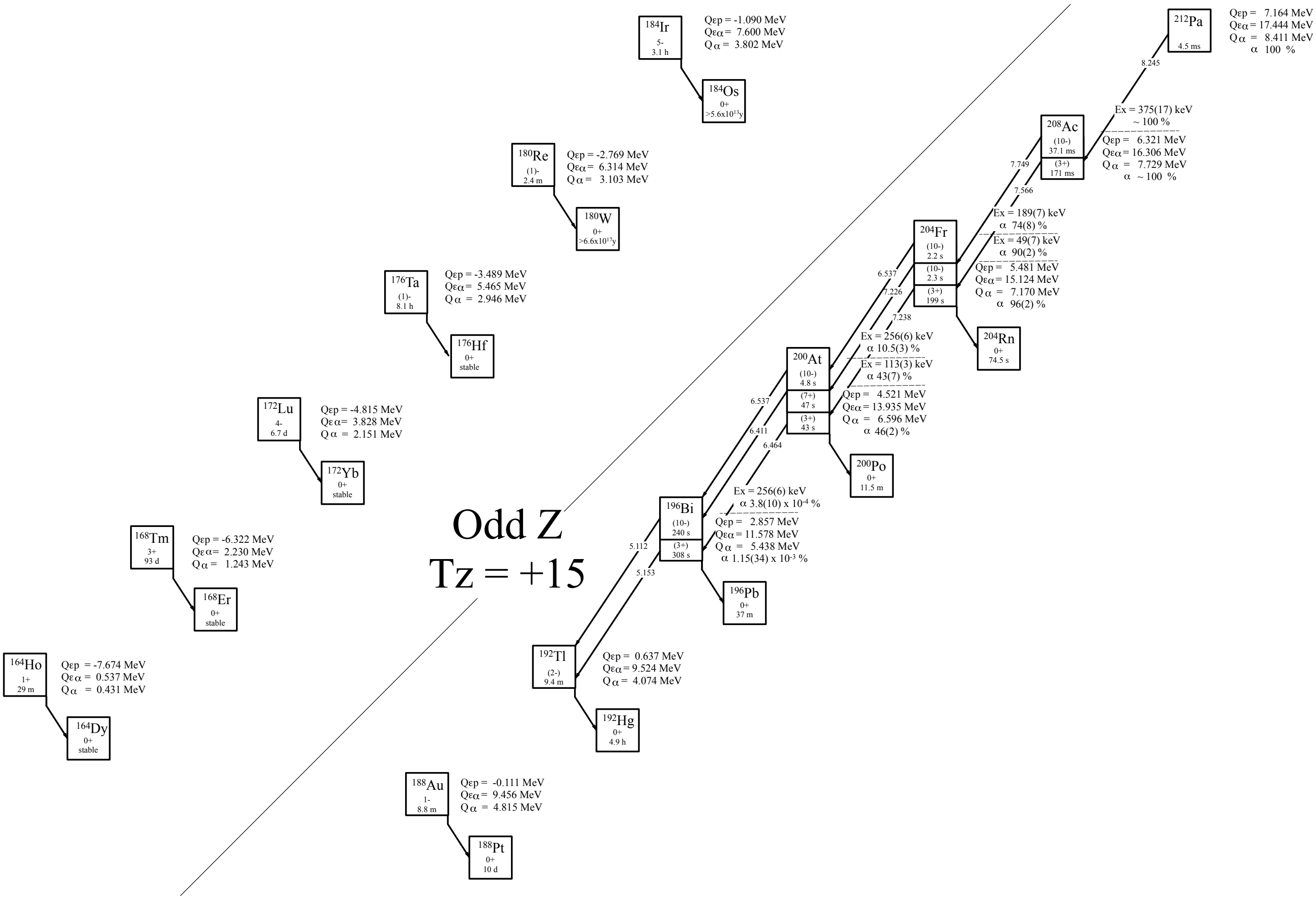

Fig. 1: Known experimental values for heavy particle emission of the odd-Z T_z= +15 nuclei.

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Table 1
Observed and predicted β-delayed particle emission from the odd-*Z*, T_z = +15 nuclei. J^{π} values for ^{164}Ho, ^{168}Tm, ^{172}Lu, ^{176}Ta, ^{180}Re, ^{184}Ir, ^{188}Au, and ^{192}Tl are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	Ex	J^{π}	$T_{1/2}$	Q_{ε}	$Q_{\varepsilon p}$	$Q_{\varepsilon\alpha}$	Experimental
^{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)	[**1979To06**]
^{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 ^{200}At α 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	S_p	S_{2p}	Q_{α}	BR_{α}	Experimental
^{164}Ho	5.889(1)	13.679(2)	0.431(2)		
^{168}Tm	5.312(2)	12.820(2)	1.243(2)		
^{172}Lu	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)	≈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 α energy, 7.729(60) in [2021Wa16].

Table 3

direct α emission from ^{196}Bi*, J_i^π = (3$^+$), $T_{1/2}$ = 308(12) s, BR_α = 1.15(34) × 10^{-3} %.

E_α(c.m.)	E_α(lab)	I_α(abs)	J_f^π	$E_{daughter}$(^{192}Tl)	coincident γ-rays	R_0 (fm)***	HF
5.260(10)	5.153(10)	1.15(34) × 10^{-3} %	(3$^+$)	0.178(40)**		1.467(24)	$2.2^{+1.9}_{-1.1}$

* All values from [1991Va04, 1992Hu04], except where noted.
** [2012Ba36].
*** Interpolated between 1.437(24) fm (^{194}Pb) and 1.4962(19) fm (^{198}Po).

Table 4

direct α emission from ^{196m}Bi*, Ex. = 256(6) keV, J_i^π = (10$^-$), $T_{1/2}$ = 240(3) s, BR_α = 3.8(10) × 10^{-4} %.

E_α(c.m.)	E_α(lab)	I_α(abs)	J_f^π	$E_{daughter}$(^{192}Tl)	coincident γ-rays	R_0 (fm)***	HF
5.219(10)	5.112(10)	3.8(10) × 10^{-4} %	(10$^-$)	0.3204 + x**		1.467(24)	$3.1^{+2.5}_{-1.5}$

* All values from [1991Va04, 1992Hu04], except where noted.
** [2012Ba36].
*** Interpolated between 1.437(24) fm (^{194}Pb) and 1.4962(19) fm (^{198}Po).

Table 5

direct α emission from ^{200}At, J_i^π = (3$^+$), $T_{1/2}$ = 43(1) s*, BR_α = 46(2)%**.

E_α(c.m.)	E_α(lab)	I_α(abs)	J_f^π	$E_{daughter}$(^{196}Bi)	coincident γ-rays	R_0 (fm)@	HF
6.596(1)	6.464(1)*	46(2)%**	(3$^+$)	0.0	—	1.5034(53)	3.3(4)

* [1992Hu04].
** Weighted average of 49(4)% [1998Bo14], 44(2)% [1996Ta18] and 57(6)% [1992Hu04].
*** [1996Ta18].
@ Interpolated between 1.4962(19) fm (^{198}Po) and 1.5106(49) (^{202}Rn).

Table 6

direct α emission from ^{200m1}At*, Ex. = 113(3) keV, J_i^π = (7$^+$), $T_{1/2}$ = 47(1) s, BR_α = 43(7)%.

E_α(c.m.)	E_α(lab)	I_α(rel)	I_α(abs)	J_f^π	$E_{daughter}$(^{196}Bi)	coincident γ-rays	R_0 (fm)**	HF
6.435(5)	6.306(5)	0.17(4)%	0.073(15)%	(10$^-$)	0.256(6)		1.5034(53)	1300^{+500}_{-300}
6.542(2)	6.411(2)	100(16)%	43(7)%	(7$^+$)	0.054(2)		1.5034(53)	$6.6^{+1.7}_{-1.3}$
6.709(3)	6.575(3)	0.84(20)%	0.36(6)%	(3$^+$)	0.0	—	1.5034(53)	1300^{+600}_{-300}

* All values from [1992Hu04], except where noted.
** Interpolated between 1.4962(19) fm (^{198}Po) and 1.5106(49) (^{202}Rn.

Table 7

direct α emission from ^{200m2}At, Ex. = 256(6) keV, J_i^π = (10$^-$), $T_{1/2}$ = 4.8(3) s*, BR_α = 10.5(3)%**.

E_α(c.m.)	E_α(lab)	I_α(abs)	J_f^π	$E_{daughter}$(^{196}Bi)	coincident 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)

* Weighted average of 6.3(5) s [1996Ta18] and 4.3(3) s [1967Tr06].
** [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 (^{198}Po) and 1.5106(49) (^{202}Rn.

Table 8
direct α emission from ^{204}Fr, J_i^π = (3$^+$), $T_{1/2}$ = 1.99(12) s, BR_α = 96(2)%**.

E_α(c.m.)	E_α(lab)	I_α(rel)	I_α(abs)	J_f^π	$E_{daughter}$(^{200}At)	coincident γ-rays	R_0 (fm)@	HF
7.054(8)	6.916(8)***	≤0.6%	≤0.6%		0.113(3)		1.5197(65)	≥18
7.172(5)	7.031(5)***	100%	95(2)%	(3$^+$)	0.0	—	1.5197(65)	2.4(4)

* [2022Ya27].
** [1995BiZZ].
*** [1992Hu04].
@ Interpolated between 1.5106(49) fm (^{202}Rn) and 1.5287(42) fm (^{206}Ra).

Table 9
direct α emission from ^{204m1}Fr*, Ex. = 49(7) keV, J_i^π = (7$^+$), $T_{1/2}$ = 2.3(3) s*, BR_α = 90(2)%**.

E_α(c.m.)	E_α(lab)	I_α(rel)	I_α(abs)	J_f^π	$E_{daughter}$(^{200}At)	coincident γ-rays	R_0 (fm)**	HF
7.108(5)	6.969(5)***	100%	89(2)%	(7$^+$)	0.113(3)		1.5197(65)	≥250
7.219(8)	7.077(8)	≤0.7%	≤0.6%	(3$^+$)	0.0	—	1.5197(65)	4.4(9)

Weighted average of 1.6$^{+0.5}_{-0.3}$ s [2005Uu02] and 2.63) s [1992Hu04].
** [1995BiZZ].
*** [1992Hu04].
@ Interpolated between 1.5106(49) fm (^{202}Rn) and 1.5287(42) fm (^{206}Ra).

Table 10
direct α emission from ^{204m2}Fr, Ex. = 189(7) keV, J_i^π = (10$^-$), $T_{1/2}$ = 0.8(2) s*, BR_α = 74(8)%**.

E_α(c.m.)	E_α(lab)	I_α(abs)	J_f^π	$E_{daughter}$(^{200}At)	coincident γ-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].
@ Interpolated between 1.4962(19) fm (^{198}Po) and 1.5106(49) (^{202}Rn.

Table 11
direct α emission from ^{208}Ac, J_i^π = (3$^+$), $T_{1/2}$ = 171(13) ms*, BR_α = ≈100%.

E_α(c.m.)	E_α(lab)	I_α(rel)	I_α(abs)	J_f^π	$E_{daughter}$(^{204}Fr)	coincident γ-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].
** 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).

Table 12
direct α emission from ^{208m}Ac, Ex. = 375(17) keV, J_i^π = (10$^-$), $T_{1/2}$ = 37.1(37) ms*, BR_α = ≈100%.

E_α(c.m.)	E_α(lab)	I_α(abs)	J_f^π	$E_{daughter}$(^{204}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).

Table 13
direct α emission from ^{212}Pa, J_i^π = , $T_{1/2} = 4.5^{+2.7}_{-1.3}$ ms*, BR_α = 100%.

E_α(c.m.)	E_α(lab)	I_α(abs)	J_f^π	$E_{daughter}$(^{208}Ac)	coincident γ-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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