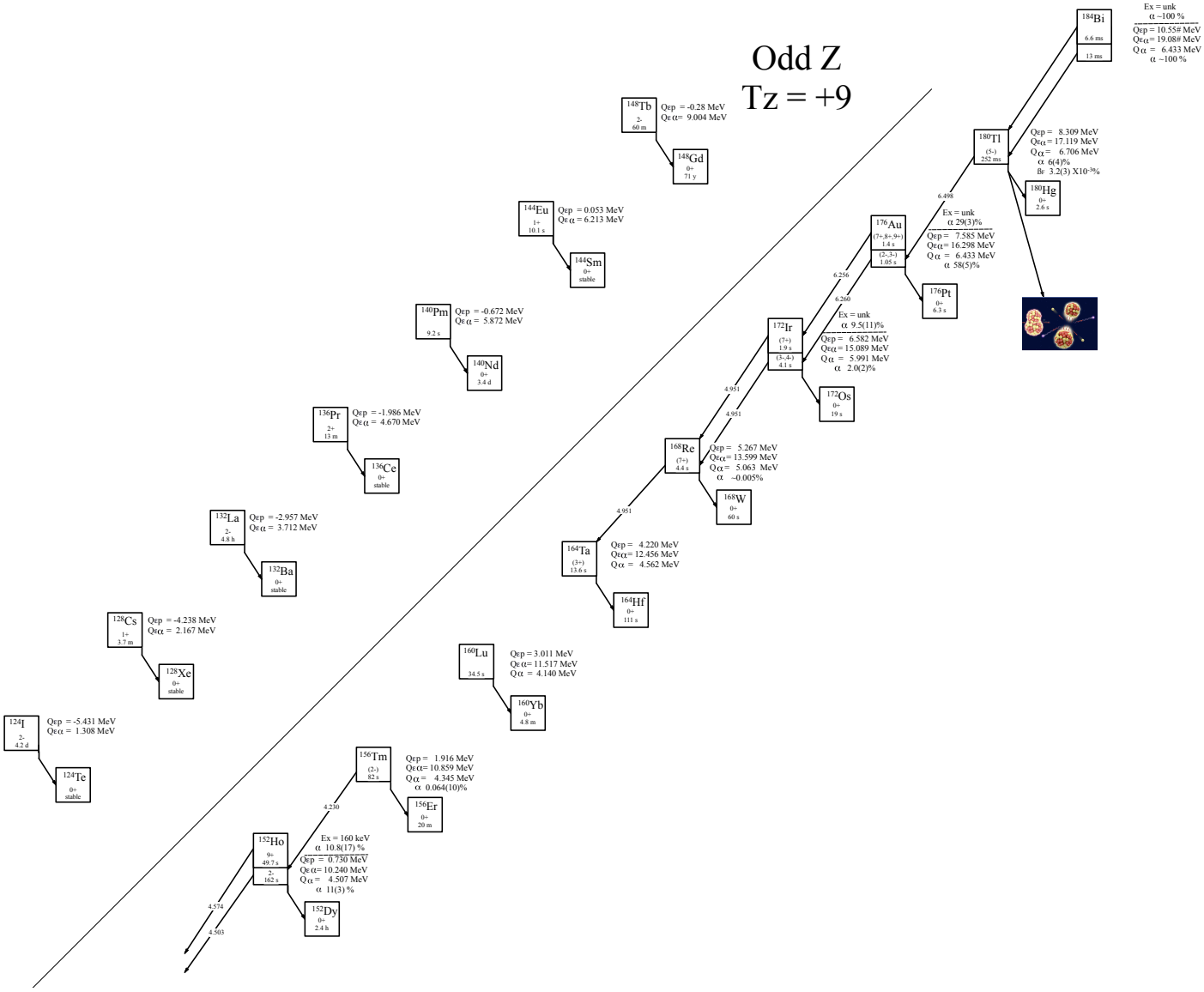

Fig. 1: Known experimental values for heavy particle emission of the odd-Z T_z= +9 nuclei.

last updated 1/23/23

Table 1
Observed and predicted β-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^π values for ^{124}I, ^{128}Cs, ^{132}La, ^{136}Pr, ^{140}Pm, ^{144}Eu, ^{148}Tb, ^{164}Ta, are taken from ENSDF.

Nuclide	Ex	J^π	$T_{1/2}$	Q$_\varepsilon$	$Q_{\varepsilon p}$	$Q_{\varepsilon\alpha}$	BR$_{\beta F}$	Experimental
^{124}I		2^-	4.1760(3) d	0.303(1.9)	-5.431(2)	1.308(2)		[**1992Wo03**]
^{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)		[**1982Bo04**]
^{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	x	(7^+)	1.89(5) s	9.860(30)+x	6.582(43)+x	15.089(35)+x		[**2023Zh03**]
^{176}Au***	y	(2^-,3^-)	1.046(11) s	10.410(40)+y	7.585(35)+y	16.298(36)+y		[**2021Ha37, 2004GoZZ**]
^{176m}Au***	x	(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)	$3.2(3)\times10^{-3}$%	[**2011El07**]
^{184}Bi***	y		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**]

* 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 ^{176}Au and ^{184}Bi isomers are unknown.

Table 2
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	S_p	S_{2p}	Q_α	BR_α	Experimental
^{124}I	5.483(2)	13.608(3)	-1.372(8)	——	
^{128}Cs	4.900(7)	12.599(7)	-0.992(6)	——	
^{132}La	4.334(36)	11.402(37)	-0.217(37)	——	
^{136}Pr	4.013(15)	10.700(23)	-0.042(38)	——	
^{140}Pm	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, 1982Bo04, 1982To14, 1977Ha48, 1974Sc19**, 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)	≈0.005%	[**1992Me10**, 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)#-y	-0.00(12)#-y	8.22(10)#+y	≈ 100%**	[**2003An27, 2003AnZZ**]
^{184}Bi	-1.55(13)#-x	-0.00(12)#-x	8.22(10)#+x	≈ 100%**	[**2003An27, 2003AnZZ**]

* Weighted average of 11(2)% [1981Ga36] and 10.5(30)% [1979To09].
** Inferred from half-life.

Table 3
direct α emission from ^{152}Ho*, $J^\pi = 2^-$, $T_{1/2}$ = 161.8(3) s**, BR_α = 11(3)%***.

E_α(c.m.)	E_α(lab)	I_α(rel)	I_α(abs)	J^π_f	$E_{daughter}$(^{148}Tb)$^{@}$	coincident γ-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 α transition.
$^{@}$ [2014Ni05].
$^{@@}$ Interpolated between 1.565(6) fm ^{150}Dy and 1.556(18) fm ^{154}Er.

Table 4
direct α emission from ^{152m}Ho*, Ex = 160(1) keV, $J^\pi = 9^+$, $T_{1/2}$ = 49.7(3) s**, BR_α = 10.8(17)%***.

E_α(c.m.)	E_α(lab)	I_α(rel)	I_α(abs)	J_f^π	$E_{daughter}$(^{148}Tb)[@]	coincident γ-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 α emission from ^{156}Tm, $J^\pi = 2^-$, $T_{1/2}$ = 82(3) s*, BR_α = 0.064(10)%**.

E_α(c.m.)	E_α(lab)	I_α(abs)	J_f^π	$E_{daughter}$(^{152}Ho)	coincident γ-rays	R_0 (fm)[@]	HF
4.341(10)	4.230(10)	0.064(10)%**	2^-	0.0	——	1.540(54)[@]	$1.5^{+2.7}_{-1.0}$

* Weighted average of 80(3) s [1982To14] and 86(4) s and [1981Ga36].
** [1981Ga36].
*** [1982To14].
[@] Interpolated between 1.556(18) fm ^{154}Er and 1.523(51) ^{158}Yb.

Table 6
direct α emission from ^{168}Re*, $J^\pi = (7^+)$, $T_{1/2}$ = 4.4(1) s, BR_α = ≈0.005%.

E_α(c.m.)	E_α(lab)	I_α(abs)	J_f^π	$E_{daughter}$(^{164}Ta)	coincident γ-rays	R_0 (fm)[@]	HF
4.951(13)	4.833(13)	≈0.005%		0.1118	0.1118	1.611(23)[@]	≈ 11

* All values from [1992Me10].
** Interpolated between 1.660(23) fm ^{166}W and 1.562(4) ^{170}Os.

Table 7
direct α emission from ^{172}Ir*, $J^\pi = (3^-, 4^-)$, $T_{1/2}$ = 4.1(2) s, BR_α = 2.0(2)%**.

E_α(c.m.)	E_α(lab)	I_α(abs)	J_f^π	$E_{daughter}$(^{168}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) ^{170}Os and 1.5553(31) ^{174}Pt.

Table 8
direct α emission from ^{172m}Ir*, Ex = unk., $J^\pi = (7^+)$, $T_{1/2}$ = 2.0(1) s**, BR_α = 9.5(11)%***.

E_α(c.m.)	E_α(lab)	I_α(rel)	I_α(abs)	J_f^π	$E_{daughter}$(^{168}Re)	coincident γ-rays	R_0 (fm)[@]	HF
5.892(7)	5.755(7)	<0.05%	<0.004%		0.224(1)	0.224(1)	1.559(5)[@@]	$>7\times10^3$
5.957(10)	5.818(4)	100%	8.8(10)%		0.1621(2)	0.1621(2)	1.559(5)[@@]	$7.1^{+1.5}_{-1.3}$
6.125(15)	5.983(15)[@]	8(2)%	0.8(2)%	(7^+)	0.0	——	1.559(5)[@@]	420^{+23}_{-13}

* All values from [2023Zh03], unless otherwise noted.
** [1992Sc16].
*** [2014An10].
[@] Only observed in [2021Ha32].
[@@] Interpolated between 1.562(4) ^{170}Os and 1.5553(31) ^{174}Pt.

Table 9
direct α emission from ^{176}Au*, J^{π} = (2^-,3^-), $T_{1/2}$ = 1.046(11) s**, BR_{α} = 58(5)%.

E_{α}(c.m.)	E_{α}(lab)	I_{α}(rel)	I_{α}(abs)	J^{π}_f	$E_{daughter}$(^{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}_{-3}
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 ^{176}Au isomers in unknown.
** [2004GoZZ].
*** Interpolated between 1.5553(31) ^{174}Pt and1.5422(27) ^{178}Hg.

Table 10
direct α emission from ^{176m}Au*, Ex = unk., J^{π} = (7^+, 8^+, 9^+), $T_{1/2}$ = 1.36(2) s**, BR_{α} = 29(5)%.

E_{α}(c.m.)	E_{α}(lab)	I_{α}(rel)	I_{α}(abs)	J^{π}_f	$E_{daughter}$(^{172m}Ir)	coincident γ-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)%		x		1.5488(41)***	170^{+60}_{-40}

* All values from [2021Ha32], unless otherwise noted. The relative ordering of the ^{176}Au isomers in unknown.
** [2004GoZZ].
*** Interpolated between 1.5553(31) ^{174}Pt and1.5422(27) ^{178}Hg.

Table 11
direct α emission from ^{180}Tl*, J^{π} = (5^-), $T_{1/2}$ = 1.09(1) s**, BR_{α} = 6(4)%**.

E_{α}(c.m.)	E_{α}(lab)	I_{α}(rel)	I_{α}(abs)	J^{π}_f	$E_{daughter}$(^{176}Au)	coincident γ-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^{+230}_{-40}
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)	$1.7^{+5.0}_{-0.8}\times10^3$
6.226(9)	6.088(9)	0.08(3)%	0.0018(14)%		0.473	473.4(4)	1.5293(67)	$3.0^{+8.0}_{-1.0}\times10^3$
6.307(8)	6.167(8)	0.23(5)%	0.00054(38)%		0.398	397.9(3)	1.5293(67)	$1.9^{+4.5}_{-0.8}\times10^3$
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^{+900}_{-200}

* All Values from [2017An16], except where noted.
** [2011El07].
*** Interpolated between 1.5422(27) ^{178}Hg and 1.5163(61) ^{182}Pb.

Table 12
direct α emission from ^{184}Bi*, J^{π} = , $T_{1/2}$ = 13(2) ms, BR_{α} =≈ 100%**.

E_{α}(c.m.)	E_{α}(lab)	I_{α}(abs)	J^{π}_{f}	$E_{daughter}$(^{180}Tl)	coincident γ-rays (keV)
7.28-7.51	7.12-7.35***				
7.354(20)	7.194(20)			0.124	

* All Values from [2003An27], except where noted. The relative ordering of the ^{184}Bi isomers in unknown.
** Inferred from half-life.
*** Complex structure with contributions from many α-decays.

Table 13
direct α emission from ^{184m}Bi*, J^{π} = , $T_{1/2}$ = 6.6(15) ms, BR_{α} =≈ 100%**.

E_{α}(c.m.)	E_{α}(lab)	I_{α}(abs)	J^{π}_{f}	$E_{daughter}$(^{180}Tl)	coincident γ-rays (keV)
7.90-8.02	7.73-7.85***				
7.380(15)	7.220(15)			0.449	
7.610(35)	7.445(35)				

* All Values from [2003An27], except where noted. The relative ordering of the ^{184}Bi isomers in unknown.
** Inferred from half-life.
*** Complex structure with contributions from many α-decays.

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