



Fig. 1: Known experimental values for heavy particle emission of the even-Z $T_z = +21$ nuclei.

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Table 1

Observed and predicted β -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^π	$T_{1/2}$	Q_ϵ	$Q_{\epsilon p}$	$Q_{\epsilon\alpha}$	Experimental
^{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]
$^{214m1}\text{Rn}$	1.473	6^+	1.0(3) ns	0.532(10)	-3.482(10)	9.520(9)	[1983Dr08, 1981Go06]
$^{214m2}\text{Rn}$	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 μs	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}	Q_α	BR_α	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}Pb	7.254(1)	13.673(1)	1.135(1)			
^{210}Po	4.983(1)	8.782	5.408	100%		[2023Av04, 2018Sh12, 1973Go39, 1960Fe04, 2015Zh41, 2014Po01, 2012Do08, 2001Gi12, 1999Oh02, 1997Ka59, 1987Er06, 1961Be13, 1961Ry05, 1960Ry01, 1958Ba45, 1958Si78, 1958Wh09, 1957Ag15, 1955Mo68, 1954Br07, 1952Ba20, 1951Ka03, 1951Ka37, 1949Me54, 1934Le01, 1933Ro03, 1902Ma02, 1898Cu02]
^{214}Rn	5.029(10)	8.528(9)	9.208(9)	100%		[1970To07, 1970Va13, 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%		[2019Pa45, 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)	$\approx 27\%$	$\approx 2\%$	[2010Kh06, 2002CaZU, 2002CaZZ, 2007KhZQ]
^{238}Cf	3.22(38)#	5.15(30)#	8.13(30)	< 5%*	> 95%	[2010Kh06, 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 μs . The events observed in [1975Te01] were likely from the SF decay of ^{241}Fm ($T_{1/2} = 0.73(6)$ ms [2008Kh10]).

Table 3direct α emission from ^{210}Po , $J^\pi = 0^+$, $T_{1/2} = 138.3787(16)$ d*, $BR_\alpha = 100\%$.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π ^{@@}	$E_{\text{daughter}}(^{206}\text{Pb})$ ^{@@}	coincident γ -rays ^{@@}	R_0 (fm)	HF
4.613(5)	4.525(5)**	0.00122(3)%	0.00122(3)%***	2 ⁺	0.803	0.803	1.40879(38)	1.34(11)
5.40733(7)	5.30433(7) [@]	100%	99.99878(3)%	0 ⁺	0.0	—	1.40879(38)	0.997929(12)

* Weighted average of 138.3763(17) d [1964EiZZ] and 138.4005(51) d [1954Ei20].

** [1960Fe04].

*** [2018Sh12].

[@] Reported as 5.30451(7) MeV in [1973Go39], modified to 5.30433(7) MeV in [1999Ry01].^{@@} [2008Ko21].**Table 4**direct α emission from ^{214}Rn , $J^\pi = 0^+$, $T_{1/2} = 259(3)$ ns*, $BR_\alpha = 100\%$.

E_α (c.m.)	E_α (lab)	I_α (abs)	J_f^π	$E_{\text{daughter}}(^{210}\text{Po})$	coincident γ -rays	R_0 (fm)	HF
9.208(9)	9.036(9)**	100%	0 ⁺	0.0	—	1.5340(25)	0.999(12)

* [2019Pa45].

** Weighted average of 9.040(20) MeV [1970To07] and 9.035(10) MeV [1970Va13].

Table 5direct α emission from $^{214m1}\text{Rn}$, $J^\pi = (6^+)$, Ex. = 1.473 MeV*, $T_{1/2} = 1.0(3)$ ns**, $BR_\alpha = \text{obs}***$.

E_α (c.m.)	E_α (lab)	I_α (abs)	J_f^π	$E_{\text{daughter}}(^{210}\text{Po})$	coincident γ -rays ^{@@}	R_0 (fm)	HF
10.659(30)	10.460(30)***		0 ⁺	0.0	—	1.5340(25)	

* [2014Ba41].

** [1987Dr08].

*** [1981Go06].

Table 6direct α emission from $^{214m2}\text{Rn}$, $J^\pi = (8^+)$, Ex. = 1.557 MeV*, $T_{1/2} = 4.8(3)$ ns**, $BR_\alpha = 4.3(7)\%***$.

E_α (c.m.)	E_α (lab)	I_α (abs)	J_f^π	$E_{\text{daughter}}(^{210}\text{Po})$	coincident γ -rays ^{@@}	R_0 (fm)	HF
10.832(30)	10.630(30)**	4.3(7)%***	0 ⁺	0.0	—	1.5340(25)	790_{-150}^{+210}

* [2014Ba41].

** [1987Dr08].

*** [1981Go06].

Table 7direct α emission from $^{218}\text{Ra}^*$, $J^\pi = 0^+$, $T_{1/2} = 25.99(10)$ μs , $BR_\alpha = 100\%$.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π ^{**}	$E_{\text{daughter}}(^{206}\text{Pb})$ ^{**}	coincident γ -rays ^{**}	R_0 (fm)	HF
7.859(40)	7.715(40)	0.123(11)%	0.123(11)%	2 ⁺	0.695(1)	0.695(1)	1.5655(13)	6.3(8)
8.537(4)	8.381(4)	100%	99.88(6)%	0 ⁺	0.0	—	1.5655(13)	0.998(4)

* All values from [2019Pa45], except where noted.

** [2021Zh35].

Table 8
direct α emission from $^{222}\text{Th}^*$, $J^\pi = 0^+$, $T_{1/2} = 1.964(2)$ ms, $BR_\alpha = 100\%$.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π	$E_{\text{daughter}}(^{218}\text{Ra})$	coincident γ -rays	R_0 (fm)	HF
7.274(4)	7.143(4)	0.014(4)%	0.014(4)%	(1 ⁻)	0.858(5)	0.858(5)	1.5571(17)	12 ⁺⁵ ₋₃
7.337(4)	7.205(4)	0.018(3)%	0.018(3)%	3 ⁻	0.7932(2)**	0.3522(1), 0.3889(1)**	1.5571(17)	15.7 ^{+3.2} _{-2.3}
7.743(3)	7.603(3)	1.84(1)%	1.81(1)%	2 ⁺	0.3889(1)**	0.3889(1)**	1.5571(17)	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 α emission from ^{226}U , $J^\pi = 0^+$, $T_{1/2} = 271(6)$ ms*, $BR_\alpha = \approx 100\%$.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)**	J_f^π	$E_{\text{daughter}}(^{222}\text{Th})$	coincident γ -rays	R_0 (fm)	HF
7.455(20)	7.323(20)**	3.7(12)%	3(1)%	(1 ⁻)	0.245(20)		1.5394(34)	4.2 ^{+2.3} _{-1.3}
7.516(4)	7.383(4)***	18.3(38)%	15(3)%	2 ⁺	0.1829(2)@@	0.1829(2)@@	1.5394(34)	1.4 ^{+0.4} _{-0.3}
7.700(3)	7.564(3)@	100%	82(5)%	0 ⁺	0.0	—	1.5394(34)	1.05(8)

* 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 α emission from $^{230}\text{Pu}^*$, $J^\pi = 0^+$, $T_{1/2} = 102(10)$ s, $BR_\alpha = \approx 100\%$.

E_α (c.m.)	E_α (lab)	I_α (rel)	I_α (abs)	J_f^π	$E_{\text{daughter}}(^{226}\text{U})$	coincident γ -rays	R_0 (fm)	HF
7.123(15)	6.999(15)	23(5)%	19(4)%	2 ⁺	0.059(18)		1.5375(56)	2.6 ^{+1.1} _{-0.8}
7.182(10)	7.057(10)	100(5)%	81(4)%	0 ⁺	0.0	—	1.5375(56)	1.01(11)

* All values from [2002CaZU], except where noted.

Table 11
direct α emission from $^{234}\text{Cm}^*$, $J^\pi = 0^+$, $T_{1/2} = 51(12)$ s, $BR_\alpha = \approx 27\%$.

E_α (c.m.)	E_α (lab)	I_α (abs)	J_f^π	$E_{\text{daughter}}(^{230}\text{Pu})$	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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