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 $\begin{array}{c} 2^{73}Rg \\ Q_{0}\alpha = & 12.651\,MeV \\ Q_{0}\alpha = & 12.651\,MeV \\ Q_{0}\alpha = & 11.1611\,MeV \end{array}$ 







Last updated 1/14/25

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +51/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values for XX are taken from ENSDF.

Nucled         Ex. $J^{\mu}$ $I_{1/2}$ $Q_{\varepsilon}$ $Q_{\beta}^{-}$ $Q_{\beta}^{-}\alpha$ Experimental 209 Au*         > 300 ns         6.38(43)#         8.35(50)#         8.35(50)#         [2010A124] 213 Tl*         (1/2 ⁺ )         23.8(44) s         -6.42(30)#         4.987(28)         8.15(15)         [2017Ca12] 217 Bi*         (9/2 ⁻ )         98.5(8) s         -3.53(30)#         2.847(19)#         9.689(19)         [2003Ku25]	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	
$^{217}\text{Bi}^*$ (9/2 ⁻ ) 98.5(8) s -3.53(30)# 2.847(19)# 9.689(19) [2003Ku25]	
221 At* 2.3(3) m -2.991(24) 2.311(15) 8.655(16) <b>[1989Bu09</b> ]	
225 Fr* $3/2^-$ 4.0(2) m -2.714(16) 1.828(12) 7.105(13) [1983Ny01]	
$\frac{1}{229}$ Ac* (3/2 ⁺ ) 62.7(5) m -1.872(20) 1.104(12) 6.452(12) [1973 Ch24]	
233 Pa* $3/2^-$ 26.975(13) d -1.242(1) 0.570(2) 5.659(3) [2000Us01]	
237 Np $5/2^+$ $2.144(7) \times 10^6$ y $-0.519(1)$ $-0.220(1)$ [1992Lo03]	
237m Np 2.850(40) 40(12) ns 2.331(40) 2.630(40) 8.558(40) [1973Wo03]	
$^{-241}$ Am $5/2^{-}$ 432.0(2) y -0.021 -0.767(1) [1975Ra35]	
$2^{241m}$ Am 2.5(1) 1.0(3) $\mu$ s 2.5(1) 1.7(1) [1969La14, 1993Ku1	5]
$Q_{\varepsilon p}$ $Q_{\varepsilon \alpha}$	
245 Bk $^{3/2^-}$ $^{4.90(3)}$ d $^{0.809(2)}$ $^{-5.354(2)}$ $^{6.434(2)}$ [1976Ah03]	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	
249 Es $7/2^+$ 1.7(1) h 1.450(30)# -4.245(58)# 7.745(30)# [1970Ah01]	
²⁵³ Md $7/2^ 6.4^{+11.6}_{-3.6}$ m $1.830(30)$ # $-3.411(59)$ # $9.026(32)$ # [1992Ka08]	
1000000000000000000000000000000000000	
$\frac{261}{\text{Db}} \qquad 1.8(6) \text{ s} \qquad 2.99(13)\# \qquad -1.26(17)\# \qquad 11.64(11)\# \qquad [1971F102]$	
265 Bh $0.94^{+0.70}_{-0.31}$ s $3.60(28)$ # $-0.16(34)$ # $12.65(25)$ # <b>[2004Ga29</b> ]	
²⁶⁹ Mt 4.81(34)# 1.30(49)# 14.08(34)#	
273 Rg $4.60(42)$ # $2.11(63)$ # $15.97(42)$ #	

* 100%  $\beta^-$  emitter.

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +51/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	Experimental
209 🗛 11	9.02(57)#	0.95(64)#			
213TI	8 53(30)#	1.60(40)#			
217 Bi	6.07(20)#	4.521(32)			
221 A t	5.770(23)	5 628(23)			
225 Er	5.770(25) 5.913(15)	4 613(18)			
229 A c	5 530(12)	4.013(10)			
233 Do	5.339(12) 5.246(1)	4.444(17)			
237 Nn	J.240(1) 4 8622(3)	4.373(12)	100%		[2002Wa03 2008Da10 2000Lu01 2000Sc04 2000Wa01 1002La03
мр	4.8022(3)	4.937(1)	100 //		$1002M_{0}03$ , $1000B_{0}44$ , $1000L_{0}04$ , $1088W_{0}01$ , $1081B_{2}68$ , $1070G_{0}12$
					1992M003, 1990B044, 1990E004, 1988W001, 1981Ba00, 1979C012, $1076B_{2}77, 1076Sk01, 1075P_{2}71, 1070C111, 1060V_{2}06, 1060H_{2}7Y$
					$1968B_{2}25$ 1968Ob02 1961B_244 1960Br12 1955St04 1949M_201
					1940Se711 1948Ma16 1948Wa041
^{237m} Np	$-2\ 102(40)$	7 807(40)		0.19%	[ <b>1977Mi09</b> 1973Wo03]
241 Am	4 4800(2)	5.6378(1)	100%	$3.6(6) \times 10^{-10}\%$	[1971Gr17, 1970Go26, 1968Go26, 1963Ba65, 1964Ba26, 2021Ta23
7 1111	1.1000(2)	5.0570(1)	10070	5.0(0)/10 //	$2020Y_{0}01 = 2016Di11 = 2010M_{0}01 = 1998Y_{2}17 = 1994B112 = 1993K_{1}16$
					1992E110 1986Pa17 1978Ge06 1978Ge17 1978Ov01 1977VaZW
					1975Ra35, 1974Po16, 1972Jo07, 1971Cl02, 1970Ga27, 1969KaZR,
					1968Ka09, 1968St02, 1966Ko06, 1966Le13, 1965Ar09, 1964Ka29.
					1964Wo03, 1963Ba35, 1963Pa06, 1962Ba51, 1962Le11, 1961Dr03,
					1957Ha10, 1957Ro20, 1956Go43, 1955Go57, 1954As05, 1953AsZZ.
					1952As04, 1952As40, 1952Be47, 1952Ha68]
^{241m} Am	2.0(1)	8.1(1)		100%	[1969La14, 1993Ku16
²⁴⁵ Bk	3.927(1)	6.455(1)	0.12(1)%		[1974Po08, 1976Ah03, 1975Ba25, 1966Ah01, 1966Ah02, 1956Ch77,
		~ /	~ /		1956Ma32, 1951Hu391
^{245m} Bk	3.927(1)-x	6.455(1)+x		obs	[ <b>1971Re11</b> , 1972Ga42, 1970ReZN]
²⁴⁹ Es	3.352(31)#	6.936(30)	0.7(1)%		[1989Ha27, 1970Ah01, 1989HaZG, 1976Ah07, 1956Ha80]
²⁵³ Md	2.933(32)#	7.573(8)	≈0.7%		[2012He09, 2005He27, 2011An13, 1992Ka08]
²⁵⁷ Lr	2.447(45)#	9.068(31)#	$\approx 100\%^{***}$		[1997He29, 1971Es01, 2010AsZY, 2009Qi04, 2009QiZZ, 2004Ga29,
					1976BeYM, 1971EsZX]
²⁶¹ Db	2.13(23)#	9.22(10)#	>82%	obs	[1998La30, 1971Fl02, 1971Gh01, 2013AsZZ, 2004Ga29, 1971Dr01,
	× /	× /	—		1971FIZV]
²⁶⁵ Bh	1.68(37)#	9.66(21)#	100%		[2004Ga29]
²⁶⁹ Mt	0.96(43)#	10.48(20)#			
²⁷³ Rg	0.49(58)#	11.16(25)#			
0	. ,				

* Deduced from the weighted average of the partial half=life for SF of  $1.29(3) \times 10^{14}$  y [1968Go26] and  $1.15(2) \times 10^{14}$  y [1970Go96] (reported as  $\lambda_F = 6.04(13) \times 10^{-15}$  y. ** Weighted average of  $1.50(60) \ \mu$ s [1969La14] and  $0.9(3) \ \mu$ s [1993Ku16]. *** [1971Es01] report an upper limit for electron capture of 15%.

Table 3	
lirect $\alpha$ emission from ²³⁷ Np*, $J^{\pi} = 5/2^+$ , $T_{1/2} = 2.144(7) \times 10^6$ y, $BR_{\alpha} = 100\%$	

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi**}$	E _{daughter} ( ²³³ Pa)**	coincident γ-rays (keV)**	HF
4.5926(19)	4.5151(19)	0.073(8)%	0.035(4)%	9/2+	0.3659	6.7, 17.4, 22.6, 29.4, 46.5, 54.4, 57.1, 63.9, 70.5, 86.5, 108.7, 106.1, 109.1, 117.7, 141.7, 153,4, 155.2, 186,7, 202.9, 212.3, 257.1, 262.4, 279.7	$58^{+8}_{-6}$
4.6283(22)	4.5502(22)	0.023(6)%	0.011(3)%		0.3280(26)*		$360^{+140}_{-80}$
4.6511(26)	4.5726(26)	0.101(48)%	0.048(23)%	(7/2 ⁻ )	0.3060(1)	8.2, 17.4, 29.4, 46.5, 49.0, 57.1, 86.5, 88.0, 94.7, 115.4, 131.1, 153.5, 162.5, 170.9, 186.8, 195.0, 201.7, 219.8, 248.9, 250.5, 257.4	$120^{+110}_{-40}$
4.6572(14)	4.5786(14)	0.775(48)%	0.369(23)%	7/2+	0.3005	5.7, 8.2, 17.4, 22.6, 29.4, 36.2, 46.5, 57.1, 62.6, 63.9, 70.5, 86.5, 88.0, 94.7, 115.4, 131.1, 134.7, 143.2, 151.4, 180.9, 191.4, 195.0, 196.9, 201.7, 214.0, 229.9, 237.9	17.1(11)
4.6781(18)	4.5991(18)	0.779(19)%	0.371(9)%	(7/2+)	0.2797	5.7, 17.4, 22.6, 29.4, 46.5, 57.1, 63.9, 70.5, 86.5, 170.6, 176.1, 193.2, 209.2, 222.6	24.2(6)
4.6990(21)	4.6197(21)	0.067(17)%	0.032(8)%	5/2-	0.2572	8.2, 17.4, 29.4, 46.5, 57.1, 86.5, 88.0, 94.7, 115.4, 131.1, 153.5, 162.5, 170.9, 186.8, 195.0, 201.7, 250.5, 257.4	$410^{+140}_{-80} \times 10^3$
4.7197(10)	4.6400(10)	13.50(7)%	6.43(3)%	5/2+	0.2379	8.2, 17.4, 29.4, 36.2, 46.5, 57.1, 86.5, 88.0, 94.7, 115.4, 131.1, 134.7, 143.2, 151.4, 180.9, 195.0, 201.7, 237.9	2.82(4)
4.7451(9)	4.6650(9)	7.301(51)%	3.478(24)%	5/2+	0.2123	6.7, 17.4, 29.4, 46.5, 57.1, 63.9, 70.5, 86.5, 108.7, 117.7, 141.7, 155.2, 212.3	2.97(10)
4.7609(18) 4.7789(8)	4.6805(18) 4.6982(8)	0.042(8)% 1.123(21)%	0.020(4)% 0.535(10)%		0.1955(23)* 0.1775(16)*		$\begin{array}{c} 1.8^{+0.5}_{-0.3} \times 10^{3} \\ 92(4) \end{array}$
4.7917(7)	4.7108(7)	2.464(27)%	1.174(13)%	$(11/2^{-})$	0.1633	22.6, 29.4, 54.4, 57.1, 86.5, 106.1	52.9(8)
4.8483(8)	4.7665(8)	19.56(61)%	9.32(29)%	9/2+	0.1091	22.6, 29.4, 57.1, 86.5	16.0(5)
4.8533(8)	4.7714(8)	48.59(61)%	23.15(29)%	7/2+	0.1037	17.4, 29.4, 46.5, 57.1, 86.5	7.02(11)
4.8702(9)	4.7880(9)	100.0(2)%	47.64(6)%	5/2+	0.0865	29.4, 57.1, 86.5	4.49(5)
4.8860(10)	4.8035(10)	4.228(36)%	2.014(17)%	5/2-	0.0705	5.7, 63.9, 70.5	136.9(18)
4.8995(10)	4.8168(10)	5.101(36)%	2.430(17)%	7/2-	0.0571	57.1	119.7(15)
4.9073(36)	4.8245(36)	0.029(23)%	0.014(11)%		0.0490(39)*		$3^{+10}_{-1} \times 10^{4}$
4.9321(49)	4.8489(49)	0.013(8)%	0.006(4)%		0.0242(51)*		$1.0^{+1.9}_{-0.4} \times 10^{-3}$
4.9499(14)	4.8664(14)	1.11(8)%	0.53(4)%	1/2-	0.0067	6.7	$1.41(13) \times 10^3$
4.9564(14)	4.8727(14)	5.02(8)%	2.39(4)%	3/2-	0.00		348(10)

* All values from [2002Wo03], except where noted. ** [2020Si28]. ***  $R_0 = 1.51670(40)$  fm.

Table 4		
direct $\alpha$ emission from ²⁴¹ Am*, $J^{\pi} = 5/2^{-@}$	, $T_{1/2} = 432.0(2) y^{**}$ ,	$BR_{\alpha} = 100\%$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi @}$	<i>E</i> _{daughter} ( ²³⁷ Np) [@]	coincident $\gamma$ -rays (keV) [@]	HF ^{@@}
4.881	4.800	$1.0 \times 10^{-4}\%$	$8.6 \times 10^{-5}\%$	7/2-	0.756	26.3, 27.9, 33.2, 42.7, 43.4, 55.6, 59.5, 69.8, 75.9, 99.0, 103.0, 125.3, 597.5, 653.0, 680.1, 696.6, 722.0, 755.9	48
4.916	4.834	8×10 ⁻⁴ %	$7 \times 10^{-4}$ %	5/2-	0.722	26.3, 27.9, 33.2, 42.7, 43.4, 55.6, 59.5, 69.8, 75.9, 99.0, 103.0, 125.3, 164.6, 208.0, 234.4, 267.5, 454.7, 563.1, 619.0, 662.4, 677.7, 722.0	10.1
5.089	5.004	$1.2 \times 10^{-4}\%$	$1 \times 10^{-4}\%$	(5/2-)	0.546	26.3, 27.9, 33.2, 42.7, 43.4, 59.5, 69.8, 75.9, 103.0, 164.6, 208.0, 234.4, 267.5, 278.0, 512.5, 545.5	$1.1 \times 10^{3}$
5.154	5.068	$1.6 \times 10^{-4}\%$	$1.4 \times 10^{-4}\%$	(9/2-)	0.486	26.3, 27.9, 33.2, 42.7, 43.4, 55.6, 59.5, 67.5, 69.8, 75.9, 99.0, 103.0, 123.0, 125.3, 150.0, 161.5, 165.8, 221.5, 249.0,250.8, 264.9, 291.3	$2.0 \times 10^{3}$
5.175	5.089	$\approx$ 5 $\times$ 10 ⁻⁴ %	$\approx 4 \times 10^{-4}\%$	$7/2^{+}$	0.460	33.2, 42.7, 75.9, 383.8, 426.5, 459.7	$\approx 1.3 \times 10^3$
5.182	5.096	$\approx 5 \times 10^{-4}\%$	$\approx$ 4.×10 ⁻⁴ %	9/2+	0.453	33.2, 42.7, 54.0, 75.9, 97.1 115.5, 260.8, 322.5, 376.7, 419.3, 452.6	$1.3 \times 10^{3}$
5.200	5.114	05×10 ⁻⁴ %	$4 \times 10^{-4}$ %	(11/2 ⁻ )	0.434	26.3, 27.9, 33.2, 42.7, 43.4, 54.0, 55.6, 59.5, 69.8, 75.9, 97.1, 99.0, 103.0, 109.7, 125.3, 146.6, 165.8, 175.1, 221.5, 249.0, 264.9, 275.8, 291.3, 304.2, 358.3	$1.5 \times 10^{3}$
5.243	5.156	08×10 ⁻⁴ %	$7 \times 10^{-4}$ %		0.396	26.3, 27.9, 33.2, 42.7, 43.4, 55.6, 59.5, 67.5, 69.8, 75.9, 99.0, 103.0, 115.0, 123.0, 125.3, 150.0, 169.6, 204.0	$1.5 \times 10^{3}$
5.265	5.178	$3 \times 10^{-4}$ %	$3 \times 10^{-4}\%$	3/2+	0.371	33.2, 337.7, 370.9	$4.9 \times 10^{3}$
5.270	5.182	$1.0 \times 10^{-3}\%$	$9 \times 10^{-4}\%$	5/2+	0.369	26.3, 33,2, 42.7, 59.5, 75.9, 292.8, 309.1, 335.4, 368.6	$1.7 \times 10^{3}$
5.282	5.194	$7 \times 10^{-4}\%$	$6 \times 10^{-4}\%$	$(5/2^{-})$	0.360	26.3, 33,2, 59.5, 300.1	$2.9 \times 10^{3}$
5.311	5.223	$1.5 \times 10^{-3}\%$	1.3×10 ⁻³ %	(7/2-)	0.324	26.3, 27.9, 33.2, 42.7, 43.4, 55.6, 59.5, 69.8, 75.9, 99.0, 103.0, 125.3, 165.8, 221.5, 249.0, 264.9, 291.3	$2.2 \times 10^{3}$
5.333	5.244	2.8×10 ⁻³ %	2.4×10 ⁻³ %	13/2-	0.305	26.3, 27.9, 33.2, 42.7, 43.4, 54.0, 55.6, 59.5, 69.8, 75.9, 97.1, 99.0, 103.0, 125.3, 146.6, 175.1	$1.6 \times 10^{3}$
5.368	5.279	$6 \times 10^{-4}\%$	$5 \times 10^{-4}\%$	3/2-	0.268	26.3, 27.9, 33.2, 42.7, 43.4, 59.5, 69.8, 75.9, 103.0, 164.6, 208.0, 234.4, 267.5	$1.3 \times 10^{4}$
5.412	5.322	0.017%	0.015%	11/2-	0.226	26.3, 27.9, 33.2, 42.7, 43.4, 55.6, 59.5, 67.5, 69.8, 75.9, 99.0, 103.0, 123.0, 125.3, 150.0	760
5.480	5.389	1.55%	1.33%	9/2-	0.159	26.3, 27.9, 33.2, 42.7, 43.4, 55.6, 59.5, 69.8, 75.9, 99.0, 103.0, 125.3	22
5.508	5.417	$\approx 0.01\%$	$\approx 0.01\%$	$11/2^{+}$	0.130	33.2, 42.7, 54.0, 75.9, 97.1	$\approx$ 4.2 $\times$ 10 ³
5.53466(13)	5.44280(13)***	14.8%	12.7%	7/2-	0.103	26.3, 27.9, 33.2, 42.7, 43.4, 59.5, 69.8, 75.9, 103.0	4.8
5.561	5.469	< 0.05%	<0.04%	9/2+	0.076	33.2, 42.7, 75.9	$>2.2\times10^{3}$
5.57814(12)	5.48556(12)***	100%	86%	5/2-	0.060	26.3, 33,2, 59.5	1.25
5.606	5.513	0.14%	0.12%	7/2+	0.033	33.2	$1.3 \times 10^{3}$
5.639	5.545	0.29%	0.25%	$5/2^{+}$	0.0		940

* All values from [1963Ba65, 1964Ba26], except where noted. ** [1975Ra35]. *** [1971Gr17]. @ [2006Ba41]. @@ R₀ = 1.508784(84) fm.

Table 5					
direct $\alpha$ emission from	$^{245}\mathrm{Bk*}, J^{\pi}$	$= 3/2^{-}, T_{1}$	$/2 = 4.90(3) d^{3}$	**, $BR_{\alpha} =$	0.12(1)%**

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	$E_{daughter}(^{241}\mathrm{Am})$	coincident γ-rays (keV)***	R ₀ (fm)	HF
5.905(4)	5.809(4)	4.2(5)%	0.1(2)%	7/2-	0.549(6)	41.2, 77.0, 455.9, 471.8, 510.0	1.49673(49)	18(3)
5.951(4)	5.854(4)	19.1(10)%	0.49(5)%	5/2-	0.503(6)	32.6, 41.2, 164.8, 205.9, 298.6,	1.49673(49)	7.0(9)
						410.8, 463.3, 504.5		
5.963(4)	5.866(4)	100(3)%	2.6(2)%		0.491(6)		1.49673(49)	1.5(2)
6.079(5)	5.980(5)	4.1(1)%	0.11(1)%		0.375(6)		1.49673(49)	153(19)
6.135(4)	6.035(4)	2.6(4)%	0.07(1)%	$11/2^{+}$	0.319(6)	41.2, 116.4, 162.4	1.49673(49)	$470^{+110}_{-80}$
6.183(4)	6.082(4)	29(2)%	0.74(7)%		0.271(6)		1.49673(49)	72(9)
6.220(4)	6.118(4)	70.7(28)%	1.82(16)%	$7/2^{+}$	0.235(6)	139.9	1.49673(49)	44(6)
6.248(4)	6.146(4)	85.1(31)%	2.20(19)%	5/2+	0.206(6)	41.2, 164.8, 205.9	1.49673(49)	51(6)
6.296(4)	6.193(4)	5.6(5)%	0.14(2)%	$11/2^{-}$	0.159(6)	41.2, 116.4	1.49673(49)	$1.3(2) \times 10^3$
6.362(4)	6.258(4)	7.0(5)%	0.18(2)%	9/2-	0.093(6)		1.49673(49)	$2.2(3) \times 10^3$
6.414(4)	6.309(4)	69.8(26)%	1.80(16)%	$7/2^{-}$	0.041(6)	41.2	1.49673(49)	390(50)
6.454(4)	6.349(4)	72.1(29)%	1.86(17)%	5/2-	0.0		1.49673(49)	590(60)

* All values from [1974Po08], except where noted.  $E_{\alpha}$  values are adjusted by +1.0 keV as recommended in [1991Ry01].

** [1976Ah03]. *** [2015Ne16].

#### Table 6

direct  $\alpha$  emission from ²⁴⁹Es*, T_{1/2} = 1.7(1) h**, BR_{$\alpha$} = 0.7(1)%**.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{245}\mathrm{Bk})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
6.826(12) 6.887(2)	6.716(12) 6.776(2)	8(5)% 100%	0.05(4)% 0.65(10)%		0.061(12) 0.0?		1.4820(36) 1.4820(36)	$16^{+47}_{-8}\\2.3^{+0.6}_{-0.5}$

* All values from [1989Ha27], except where noted.

** [1970Ah01].

# Table 7

direct  $\alpha$  emission from ²⁵³Md*, T_{1/2} = 6.4^{+11.6}_{-3.6} m**, BR_{$\alpha$} =  $\approx$ 0.7%***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{249}\mathrm{Es})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
7.217(15)	7.103(15)			7/2-	$x \sim 0.421$	390.8(4) 304 2(4) 353 2(4)		

 $\ast$  All values from [2012He09], except where noted.

** [1992Ka08].

*** [2005He27].

# Table 8

direct  $\alpha$  emission from ²⁵⁷Lr*, T_{1/2} = 0.6(1) s, BR_{$\alpha$} =  $\approx$ 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	$E_{daughter}(^{253}Md)$	coincident γ-rays (keV)	R ₀ (fm)	HF
8.773	8.636**							
8.949(20)	8.870(20)	23(3)%	19(2)%		0.061(28)		1.473(10)	$5.2^{+2.4}_{-1.9}$
9.010(20)	8.870(20)	100%	81(2)%		0.0		1.473(10)	$1.8_{-0.6}^{+0.7}$

* All values from [1971Es01], except where noted. This reference reports an upper limit for electron capture of 15%.

** Tentative assignment by [1997He29].

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{257}\mathrm{Lr})$	coincident γ-rays (keV)	R ₀ (fm)	HF
9.07	8.93	>82 %				1.477(25)	1.7
* All valu ** [1971] *** [1998	es from [1971Gh0 F102]. BLa30] determined	1], except where r the BR _F to be $\leq$	noted. 18%				
Table 10							
direct $\alpha$ emiss	ion from ²⁶⁵ Bh*, 7	$\Gamma_{1/2} = 0.94^{+0.70}_{-0.31}$ s,	$BR_{\alpha} = 100\%$	б.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\boldsymbol{\pi}}$	$E_{daughter}(^{249}\mathrm{Es})$	coincident γ-rays (keV)	R ₀ (fm)	HF

1.470(17)

 $1.2^{+0.8}_{-0.6}$ 

direct  $\alpha$  emission from ²⁶¹Db*, T_{1/2} = 1.8(6) s**, BR_{$\alpha$} = >82 %.

* All values from [2004Ga29].

9.240(50)

100%

9.392(50)

# **References used in the Tables**

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 $\begin{array}{c} 276Cn\\ Qs\alpha=1.41\#\,MeV\\ Qs\alpha=14.45\#\,MeV\\ Q\alpha=11.85\#\,MeV \end{array}$ 





Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +26 nuclei.

Last updated 2/18/25

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +26$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	Q _β -	$Q_{\beta}$ - $\alpha$	Experimental
²¹² Ho*		$0^{+}$	obs		4.57(36)#	6 69(42)#	[2017Ca12]
²¹⁶ Ph*		$0^{+}$	99 4(117) s	-7 36(36)#	1 64(20)#	6.82(28)#	[2017Ca12]
220po*		0+	obs	-5 70(30)#	0.888(23)	7 144(21)	[1998Pf02]
²²⁴ Rn*		0+	108(3) m**	-5 266(24)	0.606(25)	5.824(17)	$[1964B_902, 1973\Delta fZV]$
²²⁸ Ra*		$0^{+}$	5.75(3) y	-4.444(7)	0.046(1)	4.946(11)	[1962Ma58]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
²³² Th		$0^+$	$1.401(7) \times 10^{10}$ y	-3.708(13)			[1963Le17]
²³⁶ U		$0^+$	2.3415(14)×10 ⁷ y	-2.889			[1972Fl03]
^{236m} U	2.750(10)		115(4) ns***	-0.139			[1989Sc30, 1978Gu02, 1975Ch09]
²⁴⁰ Pu		$0^+$	6564(11) y	-2.191(17)			[1984St05]
^{240m} Pu	х		3.8(3) ns	-2.191(17)+x			[1970Bu02]
²⁴⁴ Cm			18.099(15) y	-1.427(1)			[1968Be26]
^{244m} Cm	3.0(4)	$0^+$	> 100 ns	1.6(4)	-3.5(4)	6.7(4)	[1973Br38]
²⁴⁸ Cf		$0^+$	333.5(28) d	-0.890(50)			[1973Hu01]
²⁵² Fm		$0^{+}$	25.39(4) h	-0.480(50)			[1984Ah02]
²⁵⁶ No		$0^+$	2.91(5) s	0.37(12)#	-3.266(8)#	8.104(51)#	[1990Ho03]
²⁶⁰ Rf		$0^+$	20.2(7) ms [@]	0.87(24)#	-2.22(20)#	9.267(24)#	[1985So03]
²⁶⁴ Sg		$0^{+}$	$37^{+27}_{11}$ ms	1.52(37)#	-1.26(32)#	10.081(31)#	[2006Gr24]
²⁶⁸ Hs		$0^+$	$0.38^{+1.8}_{-0.17}$ s	2.26(49)#	-0.13(40)#	11.28(38)#	[2010Ni14]
²⁷² Ds			-0.17	2.60(65)#	1.10(51)#	12.95(57)#	-
²⁷⁶ Cn				2.97(80)#	1.41(61)#	14.45(70)#	

* 100%  $\beta^-$  emitter.

** Weighted average of 114(6) m [1964Ba02] and 107(3) m [1973AfZY].
*** Weighted average of 115(5) ns [1978Gu02] and 116(7) ns [1975Ch09].
@ Weighted average of 20.0(12) ms, 21.0(11) ms and 19.0(14) ms [1985S003].

 Table 2

 Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +26$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	Experimental
²¹² Hg		1.10(50)#			
²¹⁶ Ph	9 81(36)#	2 07(36)#			
²²⁰ Po	8 35(20)#	5 33(20)#			
²²⁴ Rn	8 272(17)	4 757(20)			
²²⁸ Ra	8.031(6)	4.070(10)			
232Th	7.605(13)	4 082(1)	100%	$1.15(41) \times 10^{-9}\%$ *	[ <b>1995Bo18, 1989Sa01</b> , 1997MiZP, 1996Bo08, 1995Si05, 1983Mi30
	(1000(10))		10070	1110(11)/(10 %	1983Ro23 1982Sa36 1975Em03 1973HaZR 1967Sp12 1963Le21
					1962Ko12, 1961Ko11, 1960Fa07, 1959Ko58, 1958Fl44, 1957Ha08,
					1956Ma43, 1956Pi42, 1956Se17, 1955Po45, 1953We52, 1952Se67,
					1939Li16, 1938Ko01
²³⁶ U	7.133(14)	4.573(1)	100%	9.64(52)×10 ⁻⁸ %	[2014Ma14, 2002Ge02, 1981Vo02, 1961Ko11, 1960Ko04, 1994Tr12,
					1990BaZH, 1989Ho24, 1988TrZU, 1983Be66, 1982BeYI, 1972Fl03,
					1971Co35, 1952F120, 1949JaZZ]
^{236m} U	4.383(17)	7.323(10)		11(4)%	[1989Sc30, 1978Gu02, 1975Ch09, 1977Bo09, 1976An11, 1972Br04,
					1972ClZY, 1972DeZR, 1972Pe01, 1972PiZR, 1971Be62, 1971Bo61,
					1971Br38, 1971Br39, 1971Fe09, 1970El03, 1970Re05, 1970Vi05,
					1970Wo06, 1969La14]
²⁴⁰ Pu	6.475(1)	5.2558(1)	100%	5.796(39)×10 ⁻⁶ %	[2018Be29, 2010Si30, 1977Ba69, 2016Ob01, 2013Sa65, 2007Ah05,
					2007Bu19, 1997De11, 1992B113, 1991Iv01, 1990An33, 1989Au01,
					1989Dy01, 1989Wa29, 1988SeZY, 1984Ah06, 1984An25, 1984Be19,
					1984Ru04, 1984St06, 1979BuZC, 1978Ja11, 1972Go33, 1972Sc01,
					19/1Cl03, 19/1160/, 1969Le05, 1968Ba25, 1968Oe02, 196/Fi13,
					1963Ma50, 1963Le17, 1962Le11, 1962Wa13, 1959D064, 1956K667,
					1954Ba14, 1954Cn74, 1954Fa11, 1954Se94, 1955AsZZ, 1955K172, 1952As28, 1951Wo21, 1951Fp02, 1945Bo771
240m Du	6 475(1) x	5 2559(1) LY		oba	$[1070 \mathbf{P}_{10}\mathbf{O}] = 1026 \mathbf{P}_{0}\mathbf{O} + 1072 \mathbf{O}_{0}\mathbf{O} + 1$
гu	0.473(1)-x	J.2336(1)+X		008	1970Bu02, 1980De04, 19780010, 1974 web3, 1975Nab3, 1971B139, 1971Br7K 1970El03 1970Vi05 1960La14 1969Ma11 1969Va7X1
²⁴⁴ Cm	6.012(1)	5 90160(3)	100%	$1.37(4) \times 10^{-4}\%$	[2002Da21, 1998Ga19, 1971Gr17, 1972Ha80, 1970Ba11, 1966Ba07
Cili	0.012(1)	5.90100(5)	10070	1.57(4)×10 %	<b>1965Me02</b> 2023Na03 2008Ve05 2004Na01 2004Na44 1999Pe03
					1998Ya17, 1997Ka59, 1996Sa24, 1993Pa29, 1983Ca02, 1983Sc06
					1983Sc07, 1981Zh06, 1974Al26, 1973Da34, 1973Go46, 1972Al07,
					1972AIYR, 1972AIYX, 1972FIZS, 1972Ke29, 1971Bb10, 1970Al07,
					1969Ba57, 1969ScZZ, 1968Be26, 1967Ar09, 1965Ak02, 1965Ar09,
					1963Bj03, 1963Dz07, 1963Ma56, 1963Ma56, 1962Iv01, 1962No09,
					1961Ca01, 1956Hu96, 1955Hi68, 1954Fr19, 1953AsZZ, 1952Gh27]
^{244m} Cm	3.0(4)	8.9(4)		obs	[1973Br38, 1971Br39, 1969MeZX, 1971BrKG]
²⁴⁸ Cf	5.541(7)	6.361(5)	100%	$2.86(25) \times 10^{-3}\%$	[1984Ah02, 1973Hu01, 1996IvZZ, 1973HuYZ, 1968Sk01, 1963Fr15,
					1954Gh12]
²⁵² Fm	4.984(7)	7.154(1)	100%	$2.3(2) \times 10^{-3}\%$	[1984Ah02, 1977Be36, 1967Ch17, 1962Dr02, 1956Fr07]
²⁵⁶ No	4.308(9)	8.582(5)	100%	$5.3^{+0.6}_{-0.3}  imes 10^{-3}\%$	[2016AsZX, 1990Ho03, 2021Ke10, 1967Dr02, 1967Fl05, 1967Gh01,
					1966Ku15, 1964Do10, 1963Do12]
²⁶⁰ Rf	3.99(21)#	8.90(20)#		100%	[2008Ga08, 1985So03, 2009GoZT, 1987HuZW, 1986Hu01, 1985TeZX,
					1983SoZZ, 1977Dr10, 1977DrZU, 1976Dr06, 1970Og05, 1964Fl04]
²⁶⁴ Sg	3.62(33)#	9.21(20)#	< 36%	$\approx 100\%$	[2006Gr24, 2006Ni10, 2010Ni14, 1998Ik02, 1998IkZZ]
²⁶⁸ Hs	3.09(40)#	9.76(10)#	obs		[ <b>2010Ni14</b> , 2009Dv01]
²⁷² Ds	2.31(54)#	10.69(30)#			
²⁷⁶ Cn	2.32(67)#	11.85(66)#			

* [1995Bo01].

|--|

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{228}\mathrm{Ra})$	coincident γ-rays (keV)	R ₀ (fm)	HF
3.874(2) 4.0164(20) 4.0827(14)	3.807(2)*** 3.9472(20) 4.0123(14)	0.060(12)% 30(3)% 100%	0.046(9)% 23(2)% 77(3)%	$4^+ 2^+ 0^+$	0.2047 0.0638 0.0	140.8 63.8	1.5370(14) 1.5370(14) 1.5370(14)	$24^{+6}_{-4} \\ 0.95(8) \\ 1.04(4)$

* All values from [1989Sa01], except where noted.

** [1963Le17].

***  $E_{\alpha}$  deduced from  $\gamma$  energies coincident with  $\alpha$ 's.

#### Table 4

direct  $\alpha$  emission from ²³⁶U,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 2.3415(14) \times 10^7$  y*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pmb{\pi}}$	$E_{daughter}(^{232}\mathrm{Th})^{@}$	coincident $\gamma$ -rays (keV) [@]	R ₀ (fm)	HF
4.237(2)	4.166(2)**	0.00027(8)%	0.00020(6)% [@]	$6^{+}$	0.3335	171.2(2)	1,52595(66)	$780^{+340}_{-100}$
4.409(2)	4.334(2)**	0.166(7)%	0.123(5)% ^{@@}	$4^{+}$	0.1623	112.8(1)	1.52595(66)	32.3(18)
4.521(2)	4.445(2)**	34.61(10)%	25.68(5)% ^{@@}	$2^{+}$	0.0495	49.5(1)	1.52595(66)	1.18(4)
4.5710(21)	4.4935(21)***	100%	74.20(15)%@@	$0^+$	0.0		1.52595(66)	0.9675(21)

* [1972Fl03].

** Value deduced from  $Q_{\alpha}$  and  $\gamma$  energies from [2002Ge02].

*** Value taken from [1991Ry01], based on adjusted values from [1960Ko04] (4.888(3) keV adjusted to 4.495(3) keV) and [1961Ko11] (4.888(3) keV adjusted to 4.492(3) keV). @ [2002Ge02]. @@ [2014Ma14].

# Table 5

direct  $\alpha$  emission from ²⁴⁰Pu,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 6564(11)$  y*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{***}$	${ m J}_f^\pi$	$E_{daughter}(^{236}\mathrm{U})^{@}$	coincident $\gamma$ -rays (keV) [@]	R ₀ (fm)	HF
4.568(1)	4.492(1)	$4.4(7) \times 10^{-5}\%$	$3.2(5) \times 10^{-5}\%$	1-	0.688	45.2, 104.2, 538.1	1.51631(11)	$39^{+7}_{5}$
4.734(1)	4.655(1)	$2.4(10) \times 10^{-6}\%$	$1.72(7) \times 10^{-6}\%$	$8^+$	0.522	45.2, 104.2, 160.3, 212.5	1.51631(11)	$1.29(5) \times 10^4$
4.9458(5)	4.8634(5)**	$1.3(1) \times 10^{-3}\%$	$9.7(9) \times 10^{-4}\%$	$6^+$	0.310	45.2, 104.2, 160.3	1.51631(11)	720(70)
5.1064(5)	5.0213(5)**	0.117(6)%	0.085(44)%	4+	0.149	45.2, 104.2	1.51631(11)	97(5)
5.21036(25)	5.12352(25)**	37.43(10)%	27.21(7)%	$2^{+}$	0.045	45.2	1.51631(11)	1.296(4)
5.25573(15)	5.16813(15)**	100%	72.70(7)%	$0^+$	0.0		1.51631(11)	1.0023(20)

* Value taken from the evaluation of [1984St05].

** Values from [1977Ba69] adjusted by -0.17 keV as reccomened in [1991Ry01].

*** [2010Si30].

@ [2022Zh25].

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{***}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{240}\mathrm{Pu})^{@@}$	coincident $\gamma$ -rays (keV) ^{@@}	R ₀ (fm)	HF
5.002	4.920**	$1.7 \times 10^{-4}\%$	1.3×10 ⁻⁴ %**	2+	0.900	42.8, 98.9, 251.7, 303.0, 507.2, 554.6, 606.1, 758.6, 857.5, 900.4	1.498180(88)	2.2
5.043	4.960**	$3.9 \times 10^{-4}\%$	$3.0 \times 10^{-4}\% **$	$0^+$	0.860	42.8, 263.4, 554.6	1.498180(88)	1.8
5.302	5.215**	$1.3 \times 10^{-4}\%$	$1.0 \times 10^{-4}\% **$	$1^{-}$	0.597	42,8, 554.6	1.498180(88)	280
5.607(3)	5.515(3)***	$4.9(6) \times 10^{-3}\%$	$3.8(5) \times 10^{-3}\% * * *$	$6^+$	0.294	42.8, 98.9, 152.6	1.498180(88)	480(70)
5.758(2)	5.664(2)***	0.026(1)%	0.020(1)%@	$4^{+}$	0.142	42.8, 98.9	1.498180(88)	654(33)
5.85820(3)	5.76216(3) ^{@@}	29.55(8)%	22.80(5)% [@]	$2^{+}$	0.0428	42.8	1.498180(88)	1.989(5)
5.90152(5)	5.80477(5) ^{@@}	100.0(2)%	77.16(11)%@	$0^+$	0.0		1.498180(88)	0.9952(17)

direct $\alpha$ emission from ²⁴⁴ Cm, $J^{\pi} = 0^+$ , $T_{1/2} = 18.099(15)$ y*, $BR_{\alpha} = 100\%$ .

* [1968Be26].

** [1966Ba07].

*** [1998Ga19].

@ [2002Da21].
@@ Value taken from [1971Gr17], modifies by -0.17 keV as recommended in [1991Ry01].

#### Table 7

direct  $\alpha$  emission from ²⁴⁸Cf*,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 333.5(28) d^{**}$ ,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{***}$	${ m J}_f^\pi$	$E_{daughter}(^{236}\mathrm{U})^{@}$	coincident γ-rays (keV)@	R ₀ (fm)	HF
6.218(7) 6.319(5) 6.361(5)	6.118(7) 6.217(5) 6.258(5)	0.5(3)% 24.5(13)% 100%	0.4(2)% 19.6(10)% 80(1)%	$4^+ 2^+ 0^+$	0.142 0.043 0.0	43.0, 99.3 43.0	1.4851(24) 1.4851(24) 1.4851(24)	$40^{+40}_{-10} \\ 2.52(13) \\ 1.001(15)$

* All values from [1984Ah02], except where noted.

** [1973Hu01].

### Table 8

direct  $\alpha$  emission from ²⁵²Fm,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 25.39(4)$  h,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{248}\mathrm{Cf}$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
6.868(3)	6.759(3)	0.027(6)%	0.023(5)%	6+	0.285		1.46703(81)	$230^{+60}_{-40}$
7.015(2)	6.904(2)	1.15(5)%	0.97(4)%	$4^+$	0.137	98.3(1)	1.46703(81)	23.3(10)
7.111(2)	6.998(2)	17.9(3)%	15.0(2)%	$2^{+}$	0.042	41.5(1)	1.46703(81)	3.78(9)
7.153(2)	7.039(2)	100.0(8)%	84.0(5)%	$0^+$	0.0		1.46703(81)	1.003(6)

* All values from [1984Ah02].

#### Table 9

direct  $\alpha$  emission from ²⁵⁶No,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 2.91(5)$  s*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}$ ( ²⁵² Fm	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
8.535(6) 8.582(6)	8.402(6)** 8.448(6)	≈11% 100%	$\approx 10\%^{***}$ $\approx 90\%^{***}$	$2^+_{0^+}$	0.0421(13) 0.0	42.1(13)	1.4762(10) 1.4762(10)	${}^{6.4_{-0.7}^{+0.9}}_{0.96_{-0.11}^{+0.14}}$

* All values from [1990Ho03], except where noted.

** [2016AsZX] report a fine structure peak in coincidence with a 42.1(13) keV  $\gamma$ .

** Estmated by the evaluator based on Fig. 2 of [2016AsZX].

#### Table 10

direct $\alpha$ emission from ²⁶⁸ Hs, $J^{\pi} = 0^+$ , $T_{1/2} = 0.38^{+1.8} + -0.17$ s, $BR_{\alpha} = \text{obs}^{**}$ .										
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{264}\mathrm{Sg})$	coincident γ-rays (keV)	R ₀ (fm)	HF**			
9.622(16)	9.479(16)		$0^+$	0.0		1.458(48)	$1.0^{+5.0}_{-0.5}$			

* All values from [2010Ni14].

** Only  $\alpha$  decay observed. 100% branching is used to calculate HF.

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +26 nuclei.

Last updated 2/27/2025

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +26$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values are taken from ENSDF.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	Q _β -	Q _β - α	$BR_{\beta}$ -F	Experimental
²¹⁴ Tl* ²¹⁸ Bi* ²²² At* ²²⁶ Fr*		1-	11(2) s 33(1) s 54910) s 49(1) s	-5.31(45)# -2.41(30)# -1.530(40)) -1.227(12))	6.65(20)# 4.859(27) 4.581(16) 3.853(7)	9.53(28)# 11.154(27) 10.351(16) 8.904(6)		[2016Ca25] [2004De16] [1989Bu09] [1986Bo35]
²³⁰ Ac* ²³⁴ Pa*(UX ₂ ) ²³⁸ Np* ²³⁸ Mp* ²⁴² Am* ²⁴² m ¹ Am ²⁴² m ² Am	x 0.049 2.20(8)	$(1^+)$ $4^+$ $2^+$ $1^-$ $5^-$ (2,3)	122(3) s 6.658(23) h 2.1024(5) d 250(130) ns 16.02(2) h 141.9(17) y 13.9(2) ms**	-0.678(19) -0.274(3) 0.147(1) 0.147(1)+x -0.751(1) -0.702(1) 1.45(8)	2.976(16) 2.194(4) 1.291(1) 1.291(1)+x 0.664(1) 0.713(1) 2.86(8)	7.925(16) 7.232(4) 7.065(2) 7.065(2)+x 7.060(2) 7.109(2) 9.26(8)	1.19(40)×10 ⁻⁶ %	[2001Yu03] [1954Zi02] [2006Re09] [1970Vi05] [2005Ma90] 1979Ze05] [1996Ba52, 1976Be55, 1975Va21, 1965Fl04, 1968Er01, 1976We03,1967Fl03]
246 Bk 250 Es 254 Md 258 Lr 262 Db 266 Bh 270 Mt 274 Rg 278 Nh		2 ⁽⁻⁾ (6 ⁺ )	1.8092) d 8.6(1) h 10(3) m 3.91(22) s*** $33.8^{+4.4}_{-3.5}$ s $10.0^{+2.6}_{-1.7}$ s $0.48^{+0.66}_{-0.68}$ s $12^{+1.6}_{-1.6}$ ms $1.4^{+1.9}_{-0.5}$ ms	1.350(60) 2.06(10)# 2.55(10)# 3.30(14)# 3.86(27)# 4.49(29)# 5.60(31)# 5.42(44)# 6.19(49)#	$\begin{array}{c} \mathcal{Q}_{\varepsilon p} \\ -5.222(60) \\ -3.91(10)\# \\ -2.85(10)\# \\ -1.50(10)\# \\ -0.59(25)\# \\ 0.43(28)\# \\ 1.94(42)\# \\ 2.54(47)\# \\ 3.33(52)\# \end{array}$	$\begin{array}{c} Q_{\mathcal{E}\alpha} \\ 6.825(60) \\ 8.18(10)\# \\ 9.86(10)\# \\ 11.46(10)\# \\ 12.35(19)\# \\ 13.29(28)\# \\ 14.67(31)\# \\ 17.08(33)\# \\ 17.41(45)\# \end{array}$		[1976Ah03] [1977Fr03] [1970Fi12] [2014Ha04, 1992Gr02, 1976BeZY, 1971Es01] [2014Ha04] [2020Ha27] [2012Mo25] [2012Mo25] [2012Mo25]

* 100%  $\beta^-$  emitter.

** Weighted average of 10.2(9) ms [1975Va21], 14.0(4) ms [1965Fl04], 14.0(2) ms [1968Er01], 13.9(5) ms [1976We03], and 14.0(7) ms [1967Fl03]. *** Weighted average of  $3.54^{+0.46}_{-0.36}$  s [2014Ha04],  $3.92^{+0.35}_{-0.31}$  s [1992Gr02], 4.35(59) s [1976BeZY] and 4.2(6) s [1971Es01].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +26$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	Experimental
²¹⁴ Tl	9.02(36)#	1.36(45)#			
²¹⁸ Bi	6.33(30)#	4.33(20)#			
²²² At	6.110(25)	5.312(31)#			
²²⁶ Fr	6.303(13)	4.143(17)			
²³⁰ Ac	6.013(22)	3.893(17)			
234 Pa(UX ₂ )	5.682(4)	4.076(16)			
²³⁸ Np	5.225(1)	4.691(4)			
^{238m} Np	5.225(1)-x	4.691(4)+x		$\approx 100\%$	[1970Vi05]
²⁴² Am	4.776	5.589			
$^{242m1}Am$	4.727	5.638	0.45(1)%		[ <b>1990Ho02, 1979Ba67, 1979Ze05</b> , 2005Ma90, 1983WeZU,
2422					1979BaYF, 1961As03, 1959Ba22]
242 <i>m</i> 2Am	2,58(8)	7.79(8)		100%	[1976Be55, 1975Va21, 1965F104,1968Er01, 1976We03,1967F103,
					1996Ba52, 1993Ku16, 1992Ba67, 1992BaZW, 1985AcZZ, 1981Lu06,
					1981 VaZQ, 1985 WeZI, 1979 VaZ5, 1975 Be04, 1975 Be05, 1970 Da05,
					$19090a24, 1908E101, 1907Ca04, 19070a14, 1900D125, 1900M1a24, 19651;05, 1063E108, 1063D_27, 1062D_0001$
246 Bk	4 327(60)	6.074(60)			19051105, 19051108, 19051 027, 19021 009]
250 Es	3.79(10)#	6.83(12)#			
254 Md	3.19(10)#	7.80(14)#			
258 L r	2.75(10)#	8 904(19)	07 1(18)%		[ <b>2014Ha04 1976Ba7V 1971Fa01</b> 2020Ha27 1992Gr02 1971Fa7X]
²⁶² Db	2.75(16)#	9.05(10)#	48(4)%	52(4)%	[2014Ha04, 1970bc21, 1971Es01, 2020Ha27, 1992Gl02, 1971Es2A] [2014Ha04, 2020Ha27, 2012Mo25, 2010MoZV, 2007Mo43, 1999Dr09
20	2.35(10)	9.05(10)#	40(4)70	52(4)70	1993Zi06 1992Ga31 1992Go28 1992Sc30 1990IoZX 1989Kr17
					1989ScZW 1989YaZZ 1988Gr30 1979Dr07 1977Be43 1977BeWH
					1971Gh01]
²⁶⁶ Bh	1.98(21)#	9.426(77)#	$\approx 100\%$		[2020Ha27, 2012Mo25, 2010MoZV, 2009MoZU, 2007Mo43, 2006MoZV,
					2006Qi03, 2005MoZS, 2004Mo42, 2000Wi15]
²⁷⁰ Mt	1.07(23)#	11.31(7)*	$\approx 100\%$		[2012Mo25, 2007Mo43, 2007MoZY, 2006MoZW, 2006MoZV, 2004Mo42]
²⁷⁴ Rg	0.96(25)#	11.478(86)	$\approx 100\%$		[2012Mo25, 2007Mo43, 2007MoZY, 2006MoZW, 2006MoZV, 2004Mo42]
²⁷⁸ Nh	0.59(27)#	11.993(79)	$\approx 100\%$		[2012Mo25, 2007Mo43, 2007MoZY, 2006MoZW, 2006MoZV, 2004Mo42]

*  $Q_{\alpha}$  taken from highest energy  $\alpha$  observed in [2012Mo25], 10.18(10)# in [2021Wa16].

## Table 3

direct $\alpha$ emission from ²⁴²	2m Am, Ex. = 2.20	(8) MeV, $J^{\pi} = 5^{-1}$	$T_{1/2} = 141.9(17)$	$y^*, BR_{\alpha} = 0.45(1)\%^*.$
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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{***}$	$J_f^{\pi@}$	Edaughter ( ²³⁸ Np [@]	coincident $\gamma$ -rays (keV) [@]	HF ^{@@}
5.0583	4.9747**	$2 \times 10^{-3}\%$	$9 \times 10^{-6} \%^{**}$		0.581**		2.3×10 ³
5.116(5)	5.031(5)	0.02(1)%	$9.0(45) \times 10^{-5}\%$		0.524	26.4, 35.9, 43.8, 44.0, 62.3, 79.7, 139.1 358 3, 417 6, 461 6, 497 5	$600\substack{+600\\-200}$
5.157(3)	5.072(3)	0.28(8)%	$1.1(3) \times 10^{-3}\%$		0.484***	556.5, 417.0, 401.0, 497.5	$80^{+33}_{-10}$
5.1672	5.0818**	0.03%	$1.4 \times 10^{-4}\% **$		0.470**		820
5.179(4)	5.093(4)	0.24(8)%	$9.5(32) \times 10^{-4}\%$	$(6^{+})$	0.460	$140^{+70}_{-40}$	
24.4, 26.4, 35.0, 35.9, 43.1, 49.4, 53.7,	1.79(5)			. ,			
						59.3, 60.2, 62.3, 66.9, 73.7, 86.7, 92.5, 95.2, 96.8, 109.6, 111.2, 117.2, 121.7, 126.0, 152.7, 152.0, 162.2, 206.4	
5 2309(9)	5 1444(9)	63(2)%	0.025(1)%	6-	0.408	150.0, 152.7, 155.9, 105.5, 200.4 35.0, 43.3, 59.3, 76.0, 95.2, 121.7	11.0(5)
5.2507(7)	5.1444(5)	0.5(2)70	0.023(1)70	0	0.400	122.8, 132.6, 152.7, 153.9, 174.8, 196.5, 232.4	11.0(5)
5.2397	5.1531**	0.02%	$9 \times 10^{-5} \% **$		0.399**		$3.5 \times 10^{3}$
5.2605	5.1735**	0.04%	1.80×10 ⁻⁴ %**	(6 ⁻ )	0.377	24.4, 26.4, 32.7, 35.9, 43.3, 43.8, 46.8, 49.4, 60.2, 62.3, 73.7, 76.0, 79.5, 79.7, 86.7, 95.7, 109.6, 117.8, 122.8, 136.0, 152.7, 153.2, 156.4, 182.9, 189.1, 196.5,	2.4×10 ³
5.29598	5.20848	100.0(8)%	0.401(3)%	5-	0.342	215.5, 252.4, 270.6 24.4, 26.4, 35.0, 35.9, 43.1, 49.4, 53.7, 59.3, 60.2, 62.3, 66.9, 73.7, 86.7, 92.5, 95.2, 96.8, 109.6, 111.2, 121.7, 136.0, 152.7, 153.9, 163.3, 206.4	1.79(5)
5.3021	5.2145**	0.03%	$1.35 \times 10^{-4}\% **$		0.334**	$6.1 \times 10^3$	
5.336622	5.2484(22)	1.1(1)%	$4.5(5) \times 10^{-3}\%$	$(1)^{-}$	0.299	46.8, 95.7, 116.9, 156.4, 182.9	$290^{+40}_{-20}$
5.3380	5.2498**	0.04%	$1.80 \times 10^{-4}\% **$	(6 ⁻ )	0.297	35.0, 43.8, 44.0, 59.3, 79.7, 95.2, 121.7, 131.5, 139.1, 190.9	$7.5 \times 10^3$
5.360(3)	5.271(3)	1.2(1)%	$5.0(5) \times 10^{-3}\%$	$4^{+}$	0.276	35.0, 59.3, 95.2, 121.7, 153.9	369(35)
5.405(3)	5.316(3)	0.7(1)%	2.7(5)×10 ⁻³ %	5-	0.233	24.4, 26.4, 35.0, 35.9, 43.1, 49.4, 53.7, 59.3, 60.2, 62.3, 73.7, 86.7, 92.5, 95.2, 96.8, 109.6, 111.2, 121.7, 136.0, 152.7	$1.2^{+3}_{-2} \times 10^3$
5.421(5)	5.331(5)	0.17(11)%	6.8(45)×10 ⁻⁴ %	3-	0.216	24.4, 26.4, 32.7, 35.9, 46.8, 49.4, 60.2, 62.3, 73.7, 79.5, 86.7, 95.7, 109.6, 136.0 153.2, 156.4, 182.9, 189.1, 215.5	$6^{+13}_{-3}{ imes}10^3$
5.4593(18)	5.3691(18)	1.2(2)%	$5.0(9) \times 10^{-3}\%$	$4^{-}$	0.179	24.4, 26.4, 35.9, 43.1, 49.4, 60.2, 62.3, 73.7, 86.7, 92.5, 109.6, 136.0, 152.7	$1.4^{+0.3}_{-0.2}{\times}10^3$
5.5034(21)	5.4124(21)	1.1(2)%	$4.5(9) \times 10^{-3}\%$	3-	0.136	24.4, 26.4, 35.9, 49.4, 60.2, 62.3, 73.7, 86.7, 109.6, 136.0	$2.8^{+0.8}_{-0.5}{\times}10^3$
5.5497	5.4580**	0.16%	$6.30 \times 10^{-4}\% **$	$3^{+}$	0.087	24.4, 26.4, 60.2, 86.7	$2.7 \times 10^{3}$
5.6098	5.5171**	$7{ imes}10^{-3}\%$	$2.70 \times 10^{-5}\% **$	$3^{+}$	0.026	26.4	$2.0 \times 10^{6}$

* [1979Ze05]. ** Values taken from [1979Ba67], modifies by -0.2 keV s recommended in [1991Ry01]. *** Values taken from [1990Ho02], except where noted.

^{***} Values taken non [1220100-], ...., [2015Br06]. [@] [2015Br06]. [@]  $R_0(fm) = 1.50725(14)$ . Deduced from Interpolated between 1.51631(11) fm (240Pu) and 1.498180(88) fm (244Cm).

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{***}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{***}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{254}\mathrm{Md})$	coincident γ-rays (keV)	$R_0(fm)^@$	HF
8.685(20) 8.730(10) 8.757(10)	8.550(20) 8.595(10) 8.621(10)	47(9)% 100(9)% 45(7)%	21(4)% 46(3)% 20(3)%		0.105(22) + x 0.060(14) + x 0.033(14) + x		1.484(14) 1.484(14) 1.484(14)	$\begin{array}{c} 6.4^{+3.4}_{-2.5} \\ 4.1^{+1.8}_{-1.3} \\ 11^{+6}_{-14} \\ 2.5^{+20} \end{array}$

direct  $\alpha$  emission from ²⁵⁸Lr, T_{1/2} = 3.91(22) s*, BR_{$\alpha$} = 97.4(18)%**.

* Weighted average of  $3.54^{+0.46}_{-0.36}$  s [2014Ha04],  $3.92^{+0.35}_{-0.31}$  s [1992Gr02], 4.35(59) s [1976BeZY] and 4.2(6) s [1971Es01].

** [2014Ha04].

*** Weighted average of values from [1976BeZY] and [11971Es01]. Both papers report 4 closely spaced  $\alpha$  transitions which were fit in their spectra as a multiplet. The reported values are 8.648(10) MeV 10(2)%, 8.614(10) MeV 35(5)%, 8.589(10) MeV 45(7)% 8.510(20) MeV 10(5)% [1976BeZY] and 8.68(2) MeV 7(2)%, 8.65(2) MeV 16(3)%, 8.62(2) 47(3)%, 8.59(2) 30(4)% [1971Es01].

[@] Interpolated between 1.4762(10) fm (²⁵⁶No) and 1.492(14) fm ((²⁶⁰Rf).

#### Table 5

direct  $\alpha$  emission from ²⁶²Db*, T_{1/2} = 33.8^{+4.4}_{-3.5} s, BR_{$\alpha$} = 48(4)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{258}\mathrm{Lr})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)**	HF
8.591(40) 8.815(40)	8.460(40) 8.680(40)	100(7)% 43(8)%	33.6(37)% 14.4(27)%		x+0.224(57) x		1.482(27) 1.482(27)	$\substack{ 4^{+4}_{-2} \\ 40^{+50}_{-30} }$

* All values from [2014Ha01].

** Interpolated between 1.492(14) fm ( $(^{260}$ Rf) and 1.471(23) fm ( 264 )Sg

## Table 6

$a_1 c_1 c_2 c_1 a_3 c_1 a_3 c_1 a_3 c_1 a_3 c_1 c_1 c_1 c_1 c_1 c_1 c_1 c_1 c_1 c_1$	direct of	$\alpha$ emission	from	²⁶⁶ Bh*,	$T_{1/2} =$	$10.0^{+2.6}$	s, $BR_{\alpha}$	$= \approx$	100%
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{262}\text{Db})$	coincident γ-rays (keV)	R ₀ (fm)	HF

8.75-9.54 8.62-9.40

* All values from [2020Ha27].

### Table 7

direct  $\alpha$  emission from ²⁷⁰Mt*, T_{1/2} = 0.48^{+0.66}_{-0.38} s, BR_{$\alpha$} =  $\approx$  100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{266}\mathrm{Bh})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
10.18(7) 10.41(7)	10.03(7) 10.26(7)				0.23(10)+x x			
* All val	ues from [2012Mo	o25].						

### Table 8

direct $\alpha$ emiss	sion from ²⁷⁴ Rg*,	$T_{1/2} = 12^{+16}_{-5} \text{ ms}$	s, $BR_{\alpha} = \approx 100\%$					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{262}\text{Db})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
10.81(6)	10.65(6)							
11.32(7)	11.15(7)							
11.48(7)	11.31(7)							

* All values from [2012Mo25], based on 3 decay chains.

Table 9 direct  $\alpha$  emission from ²⁷⁸Nh*, T_{1/2} = 1.4^{+1.9}_{-0.5} ms,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	$E_{daughter}(^{262}\text{Db})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
11.69(4)	11.52(4)							
11.85(4) 11.99(6)	11.82(6)							

* All values from [2012Mo25], based on 3 decay chains.

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +53/2 nuclei.

Last updated 3/14/2025

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +53/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values are taken from ENSDF.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	0s	Qe-	$\Omega_{R}$ - a	Experimental
			- 1/2	£ι	₹p	<b>τ</b> ρ α	
²¹⁷ Pb			19.9(53) s	-6.40(50)#	3.53(30)#	8.23(30)#	[2017Ca12]
²²¹ Po			$42^{+58}_{-28}$ s	-4.43(30)#	2.991(24)	8.799(27)	[2010Ch19]
²²⁵ Rn		$7/2^{-}$	4.66(4) m	-3.77(30)#	2.714(16)	7.506(18)	[ <b>1977Bu03</b> ]
²²⁹ Ra		5/2+	4.0(2) m	-3.106(16)	1.872(20)	6.496(19)	[1975Ra03]
²³³ Th		1/2+	21.83(4) m	-2.576(13)	1.242(1)	5.797(12)	[1998Us01]
²³⁷ U		$1/2^{+}$	162.04(5) h	-2.137(13)	0.519(1)	5.656(2)	[1958Ca16]
²⁴¹ Pu		5/2+	14.327(19) y**	-1.36(10)	0.0208(2)	5.839(2)	[2013Cr05, 2009Dr05]
241m1 Pu	2.90(15)		23(1) µs	1.54(18)	2.92(15)	8.74(15)	[1970Ga10]
241m2 Pu	2.90(15) + x		31(4) ns***	1.54(18) + x	2.92(15) + x	8.74(15) + x	[2013Cr05, 2009Dr05]
				$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$		
²⁴⁵ Cm		7/2+	8445(20) y	-0.896(2)			[1982Po14]
^{245m} Cm	х		13.2(18) ns	-0.896(2)+x			[1972Wo07]
²⁴⁹ Cf		9/2-	350.6(21) y	-0.1236(4)			[1973St15]
²⁵³ Fm		$1/2^{+}$	72(3) h	0.335(1)	-3.978(3)	7.074(2)	[1967Ah02]
²⁵⁷ No		$(3/2^+)$	25.5(5) s	1.255(6)	-2.527(7)	8.812(6)	[2005As05]
²⁶¹ Rf [@]		$(11/2)^{@@@}$	68(3) s	1.76(21)#	-1.58(21)#	9.901(66)#	[2008Du09]
261m Rf [@]	х	(3/2) ^{@@@}	1.9(4) s	1.76(21)#+x	-1.58(21)#+x	9.901(66)#+x	2011Ha13]
²⁶⁵ Sg [@]		(3/2) ^{@@@}	$14.4^{+3.7}_{-2.5}$ s	2.41(26)#	-0.57(39)#	10.81(24)#	[2012Ha05]
$^{265m}Sg^{@}$	х	(11/2)@@@	$8.5^{+2.6}_{-1.6}$ s	2.41(26)#+x	-0.57(39)#+x	10.81(24)#+x	[2012Ha05]
²⁶⁹ Hs [@]		(9/2)@@@	$12.5^{+6.7}_{-2.8}$ s [@] @	3.02(40)#	0.41(49)#	11.69(26)#	[2024Og02, 2013Su04]
269mHs@	х	(1/2)	$2.8^{+13.6}_{12}$ s	3.02(40)#+x	0.41(49)#+x	11.69(26)#+x	[2024Og02]
²⁷³ Ds [@]		(11/2)	$0.18^{+0.11}_{-0.05}$ ms	3.50(45)#	1.99(53)#	14.38(40)#	[2024Og02]
^{273m} Ds [@]	х	(1/2)	$30^{+140}_{15}$ ms	3.50(45)#+x	1.99(53)#+x	14.38(40)#+X	[2024Og02]
²⁷⁷ Cn		~ /	$0.61^{+0.46}_{-0.18}$ ms	3.93(49)#	2.50(57)#	15.12(45)#	[2013Su04]

* 100%  $\beta^-$  emitter.

** Weighted average of 14.329(29) y [2013Cr05] and 14.325(24) y [2009Dr05].

*** Weighted average of 30(5) ns [1969La14] and 34(7) ns [1981Gu04].

^(a) The relative ordering of the two isomers is unclear. ^(a) ^(a) ^(a) ^(b) ^(b)

@@@ [2024Og02].

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +53/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	Experimental
217 DL	0.00(42)#	1 (4(42)#			
221 Po	9.90(42)#	1.04(42)#			
225 D m	8.473(30)# 8.466(25)	3.089(30)#			
229 D o	8.400(25)	4.333(23)			
233 Th	0.111(17)	3.003(19)			
23711	7.712(13) 7.232(14)	3.743(10)			
241 <b>D</b>	7.233(14)	4.234(1)	$2.45(8) \times 10^{-3}\%$	$\sim 2.4 \times 10^{-14}$ %	[10684601 1085000 107607N 1065026 2000005 1085002
ru	0.030(17)	5.140	2.45(8)×10 %	≈2.4×10 %	1905Allo1, 1985D109, 1970GuZIA, 1905Ba20, 2009D105, 1985He22, 1985HeZY, 1985Wi04, 1984WiZW, 1979VaZF, 1977VaYR, 1971Cl03, 1971GuZY, 1966Be24, 1963Iv01, 1962Dz09, 1961Sm03, 1960Br15,
2411					1953AsZZ, 1950Th54, 1949SeZU]
^{241<i>m</i>1} Pu	3.75(15)	8.04(15)		obs	[1981Gu04, 1970Ga10, 1970Do01, 1970GaZV]
^{241<i>m</i>2} Pu	3.75(15) - x	8.04(15) + x		obs	[ <b>1981Gu04</b> , 1969La14]
²⁴⁵ Cm	6.164(1)	5.624	100%	$6.0(9) \times 10^{-7}\%$	[ <b>1985Dr10, 1975Ba65, 1966Fr03</b> , 2009KoZV, 2008KoZP, 1998Wh01,
					1994Sh31, 1991Po17, 1982Po14, 1980Di13, 1975BaXK, 1971Ma32,
					1969Me01,1966Ba07, 1963Bo48, 1963Dz07, 1961Ca01, 1955Br02,
245m G					1954Fr19, 1954Hu50]
245mCm	6.164(1)-x	5.624+x		obs	[ <b>1972Wo07, 1971Br39</b> , 1971BrZU]
²⁴⁹ Cf	5.697(50)	6.293	100%	$4.31(59) \times 10^{-7}\%$	[ <b>2015Ah03, 1997Ar31, 1987Ta26</b> , 1996Ko29, 1996Lo73, 1991Po17,
					1986Ah02, 1977Ba67, 1976Ba68, 1973AhZM, 1973Ba80, 1973St15,
					19/1Bb10, 19/1Sc14, 19/1ScZW, 19/0BaZZ, 1969Ba57, 1969Ba59,
253 5	5.029(50)	7 100(1)	10(1)0		1969Me01, 1969Mi08, 1967Ko03, 1966An02]
255 Fm 257 M	5.238(50)	7.198(1)	12(1)%		[196/Anu2, 19595188, 195/Am59]
261 D C**	4.50(12)#	8.477(6)	≈100%		[2005AS05, 2012Ha05, 2000La34, 1994Og01, 1970ES02, 1967Gh01]
KI**	4.245(14)#	8.646(65)#	$\approx 100\%$		[2011Ha13, 1970Gn01, 2013Mu08, 2012Ha05, 2008Du09, 2006M10, 2008D-02, 2008C-08, 2002H-11, 2000L-24, 1008T-01, 1006H-12
					2008DV02, 2008Ga08, 2002H011, 2000La34, 19981u01, 1996H013,
261m <b>D</b> f**	4 245(14)# v	9 646(65)#1v	27(6)0	72(6)0/	$[2011 H_0 12 2009 D_{2} 0] = 2012 M_{2} 0 0 2012 S_{2} 0 4 2012 H_0 05 2009 D_{2} 0 2$
KI	4.243(14)#-X	8.040(0 <i>J</i> )#+X	27(0)%	73(0)%	2002Ho111
265 S a**	3 76(27)#	0.05(12)#	100%		[20240a02 2013Su04 2012Ha05 2000Ma00 2002Ha11 2012Tu01
3g	$5.70(27)\pi$	9.03(12)#	100 //		$2010G_{t}04 - 2000D_{v}01 - 2009M_{0}34 - 2007M_{0}77 - 2007M_{0}09 - 2006D_{v}01$
					2010G104, 2007D101, 2007M034, 2007M022, 2007M007, 2000D101, 2006MoZV 2005MoZO 2005MoZT 2004MoZU 2004Vo24 2003Du27
					2003Tu06 2002Du21 2001HoZY 1998Tu01 1998TuZZ 1997Sc48
					1997Sc49 1996No13 1995NoZW 1995NoZZ 1995Oc02 1994LaZX
					1994LaZZ, 1994Lo27, 1994Og04]
^{265m} Sg**	3.76(27)#-x	9.05(12)#+x	100%		[ <b>2024Og02</b> , 2012Tu01, 2010Gr04, 2009Mo09, 2009Mo34, 2007MoZZ,
					2007Mo09, 2006MoZV, 2005MoZO, 2005MoZT, 2004MoZU, 2003Du27,
					2003Tu06, 2002Du21, 2002TuZY, 2002TuZZ, 1998Tu01, 1998TuZZ]
269Hs**	3.50(40)#	9.27(17)#	100%		[2024Og02, 2013Su04, 2008Mo09, 2002Ho11, 2012Ha05, 2012Tu01,
					2010Gr04, 2009Mo34, 2007MoZZ, 2007Mo09, 2006MoZV, 2005MoZQ,
					2005MoZT, 2004MoZU, 2004Vo24, 2003Tu06, 2002Du21, 2002TuZY,
					2002TuZZ, 2001HoZY]
^{269m} Hs**	3.50(40)#-x	9.27(17)#+x	100%		[2024Og02, 2012Tu01, 2010Gr04, 2009Mo34, 2008Mo09, 2007MoZZ, 2007Mo09,
					2006Dv01, 2006MoZV, 2005MoZQ, 2005MoZT, 2004MoZU, 2003Tu06,
					2002Du21, 2002TuZY, 2002TuZZ]
²⁷³ Ds**	2.49(51)#	11.37(54)	100%		[2024Og02, 2013Su04, 2008Mo09, 2002Ho11, 2009Mo34, 2007MoZZ,
					2007Mo09, 2006MoZV, 2005MoZQ, 2005MoZT, 2004MoZU, 2001HoZY,
272					1996La12, 1996LaZY]
2/3mDs**	2.49(51)#-x	11.37(54)+x	100%		[2024Og02, 2013Su04, 2008Mo09, 2002Ho11, 2009Mo34, 2007MoZZ,
					2007Mo09, 2006MoZV, 2005MoZQ, 2005MoZT, 2004MoZU]
² //Cn	2.34(65)#	11.620(58)	100%		[2013Su04, 2008Mo09, 2002Ho11, 2009Mo34, 2007MoZZ, 2007Mo09,
					2006MoZV, 2005MoZQ, 2005MoZT, 2004MoZU, 2001HoZY]

* [1985Dr09]. ** The relative ordering of the two isomers is unclear.

Table 3		
direct $\alpha$ emission from ²⁴¹ Pu*, $J^{\pi} = 5/2^+$ ,	$T_{1/2} = 14.327(19) y^{**},$	$BR_{\alpha} = 2.45(8) \times 10^{-3}\%$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_{f}^{\pi@}$	$E_{daughter}(^{237}\mathrm{U})^{@}$	coincident $\gamma$ -rays (keV) [@]	R ₀ (fm)	HF
4.772(6)	4.693(6)	≈0.04%	$\approx$ 7.34 $\times$ 10 ⁻⁷ %	(11/2 ⁻ )	0.3670	11.4, 44.9, 56.3, 71.6, 77.1, 93, 103.7, 114.0, 148.6, 160.0	1.51540(43)	≈131
4.823(5)	4.743(5)	$\approx 0.08\%$	$pprox 1.7  imes 10^{-6}\%\%$	$13/2^{+}$	0.3173	155	1.51540(43)	≈127
4.865(5)	4.784(5)	0.24(12)%	$4.9(25) \times 10^{-6}\%$	(7/2)-	0.2740	11.4, 44.9, 56.3, 71.6, 77.1, 103.7, 114.0, 148.6, 160.0	1.51540(43)	$90^{+90}_{-30}$
4.879(3)	4.798(3)	1.68(12)%	$3.42(3) \times 10^{-5}\%$	9/2+	0.2609	11.4, 44.9, 56.3, 56.8, 71.6, 77.1, 101, 103.7, 121.2, 148.6, 160.0	1.51540(43)	15.8(13)
4.936(3)	4.854(3)	14.54(26)%	$3.0(1) \times 10^{-4}\%$	7/2+	0.2042	11.4, 44.2, 44.9, 56.3, 71.6, 77.1, 103.7, 148.6, 160.0	1.51540(43)	4.5(2)
4.980(3)	4.897(3)	100.0(6)%	$2.0(7) \times 10^{-3}\%$	5/2+	0.160	11.4, 44.9, 56.3, 71.6, 77.1, 103.7, 148.6, 160.0	1.51540(43)	1.31(5)
5.057(3)	4.973(3)	1.56(12)%	$3.(3) \times 10^{-5}\%$	7/2+	0.0829	11.4, 71.6	1.51540(43)	274(23)
5.084(4)	5.000(4)	0.49(6)%	$1.0(1) \times 10^{-5}\%$	$5/2^{+}$	0.0563	11.4, 44.9, 56.3	1.51540(43)	$1.14(2) \times 10^3$
5.128(3)	5.043(3)	1.23%***	$2.5(1) \times 10^{-5}\%$	$3/2^{+}$	0.0114	11.4	1.51540(43)	$1.0 \times 10^{3}$
5.141(5)	5.056(5)	0.42%***	$8.6(3) \times 10^{-6}\%$	$1/2^{+}$	0.0		1.51540(43)	$3.5 \times 10^{3}$

* All values from [1968Ah01], except where noted.  $E_{\alpha}$  values are adjusted by +0.6 keV as recommended in [1991Ry01].

** Weighted average of 14.329(29) y [2013Cr05] and 14.325(24) y [2009Dr05].

*** Values from [1965Ba26]. [1968Ah01] reports 1.8(1)% for the sum of the two intensities.

[@] [2006Ba41].

## Table 4

direct  $\alpha$  emission from ²⁴⁵Cm*,  $J^{\pi} = 7/2^+$ ,  $T_{1/2} = 8445(20)$  y**,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@}$	E _{daughter} ( ²⁴¹ Pu) [@]	coincident $\gamma$ -rays (keV) [@]	R ₀ (fm)	HF
≈5.236	$\approx$ 5.151	$\leq 5 \times 10^{-3}\%$	$\leq 5 \times 10^{-3}\%$	$(13/2^+)$	0.3843		1.49615(36)	$\geq 960$
≈5.245	$\approx 5.159^{@@}$	$\leq 4 \times 10^{-3}\%$	$\leq 4 \times 10^{-3}\%$		0.3761		1.49615(36)	$\geq 1.35 \times 10^{3}$
5.3213	5.2344	0.35%	0.32%	$11/2^{+}$	0.3012	42.0, 53.8, 65.5, 69.2, 79.3,	1.49615(36)	50
						95.8, 126.1, 133.1, 136.1, 139.9,		
						175.1, 190.0, 205.4, 232.0		
5.361	5.273@@@	0.08%	0.07%		0.2602		1.49615(36)	410
5.3923(12)	5.3043(12)***	5.5(4)%	5.1(4)%***	$5/2^{+}$	0.2284	42.0, 52.0, 53.8, 61.3, 65.5,	1.49615(36)	8.8(7)
						95.8, 170.9, 181.0, 223.0		
5.4501(11)	5.3611(11)***	100%	92.7(9)%***	7/2+	0.1751	42.0, 53.8, 79.3, 95.8, 133.1,	1.49615(36)	1.083(14)
						175.1		
≈5.459	≈5.370			$11/2^{+}$	0.1613	42.0, 53.8, 65.5, 95.8		
5.5263	5.4361	0.04%	0.04%	9/2+	0.0958	42.0, 53.8, 95.8	1.49615(36)	$7 \times 10^{3}$
5.5796	5.4885	0.90%	0.83%	7/2+	0.0420	42.0	1.49615(36)	700
5.6208(5)	5.5290(5)***	0.76(22)%	0.7(2)%***	5/2+	0.0		1.49615(36)	$1.4^{+0.6}_{-0.3}  imes 10^3$

* All values from [1975Ba65], except where noted.  $E_{\alpha}$  values are adjusted by -0.2 keV as recommended in [1991Ry01]. ** [1982Po14].

*** Value recommended in [1991Ry01], based on adjusted values from [1975Ba65] and [1966Fr03].

[@] ensdf
[@] Typo in [1975Ba65] lists this transition as 5.119 MeV going to 376 keV level.
[@] [@] [@] Possibly contamination from ²⁴³Am [1975Ba65].

Table 5				
direct $\alpha$ emission from	$^{249}Cf^*, J^{\pi} = 9/2^{-1}$	$-, T_{1/2} = 350.6$	$b(21) y^{**}, BR_{\alpha} =$	= 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	Edaughter ( ²⁴⁵ Cm)***	coincident γ-rays (keV)***	HF [@]
5.1909(5) 5.2388(8) 5.2217(10)	5.1075(5)*** 5.1546(8)*** 5.2262(10)	$4.0(16) \times 10^{-6}\%$ $2.4(16) \times 10^{-6}\%$ $1.8(4) \times 10^{-3}\%$	$3.3(13) \times 10^{-6}\%$ *** $2.0(13) \times 10^{-6}\%$ *** $1.5(2) \times 10^{-3}\%$		1.1026(5) 1.0547(8)	1102.6 1054.7	$2.3^{+1.5}_{-0.7} \times 10^{3}$ $8^{+15}_{-3} \times 10^{3}$ $20^{+9}$
5.3217(10)	5.2362(10)	1.8(4)×10 %	1.5(3)×10 ⁻⁵ %		0.9714	54.8, 198.1, 66.8, 121.6, 252.9 718.5, 849.9, 916.6, 971.3	$30_{-6}^{+6}$
5.3869(5) 5.3935(5)	5.3004(5)*** 5.3069(5)***	$9.0(16) \times 10^{-6}\%$ 9.7(35) × 10^{-5}\%	$7.4(13) \times 10^{-6}\%$ 8.0(29)×10 ⁻⁵ %***	(3/2+)	0.9066(5) 0.9000(5)	906.6 42.9, 54.8, 54.9, 65.9, 66.8, 121.6, 198.1, 229.2, 241.0, 252.9, 295.7 483.5	$ \begin{array}{c} 1.9(4) \times 10^{4} \\ 1.9^{+1.1}_{-0.5} \times 10^{3} \end{array} $
5.4029(5) 5.4407(10) 5.4443(5)	5.3161(5)*** 5.3533(10) 5.3568(5)***	$3.0(3) \times 10^{-5}\%$ $2.4(4) \times 10^{-3}\%$ $1.2(2) \times 10^{-4}\%$	$2.5(2) \times 10^{-5} \% ***$ 2.0(3)×10^{-3} \% 1.0(2)×10^{-4} \% ***	(9/2 ⁺ ) (11/2 ⁺ )	0.8906(5) 0.8526(1) 0.8492(5)	890.6 54.8, 66.8, 121.6, 731.0, 798.0 54.8, 108, 1, 252, 0, 596, 1, 840, 3	$7.0(6) \times 10^{3}$ $149^{+28}_{-21}$ $3.1^{+0.8} \times 10^{3}$
5.4524(5) 5.5082(5)	5.3648(5)***	$\frac{9.0(16) \times 10^{-6}\%}{1.7(2) \times 10^{-4}\%}$	$7.4(14) \times 10^{-6}\%^{***}$	(0/2+)	0.8411(5)	841.1 54.8, 66.8, 121.6, 662.7	$\frac{4.8^{+1.2}_{-0.8} \times 10^4}{5.5^{+1.0}_{-0.8} \times 10^3}$
5.5192(5) 5.5215(5)	5.4305(5)*** 5.4328(5)	$\frac{1.7(2) \times 10^{-5} \%}{2.4(12) \times 10^{-5} \%}$ $0.0125(9)\%$	$2.0(10) \times 10^{-5} \%^{***}$ 0.0103(7)%	(11/2 ⁻ )	0.7743(5) 0.7719(1)	54.8, 66.8, 121.6, 652.7 54.8, 66.8, 121.6, 652.7 42.9, 54.8, 54.9, 65.9, 66.8, 121.6, 198.1, 229.2, 241.0, 252.9, 295.7 356.1, 421.0, 650.3, 717.1	$5^{+5}_{-2} \times 10^4$ 90(7)
5.5571(5) 5.5918(5)	5.4678(5)*** 5.5020(5)	9.7(35)×10 ⁻⁵ % 0.053(2)%	8.0(29)×10 ⁻⁵ %*** 0.044(2)%	(9/2-)	0.7364(5) 0.7018	54.8, 198.1, 252.9, 483.5 42.9, 54.8, 66.8, 121.6, 198.1, 241.0, 252.9, 295.7, 405.9, 580.3, 647.0, 701.8	$1.9^{+1.1}_{-0.5} \times 10^4$ 55.2(32)
5.6193(10)	5.5290(10)	$2.7(4) \times 10^{-3}\%$	$2.2(3) \times 10^{-3}\%$ *		0.6742(10)*		$1.6^{+0.3}_{-0.2} \times 10^3$
5.6501(5)	5.5593(5)	0.140(6)%	0.115(5)%	(7/2 ⁻ )	0.6436	37.6, 42.9, 54.8, 54.9, 66.8, 92.5, 121.6, 198.1, 229.2, 241.0, 252.9, 255.6, 266.7, 295.7, 333.4, 388.2 390.8, 588.8, 643.6	46(3)
5.7081(5)	5.6164(5)	0.027(1)%	0.022(1)%	$(11/2^+)$	0.5547	42.9, 54.8, 198.1, 241.0, 252.9, 259.0, 295.7	780(50)
5.7392(10) 5.7852(5)	5.6470(10) 5.6922(5)	3.2(5)×10 ⁻³ % 0.35(1)%	2.6(4)×10 ⁻³ %* 0.29(1)%	13/2-	0.5543(10)* 0.5088	37.6, 42.9, 54.7, 54.8, 54.9, 65.9, 66.9, 92.5, 121.6, 198.1, 229.2, 241.0, 252.9, 266.7, 295.7, 321.3, 333.4, 388.2	$\begin{array}{c} 6.7^{+1.3}_{-1.0} \times 10^{3} \\ 108(5) \end{array}$
5.7977(10) 5.8509(5)	5.7046(10) 5.7569(5)	0.058(4)% 5.68(9)%	0.048(3)%* 4.68(7)%	11/2-	0.4958(10)* 0.4429	37.6, 42.9, 54.7, 54.8, 54.9, 66.8, 92.5, 121.6, 198.1, 229.2, 241.0, 252.9, 266.7, 295.7, 321.3, 333.4, 388.2	770(60) 15.5(6)
5.8768(5)	5.7824(5)	0.42(1)%	0.35(1)%	11/2+	0.4165	42.9, 54.8, 54.9, 65.9, 66.8, 121.6, 198.1, 229.2, 241.0, 252.9, 295.7	290(13)
5.9054(5)	5.8105(5)	100%	82.4(3)%	9/2-	0.3882	37.6, 42.9, 54.8, 54.9, 66.8, 92.5, 121.6, 198.1, 229.2, 241.0, 252.9, 266.7, 295.7, 333.4, 388.2	1.76(6)
5.9430(5)	5.8475(5)	1.75(4)%	1.44(3)%	9/2+	0.3506	42.9, 54.8, 54.9, 66.8, 121.6, 198.1, 229.2, 241.0, 252.9, 295.7	161(7)
5.9979(5)	5.9015(5)	3.85(6)%	3.17(5)%	7/2+	0.2957	42.9, 54.8, 198.1, 241.0, 252.9, 295.7	143(5)
6.0408(5) 6.0937(5)	5.9438(5) 5.9958(5)	3.99(6)% 0.049(4)%	3.29(5)% 0.040(3)%	5/2 ⁺ 13/2 ⁺	0.2529 0.2003	54.8, 198.1, 252.9	232(9) 3.6(3)×10 ⁴
6.1719(5) 6.2387(5) 6.2935(5)	6.0728(5) 6.1385(5) 6.1924(5)	0.41(1)% 1.602(74)% 2.96(6)%	0.34(1)% 1.320(3) 2.44(5)%	11/2 ⁺ 79/2 ⁺ 7/2 ⁺	0.1216 0.0548 0.0	54.8, 66.8, 121.6 54.8	$1.07(5) \times 10^4$ $6.0(2) \times 10^3$ $6.01(24) \times 10^3$

* All values from [2015Ah03], except where noted. ** [1973St15]. *** [1997Ar31]. @  $R_0 = 1.4839(14)$  fm.

## **Table 6** direct $\alpha$ emission from ²⁵³Fm*, $J^{\pi} = 1/2^+$ , $T_{1/2} = 72(3)$ h, $BR_{\alpha} = 12(1)\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{m{\pi}}$	Edaughter( ²⁴⁹ Cf)**	coincident γ-rays (keV)**	HF***
≈6.591	≈6.487	$\approx 0.7\%$	≈0.036%		≈0.606		≈31
6.646(5)	6.541(5)	3.5(9)%	0.18(5)%		0.5506	134, 145.0, 271.8	$11^{+5}_{-2}$
6.737(4)	6.630(4)	6.1(12)%	0.31(7)%	5/2+	0.460		$17^{+6}_{-4}$
6.757(4)	6.650(4)	5.6(9)%	0.29(5)%	3/2+	0.4376	43.0, 55.1, 58.0, 62.5, 135.4, 145.0, 191.6, 234.6, 375.1, 379.5, 437.6	$23^{+7}_{-5}$
6.780(3)	6.673(3)	54.3(25)%	2.80.3%	1/2+	0.4168	145.0, 271.8	3.0(3)
6.956(3)	6.846(3)	19.7(13)%	1.0(1)%	9/2+	0.243.1	43.0, 55.1, 145.0	$47^{+8}_{-6}$
≈6.977	$\approx 6.867$	$\approx 2.1\%$	≈0.11%	15/2-**	0.221.7	62.5, 159.3	≈550
7.013(4)	6.902(4)	23.0(13)%	1.2(1)%	7/2+	0.1880	43.0, 145.0	70(8)
7.055(3)	6.943(3)	100(4)%	5.1(4)%	5/2+	0.1450	145.0	24.3(24)
7.136(4)	7.023(4)	15.7(10)%	0.80(8)%	$11/2^{-}$	0.0625	62.5	$340^{+60}_{-50}$
7.197(4)	7.083(4)	3.0(5)%	0.16(3)%	9/2-	0.0		$3.2^{+0.9}_{-0.6} \times 10^3$

* All values from [1967Ah02], except where noted.  $E_{\alpha}$  is adjusted by -8.8 keV as recommended in [1991Ry01].

** [2024Ne04].

***  $R_0 = 1.47787(78)$  fm.

### Table 7

direct  $\alpha$  emission from ²⁵⁷No*,  $J^{\pi} = (3/2^+)$ ,  $T_{1/2} = 25.5(5)$  s,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{253}\mathrm{Fm})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
8.318	8.188**	<4.8%	<4%	(5/2 ⁺ )	0.1587	22.3, 136.4	1.477(13)	$>\!\!28 \\ 1.8^{+7}_{-5} \\ 19^{+8}_{-5}$
8.352(6)	8.222(6)	100(2)%	83(2)%	3/2 ⁺	0.1241	22.3, 24.8, 47.1, 77.0, 101.8, 124.1	1.477(13)	
8.455(7)	8.323(7)	20.5(25)%	17(2)%	(3/2 ⁺ )	0.0223	22.3	1.477(13)	

* All values from [2005As05].

** Deduced from  $\gamma$  energies.

## Table 8

direct  $\alpha$  emission from ²⁶¹Rf,  $J^{\pi} = (11/2)^*$ ,  $T_{1/2} = 68(3) \text{ s}^{**}$ ,  $BR_{\alpha} = \approx 100\%$ .

 $\approx 100\%$ 

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{257}\mathrm{No})$	coincident γ-rays (keV)	$R_0$ (fm)	HF
8.409(20)	8.280(20)***	$\approx 100\%$				1.486(14)	$1.6^{+0.7}_{-0.5}$
* [2024C ** [2008 *** [197	0g02]. Du09]. 0Gh01].						
<b>Table 9</b> direct $\alpha$ emiss	sion from ^{261m} Rf, Ex	$a. = \text{unk.}, J^{\pi} = (2$	3/2)*, T _{1/2}	$E = 1.9(4) \text{ s}^{**}, BR_{\alpha} = \approx 1$	00%.		
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	<i>E</i> _{daughter} ( ²⁵⁷ No)	coincident γ-rays (keV)	R ₀ (fm)	HF

 $1.0\substack{+0.7\\-0.5}$ 

1.486(14)

3k	[20240~0'	21
	1/11/4090	Z. L.

8.647(30)

** [2011Ha13].

8.514(30)***

*** Weighted average of 8.520(50) MeV [2011Ha13], 8.510(60) MeV [2012Ha05] and 8.510(50) MeV [2008Dv02],

direct $\alpha$ emiss	sion from ²⁰⁵ Sg, J	$\pi = (3/2)^*, T_{1/2}$	$= 14.4^{+3.7}_{-2.5}$ s [*]	$^{**}, BR_{\alpha} = 100\%.$			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{m \pi}$	$E_{daughter}(^{261}\mathrm{Rf})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
8.823(50)	8.690(50)**	100%	3/2*	х		1.457(60)	$0.7\substack{+2.6 \\ -0.6}$
* [2024O ** [2012]	g02]. Ha05].						
Table 11 direct α emiss	sion from ^{265m} Sg,	Ex. = unk., $J^{\pi}$ =	= (11/2)*, T _{1/}	$_2 = 8.5^{+2.6}_{-1.6}$ s, $BR_{\alpha} = 100$	)%.		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\rm J}_f^{\pi}$	$E_{daughter}(^{261}\mathrm{Rf})$	coincident γ-rays (keV)	R ₀ (fm)	HF
8.975(50)	8.840(50)**	100%	(11/2)*	0.0*		1.457(60)	$1^{+5}_{-1}$
* [2024O ** [2012]	g02]. Ha05].						
Table 12 direct $\alpha$ emiss	sion from ²⁶⁹ Hs*,	$J^{\pi} = (9/2), T_{1/2}$	$= 12.5^{+6.7}_{-2.8}$ s ²	**, $BR_{\alpha} = 100\%$ .			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{265}\mathrm{Sg})$	coincident γ-rays (keV)	R ₀ (fm)	HF
9.339(40)	9.200(40)	100%	(9/2)	X		1.465(38)	$6^{+10}_{-5}$
* All valu ** Weigh Table 13 direct α emiss	ted average of 13 sion from ²⁶⁹ Hs*,	02], except whe $^{+10}_{-9}$ s [2024Og0 Ex. = unk., J ^{$\pi$} =	ere noted. 2] and $12^{+9}_{-4}$ s = (1/2), $T_{1/2}$ =	[2013Su04]. = $2.8^{+13.6}_{-1.3}$ s, $BR_{\alpha} = 1009$	6.		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{265}Sg)$	coincident γ-rays (keV)	R ₀ (fm)	HF
9.22(15)	9.08(15)	100%	(1/2)	X		1.465(38)	$0.6^{+34}_{-3.1}$
* All valu	ues from [2024Og	02].					
<b>Table 14</b> direct $\alpha$ emiss	sion from ²⁷³ Ds*,	$J^{\pi} = (11/2), T_{1/2}$	$v_2 = 0.18^{+0.11}_{-0.05}$	ms, $BR_{\alpha} = 100\%$ .			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{269}\text{Hs})$	coincident γ-rays (keV)	R ₀ (fm)	HF
11.265(70)	11.100(70)	100%	(11/2)	X			
* All valu	ies from [2024Og	02].	. ,				
Table 15 direct $\alpha$ emiss	sion from ^{273m} Ds*	$F$ , Ex. = unk., $J^{\pi}$	= (1/2), T _{1/2}	$= 30^{+140}_{-15}$ ms, $BR_{\alpha} = 10$	0%.		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}$ ⁽²⁶⁹ Hs)	coincident γ-rays (keV)	R ₀ (fm)	HF

**Table 10** direct  $\alpha$  emission from ²⁶⁵Sg, J^{$\pi$} = (3/2)*, T_{1/2} = 14.4^{+3.7}/₂ s**, BR_{$\alpha$} = 100%.

* All values from [2024Og02].

10.930(20)

100%

(1/2)

х

11.093(20)

Table 16		
direct $\alpha$ emission from ²⁷⁷ Cn	$T_{1/2} = 0.61^{+0.46}_{-0.18} \text{ ms}$	$BR_{\alpha} = 100\%$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$_{\alpha}(lab)$ $I_{\alpha}(abs)$ J		$E_{daughter}(^{261}\mathrm{Rf})$ coincident $\gamma$ -rays (keV)		R ₀ (fm)	HF	
11.232(80)	11.070(80)	100%						

* All values from [2013Su04].

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# $\begin{array}{c} 277 Nh \\ Qep = 1.654 \ MeV \\ Qeq = 15.374 \ MeV \\ Q_{\alpha} = 11.644 \ MeV \end{array}$

# $\begin{array}{c} 27^5 Rg \\ Q_{0} \alpha = 15.28 \pi \, MeV \\ Q_{0} \alpha = 15.28 \pi \, MeV \\ Q_{0} \alpha = 11.87 \pi \, MeV \end{array}$







Last updated 3/14/25

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +53/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. All  $J^{\pi}$  values are taken from ENSDF.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{arepsilon}$	Q _β -	$Q_{\beta}$ - $\alpha$	Experimental
219		(0.12-)	22/5	4.20(45)#	2 (1/20) //	0.74(20) //	[A01AD A0]
219 B1*		(9/2-)	22(7) s	-4.30(45)#	3.64(20)#	9.74(30)#	[2012Be28]
223At*			50(7) s	-3,65(20)#	3.038(16)	8.502(21)	[1989Bu09]
²²⁷ Fr*		$1/2^{+}$	148(2)s	-3.203(15)	2.505(6)	7.047(10)	[1981Vo03]
²³¹ Ac*		$1/2^{+}$	7.5(2) m	-2.454(17)	1.947(13)	6.341(13)	[1973Ch24]
²³⁵ Pa*		$(3/2^{-})$	24.5(2) m**	-1.729(19)	1.370(14)	6.228(14)	[1986Mi10, 1968Tr07]
²³⁹ Np*		5/2+	2.3565(4) d	-1.262(2)	0.723(1)	6.147(2)	[1990Ab06]
					$O_{\varepsilon n}$	$O_{\varepsilon \alpha}$	
²⁴³ Am		$5/2^{-}$	7349(12) v***	-0.580(3)	<b>2</b> <i>cp</i>		[2020Ma63, 2007Ag02, 1980Ag05]
^{243m} Am	2.30(30)		5.8(7) μs [@]	1,72(30)	5.23(36)	8.90(30)	[1973Br04, 1972Wo07, 1970Po01]
²⁴⁷ Bk		3/2-	1380(250) y	-0.044(6)			[1965Mi08]
²⁵¹ Es		$3/2^{-}$	33(1) h	0.377(6)	-5.729(6)	6.554(7)	[1970Ah01]
²⁵⁵ Md		$(7/2^{-})$	27(2) m	1.042(7)	-4.441(6)	8.282(7)	[1970Fi12]
²⁵⁹ Lr		$(1/2^{-})$	6.22(28) s ^{@@}	1.770(70)#	-3.128(71)#	9.625(71)#	[1992Ha22, 1992Gr02]
²⁶³ Db			$27^{+10}_{-7}$ s	2.35(23)#	-2.28(26)#	10.61(17)#	[1992Kr01]
²⁶⁷ Bh			$13_{-3}^{+6} s^{@@@}$	2.96(37)#	-1.26(39)#	11.58(30)#	[2009Mo12, 2000Ei05, 2000Wi15]
²⁷¹ Mt			2	3.41(41)#	-0.42(45)#	12.87(42)#	
²⁷⁵ Rg				3.73(56)#	0.86(58)#	15.28(53)#	
²⁷⁹ Nh				4.44(72)#	1.65(72)#	15.37(69)#	

* 100%  $\beta^-$  emitter.

** Weighted average of 24.6(2) m [1986Mi10] and 24.2(3) m [1968Tr07].

*** Weighted average of 7345(14) y [2020Ma63], 7357(23) y [2007Ag02] and 7358(42) y [1980Ag05].

[@] Weighted average of 5.0(10)  $\mu$ s [1972Wo07] and 6.5(10)  $\mu$ s [1970Po01].

[@] Weighted average of 6.14(36) s [1992Ha22] and 6.34(46) s [1992Gr02].

@@@ Deduced from times of 12 decay chains from [2009Mo12] (1 event), [2000Ei05] (6 events), and [2000Wi15] (5 events).

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +53/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	$BR_{\alpha}$	BR _{SF}	Experimental
210-21					
²¹⁷ B1	6.60(36)#	3.87(36)#			
²²⁵ At	6.347(42)	4.68(20)			
²² /Fr	6.354(12)	3.830(15)			
²³¹ Ac	6.042(17)	3.655(14)			
²³⁵ Pa	5.613(14)	4.101(19)			
²³⁹ Np	5.286(1)	4.597(14)			
²⁴³ Am	4.831(1)	5.439(1)	100%	3.76(20)×10 ⁻⁹ %	[2002Da21, 2002Sa53, 2023Ko26, 2020Ma63, 2018Ca05, 2007Ag02,
					1998Ya17, 1996Sa23, 1996Sa23, 1996Wo05, 1992Ga01, 1991Po14,
					1986AmZY, 1984Va41, 1980Ag05, 1979Po20, 1977St35, 1974Po17,
					1969A114, 1969En02, 1968Ba22, 1968Ba25, 1968Va09, 1967Fa01,
					1966Gv01, 1964Ba26, 1963Ba65, 1960Be10, 1959Ba22, 1958Wa69,
					1956Hu96, 1955St98, 1954As05, 1953AsZZ, 1953Di27]
^{243m} Am	2.53(30)	7.74(30)		100%	[1973Br04, 1972Wo07, 1970Po01, 1980Bj02, 1973Be04, 1973Na35,
					1971Re11, 1970ReZN]
²⁴⁷ Bk	4.416(5)	5.890(5)	$\approx 100\%$		[ <b>1969Fr01</b> , 1965Mi08, 1956Ch77]
²⁵¹ Es	3.948(5)	6.597(1)	0.5(2)%		[1979Ah03, 1970Ah01, 1956Ha80]
²⁵⁵ Md	3.349(6)	7.906(2)	8.1(8)%*		[2000Ah02, 1971Ho16, 1970Fi12, 1965Si14, 2005He27, 1958Ph40]
²⁵⁹ Lr	2.92(12)#	8.584(71)#	77.9(17)%	22.1(17)%**	[1992Ha22, 1992Gr02, 2020Ha27, 1971Es01, 1971EsZX, 1970GhZY]
²⁶³ Db	2.57(28)#	8.83(15)#	42(15)%***	$56^{+13}_{-15}\%$ ***	[2003Kr20, 1992Kr01, 2002KrZY, 1995GrZV, 1992GaZU, 1991KrZS,
					1987GrZN]
²⁶⁷ Bh	2.14(36)#	9.23(20)#	100%		[2020Ha27, 2009Mo12, 2000Ei05, 2000Wi15]
²⁷¹ Mt	1.30(41)#	9.91(20)#			
²⁷⁵ Rg	1.09(59)#	11.87(30)#			
²⁷⁹ Nh	0.67(74)#	11.64(75)#			

* Weighted average of 10.0(14)% [1971Ho16], 7(1)% [1970Fi12] and 9(2)% [1965Si14].

** Weighted average of 20(3)% [1992Ha22] and 23(2)% [1992Gr02]. *** [1992Kr01] report BR_{$\alpha$} = 43(15)% and BR_{SF} = 57⁺¹³₋₁₅%, neglecting BR_{$\varepsilon$}, which was assumed to be small. [2003Kr20] report a BR_{$\varepsilon$} = 3⁺⁴₋₁%. The BR for  $\alpha$  and SF are adjusted by the evaluator to reflect this.

# **Table 3** direct $\alpha$ emission from ²⁴³Am*, $J^{\pi} = 5/2^{-}$ , $T_{1/2} = 7349(12)$ y**, $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	Edaughter( ²³⁹ Np)***	coincident γ-rays (keV)***	R ₀ (fm)	HF
4.7760	4.6974	4.4(5)×10 ⁻³ %	3.8(4)×10 ⁻³ %	(5/2-)	0.6623	31.1, 43.1, 43.5, 74.7, 86.7, 117.6, 544.5, 587.6, 631.1	1.50633(42)	3.3(4)
5.0185	4.9359	$3.0(3) \times 10^{-3}\%$	$2.6(3) \times 10^{-3}\%$		0.427		1.50633(42)	$215^{+29}_{-23}$
5.0335	4.9506	$3.2(3) \times 10^{-3}\%$	$2.8(3) \times 10^{-3}\%$		0.411		1.50633(42)	$255_{-25}^{+\overline{3}\overline{1}}$
5.0843	5.0006	3.6(5)×10 ⁻³ %	$3.1(4) \times 10^{-3}\%$	$(9/2^+)$	0.3591		1.50633(42)	510(50)
5.0959	5.0120	$6.0(5) \times 10^{-3}\%$	$5.2(4) \times 10^{-3}\%$	$(9/2^+)$	0.3473		1.50633(42)	366(28)
5.1209	5.0366	9.5(6)×10 ⁻³ %	$8.2(5) \times 10^{-3}\%$	$(13/2^{-})$	0.3174	195	1.50633(42)	365(23)
5.1763	5.0911	0.0129(7)%	0.0112(6)%		0.267		1.50633(42)	567(31)
5.1989	5.1133	0.0219(12)%	0.0190(10)%	$(11/2^{-})$	0.2413	71.2, 169	1.50633(42)	489(26)
5.2651	5.1784	1.606(8)%	1.391(7)%	9/2-	0.1731	31.1, 43.1, 43.5, 50.6, 55.4,	1.50633(42)	18.04(21)
						74.7, 86.7, 98.5, 117.6, 141.9		
5.3204	5.2328	13.30(3)%	11.52(2)%	7/2-	0.1177	31.1, 43.1, 43.5, 74.7, 86.7,	1.50633(42)	4.82(5)
						117.6		
5.3636	5.2753	100.%	86.6(7)%	5/2-	0.0747	31.1, 43.5, 74.7	1.50633(42)	1.149(15)
5.4073	5.3183	0.219(3)%	0.19(3)%	$7/2^{+}$	0.0311	31.1	1.50633(42)	$980^{+190}_{-140}$
5.4385	5.3490	0.28(4)%	0.24(3)%	5/2+	0.0	—	1.50633(42)	$1.20_{-0.14}^{+0.17} \times 10^3$

* All values from [2002Da21], except where noted.  $E_{\alpha}$  uncertainties are in units of the last significant decimal figure [2022Da21]. ** Weighted average of 7345(14) y [2020Ma63], 7357(23) y [2007Ag02] and 7358(42) y [1980Ag05]. *** [2014Br18].

# Table 4

direct  $\alpha$  emission from ²⁴⁷Bk*,  $J^{\pi} = 3/2^{-}$ ,  $T_{1/2} = 1380(250)$  y**,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi***}$	<i>E</i> _{daughter} ( ²⁴³ Am)***	coincident γ-rays (keV)***	R ₀ (fm)	HF
5.546(5)	5.456(5)	3.3(5)%	1.5(2)%	$(7/2^{-})$	0.345(1)		1.4896(15)	$11^{+4}$
5.592(5)	5.501(5)	16(2)%	7(1)%	$(5/2^{-})$	0.300(2)		1.4896(15)	$4.5^{+1.7}_{-1.2}$
5.622(5)	5.531(5)	100(6)%	45(2)%	3/2-	0.265(10)	265	1.4896(15)	1.1(3)
5.702(5)	5.610(5)	$\approx 0.9\%$	$\approx 0.4\%$	$(11/2^+)$	0.1894(6)		1.4896(15)	≈300
5.747(5)	5.654(5)	12.2(14)%	5.5(6)%	(9/2+)	0.1434(2)	25.2, 34, 41.8, 42,2, 67, 84.0, 101.3, 109.2	1.4896(15)	$45^{+15}_{-12}$
5.782(5)	5.688(5)	29(3)%	13(1)%	7/2+	0.1092(2)	25.2, 41.8, 42.2, 67, 84.0, 109.2	1.4896(15)	30(6)
5.804(5)	5.710(5)	38(3)%	17(1)%	$5/2^{+}$	0.0840(1)	41.8, 42.2, 84.0	1.4896(15)	31(6)
5.849(5)	5.754(5)	9.6(10)%	4.3(4)%	7/2-	0.0422(2)	42.2	1.4896(15)	210(50)
5.889(5)	5.794(5)	12.2(12)%	5.5(5)%	5/2-	0.0		1.4896(15)	280(60)

* All values from [1969Fr01], except where noted.  $E_{\alpha}$  is adjusted by +1.0 keV as recommended in [1991Ry01].

** [1965Mi08].

*** [2014Ne14].

## Table 5

Table 5			
direct $\alpha$ emission from	$^{251}\text{Es*}, J^{\pi} = 3/2$	$-, T_{1/2} = 33(1) h^*$	*, $BR_{\alpha} = 0.5(2)\%$ ***

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi @}$	E _{daughter} ( ²⁴⁷ Bk) [@]	coincident $\gamma$ -rays (keV) [@]	$R_0$ (fm)	HF
6.514(3)	6.410(3)	4.1(7)%	0.017(7)%	$(9/2)^+$	0.0828	40.8.42.0	1.47482(56)	33+28
6.526(3)	6.422(3)	3.7(7)%	0.015(7)%	$(7/2^{-})$	0.0716	,	1.47482(56)	$40^{+40}_{-10}$
6.556(3)	6.452(3)	4.1(9)%	0.017(7)%	7/2+	0.0408	40.8	1.47482(56)	$50^{+50}_{-20}$
6.567(3)	6.462(3)	11.6(13)%	0.047(19)%	$(5/2^{-})$	0.0299	29.9	1.47482(56)	$21_{-7}^{+\overline{16}}$
6.597(3)	6.492(3)	100(3)%	0.41(16)%	3/2-	0.0		1.47482(56)	$3.3^{+2.4}_{-1.0}$

* All values from [1979Ah03], except where noted.  $E_{\alpha}$  is adjusted by +0.8 keV as recommended in [1991Ry01].

** [1970Ah01].

*** Deduced from  $I_{\alpha}/I_{Kx} = 0.008(2)$  [1970Ah01] and  $I_{Kx}/I_{\varepsilon} = 0.64(5)$  [2005Ah09].

@ [2015Ne04].

Table 6	
direct $\alpha$ emission from ²⁵⁵ Md*, $J^{\pi} = (7/2^{-}), T_{1/2} = 27(2)$ m**, BR	$\alpha = 8.1(8)\%^{***}.$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}$ ( ²⁵¹ Es	s) coincident $\gamma$ -rays (keV)	) $R_0$ (fm)	HF		
7.390(5) 7.444(4) 7.837(8) 7.876(8)	7.274(5) 7.327(4) 7.714(8) 7.752(8)	5.4(5)% 100% 1.1(2)% 1.1(2)%	$\begin{array}{c} 0.041(6)\%\\ 0.75(8)\%\\ 8(2)\times10^{3}\\ 8(2)\times10^{3} \end{array}$	7/2-	0.515 0.4614 0.068 0.030	405.5, 453.1	1.4825(13) 1.4825(13) 1.4825(13) 1.4825(13) 1.4825(13)	$\begin{array}{c} 21^{+5}_{-4} \\ 1.9^{+0.4}_{-0.3} \\ 5.1^{+2.0}_{-1.3} \times 10^3 \\ 7.0^{+2.7}_{-1.7} \times 10^3 \end{array}$		
* All values from [2000Ah02], except where noted. ** [[1970Fi12]. *** Weighted average of 10.0(14)% [1971Ho16], 7(1)% [1970Fi12] and 9(2)% [1965Si14]. Table 7										
$\frac{\text{direct } \alpha \text{ em}}{\alpha}$	ussion from 207	$Lr^*, J^* = (1)$	$(2), 1_{1/2} = 0.2$	2(28) S*,	$BR_{\alpha} = 77.9(17)\%^{*}$	* <b>.</b>				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(ab)$	s) J	$f E_{d}$	laughter ( ²⁵⁵ Md)	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF		
8.571(10)	8.439(10)	77.9(1	17)%**				1.485(19)	$1.3^{+0.8}_{-0.5}$		
* Weighted average of 6.14(36) s [1992Ha22] and 6.34(46) s [1992Gr02]. ** Weighted average of 20(3)% [1992Ha22] and 23(2)% [1992Gr02] for BR _{SF} . $\alpha$ decay is the only other expected channel.										
<b>Table 8</b> direct $\alpha$ emission from ²⁶³ Db*, $J^{\pi} = (1/2^{-})$ , $T_{1/2} = 27^{+10}_{-7}$ s, $BR_{\alpha} = 42(15)\%^{**}$ .										
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(ab)$	$J_f^{\pi}$	$E_d$	_{aughter} ( ²⁵⁹ Lr)	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF		
8.484(27)	8.355(27)	) 42(15	5)%**				1.475(18)	$0.9^{+1.2}_{-0.6}$		

* All values from [1992Kr01], except where noted. ** [1992Kr01] report BR_{$\alpha$} = 43(15)% and BR_{SF} = 57⁺¹³₋₁₅%, neglecting *BR*_{$\varepsilon$}, which was assumed to be small. [2003Kr20] report a *BR*_{$\varepsilon$} = 3⁺⁴₋₁%. The BR for  $\alpha$  and SF are adjusted by the evaluator to reflect this.

**Table 9** direct  $\alpha$  emission from ²⁶⁷Bh*, T_{1/2} = 13⁺⁶₋₃ s**, *BR*_{$\alpha$} = 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{263}\text{Db})$	coincident γ-rays (keV)	R ₀ (fm)	HF
8.86	8.73	22%	17%				1.451(72)	$2^{+12}_{-2}$
8.97 9.05	8.84 8.91	100% 11%	75% 8%				1.451(72) 1.451(72)	$1.0^{+5.2}_{-0.9}$ $20^{+54}_{-20}$

* 12 decay chains were assigned to the decay of ²⁶⁷Bh [2009Mo12, 2000Ei05, 2000Wi15] along with 4 tentative assignments in [2009Mo12], of which 3 have significantly longer decay times than the others. The events with  $E_{\alpha}$ , decay time and ref. listed below. The events are grouped by energy into 3 peaks; 8.73 MeV (2 events), 8.84 MeV (9 events) and 8.91 (1 event). Note that [2020Ha27] discusses that these events may be due to ²⁶⁶Bh as the energies are very similair.

$E_{\alpha}$ (MeV)	decay t(s)	Ref.
8.84	11.95	[2009Mo12]
8.81	24.5	[2000Ei05]
8.85	34.4	[2000Ei05]
8.72	2.9	[2000Ei05]
8.84	26.7	[2000Ei05]
8.91	10.5	[2000Ei05]
8.81	18.4	[2000Ei05]
8.83	5.26	[2000Wi15]
8.87	24.67	[2000Wi15]
8.87	45.15	[2000Wi15]
8.73	2.71	[2000Wi15]
8.84	21.83	[2000Wi15]
8.76 (tentative)	112.2	[2009Mo12]
8.71(tentative)	5.38	[2009Mo12]
8.75 (tentative)	155.57	[2009Mo12]
8.84 (tentative)	176.77	[2009Mo12]

** Deduced from the decay times listed above.

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +27 nuclei.

Last updated 3/29/2025

Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +27$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values are taken from ENSDF.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\beta}$ -	$Q_{\beta} - \alpha$	Experimental
						·	
²¹⁸ Pb*		$0^+$	13(7) s	-8.08(50)#	2.41(30)#	6.92(36)#	[2016Ca25]
²²² Po*		$0^{+}$	$145^{+694}_{-66}$ s	-6.46(30)#	1.530(40)	7.029(48)	[2010Ch15]
²²⁶ Rn*		$0^+$	7.4(1) m	-5.91(30)#	1.227(12)	5.549(19)	[1986Bo35]
²³⁰ Ra*		$0^+$	93(2) m	-4.970(12)	0.678(19)	4.750(12)	[1978Gi07]
234 Th(UX ₁ )*		$0^{+}$	24.101(25) d	-4.228(14)	0.274(3)	4.530(16)	[1948Kn23]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
$^{238}U(U_1)$		$0^+$	4.4683(24)×10 ⁹ y	-3.586(16)			[1971Ja07]
^{238m} U	2.5575(5)	$0^+$	298(18) ns	-1.028(16)			[1992St05]
²⁴² Pu		$0^+$	$3.77(7) \times 10^5 \text{ y}^{**}$	-2.70(20)			[1976Bu23, 1976Os05, 1969Be06]
^{242m1} Pu	х		3.5(6) ns	-2.70(20)+x			[1974MeYP]
^{242m2} Pu	у		50(30) ns	-2.70(20)+y			[1969La14, 1970Po01]
²⁴⁶ Cm	-	$0^+$	4756(20) y***	-2.377(18)#			[2007Ko01, 1977Po20, 1971Ma32,
							1971Mc19, 1969Me01]
²⁵⁰ Cf		$0^+$	13.08(9) y	-1.782(3)			[1969Me01]
²⁵⁴ Fm		$0^+$	194.4(1) m	0.653(12)	-5.689(4)	5.526(3)	[1967Fi03]
²⁵⁸ No		$0^+$	1.2(2) ms	-0.21(10)#			[1989Hu09]
²⁶² Rf		$0^+$	2.1(2) s	0.29(30)#	-3.35(30)#	8.28(22)#	[1996La11]
²⁶⁶ Sg		$0^{+}$	$0.28^{+0.19}_{-0.08}$ s	0.88(37)#	-2.36(44)#	9.09(32)#	[2013Og03]
²⁷⁰ Hs		$0^+$	$7.6^{+4.9}_{-2.2}$ s	0.88(39)#	-1.87(44)#	9.95(38)#	[2013Og03]
²⁷⁴ Ds			-2.2	1.95(54)#	0.14(54)#	12.54(49)#	
²⁷⁸ Cn				2.32(59)#	0.46(59)#	13.17(58)#	

* 100%  $\beta^-$  emitter.

** Weighted average of  $3.702(14) \times 10^5$  y [1976Bu23],  $3.763(9) \times 10^5$  y [1976Os05] and  $3.869(164) \times 10^5$  y [1969Be06]. *** Weighted average of 4706(40) y [2007Ko01], 4852(76) y [1977Po20], 4820(20) y [1971Ma32], 4655(40) y [1971Mc19] and 4718(22) y 1969Me01].

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +27$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	Experimental
²¹⁸ Pb	10.32(50)#	1.43(50)#			
²²² Po	9.00(30)#	4.43(30)#			
²²⁶ Rn	8.84(30)#	3.836(41)			
²³⁰ Ra	8.441(11)	3.344(15)			
²³⁴ Th(UX ₁ ) ²³⁸ U(U ₁ )	7.984(13) 7.509(13)	3.672(11) 6.828(2)	100%	5.45(7)×10 ⁻⁵ %*	[ <b>2014Po02, 2000Ho27, 1961Ko11, 1960Vo05, 1957Ha08</b> , 2005Yo12, 2004Ab03, 2003Gu18, 2000Ga05, 1987Al28, 1985Iv01, 1984Ro21, 1984Va35, 1983Be66, 1982De22, 1980Po09, 1980PoZX, 1978Ka40, 1978Ri07, 1978ThZW, 1976Th12, 1975Wa37, 1972Ni19, 1971K114, 1971Le11, 1971Sa08, 1971Sw03, 1971Th17, 1970Ga27, 1968Ro15, 1968Ar14, 1967Is04, 1967Sp12, 1966Ra25, 1964F107, 1964Me14, 1960Sh19, 1960Vo05, 1960Yo07, 1959Ge30, 1959Ha04, 1959Ko58, 1959Ku81, 1959St45, 1957Bo98, 1957C116, 1952Za01, 1944ChZX, 1940Fl02, 1918So01, 1912Ge01]
^{238m} U	4.951(13)	4.270(2)		2.5(5)%	[ <b>1992St05</b> , 1989Ma54, 1989Ma57, 1989MaZF, 1988Ma52, 1988MaZF, 1984Ka10, 1984Ka17, 1983Dr14, 1983Ka11, 1980Me15, 1977VoZU, 1977ArZZ, 1975Ru03, 1974WoZK, 1971Ta17, 1970Po01, 1970Re05, 1970Wo06, 1969La14]
²⁴² Pu	6.89(10)	4.984(1)	100%	5.59(7)×10 ⁻⁴ %	[2013Sa65, 2011Be01, 1986Va33, 1968Ba25, 1956Hu96, 1956Ko67, 1953AsZZ, 2018Be29, 2016Ob01, 1998Se17, 1998VeZW, 1997De11, 1997SeZW, 1988SeZY, 1982A113, 1979Ag03, 1978MeZL, 1976Bu23, 1976Os05, 1973Dy01, 1973VoZB, 1972Sc01, 1970Du02, 1969Be06, 1968Bo54, 1968HaZX, 1967Ga20, 1963Ma50, 1961Dr04, 1956Bu64, 1956Cr69, 1956Me37, 1950Tb541
$242m^{1}P_{11}$	6 89(10)-x	4.984(1) + x		obs	[1974MeVP]
$^{242m^{2}Pu}$	6.89(10)-v	4.984(1)+x		obs	$[1969La14, 1970P_001]$
246Cm	6.572(2)	5.475(1)	99.97(27)%	0.02627(13)%**	[2007Ko01, 1984Sh31, 1971Ma32, 1969Me01, 1966Ba07, 1963Be48, 1963Dz07, 2008KoZP, 2008Ve05, 1981Gi02, 1977Po20, 1974UnZV, 1973Pl04, 1973PlZW, 1973St04, 1972Pr19, 1972Da34, 1971BeYS, 1971Mc19, 1970Th06, 1967Ch12, 1967Sc32, 1961Ca01, 1956Bu91, 1955Br02, 1954Fr19]
²⁵⁰ Cf	5.965(1)	6.129	99.923(2)%	0.077(2)%***	[2007Ko01, 1986Ry04, 1971Bb10, 1965Me02, 1963Ph01, 2010Ve03, 2010VeZZ, 2008KoZP, 1985Wi10, 1977Fl07, 1970Ba18, 1970BaZX, 1970BaZZ, 1969Ba57, 1969Me01, 1963Br35, 1963Le17, 1962Br45, 1962Ph02, 1957Ea01, 1955As42, 1954Gh24, 1954Ma98]
²⁵⁴ Fm	5.397(2)	7.307(1)	99.9410(3)%	0.0590(3)%	[ <b>1984Ah02, 1967Fi03</b> , 1977Gi15, 1974UnZU, 1974UnZX, 1973Ha44, 1963Bj03, 1963Br35, 1963Le13, 1962Br45, 1956Ch81, 1956Jo09, 1955As08]
²⁵⁸ No	4.80(10)#	8.15(10)#		100%	[1989Hu09, 2009Pe09, 2002PeZW, 1986Hu01, 1969NuZZ]
²⁶² Rf	4.45(30)#	8.49(20)#		100%	[ <b>1996La11, 1994La22</b> , 2013Mu08, 1998Tu01, 1994LaZX, 1994Og04, 1985So03, 1978NiZW]
²⁶⁶ Sg	4.05(33)#	8.80(10)#		100%	[ <b>2013Og03, 2008Dv02, 2006Dv01, 2003Tu05</b> , 2012Tu01, 2006Dv01, 2004Vo24, 2003Du27]
²⁷⁰ Hs	3.65(45)#	9.070(38)	$\approx 100\%$		[ <b>2013Og03, 2008Dv02, 2006Dv01, 2003Tu05</b> , 2012Tu01, 2004Vo24, 2003Du27, 2002Du21]
²⁷⁴ Ds	2.87(58)#	11.66(30)#			
²⁷⁸ Cn	2.85(64)#	11.22(20)#			

* Evaluated value from [2000Ho27], based on previous measurements.

** Deduced from a weighted average of  $T_{1/2}(SF) = 1.85(2) \times 10^7$  y [1971Ma32] and  $T_{1/2}(SF) = 1.80(1) \times 10^7$  y [1969Me01]. *** Deduced from a weighted average of  $\alpha/SF = 1260(40)$  [1965Me02] and  $\alpha/SF = 1330(45)$  [1963Ph01].

### **Table 3** direct $\alpha$ emission from ²³⁸U, $J^{\pi} = 0^+$ , $T_{1/2} = 4.4683(24) \times 10^9$ y*, $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{@}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{234}\mathrm{Th})^{@@}$	coincident $\gamma$ -rays (keV) ^{@@}	R ₀ (fm)	HF
4.107(5) 4.222(5) 4.270(3)	4.038(5)** 4.151(5)*** 4.198(3)***	0.088(1)% 29.8(1)% 100%	0.068(10)% 22.92(10)% 77.01(10)%	$4^+ 2^+ 0^+$	0.163 0.496 0.0	49.6, 113.5 49.6	1.5350(17) 1.5350(17) 1.5350(17)	$45^{+8}_{-6} \\ 1.258(6) \\ 1.0018(14)$

* [1971Ja07].

** Deduced from  $E_{\alpha}$  to the ground state and  $E_{level}$ .

*** Recommended by [1991Ry01], based on the adjusted values of [1961Ko11], [1960Vo05] and [1957Ha08].

@ [2014Po02].

@@ [2007Br04].

## Table 4

direct  $\alpha$  emission from ²⁴²Pu,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 3.77(7) \times 10^5$  y*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{@}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{238}\mathrm{U})^{@@}$	coincident $\gamma$ -rays (keV) ^{@@}	R ₀ (fm)	HF
4.6773(14)** 4.8812(14)** 4.9397(15) 4.9847(14)	4.6000(14) 4.8005(14) 4.8581(15)*** 4.9023(14)***	8.37(26)×10 ⁻⁴ % 0.0388(13)% 30.74(16)% 100%	6.40(20)×10 ⁻⁴ % 0.0297(10)% 23.51(12)% 76.46(12)%	$6^+ 4^+ 2^+ 0^+$	0.30741(4) 0.1484(4) 0.044915(13) 0.0	44.9, 103.5, 159.0 44.9, 103.5 44.9	1.51448(75) 1.51448(75) 1.51448(75) 1.51448(75)	810(30) 247(10) 1.634(32) 1.014(19)

* Weighted average of  $3.702(14) \times 10^5$  y [1976Bu23],  $3.763(9) \times 10^5$  y [1976Os05] and  $3.869(164) \times 10^5$  y [1969Be06].

** Deduced from  $E_{\alpha}$  to the ground state and  $E_{level}$ .

*** Recommended by [1991Ry01], based on the adjusted values of [1968Ba25], [1956Hu96], [1956Ko67] and [1953AsZZ].

[@] Weighted average of values from [2011Be01] and [1986Va33].

@@ [2011Be01].

#### Table 5

direct  $\alpha$  emission from ²⁴⁶Cm,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 4756(20) \text{ y}^*$ ,  $BR_{\alpha} = 99.97(27)\%^{@}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{242}\mathrm{Pu})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
5.329(3)** 5.4310(9) 5.4747(9)	5.242(3) 5.3427(9)*** 5.3857(9)***	0.025(3)% 26.43(51)% 100%	0.020(2)% 20.9(4)% 79.08(22)%	$4^+ 2^+ 0^+$	0.1473 0.0445 0.0	44.5, 102.8 44.5	1.49412(62) 1.49412(62) 1.49412(62)	$500^{+50}_{-50}$ 2.06(4) 1.006(6)

* Weighted average of 4706(40) y [2007Ko01], 4852(76) y [1977Po20], 4820(20) y [1971Ma32], 4655(40) y [1971Mc19] and 4718(22) y 1969Me01]. ** [2007Ko01].

*** Recommended by [1991Ry01], based on the adjusted values of [1984Sh31], [1966Ba07], [1963Be48] and [1963Dz07].

[@] Deduced from a weighted average of  $T_{1/2}(SF) = 1.85(2) \times 10^7$  y [1971Ma32] and  $T_{1/2}(SF) = 1.80(1) \times 10^7$  y [1969Me01].

## Table 6

direct  $\alpha$  emission from ²⁵⁰Cf,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 13.08(9)$  y*,  $BR_{\alpha} = 99.923(2)\%^{**}$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{***}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{246}\mathrm{Cm})^{@@}$	coincident $\gamma$ -rays (keV) ^{@@}	R ₀ (fm)	HF
5.835(3) 5.987(3) 6.0863(6) 6.12827(20)	5.742(3)*** 5.891(3)*** 5.9889(6) [@] 6.03022(20) [@]	0.008(2)% 0.343(18)% 20.71(16)% 100%	0.007(2)% 0.283(15)% 17.11(13)% 82.6(1)%	$6^+ 4^+ 2^+ 0^+$	0.2950 0.1420 0.0429 0.0	42.9, 99.2, 153.0 2.9, 99.2 42.942.9	1.48260(30) 1.48260(30) 1.48260(30) 1.48260(30)	$320^{+130}_{-70}$ 52.9(28) 2.896(30) 0.998(7)

* [1969Me01].

** Deduced from a weighted average of  $\alpha/SF = 1260(40)$  [1965Me02] and  $\alpha/SF = 1330(45)$  [1963Ph01].

*** [2007Ko01].

[@] Recommended by [1991Ry01], based on the adjusted values of [1971Bb10], and [1986Ry06].

@@ [2024Ne07].

Table 7	
direct $\alpha$ emission from ²⁵⁴ Fm, $J^{\pi}$ =	0 ⁺ , T _{1/2} = 194.4(1) m*, $BR_{\alpha} = 99.9410(3)\%$ *

 $\approx 100\%$ 

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{250}\mathrm{Cf})$	coincident γ-rays (keV)	R ₀ (fm)	HF		
7.008(3) 7.163(2) 7.254(2) 7.307(2)	6.898(3) 7.050(2) 7.140(2) 7.192(2)	0.0078(9)% 0.96(7)% 16.7(4)% 100%	0.0066(8)% 0.82(6)% 14.2(3)% 85.0(5)%	$6^+ 4^+ 2^+ 0^+$	0.2962 0.1419 0.0427 0.0	42.7, 141.9, 296.2 42.7, 141.9 42.7	1.48871(75) 1.48871(75) 1.48871(75) 1.48871(75)	$780_{-90}^{+110}$ $27.6(20)$ $4.03(9)$ $0.996(6)$		
* [1967Fi03]. ** [1984Ah02].										
<b>Table 8</b> direct $\alpha$ emission from ²⁷⁰ Hs*, $J^{\pi} = 0^+$ , $T_{1/2} = 7.6^{+4.9}_{-2.2}$ s, $BR_{\alpha} = \approx 100\%$ **.										
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi} = E_c$	daughter ( ²⁶	⁵⁶ Sg) coincider	nt γ-rays (keV) $R_0$ (fm	) HF			

* All values from [2013Og03].

9.150(80)

9.288(80)

** Only  $\alpha$  emission has been observed. [2013Og03] also observed events consistent with SF from heavy nuclei. They report an upper limit for SF as 50%.

1.471(27)

 $3.4^{2.2}_{-1.0}$ ***

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# $\begin{array}{c} 280 Nh \\ Q_{4} q = 2.238 \ MeV \\ Q_{4} q = 16.288 \ MeV \\ Q_{\alpha} = 11.438 \ MeV \end{array}$

 $\begin{array}{c} 2^{26}Rg \\ Q_{eQ} = 1.33\#\,MeV \\ Q_{eQ} = 15.96\#\,MeV \\ Q\,\alpha = 11.48\#\,MeV \end{array}$ 

# $\begin{array}{c} 272 Mt \\ Q_{0\alpha} = 14.268 MeV \\ Q_{\alpha} = 10.358 MeV \\ Q_{\alpha} = 10.358 MeV \end{array}$

# $\begin{bmatrix} 264 Db \\ Q_{0} q = -1.70 \text{if } MeV \\ Q_{0} q = 11.23 \text{if } MeV \\ Q_{0} q = 8.56 \text{if } MeV \end{bmatrix}$





Last updated 3/31/2025

Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +27$ nuclei.	Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced
from values therein. $J^{\pi}$ values are taken from ENSDF.	

N	TΠ	T	0	0	0	Environmental	
Nuclide	J	$I_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\beta}$ -	Qβ- α	Experimental	
²²⁰ Bi*		9.5(57) s	-3.17(50)#	5.70(30)#	16.93(30)#	[2010Al24]	
²²⁴ At*		obs	-2.20(20)#	5.266(24)	10.203(28)	[2012Ch19]	
²²⁸ Fr*	$2^{-}$	38*1) s	-1.859(19)	4.444(7)	8.694(12)	[1982Ru04]	
²³² Ac*	$(1^{+})$	119(5) s	-1.343(16)	3.708(13)	7.969(13)	[1986Gi08]	
²³⁶ Pa*	$1^{+}$		-0.921(20)	2.889(14)	7.642(14)	[1984Mi02]	
²⁴⁰ Np*	(5+)	61.9(2) m	-0.399(17)	2.191(17)	7.626(17)	[1982Pa23]	
				$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$		
²⁴⁴ Am*	(6 ⁻ )	10.01(3) h	0.073(3)	-7.220(30)#	4.739(3)	[2019Tr05]	
²⁴⁸ Bk*	(6 ⁺ )		0.740(50)	-6.31(11)#	5.899(50)	[1973Fi06]	
²⁵² Es	(5 ⁻ )	471.7(17) d	1.260(50)	-5.227(51)	7.472(50)	[1977Ah03]	
²⁵⁶ Md	$(1^{-})$	78.1(18) m	1.97(12)#	-3.92(12)#	9.00(12)#	[1993Mo18]	
²⁶⁰ Lr		180(30) s	2.67(24)#	-2.58(16)#	10.37(13)#	[1971Es01]	
²⁶⁴ Db			3.19(43)#	-1.70(33)#	11.23(31)#		
²⁶⁸ Bh			3.91(61)#	-0.60(54)#	12.201(53)#		
²⁷² Mt			4.48(70)#	0.33(62)#	14.26(68)#		
²⁷⁶ Rg			4.85(83)#	1.33(74)#	15.96(81)#		
²⁸⁰ Nh			5.59(71)#	2.23(58)#	16.28(68)#		

* 100%  $\beta^-$  emitter.

** Taken from  $\alpha$  decay of ²⁵²Es [1973Fi06], might not be the ground state.

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +27$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	Experimental	
²²⁰ Bi	6 95(50)#	3 66(42)#				
²²⁴ At	6.66(20)#	4.33(30)#				
²²⁸ Fr	6.791(16)	3.248(23)				
²³² Ac	6.351(17)	3.345(15)				
²³⁶ Pa	5.973(19)	3.755(19)				
²⁴⁰ Np	5.545(17)	4.557(22)				
²⁴⁴ Am	5.164(3)	5.138(17)				
²⁴⁸ Bk	4.691(50)	5.827(50)				
²⁵² Es	4.129(50)	6.739(1)	78(6)%		[1973Fi06, 1977Ah03, 1973AhZQ, 1965Mc11, 1956Ha80]	
²⁵⁶ Md	3.63(12)#	7.74(11)#	9.5(4)%*		[2000Ah02, 1993Mo18, 1971Ho16, 1970Fi12, 2019Ah04, 1965Si14,	
						1955Gh02]
²⁶⁰ Lr	3.09(13)#	8.40(14)#	100%		[1971Es01]	
²⁶⁴ Db	2.78(28)#	8.56(20)#				
²⁶⁸ Bh	2.39(46)#	9.02(30)#				
²⁷² Mt	1.50(56)#	10.35(30)#				
²⁷⁶ Rg	1.57(72)#	11.48(40)#				
²⁸⁰ Nh	1.07(56)#	11.43(75)#				

* Weighted average of 9.9(5)% [1971Ho16] and 8.5(8)% [1970Fi12].

Table 3				
direct $\alpha$ emission from	$^{252}\text{Es*}, J^{\pi} = (5^{-1})^{-1}$	), $T_{1/2} = 471.7(19)$	9) d**, $BR_{\alpha}$	= 78(6)%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_c^{\pi}$	Edgughter( ²⁴⁸ Bk)	coincident γ-rays (keV)	<b>R</b> o (fm)***	HF
	μ()	-u ()	-u()	- J	-uuugmer ()			
6.038(4)	5.942(4)	0.050(19)%	0.031(12)%	8+	0.700(5)		1.48566(81)	$35^{+22}_{-10}$
6.081(4)	5.984(4)	0.062(19)%	0.039(12)%	$6^{-}$	0.657(5)		1.48566(81)	$47^{+22}_{-12}$
6.113(4)	6.016(4)	0.15(4)%	0.09(2)%	$7^{+}$	0.625(5)		1.48566(81)	$29^{+11}_{-6}$
6.148(3)	6.050(3)	1.27(11)%	0.80(9)%	$5^{-}$	0.590(4)	377.4, 418.5, 590.0	1.48566(81)	$5.1_{-0.6}^{+0.8}$
6.207(5)	6.108(5)	0.15(4)%	0.09(2)%		0.531(6)	529.1	1.48566(81)	$87^{+32}_{-20}$
6.254(5)	6.155(5)	$\approx 0.05\%$	$\approx 0.03\%$		0.483(6)		1.48566(81)	$\approx 500$
6.280(5)	6.180(5)	0.10(4)%	0.06(2)%		0.458(6)		1.48566(81)	$300^{+190}_{-90}$
6.314(5)	6.214(5)	0.12(4)%	0.08(2)%		0.424(6)		1.48566(81)	$360_{-90}^{+170}$
6.339(3)	6.238(3)	0.71(6)%	0.44(5)%		0.399(4)	399.7	1.48566(81)	83 ⁺¹³ -10
6.365(3)	6.264(3)	0.94(9)%	0.59 (7)%		0.373(4)	193.5, 228.0	1.48566(81)	$85^{+13}_{-11}$
6.399(5)	6.297(5)	$\approx 0.05\%$	$\approx 0.03\%$		0.339(6)		1.48566(81)	$\approx 2 \times 10^3$
6.476(5)	6.373(5)	0.09(4)%	0.05(2)%		0.262(6)		1.48566(81)	$3.1^{+2.4}_{-1.0} \times 10^3$
6.527(5)	6.423(5)	0.56(6)%	0.35(5)%	(5 ⁻ )	0.211(6)		1.48566(81)	$840^{+150}_{-120}$
6.564(3)	6.460(3)	0.31(5)%	0.20(3)%	$(4^{-})$	0.174(4)		1.48566(81)	$1.6^{+0.3}_{-0.2} \times 10^{3}$
6.586(3)	6.481(3)	2.73(12)%	1.71(15)%	$8^+$	0.152(4)	70.7, 80.7, 151.3	1.48566(81)	326(34)
6.602(5)	6.497(5)	0.39(5)%	0.24(4)%		0.136(6)	64.4, 70.7	1.48566(81)	$2.7(5) \times 10^3$
6.667(3)	6.561(3)	17.0(4)%	10.6(9)%	7+	0.071(4)	70.7	1.48566(81)	123(12)
6.738(3)	6.631(3)	100%	62.6(7)%	$(6^{+})$	0.0		1.48566(81)	44(4)

* All values from [1973Fi06], except where noted.

** [1977Ah03].

*** Interpolated between 1.48260(30) fm ( 250 Cf) and 1.48871(75) fm ( 254 Fm).

### Table 4

direct $\alpha$ emission from $-3$ Md*, $J^{\mu} = (1^{-}), 1_{1/2} = 78.1(18) \text{ m}^{**}, BR_{\alpha} = 9.5(4)\%^{****}$
-------------------------------------------------------------------------------------------------------------------------------

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{252}\text{Es})$	coincident γ-rays (keV)	$R_0 (fm)^@$	HF
7 255(5)	7 142(5)	31(2)%	2 1(1)%		0 542(9)		1 483(24)	$36^{+3.0}$
7.320(4)	7.206(4)	100(3)%	6.8(3)%		0.477(9)		1.483(24)	$2.1^{+1.7}_{-1.0}$
7.362(5)	7.247(5)	3.5(7)%	0.24(5)%		0.436(9)		1.483(24)	$90_{-40}^{+70}$
7.763(8)	7.642(8)	3.0(7)%	0.20(5)%		0.035(11)		1.483(24)	$3.4^{+3.0}_{-1.7} \times 10^3$
7.798(8)	7.676(8)	3.5(7)%	0.24(5)%	(5 ⁻ )	0.0		1.483(24)	$3.8^{+3.3}_{-1.9} \times 10^3$

* All values from [2000Ah02], except where noted.

** [1993Mo18].

*** Weighted average of 9.9(5)% [1971Ho16] and 8.5(8)% [1970Fi12].

[@] Interpolated between 1.48871(75) fm ( 254 Fm) and 1.477(24) fm ( 258 No).

### Table 5

Table 5			
direct $\alpha$ emission from	260 Lr*, T _{1/2} =	180(30) s,	$BR_{\alpha} = 100\%$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}$ ( ²⁵⁶ Md)	coincident $\gamma$ -rays (keV)	R ₀ (fm)**	HF
8.155(20)	8.030(20)	100%	(1 ⁻ )	0.0		1.479(28)	$1.1 \stackrel{1.2}{_{-0.6}}$

* All values from [1971Es01].

** Interpolated between 1.477(24) fm ( $^{258}\mathrm{No})$  and 1.480(14) fm ( $^{262}\mathrm{Rf}).$ 

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +53/2 nuclei.

Last updated 3/14/2025

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +53/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values are taken from ENSDF.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	0s	Qe-	0e- a	Experimental
			- 1/2	£ι	₹p	<b>τ</b> ρ α	
²¹⁷ Pb			19.9(53) s	-6.40(50)#	3.53(30)#	8.23(30)#	[2017Ca12]
²²¹ Po			$42^{+58}_{-28}$ s	-4.43(30)#	2.991(24)	8.799(27)	[2010Ch19]
²²⁵ Rn		$7/2^{-}$	4.66(4) m	-3.77(30)#	2.714(16)	7.506(18)	[ <b>1977Bu03</b> ]
²²⁹ Ra		5/2+	4.0(2) m	-3.106(16)	1.872(20)	6.496(19)	[1975Ra03]
²³³ Th		1/2+	21.83(4) m	-2.576(13)	1.242(1)	5.797(12)	[1998Us01]
²³⁷ U		$1/2^{+}$	162.04(5) h	-2.137(13)	0.519(1)	5.656(2)	[1958Ca16]
²⁴¹ Pu		5/2+	14.327(19) y**	-1.36(10)	0.0208(2)	5.839(2)	[2013Cr05, 2009Dr05]
241m1 Pu	2.90(15)		23(1) µs	1.54(18)	2.92(15)	8.74(15)	[1970Ga10]
241m2 Pu	2.90(15) + x		31(4) ns***	1.54(18) + x	2.92(15) + x	8.74(15) + x	[2013Cr05, 2009Dr05]
				$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$		
²⁴⁵ Cm		7/2+	8445(20) y	-0.896(2)			[1982Po14]
^{245m} Cm	х		13.2(18) ns	-0.896(2)+x			[1972Wo07]
²⁴⁹ Cf		9/2-	350.6(21) y	-0.1236(4)			[1973St15]
²⁵³ Fm		$1/2^{+}$	72(3) h	0.335(1)	-3.978(3)	7.074(2)	[1967Ah02]
²⁵⁷ No		$(3/2^+)$	25.5(5) s	1.255(6)	-2.527(7)	8.812(6)	[2005As05]
²⁶¹ Rf [@]		$(11/2)^{@@@}$	68(3) s	1.76(21)#	-1.58(21)#	9.901(66)#	[2008Du09]
261m Rf [@]	х	(3/2) ^{@@@}	1.9(4) s	1.76(21)#+x	-1.58(21)#+x	9.901(66)#+x	2011Ha13]
²⁶⁵ Sg [@]		(3/2) ^{@@@}	$14.4^{+3.7}_{-2.5}$ s	2.41(26)#	-0.57(39)#	10.81(24)#	[2012Ha05]
$^{265m}Sg^{@}$	х	(11/2)@@@	$8.5^{+2.6}_{-1.6}$ s	2.41(26)#+x	-0.57(39)#+x	10.81(24)#+x	[2012Ha05]
²⁶⁹ Hs [@]		(9/2)@@@	$12.5^{+6.7}_{-2.8}$ s [@] @	3.02(40)#	0.41(49)#	11.69(26)#	[2024Og02, 2013Su04]
269mHs@	х	(1/2)	$2.8^{+13.6}_{12}$ s	3.02(40)#+x	0.41(49)#+x	11.69(26)#+x	[2024Og02]
²⁷³ Ds [@]		(11/2)	$0.18^{+0.11}_{-0.05}$ ms	3.50(45)#	1.99(53)#	14.38(40)#	[2024Og02]
^{273m} Ds [@]	х	(1/2)	$30^{+140}_{15}$ ms	3.50(45)#+x	1.99(53)#+x	14.38(40)#+X	[2024Og02]
²⁷⁷ Cn		~ /	$0.61^{+0.46}_{-0.18}$ ms	3.93(49)#	2.50(57)#	15.12(45)#	[2013Su04]

* 100%  $\beta^-$  emitter.

** Weighted average of 14.329(29) y [2013Cr05] and 14.325(24) y [2009Dr05].

*** Weighted average of 30(5) ns [1969La14] and 34(7) ns [1981Gu04].

^(a) The relative ordering of the two isomers is unclear. ^(a) ^(a) ^(a) ^(b) ^(b)

@@@ [2024Og02].

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +53/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	Experimental
217 DL	0.00(42)#	1 (4(42)#			
221 Po	9.90(42)#	1.04(42)#			
225 D m	8.473(30)# 8.466(25)	3.089(30)#			
229 D o	8.400(25)	4.333(23)			
233 Th	0.111(17)	3.003(19)			
23711	7.712(13) 7.232(14)	3.743(10)			
241 <b>D</b>	7.233(14)	4.234(1)	$2.45(8) \times 10^{-3}\%$	$\sim 2.4 \times 10^{-14}$ %	[10684601 1085000 107607N 1065026 2000005 1085002
ru	0.030(17)	5.140	2.45(8)×10 %	≈2.4×10 %	1905Allo1, 1985D109, 1970GuZIA, 1905Ba20, 2009D105, 1985He22, 1985HeZY, 1985Wi04, 1984WiZW, 1979VaZF, 1977VaYR, 1971Cl03, 1971GuZY, 1966Be24, 1963Iv01, 1962Dz09, 1961Sm03, 1960Br15,
2411					1953AsZZ, 1950Th54, 1949SeZU]
^{241<i>m</i>1} Pu	3.75(15)	8.04(15)		obs	[1981Gu04, 1970Ga10, 1970Do01, 1970GaZV]
^{241<i>m</i>2} Pu	3.75(15) - x	8.04(15) + x		obs	[ <b>1981Gu04</b> , 1969La14]
²⁴⁵ Cm	6.164(1)	5.624	100%	$6.0(9) \times 10^{-7}\%$	[ <b>1985Dr10, 1975Ba65, 1966Fr03</b> , 2009KoZV, 2008KoZP, 1998Wh01,
					1994Sh31, 1991Po17, 1982Po14, 1980Di13, 1975BaXK, 1971Ma32,
					1969Me01,1966Ba07, 1963Bo48, 1963Dz07, 1961Ca01, 1955Br02,
245m G					1954Fr19, 1954Hu50]
245mCm	6.164(1)-x	5.624+x		obs	[ <b>1972Wo07, 1971Br39</b> , 1971BrZU]
²⁴⁹ Cf	5.697(50)	6.293	100%	$4.31(59) \times 10^{-7}\%$	[ <b>2015Ah03, 1997Ar31, 1987Ta26</b> , 1996Ko29, 1996Lo73, 1991Po17,
					1986Ah02, 1977Ba67, 1976Ba68, 1973AhZM, 1973Ba80, 1973St15,
					19/1Bb10, 19/1Sc14, 19/1ScZW, 19/0BaZZ, 1969Ba57, 1969Ba59,
253 5	5.029(50)	7 100(1)	10(1)0		1969Me01, 1969Mi08, 1967Ko03, 1966An02]
255 Fm 257 M	5.238(50)	7.198(1)	12(1)%		[196/Anu2, 19595188, 195/Am59]
261 D C**	4.50(12)#	8.477(6)	≈100%		[2005AS05, 2012Ha05, 2000La34, 1994Og01, 1970ES02, 1967Gh01]
KI**	4.245(14)#	8.646(65)#	$\approx 100\%$		[2011Ha13, 1970Gn01, 2013Mu08, 2012Ha05, 2008Du09, 2006M10, 2008D-02, 2008C-08, 2002H-11, 2000L-24, 1008T-01, 1006H-12
					2008DV02, 2008Ga08, 2002H011, 2000La34, 19981u01, 1996H013,
261m <b>D</b> f**	4 245(14)# v	9 646(65)#1v	27(6)0	72(6)0/	$[2011 H_0 12 2009 D_{2} 0] = 2012 M_{2} 0 0 2012 S_{2} 0 4 2012 H_0 05 2009 D_{2} 0 2$
KI	4.243(14)#-X	8.040(0 <i>J</i> )#+X	27(0)%	73(0)%	2002Ho111
265 S a**	3 76(27)#	0.05(12)#	100%		[20240a02 2013Su04 2012Ha05 2000Ma00 2002Ha11 2012Tu01
3g	$5.70(27)\pi$	9.03(12)#	100 //		$2010G_{t}04 - 2000D_{v}01 - 2009M_{0}34 - 2007M_{0}77 - 2007M_{0}09 - 2006D_{v}01$
					2010G104, 2007D101, 2007M034, 2007M022, 2007M007, 2000D101, 2006MoZV 2005MoZO 2005MoZT 2004MoZU 2004Vo24 2003Du27
					2003Tu06 2002Du21 2001HoZY 1998Tu01 1998TuZZ 1997Sc48
					1997Sc49 1996No13 1995NoZW 1995NoZZ 1995Oc02 1994LaZX
					1994LaZZ, 1994Lo27, 1994Og04]
^{265m} Sg**	3.76(27)#-x	9.05(12)#+x	100%		[ <b>2024Og02</b> , 2012Tu01, 2010Gr04, 2009Mo09, 2009Mo34, 2007MoZZ,
					2007Mo09, 2006MoZV, 2005MoZO, 2005MoZT, 2004MoZU, 2003Du27,
					2003Tu06, 2002Du21, 2002TuZY, 2002TuZZ, 1998Tu01, 1998TuZZ]
269Hs**	3.50(40)#	9.27(17)#	100%		[2024Og02, 2013Su04, 2008Mo09, 2002Ho11, 2012Ha05, 2012Tu01,
					2010Gr04, 2009Mo34, 2007MoZZ, 2007Mo09, 2006MoZV, 2005MoZQ,
					2005MoZT, 2004MoZU, 2004Vo24, 2003Tu06, 2002Du21, 2002TuZY,
					2002TuZZ, 2001HoZY]
^{269m} Hs**	3.50(40)#-x	9.27(17)#+x	100%		[2024Og02, 2012Tu01, 2010Gr04, 2009Mo34, 2008Mo09, 2007MoZZ, 2007Mo09,
					2006Dv01, 2006MoZV, 2005MoZQ, 2005MoZT, 2004MoZU, 2003Tu06,
					2002Du21, 2002TuZY, 2002TuZZ]
²⁷³ Ds**	2.49(51)#	11.37(54)	100%		[2024Og02, 2013Su04, 2008Mo09, 2002Ho11, 2009Mo34, 2007MoZZ,
					2007Mo09, 2006MoZV, 2005MoZQ, 2005MoZT, 2004MoZU, 2001HoZY,
272					1996La12, 1996LaZY]
2/3mDs**	2.49(51)#-x	11.37(54)+x	100%		[2024Og02, 2013Su04, 2008Mo09, 2002Ho11, 2009Mo34, 2007MoZZ,
					2007Mo09, 2006MoZV, 2005MoZQ, 2005MoZT, 2004MoZU]
² //Cn	2.34(65)#	11.620(58)	100%		[2013Su04, 2008Mo09, 2002Ho11, 2009Mo34, 2007MoZZ, 2007Mo09,
					2006MoZV, 2005MoZQ, 2005MoZT, 2004MoZU, 2001HoZY]

* [1985Dr09]. ** The relative ordering of the two isomers is unclear.

Table 3		
direct $\alpha$ emission from ²⁴¹ Pu*, $J^{\pi} = 5/2^+$ ,	$T_{1/2} = 14.327(19) y^{**},$	$BR_{\alpha} = 2.45(8) \times 10^{-3}\%$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_{f}^{\pi@}$	$E_{daughter}(^{237}\mathrm{U})^{@}$	coincident $\gamma$ -rays (keV) [@]	R ₀ (fm)	HF
4.772(6)	4.693(6)	≈0.04%	$\approx$ 7.34 $\times$ 10 ⁻⁷ %	(11/2 ⁻ )	0.3670	11.4, 44.9, 56.3, 71.6, 77.1, 93, 103.7, 114.0, 148.6, 160.0	1.51540(43)	≈131
4.823(5)	4.743(5)	$\approx 0.08\%$	$pprox 1.7  imes 10^{-6}\%\%$	$13/2^{+}$	0.3173	155	1.51540(43)	≈127
4.865(5)	4.784(5)	0.24(12)%	$4.9(25) \times 10^{-6}\%$	(7/2)-	0.2740	11.4, 44.9, 56.3, 71.6, 77.1, 103.7, 114.0, 148.6, 160.0	1.51540(43)	$90^{+90}_{-30}$
4.879(3)	4.798(3)	1.68(12)%	$3.42(3) \times 10^{-5}\%$	9/2+	0.2609	11.4, 44.9, 56.3, 56.8, 71.6, 77.1, 101, 103.7, 121.2, 148.6, 160.0	1.51540(43)	15.8(13)
4.936(3)	4.854(3)	14.54(26)%	$3.0(1) \times 10^{-4}\%$	7/2+	0.2042	11.4, 44.2, 44.9, 56.3, 71.6, 77.1, 103.7, 148.6, 160.0	1.51540(43)	4.5(2)
4.980(3)	4.897(3)	100.0(6)%	$2.0(7) \times 10^{-3}\%$	5/2+	0.160	11.4, 44.9, 56.3, 71.6, 77.1, 103.7, 148.6, 160.0	1.51540(43)	1.31(5)
5.057(3)	4.973(3)	1.56(12)%	$3.(3) \times 10^{-5}\%$	7/2+	0.0829	11.4, 71.6	1.51540(43)	274(23)
5.084(4)	5.000(4)	0.49(6)%	$1.0(1) \times 10^{-5}\%$	$5/2^{+}$	0.0563	11.4, 44.9, 56.3	1.51540(43)	$1.14(2) \times 10^3$
5.128(3)	5.043(3)	1.23%***	$2.5(1) \times 10^{-5}\%$	$3/2^{+}$	0.0114	11.4	1.51540(43)	$1.0 \times 10^{3}$
5.141(5)	5.056(5)	0.42%***	$8.6(3) \times 10^{-6}\%$	$1/2^{+}$	0.0		1.51540(43)	$3.5 \times 10^{3}$

* All values from [1968Ah01], except where noted.  $E_{\alpha}$  values are adjusted by +0.6 keV as recommended in [1991Ry01].

** Weighted average of 14.329(29) y [2013Cr05] and 14.325(24) y [2009Dr05].

*** Values from [1965Ba26]. [1968Ah01] reports 1.8(1)% for the sum of the two intensities.

[@] [2006Ba41].

## Table 4

direct  $\alpha$  emission from ²⁴⁵Cm*,  $J^{\pi} = 7/2^+$ ,  $T_{1/2} = 8445(20)$  y**,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@}$	E _{daughter} ( ²⁴¹ Pu) [@]	coincident $\gamma$ -rays (keV) [@]	R ₀ (fm)	HF
≈5.236	$\approx$ 5.151	$\leq 5 \times 10^{-3}\%$	$\leq 5 \times 10^{-3}\%$	$(13/2^+)$	0.3843		1.49615(36)	$\geq 960$
≈5.245	$\approx 5.159^{@@}$	$\leq 4 \times 10^{-3}\%$	$\leq 4 \times 10^{-3}\%$		0.3761		1.49615(36)	$\geq 1.35 \times 10^{3}$
5.3213	5.2344	0.35%	0.32%	$11/2^{+}$	0.3012	42.0, 53.8, 65.5, 69.2, 79.3,	1.49615(36)	50
						95.8, 126.1, 133.1, 136.1, 139.9,		
						175.1, 190.0, 205.4, 232.0		
5.361	5.273@@@	0.08%	0.07%		0.2602		1.49615(36)	410
5.3923(12)	5.3043(12)***	5.5(4)%	5.1(4)%***	$5/2^{+}$	0.2284	42.0, 52.0, 53.8, 61.3, 65.5,	1.49615(36)	8.8(7)
						95.8, 170.9, 181.0, 223.0		
5.4501(11)	5.3611(11)***	100%	92.7(9)%***	7/2+	0.1751	42.0, 53.8, 79.3, 95.8, 133.1,	1.49615(36)	1.083(14)
						175.1		
≈5.459	≈5.370			$11/2^{+}$	0.1613	42.0, 53.8, 65.5, 95.8		
5.5263	5.4361	0.04%	0.04%	9/2+	0.0958	42.0, 53.8, 95.8	1.49615(36)	$7 \times 10^{3}$
5.5796	5.4885	0.90%	0.83%	7/2+	0.0420	42.0	1.49615(36)	700
5.6208(5)	5.5290(5)***	0.76(22)%	0.7(2)%***	5/2+	0.0		1.49615(36)	$1.4^{+0.6}_{-0.3}  imes 10^3$

* All values from [1975Ba65], except where noted.  $E_{\alpha}$  values are adjusted by -0.2 keV as recommended in [1991Ry01]. ** [1982Po14].

*** Value recommended in [1991Ry01], based on adjusted values from [1975Ba65] and [1966Fr03].

[@] ensdf
[@] Typo in [1975Ba65] lists this transition as 5.119 MeV going to 376 keV level.
[@] [@] [@] Possibly contamination from ²⁴³Am [1975Ba65].

Table 5				
direct $\alpha$ emission from	$^{249}Cf^*, J^{\pi} = 9/2^{-1}$	$-, T_{1/2} = 350.6$	$b(21) y^{**}, BR_{\alpha} =$	= 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	Edaughter ( ²⁴⁵ Cm)***	coincident γ-rays (keV)***	HF [@]
5.1909(5) 5.2388(8) 5.2217(10)	5.1075(5)*** 5.1546(8)*** 5.2262(10)	$4.0(16) \times 10^{-6}\%$ $2.4(16) \times 10^{-6}\%$ $1.8(4) \times 10^{-3}\%$	$3.3(13) \times 10^{-6}\%$ *** $2.0(13) \times 10^{-6}\%$ *** $1.5(2) \times 10^{-3}\%$		1.1026(5) 1.0547(8)	1102.6 1054.7	$2.3^{+1.5}_{-0.7} \times 10^{3}$ $8^{+15}_{-3} \times 10^{3}$ $20^{+9}$
5.3217(10)	5.2362(10)	1.8(4)×10 %	1.5(3)×10 ⁻⁵ %		0.9714	54.8, 198.1, 66.8, 121.6, 252.9 718.5, 849.9, 916.6, 971.3	$30_{-6}^{+6}$
5.3869(5) 5.3935(5)	5.3004(5)*** 5.3069(5)***	$9.0(16) \times 10^{-6}\%$ 9.7(35) × 10^{-5}\%	$7.4(13) \times 10^{-6}\%$ 8.0(29)×10 ⁻⁵ %***	(3/2+)	0.9066(5) 0.9000(5)	906.6 42.9, 54.8, 54.9, 65.9, 66.8, 121.6, 198.1, 229.2, 241.0, 252.9, 295.7 483.5	$ \begin{array}{c} 1.9(4) \times 10^{4} \\ 1.9^{+1.1}_{-0.5} \times 10^{3} \end{array} $
5.4029(5) 5.4407(10) 5.4443(5)	5.3161(5)*** 5.3533(10) 5.3568(5)***	$3.0(3) \times 10^{-5}\%$ $2.4(4) \times 10^{-3}\%$ $1.2(2) \times 10^{-4}\%$	$2.5(2) \times 10^{-5} \% ***$ 2.0(3)×10^{-3} \% 1.0(2)×10^{-4} \% ***	(9/2 ⁺ ) (11/2 ⁺ )	0.8906(5) 0.8526(1) 0.8492(5)	890.6 54.8, 66.8, 121.6, 731.0, 798.0 54.8, 108, 1, 252, 0, 596, 1, 840, 3	$7.0(6) \times 10^{3}$ $149^{+28}_{-21}$ $3.1^{+0.8} \times 10^{3}$
5.4524(5) 5.5082(5)	5.3648(5)***	$\frac{9.0(16) \times 10^{-6}\%}{1.7(2) \times 10^{-4}\%}$	$7.4(14) \times 10^{-6}\%^{***}$	(0/2+)	0.8411(5)	841.1 54.8, 66.8, 121.6, 662.7	$\frac{4.8^{+1.2}_{-0.8} \times 10^4}{5.5^{+1.0}_{-0.8} \times 10^3}$
5.5192(5) 5.5215(5)	5.4305(5)*** 5.4328(5)	$\frac{1.7(2) \times 10^{-5} \%}{2.4(12) \times 10^{-5} \%}$ $0.0125(9)\%$	$2.0(10) \times 10^{-5} \%^{***}$ 0.0103(7)%	(11/2 ⁻ )	0.7743(5) 0.7719(1)	54.8, 66.8, 121.6, 652.7 54.8, 66.8, 121.6, 652.7 42.9, 54.8, 54.9, 65.9, 66.8, 121.6, 198.1, 229.2, 241.0, 252.9, 295.7 356.1, 421.0, 650.3, 717.1	$5^{+5}_{-2} \times 10^4$ 90(7)
5.5571(5) 5.5918(5)	5.4678(5)*** 5.5020(5)	9.7(35)×10 ⁻⁵ % 0.053(2)%	8.0(29)×10 ⁻⁵ %*** 0.044(2)%	(9/2-)	0.7364(5) 0.7018	54.8, 198.1, 252.9, 483.5 42.9, 54.8, 66.8, 121.6, 198.1, 241.0, 252.9, 295.7, 405.9, 580.3, 647.0, 701.8	$1.9^{+1.1}_{-0.5} \times 10^4$ 55.2(32)
5.6193(10)	5.5290(10)	$2.7(4) \times 10^{-3}\%$	$2.2(3) \times 10^{-3}\%$ *		0.6742(10)*		$1.6^{+0.3}_{-0.2} \times 10^3$
5.6501(5)	5.5593(5)	0.140(6)%	0.115(5)%	(7/2 ⁻ )	0.6436	37.6, 42.9, 54.8, 54.9, 66.8, 92.5, 121.6, 198.1, 229.2, 241.0, 252.9, 255.6, 266.7, 295.7, 333.4, 388.2 390.8, 588.8, 643.6	46(3)
5.7081(5)	5.6164(5)	0.027(1)%	0.022(1)%	$(11/2^+)$	0.5547	42.9, 54.8, 198.1, 241.0, 252.9, 259.0, 295.7	780(50)
5.7392(10) 5.7852(5)	5.6470(10) 5.6922(5)	3.2(5)×10 ⁻³ % 0.35(1)%	2.6(4)×10 ⁻³ %* 0.29(1)%	13/2-	0.5543(10)* 0.5088	37.6, 42.9, 54.7, 54.8, 54.9, 65.9, 66.9, 92.5, 121.6, 198.1, 229.2, 241.0, 252.9, 266.7, 295.7, 321.3, 333.4, 388.2	$\begin{array}{c} 6.7^{+1.3}_{-1.0} \times 10^{3} \\ 108(5) \end{array}$
5.7977(10) 5.8509(5)	5.7046(10) 5.7569(5)	0.058(4)% 5.68(9)%	0.048(3)%* 4.68(7)%	11/2-	0.4958(10)* 0.4429	37.6, 42.9, 54.7, 54.8, 54.9, 66.8, 92.5, 121.6, 198.1, 229.2, 241.0, 252.9, 266.7, 295.7, 321.3, 333.4, 388.2	770(60) 15.5(6)
5.8768(5)	5.7824(5)	0.42(1)%	0.35(1)%	11/2+	0.4165	42.9, 54.8, 54.9, 65.9, 66.8, 121.6, 198.1, 229.2, 241.0, 252.9, 295.7	290(13)
5.9054(5)	5.8105(5)	100%	82.4(3)%	9/2-	0.3882	37.6, 42.9, 54.8, 54.9, 66.8, 92.5, 121.6, 198.1, 229.2, 241.0, 252.9, 266.7, 295.7, 333.4, 388.2	1.76(6)
5.9430(5)	5.8475(5)	1.75(4)%	1.44(3)%	9/2+	0.3506	42.9, 54.8, 54.9, 66.8, 121.6, 198.1, 229.2, 241.0, 252.9, 295.7	161(7)
5.9979(5)	5.9015(5)	3.85(6)%	3.17(5)%	7/2+	0.2957	42.9, 54.8, 198.1, 241.0, 252.9, 295.7	143(5)
6.0408(5) 6.0937(5)	5.9438(5) 5.9958(5)	3.99(6)% 0.049(4)%	3.29(5)% 0.040(3)%	5/2 ⁺ 13/2 ⁺	0.2529 0.2003	54.8, 198.1, 252.9	232(9) 3.6(3)×10 ⁴
6.1719(5) 6.2387(5) 6.2935(5)	6.0728(5) 6.1385(5) 6.1924(5)	0.41(1)% 1.602(74)% 2.96(6)%	0.34(1)% 1.320(3) 2.44(5)%	11/2 ⁺ 79/2 ⁺ 7/2 ⁺	0.1216 0.0548 0.0	54.8, 66.8, 121.6 54.8	$1.07(5) \times 10^4$ $6.0(2) \times 10^3$ $6.01(24) \times 10^3$

* All values from [2015Ah03], except where noted. ** [1973St15]. *** [1997Ar31]. @  $R_0 = 1.4839(14)$  fm.

## **Table 6** direct $\alpha$ emission from ²⁵³Fm*, $J^{\pi} = 1/2^+$ , $T_{1/2} = 72(3)$ h, $BR_{\alpha} = 12(1)\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{m{\pi}}$	Edaughter( ²⁴⁹ Cf)**	coincident γ-rays (keV)**	HF***
≈6.591	≈6.487	$\approx 0.7\%$	≈0.036%		≈0.606		≈31
6.646(5)	6.541(5)	3.5(9)%	0.18(5)%		0.5506	134, 145.0, 271.8	$11^{+5}_{-2}$
6.737(4)	6.630(4)	6.1(12)%	0.31(7)%	5/2+	0.460		$17^{+6}_{-4}$
6.757(4)	6.650(4)	5.6(9)%	0.29(5)%	3/2+	0.4376	43.0, 55.1, 58.0, 62.5, 135.4, 145.0, 191.6, 234.6, 375.1, 379.5, 437.6	$23^{+7}_{-5}$
6.780(3)	6.673(3)	54.3(25)%	2.80.3%	1/2+	0.4168	145.0, 271.8	3.0(3)
6.956(3)	6.846(3)	19.7(13)%	1.0(1)%	9/2+	0.243.1	43.0, 55.1, 145.0	$47^{+8}_{-6}$
≈6.977	$\approx 6.867$	$\approx 2.1\%$	≈0.11%	15/2-**	0.221.7	62.5, 159.3	≈550
7.013(4)	6.902(4)	23.0(13)%	1.2(1)%	7/2+	0.1880	43.0, 145.0	70(8)
7.055(3)	6.943(3)	100(4)%	5.1(4)%	5/2+	0.1450	145.0	24.3(24)
7.136(4)	7.023(4)	15.7(10)%	0.80(8)%	$11/2^{-}$	0.0625	62.5	$340^{+60}_{-50}$
7.197(4)	7.083(4)	3.0(5)%	0.16(3)%	9/2-	0.0		$3.2^{+0.9}_{-0.6} \times 10^3$

* All values from [1967Ah02], except where noted.  $E_{\alpha}$  is adjusted by -8.8 keV as recommended in [1991Ry01].

** [2024Ne04].

***  $R_0 = 1.47787(78)$  fm.

### Table 7

direct  $\alpha$  emission from ²⁵⁷No*,  $J^{\pi} = (3/2^+)$ ,  $T_{1/2} = 25.5(5)$  s,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{253}\mathrm{Fm})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
8.318	8.188**	<4.8%	<4%	(5/2 ⁺ )	0.1587	22.3, 136.4	1.477(13)	$>\!\!28 \\ 1.8^{+7}_{-5} \\ 19^{+8}_{-5}$
8.352(6)	8.222(6)	100(2)%	83(2)%	3/2 ⁺	0.1241	22.3, 24.8, 47.1, 77.0, 101.8, 124.1	1.477(13)	
8.455(7)	8.323(7)	20.5(25)%	17(2)%	(3/2 ⁺ )	0.0223	22.3	1.477(13)	

* All values from [2005As05].

** Deduced from  $\gamma$  energies.

## Table 8

direct  $\alpha$  emission from ²⁶¹Rf,  $J^{\pi} = (11/2)^*$ ,  $T_{1/2} = 68(3) \text{ s}^{**}$ ,  $BR_{\alpha} = \approx 100\%$ .

 $\approx 100\%$ 

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{257}\mathrm{No})$	coincident γ-rays (keV)	$R_0$ (fm)	HF				
8.409(20)	8.280(20)***	$\approx 100\%$				1.486(14)	$1.6^{+0.7}_{-0.5}$				
* [2024C ** [2008 *** [197	0g02]. Du09]. 0Gh01].										
<b>Table 9</b> direct $\alpha$ emiss	<b>Table 9</b> direct $\alpha$ emission from ^{261m} Rf, Ex. = unk., $J^{\pi} = (3/2)^*$ , $T_{1/2} = 1.9(4)$ s**, $BR_{\alpha} = \approx 100\%$ .										
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{257}\mathrm{No})$	coincident γ-rays (keV)	R ₀ (fm)	HF				

 $1.0\substack{+0.7\\-0.5}$ 

1.486(14)

3k	[20240~0'	21
	1/11/4090	Z. L.

8.647(30)

** [2011Ha13].

8.514(30)***

*** Weighted average of 8.520(50) MeV [2011Ha13], 8.510(60) MeV [2012Ha05] and 8.510(50) MeV [2008Dv02],

direct $\alpha$ emiss	sion from ²⁰⁵ Sg, J	$\pi = (3/2)^*, T_{1/2}$	$= 14.4^{+3.7}_{-2.5}$ s [*]	$^{**}, BR_{\alpha} = 100\%.$			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{m \pi}$	$E_{daughter}(^{261}\mathrm{Rf})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
8.823(50)	8.690(50)**	100%	3/2*	х		1.457(60)	$0.7\substack{+2.6 \\ -0.6}$
* [2024O ** [2012]	g02]. Ha05].						
Table 11 direct α emiss	sion from ^{265m} Sg,	Ex. = unk., $J^{\pi}$ =	= (11/2)*, T _{1/}	$_2 = 8.5^{+2.6}_{-1.6}$ s, $BR_{\alpha} = 100$	)%.		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\rm J}_f^{\pi}$	$E_{daughter}(^{261}\mathrm{Rf})$	coincident γ-rays (keV)	R ₀ (fm)	HF
8.975(50)	8.840(50)**	100%	(11/2)*	0.0*		1.457(60)	$1^{+5}_{-1}$
* [2024O ** [2012]	g02]. Ha05].						
Table 12 direct $\alpha$ emiss	sion from ²⁶⁹ Hs*,	$J^{\pi} = (9/2), T_{1/2}$	$= 12.5^{+6.7}_{-2.8}$ s ²	**, $BR_{\alpha} = 100\%$ .			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{265}\mathrm{Sg})$	coincident γ-rays (keV)	R ₀ (fm)	HF
9.339(40)	9.200(40)	100%	(9/2)	X		1.465(38)	$6^{+10}_{-5}$
* All valu ** Weigh Table 13 direct α emiss	ted average of 13 sion from ²⁶⁹ Hs*,	02], except whe $^{+10}_{-9}$ s [2024Og0 Ex. = unk., J ^{$\pi$} =	ere noted. 2] and $12^{+9}_{-4}$ s = (1/2), $T_{1/2}$ =	[2013Su04]. = $2.8^{+13.6}_{-1.3}$ s, $BR_{\alpha} = 1009$	6.		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{265}Sg)$	coincident γ-rays (keV)	R ₀ (fm)	HF
9.22(15)	9.08(15)	100%	(1/2)	X		1.465(38)	$0.6^{+34}_{-3.1}$
* All valu	ues from [2024Og	02].					
<b>Table 14</b> direct $\alpha$ emiss	sion from ²⁷³ Ds*,	$J^{\pi} = (11/2), T_{1/2}$	$v_2 = 0.18^{+0.11}_{-0.05}$	ms, $BR_{\alpha} = 100\%$ .			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{269}\text{Hs})$	coincident γ-rays (keV)	R ₀ (fm)	HF
11.265(70)	11.100(70)	100%	(11/2)	X			
* All valu	ies from [2024Og	02].	. ,				
Table 15 direct $\alpha$ emiss	sion from ^{273m} Ds*	$F$ , Ex. = unk., $J^{\pi}$	$=(1/2), T_{1/2}$	$= 30^{+140}_{-15}$ ms, $BR_{\alpha} = 10$	0%.		
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi}$	$E_{daughter}$ ⁽²⁶⁹ Hs)	coincident γ-rays (keV)	R ₀ (fm)	HF

**Table 10** direct  $\alpha$  emission from ²⁶⁵Sg, J^{$\pi$} = (3/2)*, T_{1/2} = 14.4^{+3.7}/₂ s**, BR_{$\alpha$} = 100%.

* All values from [2024Og02].

10.930(20)

100%

(1/2)

х

11.093(20)

Table 16		
direct $\alpha$ emission from ²⁷⁷ Cn	$T_{1/2} = 0.61^{+0.46}_{-0.18} \text{ ms}$	$BR_{\alpha} = 100\%$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{261}\mathrm{Rf})$	coincident γ-rays (keV)	R ₀ (fm)	HF	
11.232(80)	11.070(80)	100%						

* All values from [2013Su04].

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# $\begin{array}{c|c} 2^{279}Nh & Q_{4}\rho = -1.65\#\,MeV \\ Q_{4}\alpha = -15.37\#\,MeV \\ Q_{4}\alpha = -11.64\#\,MeV \end{array}$









Last updated 3/14/25

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +53/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. All  $J^{\pi}$  values are taken from ENSDF.

Nuclide	Fx	Iπ	Tere	0.	0	0.00	Experimental
	LA.	5	1/2	Qε	×β	ζβ ά	Experimental
²¹⁹ Bi*		(9/2-)	22(7) s	-4.30(45)#	3.64(20)#	9.74(30)#	[2012Be28]
²²³ At*			50(7) s	-3,65(20)#	3.038(16)	8.502(21)	[1989Bu09]
²²⁷ Fr*		$1/2^{+}$	148(2)s	-3.203(15)	2.505(6)	7.047(10)	[1981Vo03]
²³¹ Ac*		$1/2^{+}$	7.5(2) m	-2.454(17)	1.947(13)	6.341(13)	[1973Ch24]
²³⁵ Pa*		$(3/2^{-})$	24.5(2) m**	-1.729(19)	1.370(14)	6.228(14)	[1986Mi10, 1968Tr07]
²³⁹ Np*		5/2+	2.3565(4) d	-1.262(2)	0.723(1)	6.147(2)	[1990Ab06]
					$O_{\varepsilon n}$	$O_{\mathcal{E}\mathcal{A}}$	
²⁴³ Am		5/2-	7349(12) y***	-0.580(3)	<i>2cp</i>		[2020Ma63, 2007Ag02, 1980Ag05]
^{243m} Am	2.30(30)		5.8(7) µs [@]	1,72(30)	5.23(36)	8.90(30)	[1973Br04, 1972Wo07, 1970Po01]
²⁴⁷ Bk		3/2-	1380(250) y	-0.044(6)			[1965Mi08]
²⁵¹ Es		3/2-	33(1) h	0.377(6)	-5.729(6)	6.554(7)	[1970Ah01]
²⁵⁵ Md		(7/2-)	27(2) m	1.042(7)	-4.441(6)	8.282(7)	[1970Fi12]
²⁵⁹ Lr		$(1/2^{-})$	6.22(28) s ^{@@}	1.770(70)#	-3.128(71)#	9.625(71)#	[1992Ha22, 1992Gr02]
²⁶³ Db			$27^{+10}_{-7}$ s	2.35(23)#	-2.28(26)#	10.61(17)#	[1992Kr01]
²⁶⁷ Bh			$13^{+6}_{2} s^{@@@}$	2.96(37)#	-1.26(39)#	11.58(30)#	[2009Mo12, 2000Ei05, 2000Wi15]
²⁷¹ Mt			-5	3.41(41)#	-0.42(45)#	12.87(42)#	
²⁷⁵ Rg				3.73(56)#	0.86(58)#	15.28(53)#	
²⁷⁹ Nh				4.44(72)#	1.65(72)#	15.37(69)#	

* 100%  $\beta^-$  emitter.

** Weighted average of 24.6(2) m [1986Mi10] and 24.2(3) m [1968Tr07].

*** Weighted average of 7345(14) y [2020Ma63], 7357(23) y [2007Ag02] and 7358(42) y [1980Ag05].

[@] Weighted average of 5.0(10)  $\mu$ s [1972Wo07] and 6.5(10)  $\mu$ s [1970Po01].

[@] Weighted average of 6.14(36) s [1992Ha22] and 6.34(46) s [1992Gr02].

@@@ Deduced from times of 12 decay chains from [2009Mo12] (1 event), [2000Ei05] (6 events), and [2000Wi15] (5 events).

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +53/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	$BR_{\alpha}$	BR _{SF}	Experimental
219		2.07(2() #			
217 B1	6.60(36)#	3.87(36)#			
²²³ At	6.347(42)	4.68(20)			
²²⁷ Fr	6.354(12)	3.830(15)			
²³¹ Ac	6.042(17)	3.655(14)			
²³⁵ Pa	5.613(14)	4.101(19)			
²³⁹ Np	5.286(1)	4.597(14)			
²⁴³ Am	4.831(1)	5.439(1)	100%	3.76(20)×10 ⁻⁹ %	[2002Da21, 2002Sa53, 2023Ko26, 2020Ma63, 2018Ca05, 2007Ag02, 1998Ya17, 1996Sa23, 1996Sa23, 1996Wo05, 1992Ga01, 1991Po14, 1986AmZY, 1984Va41, 1980Ag05, 1979Po20, 1977St35, 1974Po17, 1969A114, 1969En02, 1968Ba22, 1968Ba25, 1968Va09, 1967Fa01, 1966Gv01, 1964Ba26, 1963Ba65, 1960Be10, 1959Ba22, 1958Wa69, 1956Hu96, 1955St98, 1954As05, 1953AsZZ, 1953Di27] [1973Br04, 1972Wo07, 1970Po01, 1980Bi02, 1973Bc04, 1973Na35
Am	2.33(30)	7.74(30)		100 //	1971Re11, 1970ReZN]
²⁴⁷ Bk	4.416(5)	5.890(5)	$\approx 100\%$		[1969Fr01, 1965Mi08, 1956Ch77]
²⁵¹ Es	3.948(5)	6.597(1)	0.5(2)%		[1979Ah03, 1970Ah01, 1956Ha80]
²⁵⁵ Md	3.349(6)	7.906(2)	8.1(8)%*		[2000Ah02, 1971Ho16, 1970Fi12, 1965Si14, 2005He27, 1958Ph40]
²⁵⁹ Lr	2.92(12)#	8.584(71)#	77.9(17)%	22.1(17)%**	[1992Ha22, 1992Gr02, 2020Ha27, 1971Es01, 1971EsZX, 1970GhZY]
²⁶³ Db	2.57(28)#	8.83(15)#	42(15)%***	$56^{+13}_{-15}\%$ ***	[2003Kr20, 1992Kr01, 2002KrZY, 1995GrZV, 1992GaZU, 1991KrZS, 1987GrZN]
²⁶⁷ Bh	2.14(36)#	9.23(20)#	100%		[2020Ha27, 2009Mo12, 2000Ei05, 2000Wi15]
²⁷¹ Mt	1.30(41)#	9.91(20)#			
²⁷⁵ Rg	1.09(59)#	11.87(30)#			
²⁷⁹ Nh	0.67(74)#	11.64(75)#			

* Weighted average of 10.0(14)% [1971Ho16], 7(1)% [1970Fi12] and 9(2)% [1965Si14].

** Weighted average of 20(3)% [1992Ha22] and 23(2)% [1992Gr02]. *** [1992Kr01] report BR_{$\alpha$} = 43(15)% and BR_{SF} = 57⁺¹³₋₁₅%, neglecting BR_{$\varepsilon$}, which was assumed to be small. [2003Kr20] report a BR_{$\varepsilon$} = 3⁺⁴₋₁%. The BR for  $\alpha$  and SF are adjusted by the evaluator to reflect this.

# **Table 3** direct $\alpha$ emission from ²⁴³Am*, $J^{\pi} = 5/2^{-}$ , $T_{1/2} = 7349(12)$ y**, $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi***}$	E _{daughter} ( ²³⁹ Np)***	coincident γ-rays (keV)***	R ₀ (fm)	HF
4.7760	4.6974	4.4(5)×10 ⁻³ %	3.8(4)×10 ⁻³ %	(5/2-)	0.6623	31.1, 43.1, 43.5, 74.7, 86.7, 117.6, 544.5, 587.6, 631.1	1.50633(42)	3.3(4)
5.0185	4.9359	$3.0(3) \times 10^{-3}\%$	$2.6(3) \times 10^{-3}\%$		0.427		1.50633(42)	$215^{+29}_{-23}$
5.0335	4.9506	$3.2(3) \times 10^{-3}\%$	$2.8(3) \times 10^{-3}\%$		0.411		1.50633(42)	$255_{-25}^{+31}$
5.0843	5.0006	3.6(5)×10 ⁻³ %	$3.1(4) \times 10^{-3}\%$	$(9/2^+)$	0.3591		1.50633(42)	510(50)
5.0959	5.0120	$6.0(5) \times 10^{-3}\%$	$5.2(4) \times 10^{-3}\%$	$(9/2^+)$	0.3473		1.50633(42)	366(28)
5.1209	5.0366	9.5(6)×10 ⁻³ %	$8.2(5) \times 10^{-3}\%$	$(13/2^{-})$	0.3174	195	1.50633(42)	365(23)
5.1763	5.0911	0.0129(7)%	0.0112(6)%		0.267		1.50633(42)	567(31)
5.1989	5.1133	0.0219(12)%	0.0190(10)%	$(11/2^{-})$	0.2413	71.2, 169	1.50633(42)	489(26)
5.2651	5.1784	1.606(8)%	1.391(7)%	9/2-	0.1731	31.1, 43.1, 43.5, 50.6, 55.4, 74.7, 86.7, 98.5, 117.6, 141.9	1.50633(42)	18.04(21)
5.3204	5.2328	13.30(3)%	11.52(2)%	7/2-	0.1177	31.1, 43.1, 43.5, 74.7, 86.7, 117.6	1.50633(42)	4.82(5)
5.3636	5.2753	100.%	86.6(7)%	$5/2^{-}$	0.0747	31.1, 43.5, 74.7	1.50633(42)	1.149(15)
5.4073	5.3183	0.219(3)%	0.19(3)%	$7/2^{+}$	0.0311	31.1	1.50633(42)	$980^{+190}_{-140}$
5.4385	5.3490	0.28(4)%	0.24(3)%	5/2+	0.0		1.50633(42)	$1.20^{+0.17}_{-0.14} \times 10^3$

* All values from [2002Da21], except where noted.  $E_{\alpha}$  uncertainties are in units of the last significant decimal figure [2022Da21]. ** Weighted average of 7345(14) y [2020Ma63], 7357(23) y [2007Ag02] and 7358(42) y [1980Ag05].

*** [2014Br18].

# Table 4

direct  $\alpha$  emission from ²⁴⁷Bk*,  $J^{\pi} = 3/2^{-}$ ,  $T_{1/2} = 1380(250)$  y**,  $BR_{\alpha} = \approx 100\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	<i>E</i> _{daughter} ( ²⁴³ Am)***	coincident γ-rays (keV)***	R ₀ (fm)	HF
5.546(5)	5.456(5)	3.3(5)%	1.5(2)%	$(7/2^{-})$	0.345(1)		1.4896(15)	$11^{+4}_{-3}$
5.592(5)	5.501(5)	16(2)%	7(1)%	$(5/2^{-})$	0.300(2)		1.4896(15)	$4.5^{+1.7}_{-1.3}$
5.622(5)	5.531(5)	100(6)%	45(2)%	3/2-	0.265(10)	265	1.4896(15)	1.1(3)
5.702(5)	5.610(5)	$\approx 0.9\%$	$\approx 0.4\%$	$(11/2^+)$	0.1894(6)		1.4896(15)	$\approx 300$
5.747(5)	5.654(5)	12.2(14)%	5.5(6)%	$(9/2^+)$	0.1434(2)	25.2, 34, 41.8, 42,2, 67, 84.0,	1.4896(15)	$45^{+15}_{-12}$
						101.3, 109.2		12
5.782(5)	5.688(5)	29(3)%	13(1)%	$7/2^{+}$	0.1092(2)	25.2, 41.8, 42.2, 67, 84.0, 109.2	1.4896(15)	30(6)
5.804(5)	5.710(5)	38(3)%	17(1)%	5/2+	0.0840(1)	41.8, 42.2, 84.0	1.4896(15)	31(6)
5.849(5)	5.754(5)	9.6(10)%	4.3(4)%	7/2-	0.0422(2)	42.2	1.4896(15)	210(50)
5.889(5)	5.794(5)	12.2(12)%	5.5(5)%	$5/2^{-}$	0.0		1.4896(15)	280(60)

* All values from [1969Fr01], except where noted.  $E_{\alpha}$  is adjusted by +1.0 keV as recommended in [1991Ry01].

** [1965Mi08].

*** [2014Ne14].

### Table 5

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$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi@}$	$E_{daughter}(^{247}\text{Bk})^{@}$	coincident $\gamma$ -rays (keV) [@]	R ₀ (fm)	HF
6.514(3)	6.410(3)	4.1(7)%	0.017(7)%	$(9/2)^+$	0.0828	40.8, 42.0	1.47482(56)	$33^{+28}_{-11}$
6.526(3)	6.422(3)	3.7(7)%	0.015(7)%	$(7/2^{-})$	0.0716	,	1.47482(56)	$40^{+40}_{-10}$
6.556(3)	6.452(3)	4.1(9)%	0.017(7)%	7/2+	0.0408	40.8	1.47482(56)	$50_{-20}^{+50}$
6.567(3)	6.462(3)	11.6(13)%	0.047(19)%	$(5/2^{-})$	0.0299	29.9	1.47482(56)	$21^{+16}_{-7}$
6.597(3)	6.492(3)	100(3)%	0.41(16)%	3/2-	0.0		1.47482(56)	$3.3^{+2.4}_{-1.0}$

* All values from [1979Ah03], except where noted.  $E_{\alpha}$  is adjusted by +0.8 keV as recommended in [1991Ry01].

** [1970Ah01].

*** Deduced from  $I_{\alpha}/I_{Kx} = 0.008(2)$  [1970Ah01] and  $I_{Kx}/I_{\varepsilon} = 0.64(5)$  [2005Ah09].

@ [2015Ne04].

# Table 6 direct $\alpha$ emission from ²⁵⁵Md*, $J^{\pi} = (7/2^{-})$ , $T_{1/2} = 27(2)$ m**, $BR_{\alpha} = 8.1(8)\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{251}\mathrm{Es})$	coincident γ-rays (keV)	) $R_0$ (fm)	HF				
7.390(5) 7.444(4) 7.837(8) 7.876(8)	7.274(5) 7.327(4) 7.714(8) 7.752(8)	5.4(5)% 100% 1.1(2)% 1.1(2)%	0.041(6)% 0.75(8)% $8(2) \times 10^{3}$ $8(2) \times 10^{3}$	7/2-	0.515 0.4614 0.068 0.030	405.5, 453.1	1.4825(13) 1.4825(13) 1.4825(13) 1.4825(13) 1.4825(13)	$\begin{array}{c} 21^{+5}_{-4} \\ 1.9^{+0.4}_{-0.3} \\ 5.1^{+2.0}_{-1.3} \times 10^3 \\ 7.0^{+2.7}_{-1.7} \times 10^3 \end{array}$				
** [[19'	** [[1970Fi12]. *** Weighted average of 10.0(14)% [1971Ho16] 7(1)% [1970Fi12] and 9(2)% [1965Si14]											
*** We	*** Weighted average of 10.0(14)% [1971Ho16], 7(1)% [1970Fi12] and 9(2)% [1965Si14].											
<b>Table 7</b> direct $\alpha$ emi	<b>Table 7</b> direct $\alpha$ emission from ²⁵⁹ Lr*, $J^{\pi} = (1/2^{-})$ , $T_{1/2} = 6.22(28)$ s*, $BR_{\alpha} = 77.9(17)\%$ **.											
			- 7		255							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{n}$	$E_{da}$	_{ughter} ⁽²⁵⁵ Md) c	oincident $\gamma$ -rays (keV)	$R_0$ (fm)	HF				
8.571(10)	8.439(10)	77.9(17)	)%**				1.485(19)	$1.3^{+0.8}_{-0.5}$				
* Weigł ** Weig	* Weighted average of 6.14(36) s [1992Ha22] and 6.34(46) s [1992Gr02]. ** Weighted average of 20(3)% [1992Ha22] and 23(2)% [1992Gr02] for BR _{SF} . $\alpha$ decay is the only other expected channel.											
<b>Table 8</b> direct $\alpha$ emi	<b>Table 8</b> direct $\alpha$ emission from ²⁶³ Db*, $J^{\pi} = (1/2^{-})$ , $T_{1/2} = 27^{+10}_{-7}$ s, $BR_{\alpha} = 42(15)\%^{**}$ .											
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^\pi$	Edau	_{ghter} ( ²⁵⁹ Lr) co	incident γ-rays (keV)	$R_0$ (fm)	HF				
8.484(27)	8.355(27)	42(15)9	%**				1.475(18)	$0.9^{+1.2}_{-0.6}$				

* All values from [1992Kr01], except where noted. ** [1992Kr01] report BR_{$\alpha$} = 43(15)% and BR_{SF} = 57⁺¹³₋₁₅%, neglecting *BR*_{$\varepsilon$}, which was assumed to be small. [2003Kr20] report a *BR*_{$\varepsilon$} =3⁺⁴₋₁%. The BR for  $\alpha$  and SF are adjusted by the evaluator to reflect this.

**Table 9** direct  $\alpha$  emission from ²⁶⁷Bh*, T_{1/2} = 13⁺⁶₋₃ s**, *BR*_{$\alpha$} = 100%.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{263}\text{Db})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
8.86	8.73	22%	17%				1.451(72)	$2^{+12}_{-2}$
8.97	8.84	100%	75%				1.451(72)	$1.0^{+5.2}_{-0.9}$
9.05	8.91	11%	8%				1.451(72)	$20^{+54}_{-20}$

* 12 decay chains were assigned to the decay of ²⁶⁷Bh [2009Mo12, 2000Ei05, 2000Wi15] along with 4 tentative assignments in [2009Mo12], of which 3 have significantly longer decay times than the others. The events with  $E_{\alpha}$ , decay time and ref. listed below. The events are grouped by energy into 3 peaks; 8.73 MeV (2 events), 8.84 MeV (9 events) and 8.91 (1 event). Note that [2020Ha27] discusses that these events may be due to ²⁶⁶Bh as the energies are very similair.

$E_{\alpha}$ (MeV)	decay t(s)	Ref.
8.84	11.95	[2009Mo12]
8.81	24.5	[2000Ei05]
8.85	34.4	[2000Ei05]
8.72	2.9	[2000Ei05]
8.84	26.7	[2000Ei05]
8.91	10.5	[2000Ei05]
8.81	18.4	[2000Ei05]
8.83	5.26	[2000Wi15]
8.87	24.67	[2000Wi15]
8.87	45.15	[2000Wi15]
8.73	2.71	[2000Wi15]
8.84	21.83	[2000Wi15]
8.76 (tentative)	112.2	[2009Mo12]
8.71(tentative)	5.38	[2009Mo12]
8.75 (tentative)	155.57	[2009Mo12]
8.84 (tentative)	176.77	[2009Mo12]

** Deduced from the decay times listed above.

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +27 nuclei.

Last updated 3/29/2025

Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +27$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values are taken from ENSDF.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\beta}$ -	$Q_{\beta} - \alpha$	Experimental
						·	
²¹⁸ Pb*		$0^+$	13(7) s	-8.08(50)#	2.41(30)#	6.92(36)#	[2016Ca25]
²²² Po*		$0^{+}$	$145^{+694}_{-66}$ s	-6.46(30)#	1.530(40)	7.029(48)	[2010Ch15]
²²⁶ Rn*		$0^+$	7.4(1) m	-5.91(30)#	1.227(12)	5.549(19)	[1986Bo35]
²³⁰ Ra*		$0^+$	93(2) m	-4.970(12)	0.678(19)	4.750(12)	[1978Gi07]
234 Th(UX ₁ )*		$0^{+}$	24.101(25) d	-4.228(14)	0.274(3)	4.530(16)	[1948Kn23]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
$^{238}U(U_1)$		$0^+$	4.4683(24)×10 ⁹ y	-3.586(16)			[1971Ja07]
^{238m} U	2.5575(5)	$0^+$	298(18) ns	-1.028(16)			[1992St05]
²⁴² Pu		$0^+$	$3.77(7) \times 10^5 \text{ y}^{**}$	-2.70(20)			[1976Bu23, 1976Os05, 1969Be06]
^{242m1} Pu	х		3.5(6) ns	-2.70(20)+x			[1974MeYP]
^{242m2} Pu	у		50(30) ns	-2.70(20)+y			[1969La14, 1970Po01]
²⁴⁶ Cm	-	$0^+$	4756(20) y***	-2.377(18)#			[2007Ko01, 1977Po20, 1971Ma32,
							1971Mc19, 1969Me01]
²⁵⁰ Cf		$0^+$	13.08(9) y	-1.782(3)			[1969Me01]
²⁵⁴ Fm		$0^+$	194.4(1) m	0.653(12)	-5.689(4)	5.526(3)	[1967Fi03]
²⁵⁸ No		$0^+$	1.2(2) ms	-0.21(10)#			[1989Hu09]
²⁶² Rf		$0^+$	2.1(2) s	0.29(30)#	-3.35(30)#	8.28(22)#	[1996La11]
²⁶⁶ Sg		$0^{+}$	$0.28^{+0.19}_{-0.08}$ s	0.88(37)#	-2.36(44)#	9.09(32)#	[2013Og03]
²⁷⁰ Hs		$0^+$	$7.6^{+4.9}_{-2.2}$ s	0.88(39)#	-1.87(44)#	9.95(38)#	[2013Og03]
²⁷⁴ Ds			-2.2	1.95(54)#	0.14(54)#	12.54(49)#	
²⁷⁸ Cn				2.32(59)#	0.46(59)#	13.17(58)#	

* 100%  $\beta^-$  emitter.

** Weighted average of  $3.702(14) \times 10^5$  y [1976Bu23],  $3.763(9) \times 10^5$  y [1976Os05] and  $3.869(164) \times 10^5$  y [1969Be06]. *** Weighted average of 4706(40) y [2007Ko01], 4852(76) y [1977Po20], 4820(20) y [1971Ma32], 4655(40) y [1971Mc19] and 4718(22) y 1969Me01].

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +27$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	Experimental
²¹⁸ Pb	10.32(50)#	1.43(50)#			
²²² Po	9.00(30)#	4.43(30)#			
²²⁶ Rn	8.84(30)#	3.836(41)			
²³⁰ Ra	8.441(11)	3.344(15)			
²³⁴ Th(UX ₁ ) ²³⁸ U(U ₁ )	7.984(13) 7.509(13)	3.672(11) 6.828(2)	100%	5.45(7)×10 ⁻⁵ %*	[ <b>2014Po02</b> , <b>2000Ho27</b> , <b>1961Ko11</b> , <b>1960Vo05</b> , <b>1957Ha08</b> , 2005Yo12, 2004Ab03, 2003Gu18, 2000Ga05, 1987Al28, 1985Iv01, 1984Ro21, 1984Va35, 1983Be66, 1982De22, 1980Po09, 1980PoZX, 1978Ka40, 1978Ri07, 1978ThZW, 1976Th12, 1975Wa37, 1972Ni19, 1971K114, 1971Le11, 1971Sa08, 1971Sw03, 1971Th17, 1970Ga27, 1968Ro15, 1968Ar14, 1967Is04, 1967Sp12, 1966Ra25, 1964Fl07, 1964Me14, 1960Sh19, 1960Vo05, 1960Yo07, 1959Ge30, 1959Ha04, 1959Ko58, 1959Ku81, 1959St45, 1957Bo98, 1957C116, 1952Za01, 1944ChZX, 1940Fl02, 1918So01, 1912Ge01]
^{238m} U	4.951(13)	4.270(2)		2.5(5)%	[ <b>1992St05</b> , 1989Ma54, 1989Ma57, 1989MaZF, 1988Ma52, 1988MaZF, 1984Ka10, 1984Ka17, 1983Dr14, 1983Ka11, 1980Me15, 1977VoZU, 1977ArZZ, 1975Ru03, 1974WoZK, 1971Ta17, 1970Po01, 1970Re05, 1970Wo06, 1969La14]
²⁴² Pu	6.89(10)	4.984(1)	100%	5.59(7)×10 ⁻⁴ %	[2013Sa65, 2011Be01, 1986Va33, 1968Ba25, 1956Hu96, 1956Ko67, 1953AsZZ, 2018Be29, 2016Ob01, 1998Se17, 1998VeZW, 1997De11, 1997SeZW, 1988SeZY, 1982A113, 1979Ag03, 1978MeZL, 1976Bu23, 1976Os05, 1973Dy01, 1973VoZB, 1972Sc01, 1970Du02, 1969Be06, 1968Bo54, 1968HaZX, 1967Ga20, 1963Ma50, 1961Dr04, 1956Bu64, 1956Cr69, 1956Me37, 1950Tb541
$242m^{1}P_{11}$	6 89(10)-x	4.984(1) + x		obs	[1974MeVP]
$^{242m^{2}Pu}$	6.89(10)-v	4.984(1)+x		obs	$[1969L_{2}]4$ 1970Po01]
246Cm	6.572(2)	5.475(1)	99.97(27)%	0.02627(13)%**	[2007Ko01, 1984Sh31, 1971Ma32, 1969Me01, 1966Ba07, 1963Be48, 1963Dz07, 2008KoZP, 2008Ve05, 1981Gi02, 1977Po20, 1974UnZV, 1973Pl04, 1973PlZW, 1973St04, 1972Pr19, 1972Da34, 1971BeYS, 1971Mc19, 1970Th06, 1967Ch12, 1967Sc32, 1961Ca01, 1956Bu91, 1955Br02, 1954Fr19]
²⁵⁰ Cf	5.965(1)	6.129	99.923(2)%	0.077(2)%***	[2007Ko01, 1986Ry04, 1971Bb10, 1965Me02, 1963Ph01, 2010Ve03, 2010VeZZ, 2008KoZP, 1985Wi10, 1977Fl07, 1970Ba18, 1970BaZX, 1970BaZZ, 1969Ba57, 1969Me01, 1963Br35, 1963Le17, 1962Br45, 1962Ph02, 1957Ea01, 1955As42, 1954Gh24, 1954Ma98]
²⁵⁴ Fm	5.397(2)	7.307(1)	99.9410(3)%	0.0590(3)%	[ <b>1984Ah02, 1967Fi03</b> , 1977Gi15, 1974UnZU, 1974UnZX, 1973Ha44, 1963Bj03, 1963Br35, 1963Le13, 1962Br45, 1956Ch81, 1956Jo09, 1955As08]
²⁵⁸ No	4.80(10)#	8.15(10)#		100%	[1989Hu09, 2009Pe09, 2002PeZW, 1986Hu01, 1969NuZZ]
²⁶² Rf	4.45(30)#	8.49(20)#		100%	[ <b>1996La11, 1994La22</b> , 2013Mu08, 1998Tu01, 1994LaZX, 1994Og04, 1985So03, 1978NiZW]
²⁶⁶ Sg	4.05(33)#	8.80(10)#		100%	[ <b>2013Og03, 2008Dv02, 2006Dv01, 2003Tu05</b> , 2012Tu01, 2006Dv01, 2004Vo24, 2003Du27]
²⁷⁰ Hs	3.65(45)#	9.070(38)	$\approx 100\%$		[ <b>2013Og03, 2008Dv02, 2006Dv01, 2003Tu05</b> , 2012Tu01, 2004Vo24, 2003Du27, 2002Du21]
²⁷⁴ Ds	2.87(58)#	11.66(30)#			
²⁷⁸ Cn	2.85(64)#	11.22(20)#			

* Evaluated value from [2000Ho27], based on previous measurements.

** Deduced from a weighted average of  $T_{1/2}(SF) = 1.85(2) \times 10^7$  y [1971Ma32] and  $T_{1/2}(SF) = 1.80(1) \times 10^7$  y [1969Me01]. *** Deduced from a weighted average of  $\alpha/SF = 1260(40)$  [1965Me02] and  $\alpha/SF = 1330(45)$  [1963Ph01].

### **Table 3** direct $\alpha$ emission from ²³⁸U, $J^{\pi} = 0^+$ , $T_{1/2} = 4.4683(24) \times 10^9$ y*, $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{@}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{234}\mathrm{Th})^{@@}$	coincident $\gamma$ -rays (keV) ^{@@}	R ₀ (fm)	HF
4.107(5) 4.222(5) 4.270(3)	4.038(5)** 4.151(5)*** 4.198(3)***	0.088(1)% 29.8(1)% 100%	0.068(10)% 22.92(10)% 77.01(10)%	$4^+ 2^+ 0^+$	0.163 0.496 0.0	49.6, 113.5 49.6	1.5350(17) 1.5350(17) 1.5350(17)	$45^{+8}_{-6} \\ 1.258(6) \\ 1.0018(14)$

* [1971Ja07].

** Deduced from  $E_{\alpha}$  to the ground state and  $E_{level}$ .

*** Recommended by [1991Ry01], based on the adjusted values of [1961Ko11], [1960Vo05] and [1957Ha08].

@ [2014Po02].

@@ [2007Br04].

### Table 4

direct  $\alpha$  emission from ²⁴²Pu,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 3.77(7) \times 10^5$  y*,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{@}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{238}\mathrm{U})^{@@}$	coincident $\gamma$ -rays (keV) ^{@@}	R ₀ (fm)	HF
4.6773(14)** 4.8812(14)** 4.9397(15) 4.9847(14)	4.6000(14) 4.8005(14) 4.8581(15)*** 4.9023(14)***	8.37(26)×10 ⁻⁴ % 0.0388(13)% 30.74(16)% 100%	6.40(20)×10 ⁻⁴ % 0.0297(10)% 23.51(12)% 76.46(12)%	$6^+ 4^+ 2^+ 0^+$	0.30741(4) 0.1484(4) 0.044915(13) 0.0	44.9, 103.5, 159.0 44.9, 103.5 44.9	1.51448(75) 1.51448(75) 1.51448(75) 1.51448(75)	810(30) 247(10) 1.634(32) 1.014(19)

* Weighted average of  $3.702(14) \times 10^5$  y [1976Bu23],  $3.763(9) \times 10^5$  y [1976Os05] and  $3.869(164) \times 10^5$  y [1969Be06].

** Deduced from  $E_{\alpha}$  to the ground state and  $E_{level}$ .

*** Recommended by [1991Ry01], based on the adjusted values of [1968Ba25], [1956Hu96], [1956Ko67] and [1953AsZZ].

[@] Weighted average of values from [2011Be01] and [1986Va33].

@@ [2011Be01].

#### Table 5

direct  $\alpha$  emission from ²⁴⁶Cm,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 4756(20) \text{ y}^*$ ,  $BR_{\alpha} = 99.97(27)\%^{@}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{242}\mathrm{Pu})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
5.329(3)** 5.4310(9) 5.4747(9)	5.242(3) 5.3427(9)*** 5.3857(9)***	0.025(3)% 26.43(51)% 100%	0.020(2)% 20.9(4)% 79.08(22)%	$4^+ 2^+ 0^+$	0.1473 0.0445 0.0	44.5, 102.8 44.5	1.49412(62) 1.49412(62) 1.49412(62)	$500^{+50}_{-50}$ 2.06(4) 1.006(6)

* Weighted average of 4706(40) y [2007Ko01], 4852(76) y [1977Po20], 4820(20) y [1971Ma32], 4655(40) y [1971Mc19] and 4718(22) y 1969Me01]. ** [2007Ko01].

*** Recommended by [1991Ry01], based on the adjusted values of [1984Sh31], [1966Ba07], [1963Be48] and [1963Dz07].

[@] Deduced from a weighted average of  $T_{1/2}(SF) = 1.85(2) \times 10^7$  y [1971Ma32] and  $T_{1/2}(SF) = 1.80(1) \times 10^7$  y [1969Me01].

### Table 6

direct  $\alpha$  emission from ²⁵⁰Cf,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 13.08(9)$  y*,  $BR_{\alpha} = 99.923(2)\%^{**}$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{***}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{246}\mathrm{Cm})^{@@}$	coincident $\gamma$ -rays (keV) ^{@@}	R ₀ (fm)	HF
5.835(3) 5.987(3) 6.0863(6) 6.12827(20)	5.742(3)*** 5.891(3)*** 5.9889(6) [@] 6.03022(20) [@]	0.008(2)% 0.343(18)% 20.71(16)% 100%	0.007(2)% 0.283(15)% 17.11(13)% 82.6(1)%	$6^+ \\ 4^+ \\ 2^+ \\ 0^+$	0.2950 0.1420 0.0429 0.0	42.9, 99.2, 153.0 2.9, 99.2 42.942.9	1.48260(30) 1.48260(30) 1.48260(30) 1.48260(30)	$320^{+130}_{-70}$ 52.9(28) 2.896(30) 0.998(7)

* [1969Me01].

** Deduced from a weighted average of  $\alpha/SF = 1260(40)$  [1965Me02] and  $\alpha/SF = 1330(45)$  [1963Ph01].

*** [2007Ko01].

[@] Recommended by [1991Ry01], based on the adjusted values of [1971Bb10], and [1986Ry06].

@@ [2024Ne07].
Table 7	
direct $\alpha$ emission from ²⁵⁴ Fm, $J^{\pi} = 0^+$ , $T_{1/2} = 194.4$	1) m*, $BR_{\alpha} = 99.9410(3)\%$ *

 $\approx 100\%$ 

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})^{**}$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)^{**}$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{250}\mathrm{Cf})$	coincident γ-rays (keV)	R ₀ (fm)	HF
7.008(3) 7.163(2) 7.254(2) 7.307(2)	6.898(3) 7.050(2) 7.140(2) 7.192(2)	0.0078(9)% 0.96(7)% 16.7(4)% 100%	0.0066(8)% 0.82(6)% 14.2(3)% 85.0(5)%	$6^+ \\ 4^+ \\ 2^+ \\ 0^+$	0.2962 0.1419 0.0427 0.0	42.7, 141.9, 296.2 42.7, 141.9 42.7	1.48871(75) 1.48871(75) 1.48871(75) 1.48871(75)	$780_{-90}^{+110}$ $27.6(20)$ $4.03(9)$ $0.996(6)$
* [1967 ** [198	7Fi03]. 34Ah02].							
<b>Table 8</b> direct $\alpha$ em	ission from ²⁷⁰ H	$\text{Hs}^*, J^{\pi} = 0^+, \text{T}_{1/2}$	$= 7.6^{+4.9}_{-2.2}$ s, $BR_{\alpha}$	$= \approx 100^{\circ}$	%**.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pi} = E_c$	daughter (26	⁵⁶ Sg) coincider	nt $\gamma$ -rays (keV) R ₀ (fm	) HF	

* All values from [2013Og03].

9.150(80)

9.288(80)

** Only  $\alpha$  emission has been observed. [2013Og03] also observed events consistent with SF from heavy nuclei. They report an upper limit for SF as 50%.

1.471(27)

 $3.4^{2.2}_{-1.0}$ ***

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 $0^{+}$ 

0.0

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## VECTORWORKS EDUCATIONAL VERSION







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Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z = +27$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values are taken from ENSDE.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{arepsilon}$	Q _β -	$Q_{\beta}$ - $\alpha$	Experimental	
220Bi*		9 5(57) s	-3 17(50)#	5 70(30)#	16 93(30)#	[2010A]24]	
²²⁴ At*		obs	-2.20(20)#	5.266(24)	10.203(28)	[2012Ch19]	
²²⁸ Fr*	$2^{-}$	38*1) s	-1.859(19)	4.444(7)	8.694(12)	[1982Ru04]	
²³² Ac*	$(1^{+})$	119(5) s	-1.343(16)	3.708(13)	7.969(13)	[1986Gi08]	
²³⁶ Pa*	1+		-0.921(20)	2.889(14)	7.642(14)	[1984Mi02]	
²⁴⁰ Np*	(5+)	61.9(2) m	-0.399(17)	2.191(17)	7.626(17)	[1982Pa23]	
•				$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$		
²⁴⁴ Am*	(6 ⁻ )	10.01(3) h	0.073(3)	-7.220(30)#	4.739(3)	[2019Tr05]	
²⁴⁸ Bk*	$(6^{+})$		0.740(50)	-6.31(11)#	5.899(50)	[1973Fi06]	
²⁵² Es	(5 ⁻ )	471.7(17) d	1.260(50)	-5.227(51)	7.472(50)	[1977Ah03]	
²⁵⁶ Md	$(1^{-})$	78.1(18) m	1.97(12)#	-3.92(12)#	9.00(12)#	[1993Mo18]	
²⁶⁰ Lr		180(30) s	2.67(24)#	-2.58(16)#	10.37(13)#	[1971Es01]	
²⁶⁴ Db			3.19(43)#	-1.70(33)#	11.23(31)#		
²⁶⁸ Bh			3.91(61)#	-0.60(54)#	12.201(53)#		
²⁷² Mt			4.48(70)#	0.33(62)#	14.26(68)#		
²⁷⁶ Rg			4.85(83)#	1.33(74)#	15.96(81)#		
²⁸⁰ Nh			5.59(71)#	2.23(58)#	16.28(68)#		

* 100%  $\beta^-$  emitter.

** Taken from  $\alpha$  decay of ²⁵²Es [1973Fi06], might not be the ground state.

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +27$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	Experimental	
2205.	< 0.5 (50) H					
²²⁰ B1	6.95(50)#	3.66(42)#				
²²⁴ At	6.66(20)#	4.33(30)#				
²²⁸ Fr	6.791(16)	3.248(23)				
²³² Ac	6.351(17)	3.345(15)				
²³⁶ Pa	5.973(19)	3.755(19)				
²⁴⁰ Np	5.545(17)	4.557(22)				
²⁴⁴ Am	5.164(3)	5.138(17)				
²⁴⁸ Bk	4.691(50)	5.827(50)				
²⁵² Es	4.129(50)	6.739(1)	78(6)%		[1973Fi06, 1977Ah03, 1973AhZQ, 1965Mc11, 1956Ha80]	
²⁵⁶ Md	3.63(12)#	7.74(11)#	9.5(4)%*		[2000Ah02, 1993Mo18, 1971Ho16, 1970Fi12, 2019Ah04, 1965Si14,	
						1955Gh02]
²⁶⁰ Lr	3.09(13)#	8.40(14)#	100%		[1971Es01]	
²⁶⁴ Db	2.78(28)#	8.56(20)#				
²⁶⁸ Bh	2.39(46)#	9.02(30)#				
²⁷² Mt	1.50(56)#	10.35(30)#				
276Rg	1.53(30)#	11.48(40)#				
280 NIL	$1.57(72)\pi$ 1.07(56)#	11.40(40)# 11.42(75)#				
INII	1.07(30)#	11.43(73)#				

* Weighted average of 9.9(5)% [1971Ho16] and 8.5(8)% [1970Fi12].

Table 3				
direct $\alpha$ emission from	$^{252}\text{Es*}, J^{\pi} = (5)^{32}$	$^{-}$ ), T _{1/2} = 471.7(1	9) d**, $BR_{\alpha} =$	78(6)%

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	<i>E</i> _{daughter} ( ²⁴⁸ Bk)	coincident $\gamma$ -rays (keV)	R ₀ (fm)***	HF
6.038(4)	5 942(4)	0.050(10)%	0.031(12)%	<b>e</b> +	0.700(5)		1 48566(81)	35+22
6.081(4)	5.942(4) 5.984(4)	0.050(19)%	0.031(12)% 0.039(12)%	6-	0.657(5)		1.48566(81)	$33_{-10}$ $47^{+22}$
6.001(4)	5.96+(+) 6.016(4)	0.002(17)% 0.15(4)%	0.09(2)%	7+	0.625(5)		1.48566(81)	$29^{+11}$
6.148(3)	6.050(3)	1.27(11)%	0.80(9)%	, 5-	0.590(4)	377.4, 418.5, 590.0	1.48566(81)	$5.1^{+0.8}_{-0.6}$
6.207(5)	6.108(5)	0.15(4)%	0.09(2)%		0.531(6)	529.1	1.48566(81)	$\frac{-0.6}{87^{+32}_{-20}}$
6.254(5)	6.155(5)	$\approx 0.05\%$	≈0.03%		0.483(6)		1.48566(81)	$\approx 500^{-20}$
6.280(5)	6.180(5)	0.10(4)%	0.06(2)%		0.458(6)		1.48566(81)	$300^{+190}_{-90}$
6.314(5)	6.214(5)	0.12(4)%	0.08(2)%		0.424(6)		1.48566(81)	$360^{+170}_{-90}$
6.339(3)	6.238(3)	0.71(6)%	0.44(5)%		0.399(4)	399.7	1.48566(81)	$\frac{-90}{83^{+13}_{-10}}$
6.365(3)	6.264(3)	0.94(9)%	0.59 (7)%		0.373(4)	193.5, 228.0	1.48566(81)	$85^{+13}_{-11}$
6.399(5)	6.297(5)	$\approx 0.05\%$	≈0.03%		0.339(6)		1.48566(81)	$\approx 2 \times 10^3$
6.476(5)	6.373(5)	0.09(4)%	0.05(2)%		0.262(6)		1.48566(81)	$3.1^{+2.4}_{-1.0} \times 10^3$
6.527(5)	6.423(5)	0.56(6)%	0.35(5)%	(5 ⁻ )	0.211(6)		1.48566(81)	840+150
6.564(3)	6.460(3)	0.31(5)%	0.20(3)%	$(4^{-})$	0.174(4)		1.48566(81)	$1.6^{+0.3}_{-0.2} \times 10^3$
6.586(3)	6.481(3)	2.73(12)%	1.71(15)%	8+	0.152(4)	70.7, 80.7, 151.3	1.48566(81)	326(34)
6.602(5)	6.497(5)	0.39(5)%	0.24(4)%		0.136(6)	64.4, 70.7	1.48566(81)	$2.7(5) \times 10^3$
6.667(3)	6.561(3)	17.0(4)%	10.6(9)%	7+	0.071(4)	70.7	1.48566(81)	123(12)
6.738(3)	6.631(3)	100%	62.6(7)%	(6 ⁺ )	0.0		1.48566(81)	44(4)

* All values from [1973Fi06], except where noted.

** [1977Ah03].

*** Interpolated between 1.48260(30) fm  $(^{250}Cf)$  and 1.48871(75) fm  $(^{254}Fm).$ 

#### Table 4

direct $\alpha$ em	lirect $\alpha$ emission from ²⁵⁶ Md*, $J^{\pi} = (1^{-}), T_{1/2} = 78.1(18) \text{ m**}, BR_{\alpha} = 9.5(4)\%$ ***.										
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{252}\mathrm{Es})$	coincident $\gamma$ -rays (keV)	$R_0  (fm)^@$	HF			
7.255(5)	7.142(5)	31(2)%	2.1(1)%		0.542(9)		1.483(24)	$3.6^{+3.0}_{-1.7}$			
7.320(4)	7.206(4)	100(3)%	6.8(3)%		0.477(9)		1.483(24)	$2.1^{+1.7}_{-1.0}$			
7.362(5)	7.247(5)	3.5(7)%	0.24(5)%		0.436(9)		1.483(24)	$90_{-40}^{+70}$			
7.763(8)	7.642(8)	3.0(7)%	0.20(5)%		0.035(11)		1.483(24)	$3.4^{+3.0}_{-1.7} \times 10^3$			
7.798(8)	7.676(8)	3.5(7)%	0.24(5)%	$(5^{-})$	0.0		1.483(24)	$3.8^{+3.3}_{-1.9} \times 10^3$			

* All values from [2000Ah02], except where noted.

** [1993Mo18].

*** Weighted average of 9.9(5)% [1971Ho16] and 8.5(8)% [1970Fi12].

[@] Interpolated between 1.48871(75) fm ( 254 Fm) and 1.477(24) fm ( 258 No).

#### Table 5

Table 5				
direct $\alpha$ emission from	$1^{260}$ Lr*, T _{1/2} =	180(30) s,	$BR_{\alpha} = 100\%$	ò

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{256}Md)$	coincident γ-rays (keV)	R ₀ (fm)**	HF
8.155(20)	8.030(20)	100%	(1 ⁻ )	0.0		1.479(28)	$1.1 \stackrel{1.2}{_{-0.6}}$

* All values from [1971Es01].

** Interpolated between 1.477(24) fm ( $^{258}\mathrm{No})$  and 1.480(14) fm ( $^{262}\mathrm{Rf}).$ 

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# $\begin{array}{c} 279 Cn \\ Q_{VQ} = 1.484 \ MeV \\ Q_{VQ} = 13.834 \ MeV \\ Q_{Q} = 10.934 \ MeV \end{array}$



Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +55/2 nuclei.

Last updated 4/1/2025

Observed and predicted  $\beta$ -delayed particle emission from the even-*Z*,  $T_z = +55/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values for ²¹⁹Pb, ²²³Po, ²²⁷Rn, ²³¹Ra, ²³⁵Th, ²³⁹U and ²⁴³Pu are taken from ENSDF.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{arepsilon}$	$Q_{\beta}$ -	$Q_{\beta}$ - $\alpha$	Experimental
²¹⁹ Ph			>300 ns		4 30(45)#	8 35(50)#	[2010A124]
²²³ Po			>300  ns	-5.16(45)#	3.65(20)#	8.52(28)#	[2010Al24]
²²⁷ Rn		(5/2)	20.2(4) s	-4.54(30)#	3.203(0)	7.213(20)	[1997Ku20]
²³¹ Ra		$(5/2^+)$	104.1(8) s	-3.864(14)	2.454(17)	6.289(13)	[2008Bo29]
²³⁵ Th		$(1/2^+)$	7.3(1) m	-3.339(19)	1.729(19)	6.010(18)	[1986Mi10
²³⁹ U		5/2+	23.44(2) m	-2.77(20)#	1.262(2)	6.039(14)	[1989Ab05
²⁴³ Pu		$7/2^{+}$	4.955(3) h	-2.050(30)#	0.580(3)	6.199(3)	[1968Di09]
²⁴⁷ Cm		9/2-	1.56(5)×10 ⁷ y	-1.62(10)#	0.044(6)	6.113(4)	[ <b>1971Fi01</b> ]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
²⁵¹ Cf		$1/2^{+}$	898(43) y*	-1.093(10)			[1969Me01, 1968Ch03]
²⁵⁵ Fm		$7/2^{+}$	20.54(7) h**	-0.289(10)			[1964As01, 1956Jo09]
²⁵⁹ No		$(9/2^+)$	1.6(8) h	0.52(10)#	-3.64(20)#	7.565(13)#	[2013As02]
²⁶³ Rf		(1/2)	$5.1^{+4.6}_{-1.7}$ s	1.09(27)#	-2.63(39)#	8.77(18)#	[2024Og02]
²⁶⁷ Sg		(9/2)	$9.8^{+11.3}_{-4.5}$ m	1.79(46)#	-1.62(49)#	9.71(34)#	[2024Og02]
^{267m} Sg	х	(1/2)	$100_{-39}^{+92}$ s	1.79(46)#+x	-1.62(49)#+x	9.71(34)#+x	[2024Og02]
²⁷¹ Hs		(11/2)	$46^{+56}_{-16}$ s	1.83(47)#	-1.03(54)#	11.25(47)#	[2024Og02]
^{271m} Hs	Х	(3/2)	$7.1^{+8.4}_{-2.5}$ s	1.83(47)#+x	-1.03(54)#+x	11.25(47)#+x	[2024Og02]
²⁷⁵ Ds		(3/2)	$0.43^{+0.29}_{-0.12}$ ms	2.90(52)#	0.97(58)#	13.38(51)#	[2024Og02]
²⁷⁹ Cn		. /	-0.12	3.30(58)#	1.48(65)#	13.83(55)#	

* Weighted average of 900(50) y [1969Me01] and 892(88) y [1968Ch03].

** Weighted average of 20.07(7) h [1964As01] and 21.5(1) h [1956Jo09].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +55/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	$BR_{\alpha}$	BR _{SF}	Experimental
210-4					
²¹⁹ Pb	10.38(57)#	1.09(57)#			
²²³ Po	9.16(36)#	4.03(45)#			
²²⁷ Rn	9.06(30)#	3.38(20)#			
²³¹ Ra	8.559(13)	2.906(18)			
²³⁵ Th	8.112(19)	3.376(17)			
²³⁹ U	7.610(16)	4.130(13)			
²⁴³ Pu	6.95(20)	4.757(3)			
²⁴⁷ Cm	6.750(18)	5.354(3)	100%		[2022Ah03, 1971Fi01, 1963Fi08, 1954St33]
²⁵¹ Cf	6.106(5)	6.177(1)	100%		[2003Ah07, 2003AhZZ, 1975BrZP, 1971Bb10, 1970BaZZ, 1970BrZN,
					1969Ba57, 1969Me01, 1968Ch03, 1966Rg01]
²⁵⁵ Fm	5.483(5)	7.241(1)	100%	$2.4^{+1.2}_{0.0} \times 10^{-5}\%$	[2005Ah09, 1975Ah01, 1963Ph01, 2000Ah09, 1999AhZY,
				-0.9	1991Po17, 1990Po14, 1971Ah01, 1971Bb10, 1964As01, 1963Ph01,
					1962Br45, 1961Br40, 1956Jo09, 1955Gh01]
²⁵⁹ No	4.900(7)	7.854(5)	75(4)%		[2013As02, 1982Wi08, 1978WiZT, 1973Si40, 1972SiZF, 1971SiYZ]
²⁶³ Rf	4.64(25)#	8.25(15)#		100%	[2024Og02, 2008Dv02, 2012Tu01, 2010Gr04, 2003Kr20, 2002KrZV,
					2002KrZY, 1995GrZV]
²⁶⁷ Sg	4.22(39)#	8.63(21)#	100%		[2024Og02, 2008Dv02, 2012Tu01]
$^{267m}Sg$	4.22(39)#-x	8.63(21)#+x		100%	[2024Og02, 2008Dv02, 2012Tu01, 2010Gr04]
²⁷¹ Hs	3.828(406)#	9.460(87)#	100%		[2024Og02, 2008Dv02, 2012Tu01, 2010Gr04]
²⁷¹ Hs	3.828(406)#-x	9.460(87)#+x	100%		[2024Og02, 2008Dv02, 2012Tu01, 2010Gr04
²⁷⁵ Ds	2.87(51)#	11.55(20)#	100%		[2024Og02]
²⁷⁹ Cn	2.79(55)#	10.93(20)#			

Table 3			
direct $\alpha$ emission from ²⁴⁷	Cm*, $J^{\pi} = 9/2^{-}, T_{1/2} =$	$1.56(5) \times 10^7$ y,	$BR_{\alpha} = 100\%$

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	Edaughter( ²⁴³ Pu)***	coincident γ-rays (keV)***	R ₀ (fm)	HF
4.789(4)**	4.712(4)	0.10(2)%	0.071(13)%**	$(9/2^+)$	0.565(2)	564.5**	1.4993(79)	78+27
4.899(4)	4.820(4)	6.6(4)%	4.7(3%	11/2-	0.455(5)	397.6**	1.4993(79)	$2.3^{+1.8}_{-1.6}$
4.950(4)	4.870(4)	100%	71.0(10%	9/2-	0.4026(3)	125, 278.0, 344.5, 402.6	1.4993(79)	-1.0
5.024(4)	4.943(4)	2.3(3)%	1.6(2)%	$7/2^{+}$	0.3332(2)	275.1, 333.0	1.4993(79)	1.1(3)
5.067(4)	4.985(4)	2.8(3)%	2.0(2)%	5/2+	0.2875(2)	229.3, 287.4	1.4993(79)	250(70)
5.232(4)	5.147(4)	1.7(3)%	1.2(2)%	$11/2^{+}$	0.1248(7)	125	1.4993(79)	$4.8^{+1.6}_{-1.2} \times 10^3$
5.298(4)	5.212(4)	8.0(7)%	5.7(5)%	$9/2^{+}$	0.0581(2)		1.4993(79)	$2.7(7) \times 10^3$
5.354(4)	5.267(4)	19.4(10)%	13.8(7)%	$7/2^{+}$	0.0		1.4993(79)	$2.6(6) \times 10^3$

* All values from [1971Fi01], except where noted.  $E_{\alpha}$  values are adjusted by +2.3 keV as recommended in [1991Ry01]. ** [2022Ah03].  $E_{\alpha}$  deduced from  $\alpha$ - $\gamma$  coincidence. *** [2014Ne14].

Table 4					
direct $\alpha$ emission from	$^{251}{ m Cf}^*, J^{\pi} =$	$1/2^{-}, T_{1/2} =$	898(43) y**,	$BR_{\alpha} = 1$	00%.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{247}\mathrm{Cm})$	coincident γ-rays (keV)	R ₀ (fm)	HF
5.594(2)	5.505(2)	0.76(14)%	0.27(5)%	5/2+	0.5817	38.5, 61.7, 165.7, 227.4, 265.9 315 8, 354 3	1.49187(17)	$32^{+9}_{-6}$
5.658(2)	5.568(2)	5.4(3)%	1.9(1)%	3/2+	0.5186	61.7, 113.7, 165.7, 177.5, 227.4, 354.3	1.49187(17)	10.7(8)
5.726(2)	5.635(2)	13.8(6)%	4.9(2)%	5/2+	0.450		1.49187(17)	10.3(7)
5.743(2)	5.651(2)	9.3(6)%	3.3(2)%	$3/2^{+}$	0.434		1.49187(17)	18.8(15)
5.771(2)	5.679(2)	100.0(20)%	35.4(5)%	$1/2^{+}$	0.4049	61.7, 165.7, 177.5, 227.4	1.49187(17)	2.56(13)
5.831(2)	5.738(2)	2.3(3)%	0.8(1)%	9/2+	0.3459	58.0, 60.5, 61.7, 165.7, 227.4, 284 2, 285 4, 345 9	1.49187(17)	$240^{+50}_{-40}$
5.859(2)	5.766(2)	10.2(6)%	3.6(2)%	9/2+	0.3183	38.5, 52.5, 61.7, 165.7, 227.4, 265.9, 285.9	1.49187(17)	76(6)
5.892(2)	5.798(2)	7.1(6)%	2.5(2)%	$7/2^{+}$	0.2854	58.0, 61.7, 165.7, 227.4 285.4	1.49187(17)	166(16)
5.911(2)	5.817(2)	11.3(6)%	4.0(2)%	7/2+	0.2659	38.5, 61.7, 165.7, 227.4, 265.9	1.49187(17)	132(9)
5.949(2)	5.854(2)	78.0(18)%	27.6(5)%	5/2+	0.2274	61.7, 165.7, 227.4	1.49187(17)	30.9(16)
6.042(2)	5.946(2)	1.69(17)%	0.60(6)%	$13/2^{-}$	0.1347	61.7, 73.0, 134.6	1.49187(17)	$4.4(7) \times 10^{3}$
6.114(2)	6.017(2)	35.3(10)%	12.5(3)%	$11/2^{-}$	0.0617	61.7	1.49187(17)	506(27)
6.176(2)	6.078(2)	7.3(3)%	2.6(1)%	9/2-	0.0		1.49187(17)	$5.0(3) \times 10^3$

* All values from [2003Ah07], except where noted. ** Weighted average of 900(50) y [1969Me01] and 892(88) y [1968Ch03].

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direct  $\alpha$  emission from ²⁵⁵Fm*,  $J^{\pi} = 7/2^{-}$ ,  $T_{1/2} = 20.54(7)$  h**,  $BR_{\alpha} = 100\%$ . (1 of 2)

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	π@ f	$E_{daughter}(^{251}\mathrm{Cf})^{***}$	coincident γ-rays (keV)***	HF ^{@@}
5.991(2)	5.897(2)***	1.9(1)×10 ⁻⁵ %	1.8(1)×10 ⁻⁵ %***	(1/2 ⁻ )	1.250	41.0, 45.2, 47.8, 57.9, 60.0, 63.4, 73.1, 80.9, 86.0, 98.9, 111.8, 131.1, 133.0, 152.8, 159.0, 163.7, 177.6, 186.7, 194.6, 204.1, 210.7, 211.6, 233.7, 264.2, 816.1, 991.6, 1038.3, 1072.3, 1083.9, 1144.0	28.1(22)
6.056(2)	5.961(2)***	6.2(6)×10 ⁻⁶ %	5.8(6)×10 ⁻⁶ %***		1.185	41.0, 47.8, 57.9, 80.9, 98.9, 111.8, 152.8, 163.7, 177.6, 186.7, 210.7, 211.6, 233.7, 285.5, 332.4, 366.4, 397.5, 437.7, 496.2, 519.2, 543.9, 641.6, 1019.2, 1079.1	$195^{+26}_{-22}$
6.084(2)	5.989(2)***	$\approx$ 4.3×10 ⁻⁶ %	≈4.0×10 ⁻⁶ %***	(11/2 ⁻ )	1.156	41.0, 47.8, 57.9, 60.0, 73.1, 80.9, 8.9, 9133.0, 149.2, 245.7, 286.7, 763.5, 859.8, 918.1	$\approx 400$
6.145(2)	6.049(2)***	6.7(6)×10 ⁻⁶ %	6.3(7)×10 ⁻⁶ %***	(9/2 ⁻ )	1.095	41.0, 47.8, 57.9, 80.9, 98.9, 245.7, 286.7, 702.3, 947.8, 988.8	$530^{+80}_{-60}$
6.154(2)	6.057(2)***	1.10(8)×10 ⁻⁵ %	$1.00(7) \times 10^{-5}\% ***$	(9/2-)	1.087	45.2, 47.8, 57.9, 60.0, 63.4, 73.1, 80.9, 86.0, 131.1, 133.0, 159.0, 194.6, 204.1, 264.2, 652.5, 715.8, 847.0, 920.5	370(30)
6.163(2)	6.066(2)***	5.0(2)×10 ⁻⁵ %	4.7(2)×10 ⁻⁵ %***		1.078	45.2, 47.8, 57.9, 60.0, 63.4, 73.1, 80.9, 86.0, 131.1, 133.0, 159.0, 194.6, 204.1, 264.2, 643.6, 707.0, 838.4, 911.3, 971.2	88(6)
6.196(2)	6.099(2)***	2.4(1)×10 ⁻⁵ %	2.2(1)×10 ⁻⁵ %***	(7/2 ⁻ )	1.044	41.0, 47.8, 57.9, 80.9, 98.9, 111.8, 152.8, 163.7, 172.9, 186.7, 210.7, 211.6, 213.9, 233.7, 271.9, 724.1, 785.4, 831.9, 938.1, 996.1	281(20)
6.232(2)	6.134(2)***	4.0(2)×10 ⁻⁵ %	3.7(2)×10 ⁻⁵ %***	(5/2 ⁻ )	1.009	41.0, 47.8, 57.9, 80.9, 98.9, 111.8, 152.8, 163.7, 177.6, 186.7, 210.7, 211.6, 233.7, 301.0, 408.2, 530.4, 553.0. 577.5, 601.0, 660.2, 683.2, 750.5, 797.6, 831.9, 903.1, 961.2, 984.2	252(19)
6.259(2)	6.161(2)***	4.4(2)×10 ⁻⁵ %	4.1(2)×10 ⁻⁵ %***	(3/2 ⁻ )	0.981	47.8, 152.8, 163.7, 177.6, 186.7, 211.6, 349.6, 381.0, 454.4, 553.0. 577.5, 601.0, 607.1, 632.1, 770.0, 803.8, 956.6, 981.4	516(23)
6.266(2)	6.168(2)***	$2.5(1) \times 10^{-5}\%$	2.30(1)×10 ⁻⁵ %***	(9/2+)	0.974	47.8, 57.9, 60.0, 73.1, 80.9, 133.0, 734.5, 807.7, 967.8	$611^{+34}_{-32}$
6.298(2)	6.199(2)***	$3.9(2) \times 10^{-5}\%$	$3.60(2) \times 10^{-5}\%$ ***	(5/2 ⁻ )	0.943	47.8, 57.9, 80.9, 152.8, 163.7, 177.6, 186.7, 211.6, 731.0, 764.7, 836.2	$559^{+31}_{-29}$
6.466(2)	6.365(2)***	$4.1(3) \times 10^{-5}\%$	$3.8(3) \times 10^{-5}\%$ ***	$(3/2^+)$	0.774	774	$3.6(3) \times 10^3$
6.502(2)	6.400(2)***	$pprox 6.4  imes 10^{-6}\%$	$\approx 6.0 \times 10^{-6}\%$ ***	5/2-	0.708	47.8, 152.8, 177.6, 530.4, 660.2, 683.2	$\approx 5 \times 10^4$
6.591(3)	6.488(3)	3.2(5)×10 ⁻³ %	3.0(5)×10 ⁻³ %	(9/2+)	0.649	41.0, 47.8, 57.9, 60.0, 73.1, 80.9, 98.9, 111.8, 133.0, 152.8, 172.9, 210.7, 213.9, 233.7, 245.7, 256.7, 271.9, 286.7, 329.3, 390.4, 409.6, 482.5, 502.1, 601.0	$180^{+40}_{-30}$
6.609(2)	6.505(2)***	pprox3.2 $ imes$ 10 ⁻⁶ %	$\approx 3.0 \times 10^{-6}\%$ ***	$1/2^{-}$	0.632	152.8, 177.6, 454.4, 607.1, 632.1	$\approx 3 \times 10^5$
6.616(2)	6.512(2)***	$\approx 4.3 \times 10^{-6}\%$	$\approx 4.0 \times 10^{-6} \% ***$	$7/2^{-}$	0.625	41.0, 47.8, 57.9, 80.9 , 98.9, 378.3, 577.5	$\approx 1.7 \times 10^5$
6.639(2)	6.535(2)***	$\approx$ 4.3 $\times$ 10 ⁻⁶ %	$\approx 4.0 \times 10^{-6}\%$ ***	3/2-	0.601	47.8, 553.0. 577.5, 601.0	$\approx 2.2 \times 10^5$
6.650(2)	6.546(2)	0.0150(2)%	0.014(2)%	(7/2 ⁺ )	0.590	41.0, 47.8, 57.9, 60.0, 73.1, 80.9, 98.9, 98.9, 111.8, 133.0, 152.8, 163.7, 172.9, 177.6, 186.7, 197.4, 210.7, 211.6, 213.9, 233.7, 245.7, 270.4, 271.9, 286.7, 331.5, 350.6, 378.5, 412.2, 423.7, 443.2, 483.7, 542.2, 565.2	$71^{+13}_{-10}$
6.697(2)	6.592(2)	0.018(2)%	0.017(2)%	5/2+	0.544	41.0, 47.8, 57.9, 80.9, 98.9, 111.8, 152.8, 163.7, 177.6, 186.7, 210.7, 211.6, 233.7, 285.5, 332.4, 366.4, 397.5, 437.7, 496.2, 519.2, 543.9	93 ⁺¹⁴ -12
6.727(3)	6.621(3)	$2.4(5) \times 10^{-3}\%$	$2.2(5) \times 10^{-3}\%$		0.514		$1.0(2) \times 10^3$
6.799(3)	6.692(3)	$5(2) \times 10^{-3}\%$	$5(2) \times 10^{-3}\%$		0.442		$900^{+600}_{-300}$

* All values from [1975Ah01], except where noted.
** Weighted average of 20.07(7) h [1964As01] and 21.5(1) h [1956Jo09].
[@] [2023Mo11].
[@] @</sup> R₀ = 1.4928(21) fm.

## Table 6 direct $\alpha$ emission from ²⁵⁵Fm*, $J^{\pi} = 7/2^{-}$ , $T_{1/2} = 20.54(7)$ h**, $BR_{\alpha} = 100\%$ . (2 of 2)

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	π@ f	<i>E</i> _{daughter} ( ²⁵¹ Cf)***	coincident γ-rays (keV)***	HF ^{@@}
6.806(2)	6.699(2)	0.039(2)%	0.036(2)%	9/2-	0.435	45.2, 47.8, 57.9, 60.0, 63.4, 73.1, 80.9, 86.0, 131.1, 133.0, 159.0, 194.6, 204.1, 264.2	139(11)
6.817(2)	6.710(2)	0.014(1)%	0.013(1)%	$(15/2^+)$	0.424	47.8, 57.9, 60.0, 73.1, 80.9, 133.0, 184.6	430(40)
6.848(3)	6.741(3)	0.013(4)%	0.012(4)%	$(11/2^+)$	0.392	41.0, 47.8, 57.9, 80.9, 98.9, 245.7, 286.7	$650^{+440}_{-170}$
6.871(2)	6.763(2)	0.017(2)%	0.016(2)%	11/2-	0.370	45.2, 47.8, 57.9, 60.0, 73.1, 80.9, 86.0, 131.1, 133.0, 159.0, 204.1, 264.2	$610_{-80}^{-100}$
6.915(2)	6.807(2)	1.20(6)%	0.110(6)%	(13/2+)	0.325	47.8, 57.9, 60.0, 73.1, 80.9, 86.0, 133.0, 159.0	139(11)
6.923(3)	6.814(3)	$2.1(5) \times 10^{-3}\%$	$2.0(5) \times 10^{-3}\%$	9/2+	0.318	41.0, 47.8, 57.9, 80.9, 98.9, 172.9, 213.9, 271.9	$8.2^{+2.8}_{-1.7}{\times}10^3$
6.945(2)	6.836(2)	8.6(11)×10 ⁻³ %	$8.0(10) \times 10^{-3}\%$	$(13/2^+)$	0.296	41.0, 47.8, 57.9, 80.9, 98.9, 149.2	$2.5^{+0.4}_{-0.2} \times 10^3$
6.983(2)	6.873(2)	8.6(11)×10 ⁻³ %	8.0(10)×10 ⁻³ %	7/2+	0.258	41.0, 47.8, 57.9, 80.9, 98.9, 111.8, 152.8, 210.7, 233.7	$3.7^{+0.6}_{-0.5} \times 10^3$
7.002(2)	6.892(2)	0.66(1)%	0.62(1)%	$11/2^{+}$	0.239	47.8, 57.9, 60.0, 73.1, 80.9, 133.0	57.4(32)
7.028(2)	6.918(2)	0.018(2)%	0.017(2)%	$5/2^{+}$	0.212	47.8, 163.7, 186.7, 211.6	$2.73(22) \times 10^3$
7.064(3)	6.953(3)	0.024(4)%	0.022(4)%	3/2+	0.177	152.8, 177.6	$3.0^{+0.7}_{-0.5} \times 10^3$
7.074(2)	6.963(2)	5.40(7)%	5.04(6)%	9/2+	0.167	47.8, 57.9, 60.0, 80.9	14.2(8)
7.094(2)	6.983(2)	0.14(1)%	0.13(1)%	9/2+	0.146	41.0, 47.8, 57.9, 80.9, 98.9	670(60)
7.134(2)	7.022(2)	100.0(5)%	93.4(3)%	$7/2^{+}$	0.107	47.8, 57.9, 80.9	1.36(7)
7.193(2)	7.080(2)	0.43()%	0.40(3)%	7/2+	0.048	47.8	$2.2^{+0.3}_{-0.2} \times 10^3$
7.216(2)	7.103(2)	0.10(1)%	0.090(9)%	5/2+	0.024		$3.1^{+0.4}_{-0.3} \times 10^3$
7.241(2)	7.127(2)	0.07(1)%	0.070(7)%	$1/2^{+}$	0.0		$5.0^{+0.6}_{-0.5} \times 10^3$

* All values from [1975Ah01], except where noted.

** Weighted average of 20.07(7) h [1964As01] and 21.5(1) h [1956Jo09].

*** [2005Ah09].

@ [2023Mo11].

[@]  $R_0 = 1.4928(21)$  fm.

#### Table 7

direct  $\alpha$  emission from ²⁵⁹No*,  $J^{\pi} = (9/2^+)$ ,  $T_{1/2} = 1.6(8)$  h,  $BR_{\alpha} = 75(4)\%^{**}$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	π@ f	$E_{daughter}(^{255}\mathrm{Fm})^{@}$	coincident $\gamma$ -rays (keV) [@]	R ₀ (fm)	HF
7.623(5)	7.505(5)***	75(4)%	(9/2+)	0.2314	61.7, 169.6, 231.4	1.481(15)	$1.4^{+1.0}_{-0.9}$

* All values from [2013Ah02], except where noted.

** [1982Wi08].

*** [1973Si40] reported  $\alpha$ 's of 7.455 MeV (13%), 7.500 MeV (39%), 7.533 MeV (23%), 7.605 MeV (14%), and 7.685 MeV (11%) with a T1/2 = 58(5) m. [2013Ah02] determined theat the excess peaks were either due to contaminants or summing with conversion electrons. @ [2008AsZY].

#### Table 8

Hence a emission from ${}^{267}\text{Sg}^*$ , $J^{\pi} = (9/2)$ , $T_{1/2} = 9.8^{+11.3}_{-4.5}$ m, $BR_{\alpha} = 100\%^{**}$ .								
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\pi_{f}$	$E_{daughter}(^{263}\mathrm{Rg})$	coincident γ-rays (keV)	R ₀ (fm)	HF	
8.396(20)	8.270(20)	(9/2)			1.457(60)	$1^{+5}_{-1}$		

* All values from [2024Og02],

** Only  $\alpha$ -decay has been observed.

$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\frac{\pi}{f}$	$E_{daughter}(^{267}\mathrm{Sg})$	coincident γ-rays (keV)	R ₀ (fm)	HF		
9.480(20)	9.340(20)				1.478(50)	$90^{+22}_{-13}$			
* All values from [2024Og02], ** Only α-decay has been observed.									
Table 10 direct $\alpha$ emiss	ion from ^{271m} Hs*, I	Ex. =unk, $J^{\pi} = ($	3/2), T _{1/2}	$= 7.1^{+8.4}_{-2.5}$ s, $BR_{\alpha} = 100\%$	6**.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$f^{\pi}$	E _{daughter} ( ²⁶⁷ Sg)	coincident γ-rays (keV)	R ₀ (fm)	HF		
9.180(20)	9.050(20)	(3/2)			1.478(50)	$2^{+5}_{-1}$			
* All valu ** Only c	les from [2024Og02 α-decay has been ob	e], oserved.							
Table 11 direct $\alpha$ emiss	ion from ²⁷⁵ Ds*, J ⁷	$t = (3/2), T_{1/2} =$	$0.43^{+0.29}_{-0.12}$	ms, $BR_{\alpha} = 100\%^{**}$ .					
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$_{f}^{\pi}$	$E_{daughter}(^{271}\mathrm{Hs})$	coincident γ-rays (keV)	R ₀ (fm)	HF		
11.365(20)	11.200(20)	(3/2)							
* All valu ** Only c	les from [2024Og02 α-decay has been of	2], oserved.							

direct  $\alpha$  emission from ²⁷¹Hs*,  $J^{\pi} = (11/2)$ ,  $T_{1/2} = 46^{+56}_{-16}$  s,  $BR_{\alpha} = 100\%$ **.

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 $\begin{array}{ccc} 281 Nh \\ Q_{6Q} = & 0.64\pi \; MeV \\ Q_{6Q} = & 14.29\pi \; MeV \\ Q_{Q} = & 10.98\pi \; MeV \end{array}$ 

 $\begin{array}{c} 277 Rg \\ Q\epsilon \rho = -0.19 \# \, MeV \\ Q\epsilon \alpha = 14.22 \# \, MeV \\ Q\alpha = 11.20 \# \, MeV \end{array}$ 

 $\begin{array}{c} 273 Mt \\ Q_{4\alpha} = \ -1.29 \# \, MeV \\ Q_{4\alpha} = \ 12.67 \# \, MeV \\ Q_{\alpha} = \ 10.88 \# \, MeV \end{array}$ 

 $\begin{array}{c} 269 \\ Bh \\ Qeq = -2.87 \\ MeV \\ Qeq = 10.36 \\ WeV \\ Qq = 8.67 \\ \# MeV \end{array}$ 

 $\begin{array}{c} Q_{65} Db \\ Q_{60} = -3.28 \# \, MeV \\ Q_{60} = -9.50 \# \, MeV \\ Q_{0} = -8.40 \# \, MeV \end{array}$ 





Last updated 4/8/2025

Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +55/2$ nuclei.	Unless otherwise stated, all Q-values are taken from [2021Wa16] or
deduced from values therein. $J^{\pi}$ values for XX are taken from ENSDF.	

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{arepsilon}$	Q _β -	Q _β - α	Experimental
²²¹ Bi		>300 ns		4 43(30)#	9.70(42)#	[2010A]24]
²²⁵ At		>300  ns	-4 28(42)#	3.77(30)#	8.28(30)#	[2010A124]
²²⁹ Fr		50.2(20) s	-3.694(14)	3.106(16)	6.889(12)	[1992Bo05]
²³³ Ac	$(1/2^+)$	2.3(3) m	-3.026(16)	2.576(13)	6.501(20)	[1983Ch31]
²³⁷ Pa	(1/2+)	8.7(2) m	-2.427(21)	2.137(13)	6.551(13)	[1974Ka05]
²⁴¹ Np	5/2+	13.9(2) m	-1.88(22)#	1.36(10)	6.69(10)	[1981Pa20]
²⁴⁵ Am	5/2+	122.8(5) m*	-1.278(14)	0.896(2)	6.700(2)	[1968Da02, 1983Po15]
²⁴⁹ Bk	7/2+	327.2(3) d	-0.904(3)	0.124(1)	6.597(2)	[2014Ch47]
				$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
²⁵³ Es	7/2+	20.03(1) d	-0.291(4)			[1956Jo09]
²⁵⁷ Md	$(7/2^{-})$	5.523(50) h	0.402(5)	-5.48(10)#	7.266(5)	[1993Mo18]
²⁶¹ Lr		39(12) m	1.10(28)#	-4.28(37)#	8.54(20)#	[1991HeZT]
²⁶⁵ Db			1.69(42)#	-3.28(49)#	9.50(30)#	
²⁶⁹ Bh			1.79(53)#	-2.87(65)#	10.36(52)#	
²⁷³ Mt			3.02(57)#	-1.29(68)#	12.67(56)#	
²⁷⁷ Rg			3.32(61)#	-0.19(71)#	14.22(60)#	
²⁸¹ Nh			3.86(50)#	0.64(61)#	14.29(49)#	

* Weighted average of 2.05(1) h [1968Da02] and 122.5(8) m [1983Po15].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +55/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	$BR_{\alpha}$	BR _{SF}	Experimental
²²¹ Bi ²²⁵ At ²²⁹ Fr ²³³ Ac ²³⁷ Pa ²⁴¹ Np ²⁴⁵ Am	7.22(50) # $6.90(36) #$ $6.864(18)$ $6.478(16)$ $6.017(19)$ $5.69(10)$ $5.195(3)$	3.12(50)# 3.68(42)# 2.94(30)# 3.215(14) 3.795(18) 4.36(10) 5.16(10)			
²⁴⁹ Bk	4.835(3)	5.521(1)	$1.37(10) \times 10^{-3}\%$	4.8(2)×10 ⁻⁸ %	[ <b>2013Ah03, 1969Mi08</b> , 2024Du12, 2014Ch47, 1999Po35, 1994Po30, 1993Po20, 1985Po26, 1975Ba27, 1972Ko53, 1971Bb10, 1969Ba57, 1966Ah02, 1957Ea01, 1956Ch77, 1954Di11]
²⁵³ Es	4.313(3)	6.739	100%	8.7(3)×10 ⁻⁶ %	[2005Ah03, 1975Ah01, 1971Gr17, 1965Me02, 2005AhZZ, 1987Po22, 1982Po13, 1976Fl03, 1972HaWR, 1971Ba49, 1971BaZB, 1966Rg01, 1963Le17, 1960As06, 1960As08, 1954Fi14]
²⁵⁷ Md ²⁶¹ Lr ²⁶⁵ Db ²⁶⁹ Bh ²⁷³ Mt ²⁷⁷ Rg ²⁸¹ Nh	3.781(3) 3.34(28)# 2.98(42)# 2.61(60)# 1.51(66)# 1.42(72)# 1.13(66)#	7.557(1) 8.14(20)# 8.40(10)# 8.67(30)# 10.88(20)# 11.20(20)# 10.98(56)#	15.2(26)%	obs	[ <b>1993Mo18</b> , 1986HaYZ, 1971Ho16, 1970Fi12. 1965Si14] [ <b>1991HeZT</b> , 1989HuZU]

Table 3				
direct $\alpha$ emission from ²⁴⁹ I	$3k^*, J^{\pi} = 7/2^+, T_{1/2}$	= 327.2(3) d**,	$BR_{\alpha} = 1.37(10)$	$\times 10^{-3}\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi***}$	Edaughter( ²⁴³ Pu)***	coincident γ-rays (keV)***	R ₀ (fm)	HF
5.04((4))	4.0(5(4)	- 0.01401	- 1 4 10-50	11/2+	0.4755		1 49044(52)	- (1
5.046(4)	4.965(4)	$\approx 0.014\%$	$\approx 1.4 \times 10^{-5}\%$	11/2	0.4755		1.48944(52)	≈01
5.124(2)	5.042(2)	0.17(1)%	$1.6(2) \times 10^{-4}$	$9/2^{+}$	0.3959	348.8, 376.7, 395.9	1.48944(52)	$20.3^{+2.0}_{-2.1}$
5.193(2)	5.110(2)	3.87(7)%	$3.7(3) \times 10^{-3}\%$	7/2+	0.3274	280.4, 308.3, 327.5	1.48944(52)	$2.2^{+0.6}_{-0.4}$
5.229(2)	5.145(2)	0.026(7)%	$2.5(7) \times 10^{-5}\%$	(9/2-)	0.2927		1.48944(52)	$550^{+230}_{-130}$
5.290(2)	5.205(2)	0.069(10)%	$6.6(1) \times 10^{-5}\%$	$(7/2^{-})$	0.2317		1.48944(52)	$510^{+100}_{-70}$
5.335(2)	5.249(2)	0.129(14)%	$1.2(2) \times 10^{-4}\%$	$(5/2^{-})$	0.1870		1.48944(52)	$520_{-60}^{+80}$
5.367(2)	5.281(2)	0.129(14)%	$1.2(2) \times 10^{-4}\%$	(3/2-)	0.1545		1.48944(52)	$5840^{+130}_{-100}$
5.388(2)	5.301(2)	0.066(10)%	$6.3(1) \times 10^{-5}\%$	$(13/2^+)$	0.1345		1.48944(52)	$2.2^{+5}_{-3} \times 10^3$
5.398(2)	5.311(2)	0.043(14)%	$4.1(1) \times 10^{-5}\%$	(9/2-	0.1247		1.48944(52)	$3.8^{+2.0}_{-1.0} \times 10^3$
5.433(2)	5.346(2)	3.73(2)%	3.6(3)×10 ⁻³ %	$(11/2^+)$	0.0877		1.48944(52)	75(6)
5.451(2)	5.363(2)	0.11(1)%	$1.1(1) \times 10^{-4}\%$	$(7/2^{-})$	0.0704		1.48944(52)	$1.2^{+0.5}_{-0.4} \times 10^3$
5.474(2)	5.386(2)	25.7(3)%	0.025(2)%	9/2+	0.0471		1.48944(52)	19.1(14)
5.502(2)	5.414(2)	100.0(6)%	0.095(7)%	7/2+	0.0192		1.48944(52)	7.2(5)
5.522(2)	5.433(2)	9.43(15)%	$9.0(7) \times 10^{-3}\%$	5/2+	0.0		1.48944(52)	100(8)

* All values from [2013Ah03], except where noted *** [2014Ch47] **** [1969Mi08]. @ [2023Ne07].

Table 4	
direct $\alpha$ emission from ²⁵³ Es*, $J^{\pi} = 7/2^+$ , $T_{1/2} = 20.03(1) d^{**}$ , $BR_{\alpha} = 100\%$ . (1 of	2)

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pi@}$	E _{daughter} ( ²⁴⁹ Bk) [@]	coincident $\gamma$ -rays (keV)***	HF ^{@@}
5.512(2)*** 5.517(2)***	5.425(2) 5.429(2)	$\begin{array}{c} 1.0(1) \times 10^{-6} \% \\ 8.7(5) \times 10^{-6} \% \end{array}$	9.0(9)×10 ⁻⁷ %*** 7.8(5)×10 ⁻⁶ %***	(15/2 ⁻ ) (7/2 ⁺ )	1.2275 1.2230	41.8, 52.0, 62.1, 73.4, 93.8, 114.0, 135.5, 998.3 30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 73.8, 82.6, 93.8, 95.9, 98.1, 137.7, 291.3, 306.6, 335.2, 346.4, 347.3, 349.6, 387.2, 389.2, 429.0, 794.0, 833.8, 1181.3, 1223.0	69 ⁺⁸ 8.5(6)
5.589(2)***	5.500(2)	6.0(4)×10 ⁻⁶ %	5.4(4)×10 ⁻⁶ %***	(5/2-)	1.1506	30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 73.8, 82.6, 93.8, 95.9, 98.1, 137.7, 291.3, 306.6, 335.2, 346.4, 347.3, 349.6, 387.2, 389.2, 429.0, 1150.7	23.6(25)
5.596(2)*** 5.606(2)*** 5.664(2)*** 5.684(2)***	5.507(2) 5.517(2) 5.575(2) 5.594(2)	$\begin{array}{c} 2.0(2) \times 10^{-6}\% \\ 3.3(2) \times 10^{-6}\% \\ 7.7(5) \times 10^{-6}\% \\ 8.5(6) \times 10^{-6}\% \end{array}$	$\begin{array}{c} 1.8(2) \times 10^{-6} \%^{***} \\ 3.0(2) \times 10^{-6} \%^{***} \\ 6.9(4) \times 10^{-6} \%^{***} \\ 7.6(5) \times 10^{-6} \%^{***} \end{array}$	$ \begin{array}{r} 11/2^+\\ (13/2^-)\\ 9/2^+\\ (11/2^-) \end{array} $	1.1438 1.1339 1.0751 1.0558	41.8, 52.0, 93.8, 1050.0, 1102.0 41.8, 52.0, 93.8, 1040.2 41.8, 52.0, 93.8, 981.3, 1075.1 41.8, 52.0, 62.1, 93.8, 114.0, 899.9, 962.1, 1014 4	$ \begin{array}{r}111^{+14}_{-11}\\76(5)\\74(4)\\88(6)\end{array} $
5.751(2)*** 5.805(2)***	5.661(2) 5.713(2)	$\frac{1.4(8)\times10^{-5}\%}{4.3(2)\times10^{-6}\%}$	$\frac{1.3(1)\times10^{-5}\%^{***}}{3.9(2)\times10^{-6}\%^{***}}$	(9/2 ⁻ )	0.9881 0.9346*	41.8, 52.0, 93.8, 894.5, 946.3 30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 73.8, 82.6, 93.8, 95.9, 98.1, 137.7, 244.0, 261.7, 283.7, 291.3, 306.6, 335.2, 346.4, 347.3, 349.6, 387.2, 389.2, 429.0, 590.1, 633.0, 664.0, 672.8, 852.1	124(10) 830(40)
5.807(2)***	5.716(2)	$7.1(3) \times 10^{-5}\%$	$6.4(3) \times 10^{-5}\%$ ***	(7/2-)	0.9322	41.8, 52.0, 93.8, 164.4, 726.1, 767.9, 838.5, 890.5, 932.2	52.3(25)
5.828(2)***	5.736(2)	$6.9(6) \times 10^{-6}\%$	$6.2(5) \times 10^{-6}\%$ ***	$(13/2^{-})$	0.9112	41.8, 52.0, 62.1, 93.8, 114.0, 755.3, 817.4	710(60)
5.840(2)***	5.747(2)	$\approx 1.2 \times 10^{-5}\%$	≈1.1×10 ⁻⁵ %***	(3/2-)	0.8996	30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 73.8, 82.6, 93.8, 95.9, 98.1, 137.7, 227.0, 244.0, 283.7, 291.3, 306.6, 335.2, 346.4, 347.3, 349.6, 387.2, 389.2, 429.0, 590.1, 633.0, 664.0,672.8, 860.3, 890.5	$\approx 460^{+100}_{-70}$
5.970(2)*** 5.970(2)***	5.810(2) 5.876(2)	$\begin{array}{l} 4.5(4) \times 10^{-6}\% \\ \approx 3.9 \times 10^{-6}\% \end{array}$	$\begin{array}{l} 4.1(3) \times 10^{-6}\%^{***} \\ \approx 3.5 \times 10^{-6}\%^{***} \end{array}$	(11/2 ⁻ ) (9/2 ⁺ )	0.8361 0.7692	41.8, 52.0, 93.8, 742.4, 794.2, 836.1 30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 62.1, 66.9, 73.4, 73.8, 78.6, 82.6, 93.8, 95.9, 98.1, 114.0, 122.0, 135.5, 137.7, 145.4, 162.7, 189.4, 227.1, 258.9, 270.5, 291.3, 294.1, 312.7, 319.2, 335.2, 337.3, 340.2, 346.4, 381.2, 387.2, 392.4, 404.4, 429.0, 433.2, 448.3, 475.0, 500.4	$2.8(2)) \times 10^3$ $\approx 7.6 \times 10^3$
5.972(2)***	5.877(2)	$4.1(2) \times 10^{-5}\%$	3.6(2)×10 ⁻⁵ %***		0.7679	41.8, 726.1, 767.9	750(40)
6.016(2)*** 6.028(2)***	5.921(2) 5.933(2)	$3.8(3) \times 10^{-6}\%$ \$\approx 4.0 \times 10^{-6}\%\$	3.4(3)×10 ⁻⁶ %*** 3.6×10 ⁻⁶ )%***	(9/2 ⁻ )	0.7232 0.7112	30.8, 43.0, 73.8, 82.6, 640.6 30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 62.1, 66.9, 73.8, 82.6, 93.8, 95.9, 98.1, 114.0, 122.0, 137.7, 162.7, 192.0, 236.1, 270.5, 282.2, 291.3, 319.2, 335.2, 337.3, 346.4, 381.2, 387.2, 392.4, 425.4, 429.0, 433.2, 436.8,475.0, 477.4	$1.37(12) \times 10^4$ $\approx 1.5 \times 10^4$
6.030(4)	5.935(4)	$\approx 4.5 \times 10^{-5})\%$	≈4.0×10 ⁻⁵ %	(5/2 ⁻ )	0.7091	30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 66.9, 73.8, 82.6, 87.5, 93.8, 95.9, 98.1, 102.8, 122.0, 137.7, 162.7, 185.3, 402.0, 421.4, 425.4, 436.8, 469.0, 477.4, 524.1, 567.1, 571.0, 626.5, 669.5, 700.3	$\approx 1.4 \times 10^3$
6.036(2)***	5.941(2)	7.3(1)×10 ⁻⁶ %	6.6(1)×10 ⁻⁶ %***		0.7034	30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 62.1, 66.9, 73.8, 82.6, 93.8, 95.9, 98.1, 114.0, 122.0, 137.7, 162.7, 228.4, 270.5, 274.5, 291.3, 306.6, 314.2, 319.2, 337.3, 335.2, 346.4, 347.3, 349.6, 381.2, 387.2, 389.2, 392.4, 429.0, 433.2, 475.0, 661.6, 703.6	9.0(2)×10 ³
6.039(3)	5.944(3)	$1.7(6) \times 10^{-4}\%$	$1.5(5) \times 10^{-4}\%$	(15/2+)	0.7019	41.8, 52.0, 62.1, 73.4, 93.8, 114.0, 135.5, 472.6, 545.9, 608.2	$400^{+0200}_{-100}$
6.067(2)***	5.971(2)	≈1.6(15)×10 ⁻⁵ %	≈1.5×10 ⁻⁵ %***(5/2-)		0.6728	30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 73.8, 82.6, 93.8, 95.9, 98.1, 137.7, 244.0, 283.7, 291.3, 306.6, 335.2, 346.4, 347.3, 349.6, 387.2, 389.2, 429.0, 590.1, 633.0, 664.0, 672.8	${\approx}5.8^{+1.5}_{-1.0}{\times}10^3$
≈6.070	≈5.974	$\approx 6.7 \times 10^{-5}\%$	6.0×10 ⁻⁵ %	(13/2+)	0.6711	30.8, 41.8, 43.0, 52.0, 62.1, 73.4, 73.8, 82.6, 93.8, 114.0, 135.5, 152.2, 425.4, 436.8, 441.8, 477.4, 515.5, 577.6	$\approx 1.5 \times 10^3$

* All values from [1975Ah01], except where noted. ** [1956Jo09]. *** [2005Ah03].  $E_{\alpha}$  and  $I_{\alpha}$  deduced from decay scheme of this reference. [@] Ensdf ^{@@} R₀ (fm) = 1.49492(49).

Table 5	
direct $\alpha$ emission from ²⁵³ Es*, $J^{\pi} = 7/2^+$ , $T_{1/2} = 20.03(1) d^{**}$ , $BR_{\alpha} = 100\%$ . (2)	of 2)

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$ \begin{array}{ccc} {}_{\alpha}(\text{rel}) & I_{\alpha}(\text{abs}) & J_{f}^{\pi@} & E_{daughter} \\ & & (^{249}\text{Bk})^{@} \end{array} $		coincident γ-rays (keV)***	HF ^{@@}	
6.078(2)*** 6.097(2)***	5.982(2) 6.000(2)	$3.3(3) \times 10^{-6}\%$ $5.2(5) \times 10^{-6}\%$	$3.0(3) \times 10^{-6}\%$ *** $4.7(4) \times 10^{-6}\%$ ***	(3/2-) (1/2-)	0.6615 0.6431	30.8, 283.7, 368.8 , 621.9, 652.8 30.8, 603.4, 634.3	$\begin{array}{c} 3.3^{+0.4}_{-0.3}{\times}10^4\\ 2.6(2){\times}10^4\end{array}$
6.116(3)	6.019(3)	$2.0(6) \times 10^{-4}\%$	1.8(5)×10 ⁻⁴ %	(5/2+)	0.6249	30.8, 30.9, 41.8, 43.0, 73.8, 82.6, 203.1, 235.1, 306.6, 347.3, 349.6, 389.2, 421.4, 624.3	$850^{+330}_{-190}$
6.134(3)	6.037(3)	3.2(8)×10 ⁻⁴ %	2.9(7)×10 ⁻⁴ %	(7/2-)	0.6067	30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 66.9, 73.8, 82.6, 87.5, 93.8, 95.9, 98.1, 122.0, 137.7, 162.7 185.3, 402.0, 421.4, 425.4, 436.8, 469.0, 477.4, 524.1, 567.1	$660^{+210}_{-140}$
6.143(3)	6.046(3)	4.5(10)×10 ⁻⁴ %	4.0(9)×10 ⁻⁴ %	(13/2 ⁺ )	0.5978	30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 62.1, 73.4, 73.8, 82.6 93.8, 95.9, 98.1, 114.0, 135.5, 137.7, 168.8, 291.3, 335.2, 346.4, 368.8, 387.2, 429.0, 441.8, 503.9, 555.8	$530^{+160}_{-100}$
≈6.169	≈6.071	$<5.6 \times 10^{-5})\%$	$<5.0 \times 10^{-5}\%$	$(1/2^{-})$	0.5692	30.8, 158.6, 191.6, 368.8, 402.0, 529.7, 560.4	$> 1.2 \times 10^4$
6.182(3)	6.084(3)	2.8(6)×10 ⁻⁴ %	$\overline{2.5(5)} \times 10^{-4}\%$	(3/2-)	0.5582	30.8, 30.9, 41.8, 43.0, 73.8, 82.6, 306.6, 136.8, 168.8, 180.5, 347.3, 349.6, 368.8, 389.2, 421.4, 475.4, 518.6, 549.4	$1.4^{+0.3}_{-0.2} \times 10^3$
6.198(2)	6.100(2)	3.8(2)×10 ⁻³ %	3.4(2)×10 ⁻³ %	(11/2 ⁺ )	0.5421	30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 62.1, 66.9, 73.4, 73.8, 78.6, 82.6, 93.8, 95.9, 98.1, 114.0, 122.0, 135.5, 137.7, 145.4, 162.7, 189.4, 258.9, 312.7, 404.4, 448.3, 500.4	120(7)
6.220(2)	6.122(2)	8.7(9)×10 ⁻⁴ %	7.8(8)×10 ⁻⁴ %	(9/2+)	0.5192	30.8, 41.8, 43.0, 52.0, 73.8, 82.6, 93.8, 425.4, 436.8, 477.4	$680^{+80}_{-70}$
6.265(2)	6.166(2)	0.017(1)%	0.015(2)%	(9/2+)	0.4750	30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 62.1, 66.9, 73.8, 82.6, 93.8, 95.9, 98.1, 114.0, 122.0, 137.7, 162.7, 270.5, 319.2, 337.3, 381.2, 392.4, 433.2, 475.0	59 ⁺⁹ ₋₇
6.266(2)	6.167(2)	$\approx 1 \times 10^{-5}\%$	$\approx 9 \times 10^{-6}\%$	(17/2 ⁻ )	0.4736	30.8, 30.9, 41.8, 43.0, 55.1, 66.9, 73.8, 78.6, 82.6, 90.0, 93.8, 95.9, 98.1, 100.5, 122.0, 137.7, 145.4, 162.7, 168.6, 189.4, 190.5	$1.0^{+0.3}_{-0.2} \times 10^5$
6.311(2)	6.211(2)	0.043(2)%	0.039(2)%	(7/2 ⁺ )	0.4289	30.8, 30.9, 41.8, 43.0, 52.0, 55.1, 73.8, 82.6, 93.8, 95.9, 98.1, 137.7, 291.3, 335.2, 346.4, 387.2, 429.0	39(2)
6.317(3)	6.217(3)	$\approx 1.7 \times 10^{-3})\%$	$\approx 1.5 \times 10^{-3}\%$	$(5/2^+)$	0.4214	421.4	$\approx 1.1 \times 10^3$
6.330(3)	6.230(3)	1.3(5)×10 ⁻⁴ %	$1.2(4) \times 10^{-4}\%$	$(3/2^+)$	0.4107	402.0	$1.6^{+0.8}_{-0.4} \times 10^4$
6.350(2)	6.250(2)	0.050(2)%	0.045(2)%	(5/2+)	0.3892	30.8, 30.9, 41.8, 43.0, 73.8, 82.6, 306.6, 347.3, 349.6, 389.2	52.6(24)
6.371(2)***	6.270(2)	$4.0(2) \times 10^{-4}\%$	$3.6(2) \times 10^{-4}\%$ ***		0.3688***	368.8	$6.2(5) \times 10^3$
6.367(2)	6.266(2)	8.9(9)×10 ⁻⁴ %	8.0(8)×10 ⁻⁴ %	(15/2 ⁻ )	0.3732	30.8, 30.9, 41.8, 43.0, 55.1, 66.9, 73.8, 78.6, 82.6, 90.0, 93.8, 95.9, 98.1, 122.0, 137.7, 145.4, 162.7, 168.6, 189.4	$3.5^{+0.4}_{-0.3} \times 10^3$
6.427(3)	6.325(3)	4.5(11)×10 ⁻⁴ %	4.0(10)×10 ⁻⁴ %	(17/2+)	0.3119	41.8, 52.0, 62.1, 73.4, 82.6, 93.8, 114.0, 135.5, 156.1	$1.4^{+0.5}_{-0.3} \times 10^4$
6.456(2)	6.354(2)	9.1(5)×10 ⁻³ %	8.2(4)×10 ⁻³ %		0.2831	30.8, 30.9, 41.8, 43.0, 55.1, 66.9, 73.8, 78.6, 82.6, 93.8, 95.9, 98.1, 122.0, 137.7, 145.4, 162.7, 189.4	940(50)
6.511(2)	6.408(2)	0.014(1)%	0.013(1)%	$(15/2^+)$	0.2292	41.8, 52.0, 62.1, 73.4, 93.8, 114.0, 135.5	$1.07(8) \times 10^3$
6.535(2)	6.432(2)	0.068(3)%	0.061(3)%	(11/2 ⁻ )	0.2045	30.8, 30.9, 41.8, 43.0, 55.1, 66.9, 73.8, 82.6, 95.9, 98.1, 122.0, 137.7, 162.7	297(15)
6.584(2)	6.480(2)	0.095(3)%	0.085(3)%	$13/2^+$	0.1559	41.8, 52.0, 62.1, 93.8, 114.0	359(14)
6.602(2)	6.498(2)	0.29(1)%	0.26(1)%	9/2-	0.1377	30.8, 30.9, 41.8, 43.0, 55.1, 73.8, 82.6, 95.9, 98.1, 137.7	143(6)
6.645(2)	6.540(2)	0.95(2)%	0.85(2)%	$11/2^+$	0.0938	41.8, 52.0, 93.8	69(2)
6.657(2)	6.552(2)	0.79(2)%	0.71(2)%	7/2-	0.0825	30.8, 43.0, 73.8, 82.6	93(3)
6.698(2)	6.592(2)	7.3(1)%	6.6(1)%	9/2+	0.0418@	41.8	15.4(3)
6.700	6.594	0.8%	0.7%	5/2-	0.0396	30.8	150
0.730	0.024	0.9%	U.8% 80.8(2)%	312 7/2+	0.0088~		180 1.74(4)
0.740(2)	0.035(2)	10070	07.0(2)70	112	0.0		1./4(4)

* All values from [1975Ah01], except where noted. ** [1956Jo09]. *** [2005Ah03].  $E_{\alpha}$  and  $I_{\alpha}$  deduced from decay scheme of this reference. [@] [2024Ne04]. [@] @</sup> R₀ (fm) = 1.49492(49).

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	$E_{daughter}(^{253}\mathrm{Es})$	coincident $\gamma$ -rays (keV)	$R_0$ (fm)	HF
7.125(6)	7.014(6)	$\approx 3.5\%$	$\approx 3.4\%$	9/2-	0.435	388.5	1.488(14)	$\approx 22$
7.186(1)	7.074(1)	100%	96.5%	7/2-	0.3714	325.1, 371.4	1.488(14)	$1.4^{+0.6}_{-0.5}$
7.375(2)	7.260(2)	0.021(5)%	0.020(5)%	$7/2^{-}$	0.1813	181.3	1.488(14)	$3.8^{+2.1}_{-21.5} \times 10^4$
7.418(2)	7.303(2)	0.026(5)%	0.025(5)%	5/2-	0.139		1.488(14)	$4.5^{+2.5}_{-1.7} \times 10^{4}$
7.452(3)	7.336(3)	0.014(1)%	0.014(1)%	3/2-	0.106		1.488(14)	$1.1^{+0.5}_{-0.4} \times 10^5$
7.477(7)	7.361(7)	0.010(10)%	0.010(10)%	$11/2^{+}$	0.080		1.488(14)	$1.9(19) \times 10^5$
7.418(6)	7.303(6)	0.036(2)%	0.035(2)%	9/2+	0.0463		1.488(14)	$7.4^{+3.5}_{-2.5} \times 10^4$
7.558(2)	7.440(2)	0.038(6)%	0.037(6)%	$7/2^{+}$	0.0		1.488(14)	$1.1^{+0.6}_{-0.4} \times 10^5$

**Table 6** direct  $\alpha$  emission from ²⁵⁷Md*,  $J^{\pi} = (7/2^{-})$ ,  $T_{1/2} = 5.523(50)$  h*,  $BR_{\alpha} = 15.2(26)\%$ .

* All values from [1993Mo18].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +28 nuclei.

Last updated 4/23/25

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z$  = +28 nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	Q _β -	Q _β - α	Experimental
220 ph	$0^+$	obs		3 170(50)#	7.02(50)#	[2010.4.124]
²²⁴ Po	$0^+$	obs	-7 16(45)#	2 20(20)#	6 71(36)#	[2010A]24]
²²⁸ Rn	$0^{+}$	62(3) 8	-6 64(40)#	1.859(19)	5.287(28)	[1989Bo11]
²³² Ra	$\overset{\circ}{0^+}$	250(50) s	-5.576(17)	1.343(16)	4.868(11)	[1986Gi08]
²³⁶ Th	0+	37.5(25) m	-4.970(40)	0.921(0)	4.856(19)	[1973Or06]
²⁴⁰ U	$0^{+}$	14.1(1) h	-4.30(20)#	0.399(17)	5.137(14)	[1981Hs02]
				$Q_{\varepsilon n}$	$Q_{\epsilon \alpha}$	
²⁴⁴ Pu	$0^+$	$8.12(3) \times 10^7$ y	-3.43(10)#			[2006Ag15]
²⁴⁸ Cm	$0^+$	3.487(20)×10 ⁵ y*	-3.17(20)#			[1971Mc19, 1971Ma32, 1969Me01]
²⁵² Cf	$0^+$	2.6483(10) y	-2.50(20)#			[2022Th06]
²⁵⁶ Fm	$0^+$	157(2) m	-1.70(10)#)			[1968Ho13]
²⁶⁰ No	$0^{+}$	106(8) ms**	-0.94(37)#			[1985So03]
²⁶⁴ Rf			-0.30(57)#			
²⁶⁸ Sg	$0^+$	$13^{+17}_{-4}$ s	-0.26(71)#	-3.93(74)#	8.00(64)#	[2023Og03]
²⁷² Hs	$0^+$	$160^{+190}_{-60}$ ms	0.220(74)#	-2.90(78)#	9.52(74)#	[2023Og03]
²⁷⁶ Ds	$0^{+}$	$150^{+100}_{-40} \ \mu s$	1.23(76)#	-1.24(81)#	11.33(76)#	[2023Og03]
²⁸⁰ Cn		-+0 ·	1.77(79)#	-0.66(84)#	11.92(79)#	
²⁸⁴ Fl	$0^+$	$2.5^{+1.8}_{-0.8}$ ms	2.19(85)#	0.15(90)#	12.47(85)#	[2015Ut02]

* Deduced from weighted average of  $t_{1/2}(\alpha) = 3.703(32) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^6$  y [1971M

4.20(5)×10⁶ y [1971Ma32] and  $t_{1/2}(\alpha) = 3.84(4)×10^5$  y and  $t_{1/2}(SF = 4.22(12)×10^6$  y [1969Me01]. ** Tenatively assigned as ²⁶⁰No by [1985So03], who remarked "a 100-ms half-life for ²⁶⁰No would be surprisingly long, based on an extrapolation of the known nobelium half-lives in Fig. 8 and a known half-life of only 1 ms for ²⁵⁸No. Thus, an assignment to No is supported by our cross bombardments but would be surprising in view of the nobelium half-life systematics.

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +28$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	Experimental
²²⁰ Pb		0.79(57)#			
²²⁴ Po	9.62(45)#	3.36(45)#			
²²⁸ Rn	9.48(30)#	2.901(20)#			
$^{232}Ra$	8 873(12)	2.829(20)			
²³⁶ Th	8 391(20)	333(17)			
24011	7.91(20)#	4 035(14)			
²⁴⁴ Pu	7.289(32)#	4.666(1)	99.876(6)%	0.124(6)%	[ <b>1983Mo02, 1969Be06</b> , 2006Ag15, 1998Se17, 1997SeZW, 1994Ve03, 1989Wa29, 1983Th02, 1982Al13, 1971Or03,1968HaZX, 1966Fi07, 1056Bu02, 1954St081
²⁴⁸ Cm	7.05(10)#	5,1618(3)	91.58(51)%*	8 42(7)%*	[1977Ba69, 1971Mc19, 1971Ma32, 1969Me01, 2010TeZZ
em	,100(10)	011010(0)	1100(01)/0	0112(7)/0	2008Ve05, 2005VoZX, 1997Fo11, 1993Be52, 1991Ba66.
					1973Go20, 1973Go46, 1973St04, 1973StZO, 1972Pr19,
					1971Or03, 1967Sc32, 1964Hv02, 1963Br35, 1962Br45]
²⁵² Cf	6.482(11)	6.217	96.8972(27)%	3.1028(27)%	[2018Be29, 1986Ry04, 1970Ba18, 2025De08, 2024Cz03, 2024Ma21, 2023WaZX, 2023Gj01, 2023Py01, 2022Th06, 2020Al22, 2018Be29, 2018Ch44, 2017Bl07, 2017Py01, 2016Wa03, 2014Go28, 2014Ha25, 2013Vo03, 2012VoZW, 2011KaZY, 2011Ze04, 2010TeZZ, 2010Ve03, 2010ZeZZ, 2008Mu24, 2006Da21, 2006Fo10, 2005Je04, 2004Da13, 2003Ko78, 2002Ha24, 2001Ra20, 2000Hw01, 2000MuZY, 1999Hw04, 1999Ko01, 1999Po36, 1997DaZS, 1997Fo11, 1997Go36, 1997Sa72, 1996InZY, 1994Va24, 1993DlZZ, 1993Pa29, 1989Gl05, 1988Af01, 1988Bu24, 1988Me12, 1987Sc13, 1986Bo11, 1985Az02, 1984Di11, 1984GrZK, 1984SmZV, 1983BlZT, 1983BoZS, 1983Li17, 1983Sc07, 1982Al33, 1982La25, 1981Cu05,1979Ba53, 1979Za04, 1978Ye02, 1977Ma40, 1977Wa01, 1973Fl04, 1975Pr07, 1974Ga23, 1974Sh15, 1974Sp02, 1973Ad03, 1973Fl01, 1973Me01, 1973Mi05, 1973PlZV, 1973Za10, 1972Ch31, 1970Gr40, 1972Ra19, 1971Ha29, 1960Al23, 1966BeT01, 1967Wh05, 1965Me02, 1964Fr10, 1958As64, 1964Ho32, 1963Le17, 1961Wa22, 1960Ne20, 1957Ea01, 1957Sm81, 1956Sm98, 1955As42, 1955Gl42, 1955Gl42, 1955Hi67, 1954Ma98]
²⁵⁶ Fm	5.893(11)	7.025(2)	8.1(3)%	91.7(3)%	[2019Ah04, 1970Fi12, 1968Ho13, 2019De11, 1991So16, 1990SoZY, 1989So15, 1987Po22, 1985Wi10, 1974UnZU, 1974UnZV, 1974UnZX, 1972Da11, 1972Fl04, 1972FlZS, 1965Si14, 1958Ph40, 1955Ch301
²⁶⁰ No	5 24(22)#	7 70(20)#		obs**	[1985So03]
²⁶⁴ Rf	4.88(42)#	8.04(30)#			()
268 Sg	4.50(60)#	8.30(30)#		100%	[2023Og03]
²⁷² Hs	4.14(64)#	9.78(20)#	100%	10070	[2023Og03]
276Ds	3 52(67)#	11 11(20)#	43+15%	57 ⁺¹⁵ %	[2023Og03]
280 Cn	$3.32(07)^{\#}$	10.60(20)#	-18 /0	57-18 10	[TATE OF OD]
284 E1	3.30(72)#	10.09(20)#		100%	[2015]]+02]
- FI	3.07(79)#	10.70(30)#		100%	[20130102]

* Deduced from weighted average of  $t_{1/2}(\alpha) = 3.703(32) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.20(5) \times 10^6$  y [1971Ma32] and  $t_{1/2}(\alpha) = 3.84(4) \times 10^5$  y and  $t_{1/2}(SF = 4.22(12) \times 10^6$  y [1969Me01].

** Tenatively assigned as  260 No by [1985S003], who remarked "a  $\approx$  100-ms half-life for  260 No would be surprisingly long, based on an extrapolation of the known nobelium half-lives in Fig. 8 and a known half-life of only 1 ms for  258 No. Thus, an assignment to No is supported by our cross bombardments but would be surprising in view of the nobelium half-life systematics."

Table 3	
direct $\alpha$ emission from ²⁴⁴ Pu*, $J^{\pi} = 0^+$ , $T_{1/2} = 8.12(3) \times 10^7$ y**, $BR_{\alpha} = 99.876(6)\%$ **.	

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{240}\mathrm{U})$	coincident γ-rays (keV)	R ₀ (fm)	HF
4.622(1) 4.665(1)	4.546(1) 4.589(1)	24.1(10)% 100%	19.4(8)% 80.6(8)%	$2^+_{0^+}$	0.043(1) 0.0	43	1.50549(82) 1.50549(82)	1.95(8) 0.989(11)

* All values from [1969Be06], except where noted.  $E_{\alpha}$  values are adjusted by +2.0 keV as recommended by [1991Ry01].

** Deduced from partial half-life of SF =  $6.56(30) \times 10^{10}$  y [1983Mo02].

## Table 4 direct $\alpha$ emission from ²⁴⁸Cm^{*}, $J^{\pi} = 0^+$ , $T_{1/2} = 3.487(20) \times 10^5$ y^{**}, $BR_{\alpha} = 91.58(51)\%^{**}$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	$E_{daughter}(^{244}\mathrm{Pu})$	coincident γ-rays (keV)	R ₀ (fm)	HF
4.8541(15) 5.01181(50) 5.11743(25) 5.16166(25)	4.7758(15) 4.93097(50) 5.03489(25) 5.07841(25)	≤0.01% 0.093(15)% 22.02(26)% 100.00	≤0.009% 0.070(1)% 16.51(20)% 74.99(56)%	$6^+ \\ 4^+ \\ 2^+$	0.3130*** 0.1499 0.0442 0.00	163.1***	1.49627(74) 1.49627(74) 1.49627(74) 1.49627(74)	>58 107 ⁺²¹ 2.326(31) 1.000(10)

* All values from [1977Ba69], except where noted.  $E_{\alpha}$  values are adjusted by -0.17 keV as recommended by [1991Ry01].

* Deduced from weighted average of  $t_{1/2}(\alpha) = 3.703(32) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y and  $t_{1/2}(SF = 4.115(34) \times 10^6$  y [1971Mc19],  $t_{1/2}(\alpha) = 3.94(4) \times 10^5$  y [1971Mc19], t_{1/2}(\alpha) = 3.94(4) \times 10^5 y [1971Mc  $4.20(5) \times 10^6$  y [1971Ma32] and  $t_{1/2}(\alpha) = 3.84(4) \times 10^5$  y and  $t_{1/2}(SF = 4.22(12) \times 10^6$  y [1969Me01].

*** [2017Ne10]

[@] The much lower than expected HF makes this branch reported by [1977Ba69] questionable.

#### Table 5

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direct \alpha emission from <sup>252</sup>Cf, J^{\pi} = 0^+, T_{1/2} = 2.6483(10) y*, BR_{\alpha} = 96.8972(27)\%**.
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$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_{f}^{\pi@@}$	$E_{daughter}(^{248}\mathrm{Cm})^{@@}$	coincident $\gamma$ -rays (keV) ^{@@}	R ₀ (fm)	HF
5.707 5.9202 6.0729 6.17362(11) 6.21678(4)	5.616*** 5.8262*** 5.9765*** 6.07563(11) 6.11810(4)	$\approx 7 \times 10^{-5}\%$ $2 \times 10^{-3}\%$ 0.24% 18.4(6)% 100.0(4)%	$\approx 6 \times 10^{-5} \%$ $2 \times 10^{-3} \%$ 0.2 % $15.0(5) \%^{@@@}$ $81.7(4) \%^{@@@}$	$8^+ 6^+ 4^+ 2^+ 0^+$	0.5064 0.2989 0.1438 0.0434 0.0	207.4 155.1 100.4 43.4	1.50113(23) 1.50113(23) 1.50113(23) 1.50113(23) 1.50113(23)	$\approx 2.8 \times 10^{3}$ $1.3 \times 10^{3}$ 78 3.28(11) 0.997(4)

* Value from evaluated data [2022Th06].

** [2018Be29].

*** [1970Ba18].  $E_{\alpha}$  values adjusted by +1.5 keV due to calibration changes.

[@] [1986Ry04].  $E_{\alpha}$  values adjusted by -0.14 keV as recommended in [1991Ry01].

^{@@} [2014Ma86].

#### Table 6

direct  $\alpha$  emission from ²⁵⁶Fm*,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 157(2)$  m*,  $BR_{\alpha} = 8.1(3)\%$ *.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$J_f^{\pi***}$	$E_{daughter}(^{244}\mathrm{Pu})$	coincident $\gamma$ -rays (keV)	R ₀ (fm)	HF
6.983 7.0248(20)	6.874** 6.915(20)***	16.3(24)% [@] 100% [@]	1.1(2)% 7.0(3)%	$2^+_{0^+}$	0.0457 ^{@@} 0.0	45.7 ^{@@}	$3.8^{+0.7}_{-0.5}$ $1.4989(35)$	0.97(5)

* [1968Ho13].

** Deduced from the level energy. Original value from [1970Fi12] = 6.868 MeV.

*** [2019Ah04].

[@] [1970Fi12]. ^{@@} [2021Ma19].

## Table 7

Table /			
direct $\alpha$ emission from	272 Hs*, $J^{\pi} = 0^+$ , $T_{1/2}$	$_2 = 160^{+190}_{-60}$ ms,	$BR_{\alpha}=100\%.$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{268}Sg)$	coincident $\gamma$ -rays (keV)	$R_0$ (fm)	HF		
9.772(21)	9.628(21)	100%	$0^+$	0.0		1.484(72)	$2.5^{+3.0}_{-1.0}$		
* All valu	* All values from [2023Og03].								
<b>Table 8</b> direct $\alpha$ emission from ²⁷⁶ Ds*, $J^{\pi} = 0^+$ , $T_{1/2} = 150^{+100}_{-40} \ \mu$ s, $BR_{\alpha} = 43^{+15}_{-18}\%$ .									
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{268}Sg)$	coincident γ-rays (keV)	R ₀ (fm)	HF		
10.904(28)	10.746(28)	$43^{+15}_{-18}\%$	$0^+$	0.0					

* All values from [2023Og03].

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Observed and predicted  $\beta$ -delayed particle emission from the odd-*Z*,  $T_z = +28$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values are taken from ENSDE.

Nuclide	$J^{\pi}$	Ex.	$T_{1/2}$	$Q_{\mathcal{E}}$	Q _β -	Q _β - α	Experimental
²²² Bi			obs		6.46(30)#	11.08(42)#	[2010Al24]
²²⁶ At			obs	-2.89(50)#	5.91(30)#	9.93(30)#	[2010Al24]
²³⁰ Fr*			19.1(5) s	-2.68(20)#	4.970(12)	8.495(12)	[1987Ku04]
²³⁴ Ac*			44(7) s	-2.089(16)	4.228(14)	8.080(17)	[1986Gi08]
²³⁸ Pa*		(3 ⁻ )	2.3(1) m	-1.63(28)#	3.586(16)	8.036(16)	[1968Tr07]
²⁴² Np*		$(1^{+})$	2.2(2) m	-1.20(28)#	2.70(20)	7.87(20)	[1979Ha26]
²⁴⁶ Am*		(7-)	39(3) m	-0.401(14)#	2.377(18)#	8.032(18)	[1968Fi03]
²⁵⁰ Bk*		$2^{-}$	192.7(3) m	-0.038(11)	1.782(3)	8.090(3)	[1979Re01]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	
²⁵⁴ Es		(7+)	275.7(5) d	0.653(12)	-6.22(36)#	6.580(11)	[1975Ah04]
^{254m} Es	0.082(5)	$2^{+}$	39.3(2) h	0.735(13)	-6.23(36)#	6.662(12)	[1962Un01]
²⁵⁸ Md		8-	51.50(29) d	1.26(20)#	-5.00(41)#	7.924(12)#	[1993Mo18]
²⁶² Lr			$\approx 4 h$	2.00(41)#	-3.76(55)#	9.25(28)#	[1989HuZU]
²⁶⁶ Db			$11^{+21}_{-4}$ m	2.60(50)#	-2.78(62)#	10.22(46)#	[2022Og08]
²⁷⁰ Bh			$2.4^{+4.4}_{-0.9}$ m	2.80(55)#	-2.21(69)#	11.67(55)#	[2022Og08]
²⁷⁴ Mt			$0.64^{+0.76}_{-0.23}$ s	3.84(60)#	-0.72(76)#	13.39(59)#	[2022Og08]
²⁷⁸ Rg			$4.6^{+5.5}_{-1.6}$ ms	4.27(64)#	0.22(77)#	14.69(64)#	[2022Og08]
²⁸² Nh			$61^{+73}_{-22}$ ms	4.90(68)#	1.11(87)#	15.05(68)#	[2022Og08]
²⁸⁶ Mc			$20^{+98}_{-9}$ ms	5.41(68)#**	1.96(88)#**	20.61(68)#**	[2022Og08]

* 100%  $\beta^-$ -emitter.

** Deduced from measured  $E_{\alpha}$  and mass excesses of daughter nuclei [2021Wa16].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +28$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	Experimental
222 p:		2 825(50)#			
226 •	7.01(40)#	2.823(30)#			
220 At	7.21(42)#	3.29(42)#			
250 Fr	7.165(15)	2.40(30)#			
²⁵⁴ Ac	6.782(16)	2.930(15)			
²³⁸ Pa	6.350(22)	3.628(21)			
²⁴² Np	6.07(28)#	4.10(20)			
²⁴⁶ Am	5.473(22)#	5.15(20)#			
²⁵⁰ Bk	5.088(4)	5.533(18)			
²⁵⁴ Es	4.596(5)	6.617(1)	100%*		[2008Ah02, 1999Po35, 1988Po05, 1987Po22, 1985Ok04, 1975Ah04,
					1972Bb24, 1971Bb10, 1966Mc02, 1965Me02, 1964Mc13, 1958Sc35,
					1956Jo09, 1955Ha35]
^{254m} Es	4.678(7)	6.699(5)	0.33(1)%		[1973Ah04, 1972AhZS, 1972HaWO, 1972HaWR, 1967Fi03, 1964Mc13,
					1956Jo09, 1954Ch23, 1954Fi14]
²⁵⁸ Md	4.189(6)	7.271(2)	100%		[ <b>1993Mo18</b> , 1970Fi12, 1968Hu06]
²⁶² Lr	3.64(28)#	7.99(20)#		obs	[1989HuZU, 1987LoZR, 1990HuZV, 1991HeZT]
²⁶⁶ Dh	3.24(46)#	8.21(20)#		obs	[ <b>20220908, 20130901, 20070902</b> , 2023Ko22, 201209ZZ, 20110907.
20	0.2.1(10).1	0121(20)		000	2007Og05, 2007Og01]
²⁷⁰ Bh	2,75(47)#	9.064(95)#	100%**		[ <b>2022Og08, 2013Og01, 2007Og02</b> , 2023Ko22, 2012Og77, 2011Og07.
		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			2007Og05, 2007Og01]
²⁷⁴ Mt	1.801(53)#	10.60(23)#	100%**		[20220908, 20130901, 20070902, 2023Ko22, 2012097Z, 20110907.
					2007Og05, 2007Og01]
278Rg	1.86(55)#	10.85(95)#	100%**		[2022Qg08, 2013Qg01, 2007Qg02, 2023Ko22, 2012Qg77, 2011Qg07,
8					2007Og05, 2007Og01]
²⁸² Nh	1.51(56)#	10.783(95)#	100%**		[2022Og08, 2013Og01, 2007Og02, 2023Ko22, 2012OgZZ, 2011Og07,
					2007Og05, 2007Og01]
²⁸⁶ Mc	1.20(57)#***	10.86(2)	100%**		[ <b>2022Og08</b> , 2023Ko22]

* [1985Ok04] report a  $\beta^-$  branch of 1.74(8)×10⁻⁴%.

** Only  $\alpha$ -decay has been observed.

*** Deduced from measured  $E_{\alpha}$  and mass excesses of daughter nuclei [2021Wa16].

Table 3			
direct $\alpha$ emission from	$^{254}\text{Es}^*, J^{\pi} = (7^+), 7$	$\Gamma_{1/2} = 275.7(5)  \mathrm{d*},$	$BR_{\alpha} = 100\%^{***}$

$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{250}\mathrm{Bk})$	coincident $\gamma$ -rays (keV)	HF [@]
5.879(3)	5.786(3)	6.1(3)×10 ⁻⁴ %	5.6(3)×10 ⁻⁴ %		0.739		238(25)
5.888(3)	5,795(3)	$4.0(2) \times 10^{-4}\%$	$3.7(2) \times 10^{-4}\%$		0.730		400(40)
5.902(3)	5.809(3)	$1.2(5) \times 10^{-3}\%$	$1.1(5) \times 10^{-3}\%$		0.716		$160^{+140}_{-50}$
5.928(3)	5.835(3)	$3.3(9) \times 10^{-3}\%$	$3.0(8) \times 10^{-3}\%$		0.689		$84^{+32}_{10}$
5.964(3)	5.870(3)	2.6(8)×10 ⁻³ %	2.4(7)×10 ⁻³ %		0.654		$\frac{-15}{160+70}$
5.979(3)	5.885(3)	$1.0(4) \times 10^{-3}\%$	$9.3(4) \times 10^{-4}\%$	$(9^{+})$	0.637		520(50)
6.018(3)	5.923(3)	$1.7(7) \times 10^{-3}\%$	$1.6(6) \times 10^{-3}\%$		0.600		$470^{+290}_{-140}$
6.032(3)	5.937(3)	8.2(4)×10 ⁻⁴ %	$7.5(4) \times 10^{-4}\%$		0.586		$1.20(12) \times 10^3$
6.072(3)	5.976(3)	0.105(5)%	0.096(5)%	8+	0.5450	310.2, 390.3, 460.8	15.4(16)
6.096(3)	6.000(3)	$5.3(1) \times 10^{-3}\%$	$4.9(10) \times 10^{-3}\%$	(9-)	0.520		$410^{+110}_{-80}$
6.142(2)	6.045(2)	$2.2(2) \times 10^{-3}\%$	$2.1(2) \times 10^{-3}\%$	$8^+$	0.4748	320.6, 390.3	$1.63(21) \times 10^3$
6.151(2)	6.054(2)	0.22(6)%	0.20(5)%	$7^{+}$	0.4648	310.2, 380.4	$19^{+7}_{-4}$
6.174(3)	6.077(3)	4.9(11)×10 ⁻³ %	4.5(10)×10 ⁻³ %	9-	0.442		$1.1^{+0.3}_{-0.2} \times 10^3$
6.185(2)	6.088(2)	0.083(2)%	0.076(2)%	$(8^{-})$	0.431	346.6	76(7)
6.211(2)	6.113(2)	0.59(11)%	0.54(10)%	$6^+$	0.4050	320.6	$14^{+4}_{-3}$
6.246(2)	6.148(2)	2.2(3)×10 ⁻³ %	2.0(3)×10 ⁻³ %	$6^{+}$	0.3696	285.2	$5.9^{+1.2}_{-0.9} \times 10^3$
6.263(2)	6.164(2)	0.033(2)%	0.030(2)%	$6^{+}$	0.3539	269.5	470(50)
6.277(2)	6.178(2)	0.038(2)%	0.035(2)%	8-	0.339		480(50)
6.289(2)	6.190(2)	0.015(8)%	0.0142(7)%	$10^{+}$	0.3273		$1.35(14) \times 10^3$
6.300(2)	6.201(2)	$5.9(5) \times 10^{-3}\%$	$5.4(5) \times 10^{-3}\%$	$5^{+}$	0.3165	35.6, 42.6, 238.2, 280.9	$4.0(5) \times 10^3$
6.353(3)	6.253(3)	0.0113(6)%	0.0104(5)%	$8^{+}$	0.263		$3.8(4) \times 10^3$
6.368(2)	6.268(2)	0.26(6)%	0.243(5)%	7-	0.248		194(17)
6.380(2)	6.280(2)	0.18(6)%	0.168(5)%	$9^{+}$	0.2355		$322^{+31}_{-29}$
6.413(3)	6.312(3)	$1.5(2) \times 10^{-3}\%$	$1.4(2) \times 10^{-3}\%$	$4^{-}$	0.203		$5.6^{+1.1}_{-0.9} \times 10^4$
6.424(2)	6.323(2)	0.050(1)%	0.046(1)%	7+	0.192		$1.9(2) \times 10^3$
6.450(2)	6.348(2)	0.98(1)%	0.90(1)%	6-	0.167		129(11)
6.462(2)	6.360(2)	3.31(1)%	3.04(1)%	$8^{+}$	0.1547		44(4)
6.487(3)	6.385(3)	0.163(7)%	0.150(5)%	$6^{+}$	0.129		$1.17(11) \times 10^3$
6.502(3)	6.400(3)	0.049(2)%	0.045(2)%	3+	0.114		$4.6(5) \times 10^3$
6.520(3)	6.417(3)	2.50(2)%	2.29(2)%	$5^{-}$	0.0975	35.6, 61.9	108(9)
6.532(2)	6.429(2)	100%	91.8(2)%	$7^{+}$	0.0844		3.1(3)
6.581(2)	6.477(2)	0.34(1)%	0.31(1)%	4+	0.0356	35.6	$1.55(14) \times 10^3$
6.616(3)	6.512(3)	$2.6(3) \times 10^{-3} \sqrt{\%}$	$2.4(3) \times 10^{-3} \sqrt{\%}$	2-	0.0		$2.9^{+0.5}_{-0.4} \times 10^5$

* All values from [2008Ah02], except where noted.

** [1975Ah04].

*** There is also a  $\beta^-$  branch of 1.74(8)×10⁻⁴% [1985Ok04].

[@]  $R_0 = 1.5000(35)$  fm. Value is interpolated between 1.50113(23) (²⁵²Cf) and 1.4989(35) (²⁵⁶Fm).

# Table 4

direct  $\alpha$  emission from ^{254m}Es*, Ex. = 82(5) keV,  $J^{\pi} = 2^+$ ,  $T_{1/2} = 39.3(2)$  h*,  $BR_{\alpha} = 0.33(1)\%$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{250}\mathrm{Bk})$	coincident $\gamma$ -rays (keV)	HF [@]
6.383(3)	6.282(3)	0.21(4)%	$5.3(10) \times 10^{-4}\%$	5+	0.316	34.5, 42.7, 238.1***, 280.9***	$620^{+100}_{-110}$
6.400(2)	6.299(2)	0.64(8)%	$1.6(2) \times 10^{-3}\%$		0.298		$250^{+50}_{-40}$
6.428(2)	6.327(2)	2.9(3)%	$7.3(7) \times 10^{-3}\%$	$4^{+}$	0.270	34.5, 58.6***, 42.7, 52.2***, 79.9, 96.3,	75(10)
						177.3, 211.8, 236.0***	
6.461(2)	6.359(2)	11.1(7)%	0.027(2)%	$3^{+}$	0.2367***	34.5, 79.9***, 121.3***, 202.3***	$28.7^{3.3}_{-3.1}$
6.486(2)	6.384(2)	100(2)%	0.248(8)%	$2^{+}$	0.2118	34.5, 42.7, 52.2***, 79.9, 96.3, 177.3, 211.8	4.2(4)
6.520(2)	6.417(2)	2.4(3)%	$5.9(7) \times 10^{-3}\%$	$(1^{+})$	0.1753	50.1, 71.3, 90.7, 104.0, 126.0, 175.1***	260(40)
6.560(3)	6.457(3)	0.16(5)%	4.0(13)×10-4%	(5 ⁻ )***	0.1373***	34.5, 45,8***, 57.1***, 80.3***, 102.8***	$5.8^{+3.0}_{-1.6} \times 10^3$
6.568(2)	6.465(2)	0.83(9)%	$2.0(2) \times 10^{-3}\%$	$6^{+}$	0.1319	34.5, 42.7, 52.2***, 96.3	$1.2(2) \times 10^3$
6.575(4)	6.471(4)	$\approx 0.11\%$	$\approx 2.6 \times 10^{-4} \%$		0.1253	34.5, 90.7	$\approx 10^4$
6.619(2)	6.515(2)	1.9(2)%	$4.6(5) \times 10^3\%$		0.079	34.5,42.7	$930^{+140}_{-120}$
6.664(2)	6.559(2)	7.7(5)%	0.019(1)%	3-	0.0345	34.5	360(40)
6.698(4)	6.593(4)	5.3(7)%	0.013(2)%	$2^{-}$	0.0		$740^{+140}_{-110}$

* All values from [1973Ah04], except where noted.  $E_{\alpha}$  values are adjusted by +1.9 keV as recommended in [1991Ry01].

** [1962Un01].

*** [2019Si11].

[@]  $R_0 = 1.5000(35)$  fm. Value is interpolated between 1.50113(23) (²⁵²Cf) and 1.4989(35) (²⁵⁶Fm).

# Table 5 direct $\alpha$ emission from ²⁵⁸Md*, $J^{\pi} = (7^+)$ , $T_{1/2} = 275.7(5)$ d*, $BR_{\alpha} = 100\%$ ***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{254}\mathrm{Es})$	coincident $\gamma$ -rays (keV)	HF**
6.802(2) 6.824(2)	6.697(2) 6.718(2)	5.2(21)% 100(19)%	3.4(14)% 65.8(13)%	9- 8-	0.4692 0.4479	80.1, 91.0, 171.1, 298.1, 389.1 71.1, 80.1, 86.9, 91.0, 171.1, 205.7,	$180^{+130}_{-60} \\ 11.7^{+2.0}_{-1.7}$
6.870(4) 6.895(2)	6.763(4) 6.788(2)	31.6(18)% 15.1(15)%	20.8(12)% 9.9(10)%	(7 ⁻ ,8 ⁻ ) 8 ⁻	0.4038 0.3768	189.7, 214.7 80.1, 86.9, 91.0, 171.1, 205.7, 296.7,	$58^{+10}_{-9}$ $161^{+33}_{-22}$
	,					376.8	-28
7.100(2)	6.99(2) 7.08(2)	$\leq 0.3\%$	$\leq 0.2\%$	$9^+$	0.1711	80.1, 91.0, 171.1	$\geq 6.1 \times 10^4$
7.191(2)	7.08(2)	$\leq 0.3\%$ $\leq 0.3\%$	$\leq 0.2\%$ $\leq 0.2\%$	8 7+	0.0801	80.1 	$\geq 1.5 \times 10^{-5}$ $\geq 3.1 \times 10^{5}$

* All values from [1993Mo18], **  $R_0 = 1.4921(62)$  fm. Value is interpolated between 1.4989(35) (²⁵⁶Fm) and 1.4852(51) (²⁶⁰No).

Table 6	able 6 $(270)$ The second state of the second										
direct $\alpha$ emis	sion from $^{2/0}$ Bh, T ₁	$_{1/2} = 2.4^{+4.4}_{-0.9} \text{ m}^*, B$	$R_{\alpha} = 100\%$	***.							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{266}\text{Db})$	coincident γ-rays (keV)	HF***					
9.06(2)	8.93(2)**	100%***									
* [20220 ** [2011 *** Only	Dg08]. Og07]. γ α-decay has been	observed.									
<b>Table 7</b> direct $\alpha$ emis	sion from ²⁷⁴ Mt, T ₁	$_{/2} = 0.64^{+0.76}_{-0.23}$ s*,	$BR_{\alpha} = 100\%$	6***.							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{270}\mathrm{Bh})$	coincident $\gamma$ -rays (keV)	HF**					
10.1(11)	10.0(11)**	100%***									
* [20220 ** [2011 *** Only	Dg08]. Og07]. γ α-decay has been	observed.									
Table 8 direct $\alpha$ emis	sion from ²⁷⁸ Rg, T ₁	$_{/2} = 4.6^{+5.5}_{-1.6} \mathrm{ms}^*,$	$BR_{\alpha} = 100\%$	6***.							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{274}\mathrm{Mt})$	coincident $\gamma$ -rays (keV)	HF**					
10.84(8)	10.69(8)**	100%***									
* [20220 ** [2011 *** Only	Dg08]. Og07]. γ α-decay has been	observed.									
Table 9 direct $\alpha$ emis	sion from ²⁸² Nh, T ₁	$_{1/2} = 61^{+73}_{-22} \text{ ms*}, B$	$R_{\alpha} = 100\%$	***.							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{278}\mathrm{Rg})$	coincident $\gamma$ -rays (keV)	HF**					
10.78(8)	10.63(8)**	100%***	4	~							
* [20220	Dg08].										

** [2011Og07]. *** Only α-decay has been observed.

**Table 10** direct  $\alpha$  emission from ²⁸⁶Mc*,  $T_{1/2} = 20^{+98}_{-9}$  ms,  $BR_{\alpha} = 100\%^{**}$ .

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{282}\mathrm{Nh})$	coincident $\gamma$ -rays (keV)	HF**	
10.86(2)	10.71(2)	100%**					

* All values from [2022Og08].

** Only  $\alpha$ -decay has been observed.

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 $\begin{array}{c} 293 Og\\ Qvp = 3.48~MeV\\ QvQ = 15.78~MeV\\ Q\alpha = 10.928~MeV \end{array}$ 





Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +57/2 nuclei.

Last updated 5/2/25

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +57/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.  $J^{\pi}$  values are taken from ENSDE.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{arepsilon}$	Q _β -	$Q_{\beta}$ - $\alpha$	Experimental	
²²⁹ Rn*		$12.0^{+1.2}$ s	-5 53(40)#	3 694(14)	6 82(30)#	[2009Ne03]	
²³³ Ra*	$(1/2^+)$	30(5) s	-4 586(21)	3.026(16)	6 421(10)	[1990Me13]	
²³⁷ Th*	$(5/2^+)$	4.69(60) m	-4.07(40)#	2.427(21)	6.402(21)	[2000Xu02]	
²⁴¹ U*	(0,2 )	obs	-3.54(36)#	1.88(22)#	6.43(20)#	[2023Ni04]	
²⁴⁵ Pu*	(9/2-)	10.59(2) h	-2.67(20)#	1.278(14)	6.61(10)	[1967Bu09]	
²⁴⁹ Cm*	1/2+	64.15(3) m	-2.35(30)#	0.904(3)	6.605(3)	[1973DrZM]	
²⁵³ Cf	$(7/2^+)$	17.81(8) d	-1.63(36)#	0.291(4)	7.211(4)	[1969DrZZ]	
				$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$		
²⁵⁷ Fm	$(9/2^+)$	100.5(2) d	-0.81(41)#			[1973Wi03]	
²⁶¹ No			-0.12(55)#				
²⁶⁵ Rf		$1.1^{+0.8}_{-0.3}$ m	0.46(66)#	-3.61(69)#	7.689(66)#	[2018Ut02]	
²⁶⁹ Sg		$14^{+10}_{-4}$ m	0.54(72)#	-3.07(76)#	9.03(72)#	[2018Ut02]	
²⁷³ Hs		$0.51^{+0.30}_{-0.14}$ s	1.08(75)#	-2.04(79)#	10.19(75)#	[2018Ut02]	
²⁷⁷ Ds		$3.5^{+2.1}_{0.0}$ ms	2.08(77)#	-0.38(82)#	11.98(77)#	[2018Ut02]	
²⁸¹ Cn		$180^{+100}_{-50}$ ms	2.61(87)#	0.34(85)#	12.51(77)#	[2018Ut02]	
²⁸⁵ Fl		$100^{+60}_{-20}$ ms	3.16(87)#	1.23(86)#	13.17(87)#	[2018Ut02]	
²⁸⁹ Lv		-30	3.77(93)#	2.25(91)#	14.27(92)#		
²⁹³ Og			4.4(11)#	3.4(10)#	15.7(11)#		

* 100%  $\beta^-$ -emitter.

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +57/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	Experimental
²²⁹ Rn ²³³ Ra ²³⁷ Th ²⁴¹ U	9.81(40)# 9.028(16) 8.555(41) 8.10(28)#	2.36(30)# 2.547(16) 3.196(18) 3.82(20)#			
²⁴⁵ Pu ²⁴⁹ Cm ²⁵³ Cf ²⁵⁷ Fm	7.35(10)# 7.10(20)# 6.52(20)# 5.88(10)#	4.56(20)# 5.148(13) 6.126(4) 6.864(1)	0.31(4)% 99.790(4)%	0.210(4)%	[ <b>1968Be21, 1966Rg01</b> , 1968BeZY, 1966Rg01] [ <b>1982Ah01, 1973Wi03</b> , 2000Ho27, 1998SiZX, 1985Wi10, 1974BaXU, 1973BaTX, 1973Ve10, 1971Ba03, 1971Ch14, 1971Jo13, 1967As02, 1966Rg01, 1965Si14, 1964Hu02, 1962Br45, 1962Ga24]
²⁶¹ No 265 Rf 269 Sg 273 Hs 277 Ds 281 Cn 285 Fl 289 Lv 293 Og	5.38(37)# 4.97(57)# 4.66(65)# 4.301(65)# 3.51(66)# 3.23(66)# 2.95(67)# 2.50(74)# 2.11(98)#	7.44(20)# 7.81(30)# 8.577(75) 9.650(64) 10.90(12)# 10.430(64) 10.560(71) 11.10(30)# 11.92(50)#	100%* 100%* 100%* 100%* 100%*	100%	[2018Ut02, 2015Ut02, 2010El06] [2018Ut02, 2015Ut02, 2010El06] [2018Ut02, 2015Ut02, 2010El06] [2018Ut02, 2015Ut02, 2010El06] [2018Ut02, 2015Ut02, 2010El06] [2018Ut02, 2015Ut02, 2010El06]

* Only  $\alpha$ -decay has been observed.

Table 3			
direct $\alpha$ emission from	$^{253}Cf^*, J^{\pi} = (7/2^+),$	$T_{1/2} = 17.81(8) d^{**}$	$BR_{\alpha} = 0.31(4)\%^{***}$

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{249}\mathrm{Cm})$	coincident γ-rays (keV)	HF	
6.015(5) 6.076(5)	5.920(5) 5.978(5)	5.5(20)% 100%	0.016(6)% 0.29(4)%	(9/2 ⁺ ) (7/2 ⁺ )	0.110 0.050		1.509(12) 1.509(12)	$11^{+8}_{4}\\1.3^{+0.5}_{-0.4}$

* All values from [1993Mo18], except where noted.  $E_{\alpha}$  values are adjusted by -0.6 keV as recommended in [1991Ry01]. *** [1969DrZZ]. *** [1966Ryg01].

## Table 4

|--|

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{253}\mathrm{Cf})$	coincident γ-rays (keV)	HF	
( 117(5)	( 247(5)	0.2(1)0/	0.2(1)0/	$(12/2^{\pm})$	0.417		1 5040(52)	(0 ⁺³²
6.447(5)	6.347(5)	0.3(1)%	0.3(1)%	$(13/2^+)$	0.417		1.5040(53)	$60^{+52}_{-17}$
6.544(3)	6.442(3)	2.1(2)%	2.0(2)%	$(7/2^+)$	0.3212	61.6, 75.0, 80.2, 104.4, 136.7, 179.4, 241.0	1.5040(53)	$26^{+3}_{-4}$
6.624(2)	6.521(2)	100%	93.6(10)%	$(11/2^+)$	0.2410	61.6, 75.0, 104.4, 136.7, 179.4, 241.0	1.5040(53)	1.3(2)
6.802(3)	6.696(3)	3.7(3)%	3.5(3)%	$(9/2^+)$	0.0616	61.6	1.5040(53)	230(40)
6.864(3)	6.757(3)	0.64(6)%	0.60(6)%	$(7/2^+)$	0.0		1.5040(53)	$2.5^{+0.5}_{-0.4}  imes 10^3$

* All values from [1982Ah01], except where noted.  $E_{\alpha}$  values are adjusted by +0.5 keV as recommended in [1991Ry01]. ** [1973Wi03].

# Table 5

direct $\alpha$ emis	ssion from ²⁶⁹ Sg*	, $T_{1/2} = 14^{+10}_{-4}$ m	n, $BR_{\alpha} = 100$	0%**.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{265}\mathrm{Rf})$	coincident γ-rays (keV)	HF	
8.54(4)	8.41(4)	100%					
* All val ** Only	lues from [2018U $\alpha$ -decay has been	t02]. The reportent observed.	ed values are	e from that work and [201	5Ut02, 2010El06].		
Table 6 direct $\alpha$ emis	ssion from ²⁷³ Hs*	$T_{1/2} = 0.51^{+0.2}_{-0.1}$	$^{30}_{14}$ s, $BR_{\alpha} = 1$	100%**.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{269}Sg)$	coincident γ-rays (keV)	HF	
9.65(4)	9.51(4)	100%					
* All val ** Only	lues from [2018U $\alpha$ -decay has been	t02]. The reportent observed.	ed values are	from that work and [201	5Ut02, 2010El06].		
<b>Table 7</b> direct $\alpha$ emised	ssion from ²⁷⁷ Ds*	$T_{1/2} = 3.5^{+2.1}_{-0.9}$	ms, $BR_{\alpha} = 1$	100%**.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{273}\mathrm{Hs})$	coincident γ-rays (keV)	HF	
10.70(4)	10.55(4)	100%					
* All val ** Only	lues from [2018U $\alpha$ -decay has been	t02]. The reportent observed.	ed values are	from that work and [201	5Ut02, 2010El06].		
<b>Table 8</b> direct $\alpha$ emised	ssion from ²⁸¹ Cn*	$^{4}, T_{1/2} = 180^{+100}_{-50}$	0 ms, $BR_{\alpha}$ =	100%**.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_{f}^{\pi}$	$E_{daughter}(^{277}\text{Ds})$	coincident $\gamma$ -rays (keV)	HF	

10.43(4) 10.28(4) 100%

 $\ast$  All values from [2018Ut02]. The reported values are from that work and [2015Ut02, 2010El06].

** Only  $\alpha$ -decay has been observed.

Table 9	
direct $\alpha$ emission from ²⁸⁵ Fl*, T _{1/2} = 100 ⁺⁶⁰ ₋₃₀ ms, BR _{$\alpha$} = 100%*:	*.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{277}\mathrm{Ds})$	coincident $\gamma$ -rays (keV)	HF	
10 56(4)	10 41(4)	100%					

* All values from [2018Ut02]. The reported values are from that work and [2015Ut02, 2010El06]. ** Only  $\alpha$ -decay has been observed.

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# $\begin{array}{c|c} 291 T_S \\ Q_{10} = & 1.570 \ \text{MeV} \\ Q_{10} = & 15.300 \ \text{MeV} \\ Q_{11} = & 1.480 \ \text{MeV} \end{array}$



Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +59/2 nuclei.

Last updated 5/25/25

Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +59/2$ nuclei.	Unless otherwise stated, all Q-values are taken from [2021Wa16] or
deduced from values therein. $J^{\pi}$ values for ²³³ Fr is taken from ENSDF.	

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\beta}$ -	$Q_{\beta}$ - $\alpha$	Experimental
		-/ -		F	P	
²³³ Fr*	$(1/2^+)$	0.9(10) s		4.586(21)		[2014Kr09]
²³⁷ Ac				4.07(40)#		
²⁴¹ Pa				3.54(36)#		
²⁴⁵ Np*		**		2.67(20)#		[1960Di03]
²⁴⁹ Am*		**		2.35(30)#		[1960Di03]
²⁵³ Bk*		> 10 m		1.63(36)#		[1992KrZK]
²⁵⁷ Es		7.7(2) d		0.81(41)#		[1987Po22]
²⁶¹ Md				0.12(55)#		
				$Q_{\varepsilon_P}$	$Q_{\varepsilon \alpha}$	
²⁶⁵ Lr						
²⁶⁹ Db						
²⁷³ Bh			0.76(77)#			
²⁷⁷ Mt		5 $^{+9}_{-2}$ ms	1.63(80)#	-3.23(89)#	10.66(77)#	[2013Og04]
²⁸¹ Rg		$11^{+3}_{-1}$ s	2.06(92)#	-2.47(98)#	11.53(89)#	[2022Og07, 2022Og08]
²⁸⁵ Nh		$2.1^{+0.6}_{-0.2}$ ms	2.68(93)#	-1.49(92)#	12.07(92)#	[2022Og07, 2022Og08]
²⁸⁹ Mc		$250^{+51}_{-25}$ ms	3.22(93)#	-0.6(10)#	13.17(93)#	[2022Og07, 2022Og08]
²⁹³ Ts		$22_{-4}^{+8}$ ms	3.86(93)#	0.5(10)#	14.54(93)#	[2013Og04]

* 100%  $\beta^-$ -emitter.

** Indirectly observed by the  $\beta^-$  daughter being present in bomb debris [1960Di03].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +59/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	Experimental
233		1 (1(40))			
235 Fr 237		1.61(40)#			
237 Ac		2.68(40)#			
241 Pa		3.33(30)#			
²⁴⁵ Np		3.69(36)#			
²⁴⁹ Am		4.83(36)#			
²⁵³ Bk	5.42(47)#	5.40(20)#			
²⁵⁷ Es	4.93(52)#	6.05(20)#			
²⁶¹ Md	4.48(67)#	6.75(30)#			
²⁶⁵ Lr	4.07(81)#	7.23(20)#			
²⁶⁹ Db	3.62(91)#	8.49(30)#			
²⁷³ Bh	3.13(95)#	9.11(20)#			
²⁷⁷ Mt	2.47(98)#	9.90(10)#		100%	[ <b>2013Og04</b> , 2022Og07, 2022Og08, 2017Ak02]
²⁸¹ Rg	2.3(11)#	9.90(40)#	10%	90%	[2022Og07, 2022Og08, 2013Og04, 2023Ko22, 2019Kh04, 2017Ak02,
					2013Og01, 2013Og04, 2012Og02, 2011Og04, 2011Og07, 2011OgZZ,
					2010Og01]
²⁸⁵ Nh	1.9(11)#	10.010(40)	100%		[2022Og07, 2022Og08, 2013Og04, 2023Ko22, 2019Kh04, 2017Ak02,
					2013Og01, 2013Og04, 2012Og02, 2011Og04, 2011Og07, 2011OgZZ,
					2010Og01]
²⁸⁹ Mc	1.5(11)#	10.490(50)	100%		[2022Og07, 2022Og08, 2013Og04, 2023Ko22, 2019Kh04, 2017Ak02,
					2013Og01, 2013Og04, 2012Og02, 2011Og04, 2011Og07, 2011OgZZ,
					2010Og01]
²⁹³ Ts	0.9(11)#	11.320(50)	100%		[2013Og04, 2019Kh04, 2012Og02, 2011Og04, 2011Og07, 2011OgZZ,
					2010Og01]
					-

# Table 3

direct $\alpha$ emiss	lirect $\alpha$ emission from ²⁸¹ Rg*, $T_{1/2} = 11^{+3}_{-1}$ s**, $BR_{\alpha} = 10\%$ .									
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pmb{\pi}}$	$E_{daughter}(^{277}\mathrm{Mt})$	coincident $\gamma$ -rays (keV)	HF				
9.52-9.69	9.38-9.55	10%								

* All values from [2013Og04], except where noted.

** [2022Og08].

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rect $\alpha$ emission from ²⁶⁵ Nh*, $T_{1/2} = 2.1^{+0.3}_{-0.3}$ ms**, $BR_{\alpha} = 100\%$ .										
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{281}\mathrm{Rg}$	coincident γ-rays (keV)	HF				
9.66-10.32	9.47-10.18	100%								
* All values ** [2022Og	* All values from [2013Og04], except where noted. ** [2022Og08].									
Table 5										
direct $\alpha$ emissio	n from 289 Mc*, T _{1/2}	$= 250^{+51}_{-35} \text{ ms}^{**},$	$BR_{\alpha} = 100^{\circ}$	%.						
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{285}\mathrm{Nh}$	coincident γ-rays (keV)	HF				
10.29-10.49	10.15-10.34	100%								
* All values ** [2022Og	from [2013Og04], e 08].	except where note	d.							
<b>Table 6</b> direct $\alpha$ emissio	n from ²⁹³ Ts*, $T_{1/2}$	$=22^{+8}_{-4}$ ms, $BR_{\alpha}$	= 100%.							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{277}\mathrm{Mt})$	coincident γ-rays (keV)	HF				
10.75-11.36	10.60-11.20	100%								

* All values from [2013Og04].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +29 nuclei.

Last updated 5/12/25

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +29$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	Q _β -	Q _β - α	Experimental	
230 р	0+	1		2 (8/20) //	5.07(2)()	[2010.4.12.4]	
230 Kn	0	ODS		2.68(20)#	5.27(36)#	[2010A124]	
²³⁴ Ra*	0+	30(10) s		2.089(16)	5.199(10)	[1992B044]	
²³⁸ Th*	$0^+$	9.4(20) m		1.63(28)#	5.44(28)#	[1999He01]	
²⁴² U*	$0^+$	16.8(5) m		1.20(28)#	5.48(20)#	[1979Ha26]	
²⁴⁶ Pu*	$0^{+}$	10.85(2) d		0.401(14)#	5.73(20)#	[1956Ho23]	
²⁵⁰ Cm	$0^+$	1.13(5)×10 ⁴ y		0.038(11)	5.751(21)#	[1967Me16]	
				$O_{\mathcal{E}D}$	$O_{\mathcal{E}\mathcal{A}}$		
²⁵⁴ Cf	$0^+$	60.2(2) d	-3.05(30)#	<del>~</del>		[1968Be21]	
²⁵⁸ Fm	$0^+$	360(20) µs	-2.28(45)#			[1986Hu05]	
²⁶² No	$0^+$	$\approx 5 \text{ ms}$	-1.57(58)#			[ <b>1989HuZU</b> ]	
²⁶⁶ Rf			-1.53(68)#				
²⁷⁰ Sg			-0.97(74)#				
²⁷⁴ Hs			-0.36(74)#				
²⁷⁸ Ds			0.48(77)#	-2.41(68)#	10.07(77)#		
²⁸² Cn	$0^+$	$880^{+190}_{-130} \ \mu s$	1.08(80)#	-1.74(74)#	10.64(80)#	[2024Ga31]	
²⁸⁶ Fl	$0^+$	$106^{+17}_{-13}$ ms	1.65(81)#	-0.77(75)#	11.44(81)#	[2024Ga31]	
²⁹⁰ Lv	$0^+$	$8.2^{+3.2}_{-1.8}$ ms	2.24(81)#	0.27(75)#	12.65(81)#	[2024Ga31]	
²⁹⁴ Og	$0^+$	$580^{+440}_{-180} \ \mu s$	2.92(81)#	1.46(76)#	14.10(81)#	[2018Br13]	

* 100%  $\beta^-$ -emitter.

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +29$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	Experimental
230 <b>P</b> n	10.01(45)#	2 20(45)#			
234 <b>D</b> o	$10.01(+3)\pi$ 0.278(21)	2.20(43)#			
238 TL	9.276(21)	2.34(20)#			
242 T	8.78(49)#	3.17(28)#			
2465	8.41(36)#	3.67(200)#			
²⁴⁰ Pu	7.744(201)#	4.350(20)#			
²⁵⁰ Cm	7.40(30)#	5.170(18)		100%*	[ <b>1967Me16</b> , 1973Ho02, 1971Or03, 1966Rg01, 1957Hu76]
²⁵⁴ Cf	6.88(36)#	5.927(5)	0.310(16)%	99.690(16)%	[ <b>1968Be21</b> , 2019De11, 1991So16, 1990SoZY, 1981SeZW, 1980ChZM,
					1980Ho01, 1979SeZV, 1974UnZU, 1974UnZX, 1971Or03, 1968BeZY,
					1966Rg01, 1965Me02, 1963Br35, 1963Fr15, 1963Ph01, 1962Br45,
					1956Fi11]
²⁵⁸ Fm	6.27(46)#	6.66(20)#		100%*	[1989Hu09, 1986Hu05, 1986Hu01, 1980Ho04, 1971Hu03, 1971HuZX,
					1971Jo13]
²⁶² No	5.77(62)#	7.25(30)#		100%*	[ <b>1989HuZU</b> , 1989LoZW, 1988LOZV]
²⁶⁶ Rf	5.39(69)#	7.61(20)#			
²⁷⁰ Sg	5.01(77)#	8.87(20)#			
²⁷⁴ Hs	4.57(81)#	9.55(10)#			
²⁷⁸ Ds	4.05(84)#	10.420(20)#			
²⁸² Cn	3.80(95)#	10.15(20)#		100%*	[2024Ga31, 2018Br13, 2023Sa03, 2021Sa01, 2012Og06, 2011Og07,
					2010El06, 2007Og05, 2006Og05, 2005Og03, 2005OgZZ, 2004Og10,
					2004Og12, 2004OgZZ, 2002OgZX]
²⁸⁶ Fl	3.45(95)#	10.355(41)	57(5)%	43(5)%	[2024Ga31, 2023Sa03, 2021Sa01, 2018Br13, 2012Og06, 2011Og07,
					2010E106, 2007Og05, 2006Og05, 2005Og03, 2005OgZZ, 2004Og10,
					20040g12, 20040gZZ, 20020gZX]
²⁹⁰ Lv	2 94(95)#	10 997(58)	100%**		$[2024G_{8}31, 2018Br13, 2012O_{9}06, 2011O_{9}07, 2007O_{9}05, 2006O_{9}05]$
Lv	2.7 1(75)11	10.777(50)	10070		$2005 \Omega_{\sigma} \Omega_{\sigma}^{3}$ 2005 $\Omega_{\sigma}^{2} ZZ$ 2004 $\Omega_{\sigma} \Omega_{\sigma}^{3}$ 2004 $\Omega_{\sigma}^{2} \Omega_{\sigma}^{2}$ 2004 $\Omega_{\sigma}^{2} ZZ$ 2002 $\Omega_{\sigma}^{2} ZX^{1}$
294 Og	2 40(96)#	11.867(31)	100%**		[ <b>2018Br13</b> 20120a06 20110a07 20070a05 20060a05
Og	2.40(90)#	11.007(31)	10070		[2010D113, 20120g00, 20110g07, 20070g03, 20000g03, 20000g02, 20000g03, 20000g02, 20000000, 20000000, 20000000000
					2005Og05, 2005OgZZ, 2002OgZAJ

 $\ast$  Only SF has been observed.

** Only  $\alpha$ -decay has been observed.

direct $\alpha$ em	ission from ²⁵⁴	$Cf^*, J^{\pi} = 0^+,$	$T_{1/2} = 60.2(2$	) d, $BR_{\alpha} =$	8.66(43)%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{250}\mathrm{C}$	m) coincident γ-rays (keV	) HF	
5.884(5) 5.926(5)	5.791(5) 5.833(5)	20.5(24)% 100%	0.053(7) 0.26(1)%	$5 - 2^+ 0^+$	0.042(7) 0.0	_	1.517(24) 1.517(24)	$2.9^{+0.6}_{-0.5}\\0.99(5)$
* All va	alues from [196	$58Be21], E_{\alpha}$ v	alues are adju	sted by -0.6	5 keV as recomende	d in [1991Ry01].		
Table 4 direct $\alpha$ emi	ission from ²⁸⁶	Fl*, $J^{\pi} = 0^+, T$	$\Gamma_{1/2} = 106^{+17}_{-13}$	ms, $BR_{\alpha}$ =	= 57(5)%.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{282}\mathrm{Cn})$	coincident γ-rays (keV)	HF	
9.71(3) 10.32(2)	9.57(3) 10.18(2)	3% 100%	1.8% 55%	$0^{+**} \\ 0^{+}$	0.620** 0.0	***	1.441(15) 1.441(15)	$\begin{array}{c} 0.31\substack{+0.24 \\ -0.21 \\ 0.51(9) \end{array}$
* All va ** Dec *** α i	alues from [202 ay scenario from in coincidence	24Ga31], whic m [2021Sa01] with a 0.36(1)	h contains all , [2023Sa03] ( MeV electron	previously offer three a	measured data. additional possibiliti	ies.		
Table 5 direct $\alpha$ emi	ission from ²⁹⁰	$Lv^*, J^{\pi} = 0^+,$	$T_{1/2} = 8.2^{+3.2}_{-1.3}$	$\frac{2}{8}$ ms, $BR_{\alpha}$	= 100%**.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs$	) $J_f^{\pi}$	$E_{dd}$	aughter ( ²⁸⁶ Fl)	coincident $\gamma$ -rays (keV)	HF	
10.99(7)	10.84(7)	100%*	** 0+	_	-	1.486(28)	0.935(10)	
* All va ** Only	alues from [202 y α-decay has t	24Ga31], whic been observed	h contains all	measured o	lata.			
Table 6 direct $\alpha$ emi	ission from ²⁹⁴	Og*, $J^{\pi} = 0^+$ ,	$T_{1/2} = 580^{+4}_{-1}$	$^{40}_{80}$ µs, BR _{$\alpha$}	= 100%**.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(ab)$	s) $J_f^{\pi}$	E	Edaughter ( ²⁹⁰ Lv)	coincident γ-rays (keV)	HF	
11.86(3)	11.70(3)	100%	»** 0 ⁻	+ _		1.461(24)	1.01	

* All values from [2018Br13], which contains all measured data.

** Only  $\alpha$ -decay has been observed.

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Table 3

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Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +29 nuclei.

Last updated 5/27/25

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +29$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{arepsilon}$	Q _β -	$Q_{\beta}$ - $\alpha$	$BR_{\beta-F}$	Experimental
228 At*			obs		6 64(40)#	9 73(45)#		[20104]24]
232 Fr*			5 5(6) s		5 576(17)	8 585(23)		[2010/1124] [2004Pe17]
²³⁶ Ac*			$72^{+345}_{-22}$ s		4 970(40)	8 483(41)		[2010Ch19]
²⁴⁰ Pa			-33 5		4.30(20)#	8.51(20)#		[_0100113]
²⁴⁴ Np			2.29(16) m		3.43(10)#	8.28(10)#		[1987Mo29]
²⁴⁸ Am					3.17(20)#	8.51920)#		
²⁵² Bk				-0.52(36)#	2.50(20)#	8.90(20)#		
²⁵⁶ Es*			25.4(24) m	-0.14(33)#	1.70(10)#	8.91(10)#		[1981Lo15]
256mEs*	Х		7.6 h	-0.14(33)#	1.70(10)#	8.91(10)#	$2 \times 10^{-3}\%$	[1989Ha10, 1976HoZB, 1987HaZL]
					$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$		
²⁶⁰ Md			30.7(5) d**	0.78(54)#		7.08(45)#		[1986Lo1, 1992LoZV]
²⁶⁴ Lr			$4.8^{+2.2}_{-1.3}$ h	1.36(73)#		8.18(62)#		[2022Og08]
²⁶⁸ Db			$16^{+6}_{-4}$ h	1.58(85)#		9.62(79)#		[2022Og07]
²⁷² Bh			8.8(7) s	2.270(87)#		10.889(85)#		[2022Og08]
²⁷⁶ Mt			$620^{+60}_{-40}$ ms	3.13(90)#	-1.76(80)#	12.37(87)#		[2022Og08]
²⁸⁰ Rg			3.9(3) s	3.57(92)#	-0.99(86)#	13.28(90)#		[2022Og08]
²⁸⁴ Nh			$900^{+70}_{-60}$ ms	4.18(93)#	-0.078(86)#	13.85(92)#		[2022Og08]
²⁸⁸ Mc			193 ¹⁵ ₋₁₃ ms	4.75(93)#	0.92(89)#	14.83(93)#		[2022Og08]
²⁹² Ts			10	5.5(10)#	2.15(99)#	16.3(10)#		

* 100%  $\beta^-$ -emitter.

** Weighted average of 31.8(5) d [1986Lo16] and 27.8(8) d [1992LoZV].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +29$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	$BR_{\alpha}$	BR _{SF}	Experimental
220					
²²⁸ At	7.69(57)#	2.39(57)#			
²³² Fr	7.77(30)	1.77(40)#			
²³⁶ Ac	7.20(30)#	2.723(41)			
²⁴⁰ Pa	6.78(45)#	3.36(20)#			
²⁴⁴ Np	6.53(32)#	3.81(22)#			
²⁴⁸ Am	5.94(28)#	4.90(22)			
²⁵² Bk	5.40(20)#	5.55(28)			
²⁵⁶ Es	4.91(22)#	6.23(22)#			
²⁶⁰ Md	4.44(42)#	6.94(30)#	$\leq 10\%$	100%*	[1986Lo16, 1992LoZV, 1990Wi01, 1989Hu09, 1987HuZW]
²⁶⁴ Lr	4.04(66)#	7.40(30)#		100%*	[2022Og07, 2022Og08, 2023Ko22]
²⁶⁸ Db	3.67(78)#	8.26(30)#	$55^{+20}_{15}\%$	$45^{+15}_{-20}\%$	[2022Og08, 2023Ku17, 2022Og07, 2016Fo10, 2015Ga24, 2015Ru11,
		. ,	-15	-20	2014Ru04, 2013Og01, 2013Ru11, 2012Og02, 2012OgZZ, 2004Og03,
					2004Og10, 2003OgZY]
²⁷² Bh	3.12(80)#	9.303(54)	100%**		[2022Og08, 2004Og03,2023Ku17, 2022Og07, 2018Ga34, 2016Fo10,
					2015Ga24, 2015Ru11, 2014Ru04, 2013Og01, 2013Ru11,
					2012Og02, 2012OgZZ, 2007Og05, 2005Og02, 2004Og10, 2003OgZY]
²⁷⁶ Mt	2.47(80)#	10.100(10)	100%**		[2022Og08, 2015Ga24, 2014Ru04, 2004Og03,2023Ku17, 2022Og07,
					2018Ga34, 2016Fo10, 2015Ru11, 2013Og01, 2013Ru11, 2012Og02,
					2012OgZZ, 2007Og05, 2005Og02, 2004Og10, 2003OgZY]
²⁸⁰ Rg	2.43(81)#	10.149(10)	100%**		[2022Og08, 2015Ga24, 2004Og03, 2023Ku17, 2022Og07, 2018Ga34,
					2016Fo10, 2015Ru11, 2014Ru04, 2013Og01, 2013Ru11, 2012Og02,
					2012OgZZ, 2007Og05, 2005Og02, 2004Og10, 2003OgZY]
²⁸⁴ Nh	2.04(81)#	10.280(38)	100%**		[2022Og08, 2004Og03, 2023Ku17, 2022Og07, 2018Ga34, 2017Ak02,
					2016Fo10, 2015Ga24, 2015Ru11, 2014Ru04, 2013Og01, 2013Ru11,
					2012Og02, 2012OgZZ, 2007Og05, 2005Og02, 2004Og10, 2003OgZY]
²⁸⁸ Mc	1.55(82)#	10.650(50)	100%**		[2022Og08, 2004Og03, 2023Ku17, 2022Og07, 2018Ga34, 2017Ak02,
					2017Ak02, 2016Fo10, 2015Ga24, 2015Ru11, 2014Ru04, 2013Og01, 2013Ru11,
					2012Og02, 2012OgZZ, 2007Og05, 2005Og02, 2004Og10, 2003OgZY]
²⁹² Ts	0.91(91)#	11.53(40)#			

* Only SF has been observed.

** Only  $\alpha$ -decay has been observed.

direct $\alpha$ emission	lirect $\alpha$ emission from ²⁶⁸ Db*, $T_{1/2} = 16^{+6}_{-4}$ h, $BR_{\alpha} = 55^{+20}_{-15}\%$ .											
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{264}\mathrm{Lr})$	coincident γ-rays (keV)	HF						
7.7-8.1	7.6-8.0	$55^{+20}_{-15}\%$										

* All values from [2022Og07], which contains all measured data. As an odd-odd nucleus, one would expect that several transitions to low-lying levels would be present. Due to low statistics, the  $E_{\alpha}$  is presented as a range of energies that includes x number of unresolved peaks.

#### Table 4

direct $\alpha$ emiss	direct $\alpha$ emission from ²⁷² Bh*, T _{1/2} = 8.8(7) s, <i>BR</i> _{$\alpha$} = 100%**.											
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{268}\text{Db})$	coincident γ-rays (keV)	HF						
8.41-9.35	8.29-9.21	100%**										

* All values from [2022Og07], which contains all measured data. As an odd-odd nucleus, one would expect that several transitions to low-lying levels would be present. Due to low statistics, the  $E_{\alpha}$  is presented as a range of energies that includes x number of unresolved peaks.

** Only  $\alpha$ -decay has been observed.

Table 5 direct  $\alpha$  emission from ²⁷⁶Mt*, T_{1/2} = 620⁺⁶⁰₋₄₀ ms**, BR_{$\alpha$} = 100%***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{272}\mathrm{Bh})$	coincident γ-rays (keV)	HF
9.62	9.48@	6%	5% [@]		0.480	480 [@]	
9.67	9.53 [@]	6%	5% [@]		0.434	434 [@]	
9.74	9.60	100%	80%		0.362	136, 166, 302 [@] , 362	
10.04	9.90 [@]	13%	10%@		0.042		

* All values from [2015Ga24], except where noted.

** [2022Og07].  $E_{\alpha}$  reported as 8.52-10.1 MeV.

*** Only  $\alpha$ -decay has been observed.

[@] Tentative assignment.

#### Table 6

direct  $\alpha$  emission from ²⁸⁰Rg*, T_{1/2} = 3.9(3) s**, BR_{$\alpha$} = 100%***.

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{276}\mathrm{Mt})$	coincident $\gamma$ -rays (keV)	HF
9.41	9.28 [@]	17%	10%@		0.732@	237 280 [@] 494 [@]
9.86	9.72 [@]	17%	10%@		0.280@	280 [@]
9.90	9.76	100%	60%		0.237	237
9.94	9.80	33%	20%		0.194	194
*** Only @ Tentat	$\alpha$ -decay has b ive assignment	been observed.				
Table 7						
direct $\alpha$ emis	sion from ²⁸⁴ N	$h^*, T_{1/2} = 900^-$	$^{+70}_{-60}$ ms, $BR_{\alpha}$ =	= 100%**.		
		,				
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}($	abs)	$J_f^{\pi} = E_{daughter}(^{280}H)$	Rg) coincident $\gamma$ -rays (	(keV) HF

9.23-10.31 9.10-10.16 100%**

* All values from [2022Og08], which contains all measured data. Fig. 1 of this reference suggests a 100% peak at  $\approx$ 9.97 MeV.

** Only  $\alpha$ -decay has been observed.

direct $\alpha$ emission	direct $\alpha$ emission from ²⁸⁸ Mc*, $T_{1/2} = 193^{15}_{-13}$ ms, $BR_{\alpha} = 100\%$ **.											
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{m \pi}$	$E_{daughter}(^{284}\mathrm{Nh})$	coincident $\gamma$ -rays (keV)	HF						
10.35-10.82	10.21-10.67	100%**										

* All values from [2022Og08], which contains all measured data. Fig. 1 of this reference suggests two major peaks at 10.36 MeV (≈30 counts) and 10.50 MeV (≈90 counts).

** Only  $\alpha$ -decay has been observed.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +59/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{arepsilon}$	Q _β -	$Q_{\beta}$ - $\alpha$	Experimental	
²³¹ Rn		obs		4 47(30)#		[20104124]	
235 R.a		005		3.77(30)#			
²³⁹ Th				3.16(45)#			
24311				2 67(30)#			
²⁴⁷ Pu*		2.27(23) d		2.06(22)#		[1983Po14]	
²⁵¹ Cm*		16.8(2) m		1.420(20)		[1978Lo13]	
²⁵⁵ Cf*		85(18) m		0.72(20)#		[1981Lo15]	
²⁵⁹ Fm		1.57(9) s**		0.14(30)#		[1985So03, 1981Ho32, 1980Hu03]	
				$Q_{\varepsilon p}$	$Q_{\mathcal{E} \alpha}$		
²⁶³ No							
²⁶⁷ Rf		$1.3^{+2.3}_{-0.5}$ h				[2011Og07]	
²⁷¹ Sg		$1.9^{+2.4}_{-0.6}$ m				[2011Og07]	
²⁷⁵ Hs		$190^{+220}_{-70}$ s	0.71(84)#			[2011Og07]	
²⁷⁹ Ds		$200^{+70}_{-40}$ ms	1.44(90)#	-1.49(68)#	10.82(85)#	[2011Og07]	
²⁸³ Cn		$3.8^{+1.2}_{-0.7}$ s	1.96(92)#	-0.74(68)#	11.33(91)#	[2011Og07]	
²⁸⁷ Fl		$480^{+160}_{-00}$ ms	2.47(84)#	0.19(93)#	12.12(92)#	[2011Og07]	
²⁹¹ Lv		$18_{-6}^{+22}$ ms	3.06(96)#	1.22(94)#	13.36(94)#	[2011Og07]	
²⁹⁵ Og		-0				-	

* 100%  $\beta^-$ -emitter.

** Weighted average of 1.6(1) s [1985So03], 1.5(2) s [1981Ho32] and 1.5(3) s [198Hu003].

## Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +59/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	Experimental
235 D		0.16(40)#			
230 Ka		2.16(42)#			
²³⁹ Th		2.95(50)#			
²⁴³ U		3.56(50)#			
²⁴⁷ Pu		4.31(36)#			
²⁵¹ Cm		5.01(20)#			
²⁵⁵ Cf	6.87(36)#	5.74(20)#			
²⁵⁹ Fm	6.29(49)#	6.47(20)#		100%	[1985So03, 1981Ho32, 1980Hu03, 1982GhZZ, 1976HoYT, 1976HoZP,
		~ /			1976HoZS]
²⁶³ No	5.83(66)#	7.00(40)#			
²⁶⁷ Rf	5.51(79)#	7.89(30)#		100%	[2016Ho09, 2011Og07]
²⁷¹ Sg	5.07(82)#	8.75(14)#	70%	30%	[2016Ho09, 2011Og07, 2006Og05, 2005Og03, 2005OgZZ, 2004OgZZ]
²⁷⁵ Hs	4.56(83)#	9.450(54)#	100%		[2016Ho09, 2011Og07, 2006Og05, 2005Og03, 2005OgZZ, 2004OgZZ]
²⁷⁹ Ds	4.03(84)#	10.11(12)#	10%	90%	[2016Ho09, 2011Og07, 2006Og05, 2005Og03, 2005OgZZ, 2004Og12,
					2004OgZZ]
²⁸³ Cn	3.69(85)#	9.89(11)#	100%		[2016Ho09, 2011Og07, 2006Og05, 2005Og03, 2005OgZZ, 2004Og12,
		. ,			2004OgZZ]
²⁸⁷ Fl	3.32(85)#	10.170(50)	100%		[2016Ho09, 2011Og07, 2006Og05, 2005Og03, 2005OgZZ, 2004Og12,
					2004OgZZ]
²⁹¹ Lv	2.84(86)#	10.791(12)	100%		[2016Ho09, 2011Og07, 2006Og05, 2004Og12]
²⁹⁵ Og	2.32(88)#	11.70(20)#			
- 5	=:==(00)	(=0)			

direct $\alpha$ emiss	sion from ²⁷¹ Sg*,	$T_{1/2} = 1.9^{+2.4}_{-0.6} m,$	$BR_{\alpha} = 70\%$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{m{\pi}}$	$E_{daughter}(^{267}\mathrm{Rf})$	coincident $\gamma$ -rays (keV)	HF	
8.67(8)	8.54(8)	70%					
* All valu	ues from [2011Og	07], which contai	ns all measu	red data.			
<b>Table 4</b> direct $\alpha$ emission	sion from ²⁷⁵ Hs*,	$T_{1/2} = 190^{+220}_{-70} s.$	$BR_{\alpha} = 100^{\circ}$	%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{271}\mathrm{Sg})$	coincident γ-rays (keV)	HF	
9.44(6)	9.30(6)	100%					
* All valu	ues from [2011Og	07], which contai	ns all measu	red data.			
<b>Table 5</b> direct $\alpha$ emiss	sion from ²⁷⁹ Ds*,	$T_{1/2} = 200^{+50}_{-40} \text{ ms}$	s, $BR_{\alpha} = 10^{\circ}$	%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{275}\mathrm{Hs})$	coincident γ-rays (keV)	HF	
9.84(6)	9.70(6)	10%					
* All valu	ues from [2011Og	07], which contai	ns all measu	red data.			
<b>Table 6</b> direct $\alpha$ emission	sion from ²⁸³ Cn*,	$T_{1/2} = 3.8^{+1.2}_{-0.7} $ s,	$BR_{\alpha} = 100\%$	б.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{275}\text{Hs})$	coincident γ-rays (keV)	HF	
9.67(6)	9.54(6)	100%					
* All valu	ues from [2011Og	07], which contai	ns all measu	red data.			
<b>Table 7</b> direct $\alpha$ emiss	sion from ²⁸⁷ Fl*, 7	$\Gamma_{1/2} = 480^{+160}_{-90} \text{ m}$	s, $BR_{\alpha} = 10$	0%.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{283}Cn)$	coincident $\gamma$ -rays (keV)	HF	
10.16(6)	10.02(6)	100%					
* All valu	ues from [2011Og	07], which contai	ns all measu	red data.			
<b>Table 8</b> direct $\alpha$ emission	sion from ²⁹¹ Lv*,	$T_{1/2} = 18^{+22}_{-6} ms,$	$BR_{\alpha} = 100^{\circ}$	%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{287}\mathrm{Fl})$	coincident γ-rays (keV)	HF	
10.89(6)	10.74(6)	100%	J				

* All values from [2011Og07], which contains all measured data.

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# $\begin{array}{c|c} 291 T_S \\ Q_{10} = & 1.570 \ \text{MeV} \\ Q_{10} = & 15.300 \ \text{MeV} \\ Q_{11} = & 1.480 \ \text{MeV} \end{array}$



Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +59/2 nuclei.

Last updated 5/25/25
Observed and predicted $\beta$ -delayed particle emission from the odd-Z, $T_z = +59/2$ nuclei.	Unless otherwise stated, all Q-values are taken from [2021Wa16] or
deduced from values therein. $J^{\pi}$ values for ²³³ Fr is taken from ENSDF.	

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\beta}$ -	$Q_{\beta}$ - $\alpha$	Experimental
		-/ -		F	P	
²³³ Fr*	$(1/2^+)$	0.9(10) s		4.586(21)		[2014Kr09]
²³⁷ Ac				4.07(40)#		
²⁴¹ Pa				3.54(36)#		
²⁴⁵ Np*		**		2.67(20)#		[1960Di03]
²⁴⁹ Am*		**		2.35(30)#		[1960Di03]
²⁵³ Bk*		> 10 m		1.63(36)#		[1992KrZK]
²⁵⁷ Es		7.7(2) d		0.81(41)#		[1987Po22]
²⁶¹ Md				0.12(55)#		
				$Q_{\varepsilon_P}$	$Q_{\varepsilon \alpha}$	
²⁶⁵ Lr						
²⁶⁹ Db						
²⁷³ Bh			0.76(77)#			
²⁷⁷ Mt		$5^{+9}_{-2}$ ms	1.63(80)#	-3.23(89)#	10.66(77)#	[2013Og04]
²⁸¹ Rg		$11^{+3}_{-1}$ s	2.06(92)#	-2.47(98)#	11.53(89)#	[2022Og07, 2022Og08]
²⁸⁵ Nh		$2.1^{+0.6}_{-0.2}$ ms	2.68(93)#	-1.49(92)#	12.07(92)#	[2022Og07, 2022Og08]
²⁸⁹ Mc		$250^{+51}_{-25}$ ms	3.22(93)#	-0.6(10)#	13.17(93)#	[2022Og07, 2022Og08]
²⁹³ Ts		$22_{-4}^{+8}$ ms	3.86(93)#	0.5(10)#	14.54(93)#	[2013Og04]

* 100%  $\beta^-$ -emitter.

** Indirectly observed by the  $\beta^-$  daughter being present in bomb debris [1960Di03].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +59/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	BRα	BR _{SF}	Experimental
233		1 (1(40))			
235 Fr 237		1.61(40)#			
237 Ac		2.68(40)#			
241 Pa		3.33(30)#			
²⁴⁵ Np		3.69(36)#			
²⁴⁹ Am		4.83(36)#			
²⁵³ Bk	5.42(47)#	5.40(20)#			
²⁵⁷ Es	4.93(52)#	6.05(20)#			
²⁶¹ Md	4.48(67)#	6.75(30)#			
²⁶⁵ Lr	4.07(81)#	7.23(20)#			
²⁶⁹ Db	3.62(91)#	8.49(30)#			
²⁷³ Bh	3.13(95)#	9.11(20)#			
²⁷⁷ Mt	2.47(98)#	9.90(10)#		100%	[ <b>2013Og04</b> , 2022Og07, 2022Og08, 2017Ak02]
²⁸¹ Rg	2.3(11)#	9.90(40)#	10%	90%	[2022Og07, 2022Og08, 2013Og04, 2023Ko22, 2019Kh04, 2017Ak02,
					2013Og01, 2013Og04, 2012Og02, 2011Og04, 2011Og07, 2011OgZZ,
					2010Og01]
²⁸⁵ Nh	1.9(11)#	10.010(40)	100%		[2022Og07, 2022Og08, 2013Og04, 2023Ko22, 2019Kh04, 2017Ak02,
					2013Og01, 2013Og04, 2012Og02, 2011Og04, 2011Og07, 2011OgZZ,
					2010Og01]
²⁸⁹ Mc	1.5(11)#	10.490(50)	100%		[2022Og07, 2022Og08, 2013Og04, 2023Ko22, 2019Kh04, 2017Ak02,
					2013Og01, 2013Og04, 2012Og02, 2011Og04, 2011Og07, 2011OgZZ,
					2010Og01]
²⁹³ Ts	0.9(11)#	11.320(50)	100%		[2013Og04, 2019Kh04, 2012Og02, 2011Og04, 2011Og07, 2011OgZZ,
					2010Og01]
					-

# Table 3

direct $\alpha$ emiss	ect α emission from ²⁸¹ Rg*, $T_{1/2} = 11^{+3}_{-1}$ s**, $BR_{\alpha} = 10\%$ .										
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\pmb{\pi}}$	$E_{daughter}(^{277}\mathrm{Mt})$	coincident $\gamma$ -rays (keV)	HF					
9.52-9.69	9.38-9.55	10%									

* All values from [2013Og04], except where noted.

** [2022Og08].

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direct $\alpha$ emissio	n from ²⁶³ Nh*, $T_{1/2}$	$= 2.1^{+0.0}_{-0.3} \text{ ms}^{**},$	$BR_{\alpha} = 100\%$	6.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${\sf J}_f^\pi$	$E_{daughter}(^{281}\mathrm{Rg}$	coincident γ-rays (keV)	HF	
9.66-10.32	9.47-10.18	100%					
* All values ** [2022Og	from [2013Og04], e 08].	except where note	ed.				
Table 5							
direct $\alpha$ emissio	n from 289 Mc*, T _{1/2}	$= 250^{+51}_{-35} \text{ ms}^{**},$	$BR_{\alpha} = 100^{\circ}$	%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{285}\mathrm{Nh})$	coincident γ-rays (keV)	HF	
10.29-10.49	10.15-10.34	100%					
* All values ** [2022Og	from [2013Og04], e 08].	except where note	ed.				
<b>Table 6</b> direct $\alpha$ emissio	n from ²⁹³ Ts*, $T_{1/2}$	$=22^{+8}_{-4}$ ms, $BR_{\alpha}$	= 100%.				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{277}\mathrm{Mt})$	coincident γ-rays (keV)	HF	
10.75-11.36	10.60-11.20	100%					

* All values from [2013Og04].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$ = +30 nuclei.

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Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +30$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	Q _β -	$Q_{\beta}$ - $\alpha$	Experimental
²⁵⁶ Cf ²⁶⁰ Fm ²⁶⁴ No ²⁶⁸ Rf ²⁷² Sg	0+	12.3(12) m		-0.14(33)# -0.78(54)# -1.36(73)# -1.58(85)# -2.27(87)#		[1980Ho04]
²⁷⁶ Hs ²⁸⁰ Ds ²⁸⁴ Cn ²⁸⁸ Fl ²⁹² Lv	$0^+ \\ 0^+ \\ 0^+ \\ 0^+$	$\begin{array}{c} 0.36^{+1.72}_{-0.16} \text{ ms} \\ 114^{+17}_{-11} \text{ ms}^* \\ 688^{+170}_{-110} \text{ ms}^{**} \\ 18^{+16}_{-6} \text{ ms} \end{array}$	-0.77(94)# -0.19(96)# 0.45(91)# 1.0(10)# 1.5(10)#		$ \begin{array}{c}                                     $	[2021Sa01] [2021Sa01, 2011Og07] [2021Sa01, 2011Og07] [2011Og07]

* Weighted average of  $121^{+20}_{-13}$  ms [2021Sa01] and  $97^{+31}_{-19}$  ms [2011Og07]. ** Weighted average of  $650^{+120}_{-80}$  ms [2021Sa01] and  $800^{+270}_{-160}$  ms [2011Og07].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +30$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	Experimental
256Cf		5 56(10)#		100%	[1980Ha04]
²⁶⁰ Fm		6 30(30)#		10070	
²⁶⁴ No		6 82(40)#			
²⁶⁸ Rf		8.04(30)#			
²⁷² Sg		8.62(20)#			
²⁷⁶ Hs	4.88(94)#	9.24(20)#			
²⁸⁰ Ds	4.5(1)#	9.71(20)#		100%	[2023Sa03, 2021Sa01, 1999OgZW]
²⁸⁴ Cn	4.3(10)#	9.67(15)#	2%	98%	[2023Sa03, 2021Sa01, 2017Ka66, 2011Og07, 2014MoZV, 2014MoZU,
					2010Du06, 2005Og03, 2005OgZZ, 2002Og03, 2002Og09, 2003Og13,
					2002Og03, 2002Og13, 2001Og01, 2001Og06, 2001Og11, 2002OgZY,
					2000Og05, 2000Og07, 2000OgZS]
²⁸⁸ Fl	3.8(10)#	10.076(12)	100%	$\leq 2\%$	[2023Sa03, 2021Sa01, 2017Ka66, 2011Og07, 2014MoZV, 2014MoZU,
					2010Du06, 2010Ei01, 2005Og03, 2005OgZZ, 2002Og03, 2002Og09,
					2003Og13, 2002Og03, 2002Og13, 2001Og01, 2001Og06, 2001Og11,
					2002OgZY, 2000Og05, 2000Og07, 2000OgZS]
²⁹² Lv	3.3(11)#	10.791(12)	100%		[2017Ka66, 2011Og07, 2014MoZV, 2014MoZU, 2005Og03, 2005OgZZ,
					2002Og03, 2002Og09, 2003Og13,2002Og03, 2002Og13, 2001Og01,
					2001Og06, 2001Og11,2002OgZY, 2000Og05, 2000Og07, 2000OgZS]

### Table 3

direct  $\alpha$  emission from ²⁸⁴Cn*,  $J^{\pi} = 0^+$ ,  $T_{1/2} = 114^{+17}_{-11}$  ms**,  $BR_{\alpha} = 2\%$ ***.

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{280}\mathrm{Ds})$	coincident $\gamma$ -rays (keV)	HF					
9.30(5)	9.17(5)	100%	$0^+$								
* All val ** Weigl *** [202 <b>Table 4</b> direct α emis	* All values from [2017Ka66], except where noted ** Weighted average of $121^{+20}_{-13}$ ms [2021Sa01] and $97^{+31}_{-19}$ ms [2011Og07]. *** [2023Sa03]. <b>Table 4</b> direct $\alpha$ emission from ²⁸⁸ Fl*, $J^{\pi} = 0^+$ , $T_{1/2} = 688^{+170}_{-110}$ ms**, $BR_{\alpha} = 100\%$ .										
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{284}Cn)$	coincident γ-rays (keV)	HF					
9.98(5)	9.84(5)	100%	$0^+$								
* All val	* All values from [2017Ka66], except where noted										

** Weighted average of  $650^{+120}_{-80}$  ms [2021Sa01] and  $800^{+270}_{-160}$  ms [2011Og07].

### Table 5

direct $\alpha$ emiss	rect $\alpha$ emission from ²⁹² Lv*, $J^{\pi} = 0^+$ , $T_{1/2} = 18^{+16}_{-6}$ ms, $BR_{\alpha} = 100\%$ .									
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_{f}^{\pmb{\pi}}$	$E_{daughter}(^{288}\text{Fl})$	coincident $\gamma$ -rays (keV)	HF				
11.00(8)	10.84(8)	100%	$0^+$							

* All values from [2011Og07].

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258Es Stable to B+-decay  $Q_{\alpha} = 5.88 \# \text{ MeV}$ 

Fig. 1: Known experimental values for heavy particle emission of the odd-Z  $T_z$ = +30 nuclei.

Last updated 5/25/25

Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_z = +30$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	Q _β -	$Q_{\beta}$ - $\alpha$	Experimental	
258				2 220/45>#	0.14(40)#		
262				2.280(45)#	9.14(40)#		
²⁰² Md				1.57(58))#	9.00(49)#		
²⁶⁶ Lr		$11^{+21}_{-5}$ h		1.53(68)#	10.96(58)#	[2019Ko04, 2014Ko04]	
²⁷⁰ Db		$1.0^{+1.9}_{-0.4}$ h		0.97(74)#	10.02(71)#	[2019Ko04, 2014Ko04]	
²⁷⁴ Bh		$44^{+34}_{-13}$ s		0.36(74)#	11.83(69)#	[2017Og01]	
				$Q_{\varepsilon p}$	$Q_{\epsilon \alpha}$		
²⁷⁸ Mt		$4.5^{+3.5}_{-1.3}$ s	2.55(65)#	-2.62(83)#		[2017Og01]	
²⁸² Rg		$100^{+70}_{-30}$ s	2.95(66)#	-1.95(84)#	12.10(66)#	[2017Og01]	
²⁸⁶ Nh		$9.5^{+6.3}_{-2.7}$ s	3.51(92)#	-1.06(84)#	12.74(66)#	[2017Og01]	
²⁹⁰ Mc		$650^{+490}_{-200}$ ms	4.06(92)#	-0.05(78)#	13.92(92)#	[2017Og01]	
²⁹⁴ Ts		$51^{+38}_{-16}$ ms			15.241(918)	[2017Og01]	

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z,  $T_z = +30$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$\mathbf{S}_p$	Qα	$BR_{\alpha}$	BR _{SF}	Experimental
258 Fs		5 88(50)#			
²⁶² Md		6 54(20)#			
²⁶⁶ Lr		7.57(30)#		100%	[2019Ko04, 2014Ko04]
²⁷⁰ Db		8.31(20)#	$\approx 83\%$	$\approx 17\%$	[ <b>2019Ko04, 2014Ko04,</b> 2017Og01, 2013Og01, 2013Og04, 2012Og06,
					2012OgZZ, 2010Og01, 2010Og04]
²⁷⁴ Bh	3.45(70)#	8.940(60)	100%*		[2017Og01, 2013Og01, 2013Og04, 2012Og06, 2012OgZZ, 2010Og01,
					2010Og04]
²⁷⁸ Mt	2.90(73)#	9.580(30)	100%*		[2017Og01, 2013Og01, 2013Og04, 2012Og06, 2012OgZZ, 2010Og01,
					2010Og04]
²⁸² Rg	2.42(77)#	9.55(10)#	100%*		[2017Og01, 2013Og01, 2013Og04, 2012Og06, 2012OgZZ, 2010Og01,
					2010Og04]
²⁸⁶ Nh	2.42(78)#	9.790(50)	100%*		[2017Og01, 2013Og01, 2013Og04, 2012Og06, 2012OgZZ, 2010Og01,
					2010Og04]
²⁹⁰ Mc	1.8(10)#	10.410(40)	100%*		[2017Og01, 2013Og01, 2013Og04, 2012Og06, 2012OgZZ, 2010Og01,
					2010Og04]
²⁹⁴ Ts	1.46(79)#	11.180(40)	100%*		[2017Og01, 2013Og01, 2013Og04, 2012Og06, 2012OgZZ, 2010Og01,
					2010Og04]

* Only  $\alpha$ -decay has been observed.

### Table 3

direct $\alpha$ emiss	rect $\alpha$ emission from ²⁷⁰ Db*, $T_{1/2} = 1.0^{+1.9}_{-0.4}$ h, $BR_{\alpha} = \approx 83\%$ .										
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{266}\mathrm{Lr})$	coincident γ-rays (keV)	HF					
8.02(3)	7.90(3)	$\approx 83\%.$									
* All valu	ues from [2014Kh	n04, 2019Kh04].									
Table 4 direct $\alpha$ emiss	sion from ²⁷⁴ Bh*,	, $T_{1/2} = 44^{+34}_{-13}$ s,	$BR_{\alpha} = 100\%$	б.							
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${ m J}_f^{\pi}$	$E_{daughter}(^{270}\text{Db})$	coincident $\gamma$ -rays (keV)	HF					
8.86-8.97	8.73-8.84	100%									

* All values from [2017Og01], based on all available measurements.

direct $\alpha$ emiss	ion from ²⁷⁸ Mt*, T	$_{1/2} = 4.5^{+3.5}_{-1.3}$ s, <i>I</i>	$BR_{\alpha} = 100\%$				
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{274}\mathrm{Bh})$	coincident γ-rays (keV)	HF	
9.52-9.69	9.38-9.55	100%					
* All valu	es from [2017Og0]	], based on all a	vailable me	asurements.			
<b>Table 6</b> direct $\alpha$ emiss	ion from ²⁸² Rg*, T	$_{1/2} = 100^{+70}_{-30}$ s, <i>I</i>	$BR_{\alpha} = 100\%$	·.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{m \pi}$	$E_{daughter}(^{278}\mathrm{Mt})$	coincident γ-rays (keV)	HF	
8.99-9.18	8.86-9.05	100%					
* All valu	es from [2017Og0]	], based on all a	vailable me	asurements.			
<b>Table 7</b> direct $\alpha$ emiss	ion from ²⁸⁶ Nh*, T	$f_{1/2} = 9.5^{+6.3}_{-2.7}$ s, <i>I</i>	$3R_{\alpha} = 100\%$	·.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$J_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{282}\mathrm{Rg})$	coincident γ-rays (keV)	HF	
9.75-9.89	9.61-9.75	100%					
* All valu	es from [2017Og0]	], based on all a	vailable me	asurements.			
Table 8 direct $\alpha$ emiss	ion from ²⁹⁰ Mc*, T	$\Gamma_{1/2} = 650^{+490}_{-200} \text{ m}$	is, $BR_{\alpha} = 10$	00%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	E _{daughter} ( ²⁸⁶ Nh)	coincident γ-rays (keV)	HF	
9.92-10.45	9.78-10.31	100%					
* All valu	es from [2017Og0]	], based on all a	vailable me	asurements.			
<b>Table 9</b> direct $\alpha$ emiss	ion from ²⁹⁴ Ts*, T	$_{1/2} = 51^{+38}_{-16} \text{ ms}, 1$	$BR_{\alpha} = 100\%$	6.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{m{\pi}}$	$E_{daughter}(^{290}\mathrm{Mc})$	coincident γ-rays (keV)	HF	
10.96-11.22	10.81-11.07	100%					

* All values from [2017Og01], based on all available measurements.

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$  = +61/2 nuclei.

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### Table 1

Observed and predicted  $\beta$ -delayed particle emission from the even-Z,  $T_z = +61/2$  nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex.	$J^{\pi}$	<i>T</i> _{1/2}	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$Q_{\mathcal{E}\alpha}$		Experimental
²⁷⁷ Hs			$6^{+15}_{-2}$ s*	0.28(75)#			[2023Co04, 2011Ga19]	
²⁸¹ Ds			$15^{+3}_{-2}$ s**	0.87(78)#	-2.44(78)#	9.75(78)#	[2023Co04, 2004Og12]	
²⁸⁵ Cn			$36_{-5}^{+8}$ s***	1.36(79)#	-1.66(71)#	10.26(79)#	[2023Co04, 2004Og12]	
²⁸⁹ Fl			$2.5^{+0.8}_{-0.5}$ s	1.92(72)#	-0.75(87)#	11.31(79)#	[2023Co04]	
289mFl	0.070(36)		$1.1^{+1.1}_{-0.4}$ s	1.99(81)#	-0.05(94)#	11.38(87)#	[2023Co04]	
²⁹³ Lv			$61^{+57}_{-20}$ ms			12.60(72)#	[2004Og12]	

* Weighted average of  $18^{+25}_{-7}$  ms [2023Co04] and  $3^{+15}_{-2}$  ms [2011Ga19]. ** Weighted average of  $19^{+4}_{-3}$  ms [2023Co04] and  $11.1^{+5.0}_{-2.7}$  ms [2004Og12]. *** Weighted average of  $42^{+10}_{-7}$  s [2023Co04] and  $29^{+13}_{-13}$  ms [2004Og12].

### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +61/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	Experimental
277	4.96(75)#	0.02(20)		1000	
HS	4.86(75)#	9.03(20)#		100%	[ <b>2023C004, 2011Ga19</b> , 2012H012]
²⁸¹ Ds	4.53(78)#	9.47(21)#	10%	90%	[2023Co04, 2011Ga19, 2004Og12, 2017Ka66, 2014MoZU, 2014Ya33,
					2012Ho12, 2010Du06, 2010DuZY, 2007Og05, 2005Og02, 2005OgZZ,
					2004Og12, 2004Og07, 2004OgZZ, 2000Og01]
²⁸⁵ Cn	4.17(71)#	9.39(12)#	100%		[2023Co04, 2011Ga19, 2004Og12, 2017Ka66, 2014MoZU, 2014Ya33,
					2012Ho12, 2010Du06, 2010DuZY, 2007Og05, 2005Og02, 2005OgZZ,
					2004Og12, 2004Og07, 2004OgZZ, 2002Og09, 2001Og01, 2000Og01]
²⁸⁹ Fl	3.79(87)#	9.954(65)#	100%		[2023Co04, 2011Ga19, 2004Og12, 2017Ka66, 2014MoZU, 2014Ya33,
					2012Ho12, 2010Du06, 2010DuZY, 2007Og05, 2005Og02, 2005OgZZ,
					2004Og12, 2004Og07, 2004OgZZ, 2002Og09, 2001Og01, 2000Og01]
^{289m} Fl	3.72(94)#	10.024(74)#	100%		[2023Co04]
²⁹³ Lv	3.32(87)#	10.677(64)	100%		2004Og12, 2017Ka66, 2014MoZU, 2014Ya33, 2012Ho12, 2010Du06,
	~ /				2010DuZY, 2007Og05, 2005Og02, 2005OgZZ, 2004Og12, 2004Og07,
					2004OgZZ, 2002Og09, 2001Og01, 2000Og01]
					2004OgZZ, 2002Og09, 2001Og01, 2000Og01]

## Table 3

$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\pi}$	$E_{daughter}(^{277}\text{Hs})$	coincident γ-rays (keV)	HF	
8.88(2)	8.75(2)	10%		0.090			
** Weig Table 4	nted average of 1	$3^{+25}_{-7}$ ms [2023Co	$(5004]$ and $3^+_{-1}$	¹⁵ ms [2011Ga19].			
$\frac{1}{2} \frac{1}{2} \frac{1}$	sion from $^{285}Cn^*$	$rac{1}{3}rac{1}{2}rac{1}{2}rac{1}{3}rac{1}{2}rac{1}{3}rac{1}{2}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}rac{1}{3}r$	$5004$ ] and $3^+_{-}$ *, $BR_{\alpha} = 10$	¹⁵ ms [2011Ga19]. 00%.	coincident of rays (IroV)	UE	
** Weight <b>Table 4</b> direct $\alpha$ emist $E_{\alpha}(c.m.)$	sion from ²⁸⁵ Cn* $E_{\alpha}(\text{lab})$	$T_{1/2} = 36^{+8}_{-5} \text{ s*}$ $I_{\alpha}(\text{abs})$	*, $BR_{\alpha} = 10^{-10}$	¹⁵ ms [2011Ga19]. 00%. <i>E_{daughter}</i> ( ²⁸¹ Ds)	coincident γ-rays (keV)	HF	

* All values from [2023Co04], except where noted. ** Weighted average of  $42^{+10}_{-7}$  s [2023Co04] and  $29^{+13}_{-7}$  ms [2004Og12].

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direct $\alpha$ emis	sion from ²⁸⁹ Fl*,	$T_{1/2} = 2.5^{+0.8}_{-0.5} s$	$BR_{\alpha} = 100$	%.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	${f J}_f^{\pi}$	$E_{daughter}(^{285}\mathrm{Cn})$	coincident γ-rays (keV)	HF	
9.94(2)	9.80(2)	100%		0.030			
* All val	ues from [2023Co	o04].					
Table 6 direct $\alpha$ emis	sion from ^{289m} Fl [?]	*, Ex. = 70(36) k	eV, $T_{1/2} = 1$	$1.1^{+1.1}_{-0.4}$ s, $BR_{\alpha} = 100\%$ .			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}_f^{\boldsymbol{\pi}}$	$E_{daughter}(^{285}\mathrm{Cn})$	coincident γ-rays (keV)	HF	
10.04(3)	9.90(3)	100%		0.0			
* All val	ues from [2023Co	o04].					
Table 7 direct $\alpha$ emis	sion from ²⁹³ Lv*	, $T_{1/2} = 61^{+57}_{-20}$ m	ns, $BR_{\alpha} = 10$	00%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	<i>E</i> _{daughter} ( ²⁸⁵ Cn)	coincident $\gamma$ -rays (keV)	HF	
10.69(6)	10.54(6)	100%					

* All values from [2004Og12].

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Fig. 1: Known experimental values for heavy particle emission of the even-Z  $T_z$  = +31 nuclei.

Last updated 5/25/25

Observed and predicted $\beta$ -delayed particle emission from the even-Z, $T_z = +31$ nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or ded	uced
from values therein.	

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\mathcal{E}}$	$Q_{\varepsilon p}$	$Q_{\varepsilon \alpha}$	Experimental
²⁷⁸ Hs	$0^+$	$690^{+3300}_{-210}$ s	-1.15(50)#			[ <b>2016H</b> 009]
²⁸² Ds	$0^+$	$42^{+146}_{-13}$ s*	-0.67(54)#			[2023Sa03, 2016Ho09]
²⁸⁶ Cn	$0^+$	$10.3^{+37.0}_{-3.5}$ s**	-0.06(84)#			[2023Sa03, 2017Ka66]
²⁹⁰ Fl	$0^+$	$0.31_{0.14}^{+1.48}$ s	0.42(84)#		9.80(84)#	[2023Sa03]

* Weighted average of  $38^{+165}_{-15}$  s [2023Sa03] and  $67^{+320}_{-30}$  s [2016Ho09]. ** Weighted average of  $19^{+91}_{-8}$  s [2023Sa03] and  $8.4^{+40.5}_{-3.9}$  s [2017Ka66].

#### Table 2

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +31$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	Qα	BRα	BR _{SF}	Experimental
²⁷⁸ Hs ²⁸² Ds ²⁸⁶ Cn ²⁹⁰ Fl	5.17(67)# 4.90(67)# 4.57(92)# 4.11(86)#	9.15(42)# 9.24(76)# 9.856(30)	obs obs 100%	100% obs obs	[2016Ho09] [2023Sa03, 2016Ho09] [2023Sa03, 2017Ka66, 2016Ho09] [2023Sa03, 2017Ka66, 2016Ho09]

## Table 3

direct $\alpha$ emiss	sion from ²⁸² Ds*	, $T_{1/2} = 42^{+146}_{-13}$ s	**, $BR_{\alpha} = 0$	bs.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	${ m J}_f^\pi$	$E_{daughter}(^{278}\mathrm{Hs})$	coincident γ-rays (keV)	HF	
8.96(18)	8.83(18)						
* All valu ** Weigh	ues from [2016He ated average of 38	$^{(009]}_{-15}$ , except when $^{(100)}_{-15}$ s [2023Sa0	re noted. 3] and $67^{+32}_{-34}$	²⁰ s [2016Ho09].			
Table 4 direct $\alpha$ emiss	sion from ²⁸⁶ Cn*	, $T_{1/2} = 10.3^{+37.0}_{-3.5}$	⁰ s**, <i>BR</i> α =	= obs.			
$E_{\alpha}(c.m.)$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	$E_{daughter}(^{282}\mathrm{Ds})$	coincident γ-rays (keV)	HF	
8.793(45)	8.670(45)						
* All valu ** Weigh	ues from [2016Ho nted average of 19	$p_{-8}^{009}$ , except when $p_{-8}^{+91}$ s [2023Sa03	re noted. [3] and $8.4^{+40}_{-3.}$	9.5 s [2017Ka66].			
Table 5 direct $\alpha$ emiss	sion from ²⁹⁰ Fl*,	$T_{1/2} = 0.31_{0.14}^{+1.48}$	s, $BR_{\alpha} = 10$	00%.			
$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\text{lab})$	$I_{\alpha}(abs)$	$\mathrm{J}_f^\pi$	E _{daughter} ( ²⁸⁶ Cn)	coincident γ-rays (keV)	HF	
9.86(3)	9.72(3)	100%					

* All values from [2023Sa03].

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