

Table 1

Observed and predicted β -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^π values for ^{209}Pb , ^{213}Po , and ^{217}Rn are taken from ENSDF.

Nuclide	Ex.	J^π	$T_{1/2}$	Q_ϵ	$Q_{\epsilon p}$	$Q_{\epsilon\alpha}$	Experimental
$^{209}\text{Pb}^*$		9/2 ⁺	3.232(5) h	-3.970(6)	—	—	[2013Su13]
^{213}Po		9/2 ⁺	3.6984(6) μs	-1.422(5)	—	—	[2023Al22]
^{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)	[1973Ja06]
^{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]
^{253m}Rf	x		52.8(44) μs	5.12(44)#+x	3.48(41)#+x	14.04(44)#+x	[2022Lo03]

* 100% β^- 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	Q_α	BR_α	BR_{SF}	$\text{BR}_{cluster}$	type	Experimental
^{209}Pb	8.153(2)	2.248(4)					
^{213}Po	5.825(3)	8.536(3)	100%				[1982Bo04, 1964Va20, 2023Al22, 2020Ko06, 2018Al32, 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%				[1982Bo04, 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)*	$\approx 20\%$				[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]
^{253m}Rf	2.18(45)#-x	9.4460(20)*+x		100%			[2022Lo03, 2022Te01, 2021Kh07]

* Deduced from α energies. Values from [2021Wa16] are 6.476(3) MeV (^{229}U); 6.416(54) MeV (^{233}Pu); 7.66(15)# MeV (^{241}Cf); 8.44(10)# MeV (^{245}Fm); 9.17(20)# MeV (^{249}No) and 9.43(30)# MeV (^{253}Rf).

** [1994Bo28].

Table 3
direct α emission from ^{213}Po , $J^\pi = 9/2^+$, $T_{1/2} = 3.6984(6) \mu\text{s}^*$, $BR_\alpha = 100\%$.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	$J_f^{\pi**}$	$E_{daughter}(^{209}\text{Pb})^{**}$	coincident γ -rays**	R_0 (fm)	HF
7.760(10)	7.614(10)***	0.003(1)%***	0.003(1)%	11/2 ⁺	0.7789(1)	0.7789(1)	1.53069(10)	360 ⁺¹⁸⁰ ₋₉₀
8.536(3)	8.376(3) [@]	100%	99.997(1)%	9/2 ⁺	0.0	—	1.53069(10)	1.486(26)

* [2023Al22].

** [2015Ch30].

*** From [1964Va20], E_α adjusted by -0.5 keV in [1991Ry01].

[@] [1982Bo04].

Table 4
direct α emission from ^{217}Rn , $J^\pi = 9/2^+$, $T_{1/2} = 0.59(4) \text{ms}^*$, $BR_\alpha = 100\%$.

E_α (c.m.)	E_α (lab)	I_α (abs)	J_f^π	$E_{daughter}(^{213}\text{Po})$	coincident γ -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
direct α emission from $^{221}\text{Ra}^*$, $J^\pi = 5/2^+$, $T_{1/2} = 26.20(39) \text{s}^{**}$, $BR_\alpha = 100\%$.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π	$E_{daughter}(^{217}\text{Rn})$	coincident γ -rays	R_0 (fm)	HF
6.260	6.147	0.13%	$\approx 0.05\%$	(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%	$\approx 0.05\%$	(7/2, 11/2)	0.4745	0.4745	1.5516(38)	≈ 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%	$\approx 0.1\%$	(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%	$\approx 0.05\%$	(3/2 ⁺)	0.2352	0.0562, 0.0860, 0.0930,	1.5516(38)	$\approx 1.1 \times 10^3$
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_α or I_α were given.

** Weighted average of 26.37(17 st.)(50 sys.)s and 26.00(18 st.)(55 sys.) s [2024Ba08].

Table 6
direct α emission from $^{225}\text{Th}^*$, $J^\pi = (3/2^+)$, $T_{1/2} = 8.72(4)$ m**, $BR_\alpha = 100\%$.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π ***	$E_{daughter}(^{221}\text{Ra})$ ***	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_{-3}^{+9}
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_{-4}^{+11}
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_{-110}^{+320}
6.861(5)	6.739(5)	16(2)%	7(1)%	$7/2^+$	0.0531	0.0531	1.5380(16)	141_{-19}^{+25}
6.916(5)	6.793(5)	21(3)%	9(1)%	$5/2^+$	0.0	—	1.5380(16)	177_{-21}^{+25}

* All values from [1961Ru06], except where noted.

** [1987Mi10].

*** [1988LiZN].

Table 7
direct α emission from $^{229}\text{U}^*$, $J^\pi = (3/2^+)$, $T_{1/2} = 58(3)$ m**, $BR_\alpha \approx 20\%$.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π	$E_{daughter}(^{225}\text{Th})$	coincident γ -rays	R_0 (fm)	HF
6.290(4)	6.180(4)	1.6(8)%	$\approx 0.2\%$		0.178(4)		1.5278(27)	≈ 15
6.329(3)	6.218(3)	4.7(16)%	$\approx 0.6\%$		0.139(3)		1.5278(27)	≈ 8
6.366(3)	6.255(3)	1.6(8)%	$\approx 0.2\%$		0.102(3)		1.5278(27)	≈ 30
6.404(2)	6.292(2)	17.2(16)%	$\approx 2.2\%$		0.064(2)		1.5278(27)	≈ 4.5
6.439(2)	6.327(2)	31.3(31)%	$\approx 4\%$		0.028(2)		1.5278(27)	≈ 3.6
6.468(3)	6.355(3)	100%	$\approx 13\%$	$(3/2^+)$	0.0	—	1.5278(27)	≈ 1.5

* All values from [1961Ru06], except where noted.

** [1951Me10].

Table 8
direct α emission from $^{233}\text{Pu}^*$, $T_{1/2} = 20.9(4)$ m**, $BR_\alpha = 0.12(5)\%$.

E_α (c.m.)	E_α (lab)	I_α (abs)	J_f^π	$E_{daughter}(^{229}\text{U})$	coincident γ -rays	R_0 (fm)	HF
6.410(20)	6.300(20)	0.12(5)%	$(3/2^+)$	0.0	—	1.503(39)	3_{-2}^{+4}

* All values from [1957Th10], except where noted.

** [1973ja06].

Table 9
direct α emission from ^{237}Cm , $BR_\alpha < 1\%*$.

E_α (c.m.)	E_α (lab)	I_α (abs)	J_f^π	$E_{daughter}(^{233}\text{Pu})$	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].

Table 10
direct α emission from ^{241}Cf , $T_{1/2} = 141(11)$ s, $BR_{\alpha} = 15(1)\%^{**}$.

E_{α} (c.m.)	E_{α} (lab)	I_{α} (abs)	J_f^{π}	$E_{\text{daughter}}(^{237}\text{Cm})$	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 values from [2010AsZX], except where noted.
** [2020Kh10].

Table 11
direct α emission from ^{245}Fm , $T_{1/2} = 5.5(7)$ s^{**}, $BR_{\alpha} = 88.5^{+6.8}_{-5.0}\%^{**}$.

E_{α} (c.m.)	E_{α} (lab)	I_{α} (abs)	J_f^{π}	$E_{\text{daughter}}(^{241}\text{Cf})$	coincident γ -rays	R_0 (fm)	HF
8.290(7)	8.155(7)	100%		0.0	—	1.506(33)	$1.5^{+1.8}_{-0.9}$

* All values from [2020Kh10], except where noted.
** [2022Te01].

Table 12
direct α emission from ^{249}No , $T_{1/2} = 38.3(28)$ ms, $BR_{\alpha} = 100\%$.

E_{α} (c.m.)	E_{α} (lab)	I_{α} (abs)	J_f^{π}	$E_{\text{daughter}}(^{245}\text{Fm})$	coincident γ -rays	R_0 (fm)	HF
9.278(22)	9.129(22)	100%		0.0	—	1.504(24)	$1.8^{+1.4}_{-0.8}$

* All values from [2022Te01, 2021Sv02].

Table 13
direct α emission from ^{253}Rf , $T_{1/2} = 9.9(12)$ ms, $BR_{\alpha} = 17(6)\%$.

E_{α} (c.m.)	E_{α} (lab)	I_{α} (rel)	I_{α} (abs)	J_f^{π}	$E_{\text{daughter}}(^{249}\text{No})$	coincident γ -rays	R_0 (fm)	HF
9.358(20)	9.210(20)	$\approx 67\%^{**}$	$\approx 7\%$		0.102		1.479(46)	≈ 1.5
9.460(20)	9.310(20)	$100\%^{**}$	$\approx 10\%$		0.0	—	1.479(46)	≈ 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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