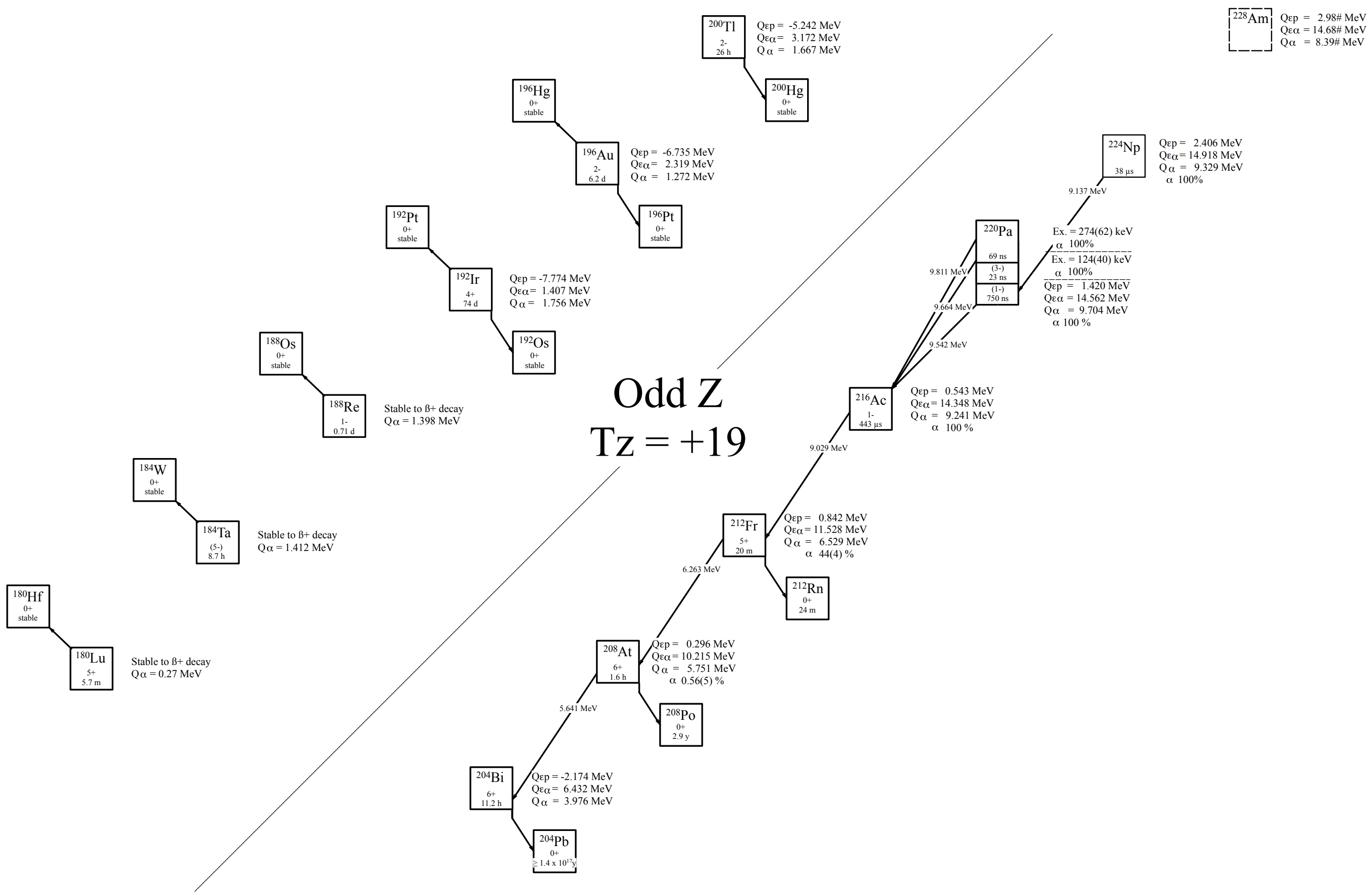

Fig. 1: Known experimental values for heavy particle emission of the odd-Z T_z= +19 nuclei.

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Table 1
Observed and predicted β-delayed particle emission from the odd-Z, T_z = +19 nuclei. J^π values for ^{180}Lu, ^{184}Ta, ^{188}Re, ^{192}Ir, ^{196}Au, ^{200}Tl and ^{204}Bi are taken from ENSDF. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	J^π	Ex.	$T_{1/2}$	Q_ε	$Q_{\varepsilon p}$	$Q_{\varepsilon\alpha}$	Experimental
^{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**]
^{196}Au***		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} μs	6.290(30)	2.406(81)	14.918(32)	[**2018Hu13**]
^{228}Am				6.74(20)#	2.98(22)#	14.68(20)#	

* 100% β^- emitter.
** 92.24(4)% β^-, 4.76(4)% ε emitter [2012Ba36].
*** 97.0(3)% β^-, 93(3)% ε 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}	Q_α	BR_α	Experimental
^{180}Lu	7.33(21)#	17.04(31)#	0.27(12)		
^{184}Ta	6.845(40)	15.65(20)	1.412(75)		
^{188}Re	6.402(1)	14.987(60)	1.398(26)		
^{192}Ir	5.729(1)	13.831(5)	1.756(1)		
^{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/α ratio of 1.3(1)% [1950Hy01].

Table 3
direct α emission from ^{208}At, J^{π} = 6^{+}, $T_{1/2}$ = 1.63(3) h*, BR_{α} = 0.56(6)%**.

E_{α}(c.m.)	E_{α}(lab)***	I_{α}(rel)***	I_{α}(abs)	$J_f^{\pi @}$	$E_{daughter}$(^{204}Bi)$^{@}$	coincident γ-rays$^{@}$	R_0 (fm)$^{@@@}$	HF
≈5.615	≈5.507$^{@@}$	≈0.2$^{@@}$%	≈1.1 × 10^{-3}%		0.137		1.4558(24)	420
5.696(2)	5.586(2)	0.9(1)%	4.9(8) × 10^{-3}%	7^{+}	0.0534(2)	0.0534(2)	1.4558(24)	250^{+50}_{-40}
5.736(4)	5.626(4)	2.2(2)%	1.2(2) × 10^{-2}%	4^{+}	0.0151(1)		1.4558(24)	160^{+40}_{-30}
5.752(3)	5.641(3)	100(3)%	0.54(6)%	6^{+}	0.000		1.4558(24)	$4.2^{+0.7}_{-0.5}$

* [1964Th07].
** Based on the ratio of K x-ray/α from ^{208}At [1950Hy27].
*** [1981Va27, 1981Va29], except where noted.
$^{@}$ [2010Ch02].
$^{@@}$ From [1970GoZZ]. Not observed in [1981Va27, 1981Va29], but may have been below statistical threshold.
$^{@@@}$ Interpolated between 1.4547(10) fm (^{206}Po) and 1.4568(22) fm (^{210}Rn).

Table 4
direct α emission from ^{212}Fr, J^{π} = 5^{+}, $T_{1/2}$ = 20.3(3) m*, BR_{α} = 44(4)%**.

E_{α}(c.m.)	E_{α}(lab)***	I_{α}(rel)***	I_{α}(abs)	J_f^{π}	$E_{daughter}$(^{208}At)$^{@@@}$	coincident γ-rays$^{@@@}$	R_0 (fm)$^{@}$	HF
5.848(6)	5.738(6)$^{@@@}$	≈0.005%$^{@@@}$	≈0.002%		0.6817	0.6871	1.4563(25)	≈200
5.940(6)	5.828(6)	0.13(8)%	0.022(13)%		0.5879	0.0235, 0.0401, 0.0503, 0.5879 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	1.4563(25)	22^{+35}_{-9}
6.098(4)	5.983(4)$^{@@}$	0.19(3)%	0.031(5)%		0.4295	0.0235, 0.0401, 0.0719, 0.1245 0.1479, 0.1635, 0.2023, 0.2037, 0.2272, 0.2816, 0.3577, 0.4058	1.4563(25)	90^{+40}_{-20}
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 0.2601, 0.2835	1.4563(25)	21.0(23)
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^{+5}_{-4}
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].
** based on the K-xray/α ratio of 1.3(1)% [1950Hy01].
*** Weighted average of values from [2005Ku06] and [1981Va27, 1981Va29].
$^{@}$ Interpolated between 1.4568(22) fm (^{210}Rn) and 1.4557(12) fm (^{214}Ra).
$^{@@}$ [1981Va27, 1981Va29].
$^{@@@}$ [2005Ku06].

Table 5
direct α emission from ^{216}Ac*, J^{π} = 1^{-}, $T_{1/2}$ = 443(7) μs**, BR_{α} = 100%.

E_{α}(c.m.)	E_{α}(lab)***	I_{α}(rel)***	I_{α}(abs)	J^{π}_{f}	$E_{daughter}$(^{212}Fr)	coincident γ-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 × 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 × 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 × 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 × 10^4
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), 0.5007(1), 0.7713(1), 0.8537(1)	1.5022(32)	69(7)
8.503(7)	8.346(7)	>0.21%	<0.1%		0.7773(2)	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 × 10^4
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 × 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 × 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 × 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 × 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)	$3.4^{+1.1}_{-0.7}$ × 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 α's as decaying from both a 1^{-} ground state and a 9^{-} isomer. [2004Ku24] demonstrated that all α's could be accounted for using HF and coincident γ-rays.
** [2000He17].
*** Interpolated between 1.4557(12) fm (^{214}Ra) and 1.5487(30) ^{218}Th

Table 6
direct α emission from ^{220}Pa, J^{π} = (1^{-}), $T_{1/2}$ = 0.75(4) μs*, BR_{α} = 100%.

E_{α}(c.m.)	E_{α}(lab)**	I_{α}(abs)	J^{π}_{f}	$E_{daughter}$(^{216}Ac)	coincident γ-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 ^{218}Th and 1.529(15) fm ^{222}U.

Table 7
direct α emission from ^{220m2}Pa*, Ex. = 124(40) keV, J^{π} = (3^{-}), $T_{1/2}$ = 233^{+108}_{-56} ns, BR_{α} = 100%.

E_{α}(c.m.)	E_{α}(lab)	I_{α}(abs)	J^{π}_{f}	$E_{daughter}$(^{216}Ac)	coincident γ-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^{π} = (3^{-}). However the HF indicates a unhindered decay, suggesting 1^{-} as a more likely value.
** Interpolated between 1.5487(30) fm ^{218}Th and 1.529(15) fm ^{222}U.

Table 8
direct α emission from ^{220m2}Pa*, Ex. = 274(62) keV, $T_{1/2}$ = 69^{+330}_{-30} ns, BR_{α} = 100%.

E_{α}(c.m.)	E_{α}(lab)	I_{α}(abs)	J^{π}_{f}	$E_{daughter}$(^{216}Ac)	coincident γ-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^{π} = (3^{-}). However the HF indicates a unhindered decay, suggesting 1^{-} as a more likely value.
** Interpolated between 1.5487(30) fm ^{218}Th and 1.529(15) fm ^{222}U.

Table 9
direct α emission from ^{224}Np*, $T_{1/2} = 38^{+26}_{-11}$ μs, BR_{α} = 100%.

E_{α}(c.m.)	E_{α}(lab)	I_{α}(rel)	I_{α}(abs)	J^{π}_{f}	$E_{daughter}$(^{220}Pa)	coincident γ-rays	R_0 (fm)**	HF
9.029(62)	8.868(62)	≈20%	0.17(17)%		0.274(62)		1.503(50)	$0.3^{+8.5}_{-0.2}$
9.303(20)	9.137(20)	100%	83(51)%	0.0	—	1.503(50)	$0.3^{+1.0}_{-0.2}$	

* All values form [2018Hu13].
** Interpolated between 1.521(15) fm (^{220}U) and 1.484(48) fm (^{224}Pu).

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