

## Purpose of this horizontal evaluation/database

Provides an up to date database of relevant information on nuclei that decay by heavy charged particles - It is being updated as new results are published. Web-site update ~ bimonthly

## Currently known: 1456 nuclei

(isomers counted separately)

#### β –delayed emitters

203 β<sup>+</sup>-p emitters

13  $\beta^+$ -2p emitters

5 β<sup>+</sup>-3p emitters

 $2 \beta^+$ - $\alpha p$  or  $\beta^+$ - $p\alpha$  emitters

26 β<sup>+</sup>-α emitters

29 β+-fission emitters

2 β- $\alpha$  emitters

2 β--α emitters

#### **Direct emitters**

81 direct proton emitters

(many inferred from  $T_{1/2}$ )

9 direct 2p emitters

907 direct alpha emitters

155 Spontaneous fission

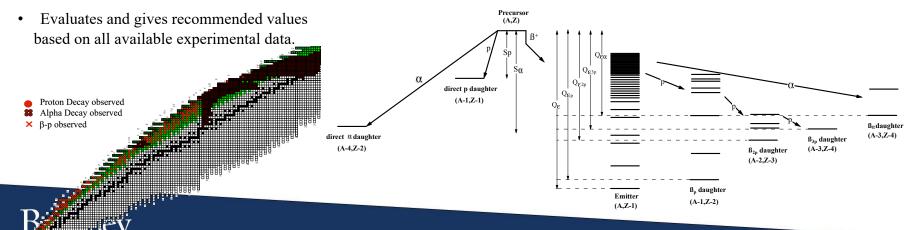
22 cluster (14C, 24Ne, etc.) emitters



## Purpose of this horizontal evaluation/database

- Physics motivated! In many cases levels in daughter nuclei have only been observed via heavy charged particles
- Goal is to aid researchers on the topic. Also useful as a teaching tool.
  - systematics
  - Relationships between Energy and B.R.
  - Competition between different decay modes
- Involves the entire chart of the nuclides, provides a comprehensive overview of the topic.

- Is being kept up to date as new papers come out Anything published is out of date.
- Complete (as possible) evaluation of heavy charged particle emitters
- All of the information in one place
  - this allows the user to look at patterns and trends in the data which can lead to the discovery of new physical phenomena.



### Purpose of this horizontal evaluation/database

Builds on and expands on recent horizontal database
("Recommended Values for Beta-Delayed Proton Alpha Emission"
J. C. Batchelder, Atomic Dat. Nucl. Data Tables 132, 101323 (2020).)

Recommended values for  $\beta^+$ -delayed proton and  $\alpha$  emission

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Article Binstry:

A B S T R A C T

\*\*Received 15 Aprell 2018

\*\*Received 15

Greatly expanded it to include all beta delayed and direct p,  $\alpha$ , cluster and fission decays.

Uses the latest mass evaluation used for level energies. **Q and S values** taken or derived from from:

2021Wa16 M. Wang, W. J. Huang, F. G. Kondev, G. Audi, S. Naimi, Chin. Phys. C 45, 030003 (2021),

unless a more accurate value can be obtained from the particle energies (typically from new papers)—examples:



**Table 2**Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +19/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

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Purpo	Nuclide	$S_p$	$S_{2p}$	$Q_{lpha}$	$\mathrm{BR}_lpha$	Experimental
1	<sup>135</sup> Ce	6.687(22)	11.641(10)	-0.362(10)		
	<sup>139</sup> Nd	6.177(29)	10.676(28)	0.174(29)		
D '11	<sup>143</sup> Sm	5.665(24)	9.904(4)	0.075(28)		
Builds on ADNDT art	<sup>147</sup> Gd	5.528(6)	9.283(1)	1.735(2)		
	<sup>151</sup> Dy	4.936(8)	8.203(4)	4.180(3)	5.6(4)%	[1974To07, 1982Bo04, 1978MoZH, 1973Bi06,
						<b>1965Ma51, 1964Ma19</b> , 1990KaZM, 1989KaYU,
Uses the latest mass e						1988KaZK, 1987KaZI, 1985Ne09, 1982De11,
Oses the latest mass e						1981HoZM, 1979Ho10, 1978AfZZ,
						1976ToZT, 1974ToZN, 1974ToZQ,
						1974ToZU, 1973BoXL, 1972OkZZ, 1968Go13,
<b>2021Wa16</b> M. Wang,	155					1967Go32, 1960Ma47]
	<sup>155</sup> Er	4.859(10)	7.644(7)	4.118(5)	<0.022(7)%	[1974To07, 1990Po13, 1990KaZM, 1978AfZZ,
unless a more accurate	150					1975ToZT, 1974PeZS, 1970Ma23, 1969To06]
	<sup>159</sup> Yb	4.419(31)	6.998(32)	3.951(18)	<0.0001%***	[1995Hi12]
	<sup>163</sup> Hf	3.727(79)	6.013(30)	4.139(31)		
	$^{167}W$	3.284(34)	5.036(34)	4.751(30)	<0.04(1)%	[1991Me05, 1989Me02]
	<sup>171</sup> Os	2.682(22)	3.957(24)	5.371(4)	1.8(3)%*	[ <b>1995Hi02, 1979Ha10</b> , 2004GoZZ, 1996Pa01,
						1978Sc26, 1976HoZD, 1972To06, 1972ToZC,
	175					1972ToZL, 1972ToZO, 1972ToZW]
	<sup>175</sup> Pt	2.212(22)	2.848(24)	6.164(4)	64.5(13)%	[2014Pe02, 1979Ha10, 2004GoZZ, 2002Ko09,
						1996Pa01, 1986Ke03, 1982De11, 1981DeZA,
						1981DeZL, 1976HoZD, 1973Ga08, 1971Ha03,
	170					1970Ha18, 1966Si08]
	<sup>179</sup> Hg	1.919(30)	2.140(33)	6.430(4)**	75(4)%	[2012Ve04, 2002Ko09, 1979Ho10, 2002Ro17,
						1996Pa01, 1982HeZM, 1971Ha03, 1971Ho17,
	192					1970Ha18, 1969NaZT, 1968De01]
	<sup>183</sup> Pb	1.542(31)#	1.497(33)#	6.928(7)	obs <sup>@</sup>	[ <b>2002Je09</b> , <b>1989To01</b> , 2012Ve04, 1987To09,
	192					1986Ke03, 1980Sc09]
	$^{183m}$ Pb	1.463(31)#	1.418(33)#	7.007(9)	obs <sup>@</sup>	[ <b>2002Je09</b> , <b>1989To01</b> , 1987To09, 1986Ke03,
2500 P	197					1984ScZQ, 1980Sc09]
	<sup>187</sup> Po	1.320(37)	0.213(36)	7.979(15)	100%	[ <b>2006An11</b> , 2007An19, 2005An17, 2005AnZY]

1979Ha10].



<sup>\*\*</sup> Deduced from  $\alpha$  energy, 6.351(31) in [2021Wa16].

<sup>&</sup>lt;sup>®</sup> Not measured, expected to be 80-90% based on half-life.

#### What is included (and what is not)

All available measured and predicted  $Q_{\epsilon x}$ ,  $Q_{\alpha}$ ,  $S_p$ ,  $S_{2p}$  values for nuclei where these decays are energetically possible.

All known charged particle decays – BR,  $T_{1/2}$ , individual transitions (E &  $J^{\pi}$ , initial and final states)

Complete listing of relevant references for all direct and beta delayed  $\alpha$ , p, c and f emitters in one place.

Up to date and evaluated data. Where there are large discrepancies between papers, this is noted.

#### Example:

**Table 12**  $\beta$ -p emission from <sup>39</sup>Ti\*,  $T_{1/2} = 28.5(9)$  ms,  $BR_{\beta p} = 93.7(28)\%$ \*\*.

$E_p(\text{c.m.})$	$I_p(\text{rel})***$	$I_p(abs)***$	$E_{emitter}$ ( $^{39}$ Sc)	$E_{daughter}(^{38}\mathrm{Ca})$	coincident γ-rays <sup>@</sup>	
3.27(2) 5.17(3) <sup>a</sup>	70(20) 100(30)	7(2) 10(3)				

<sup>\*</sup> All values taken from [2007Do17], except where noted.

\*\*\* Note that there is considerable disagreement between the published works in this nucleus, and many  $\beta$ -p transitions are unknown.

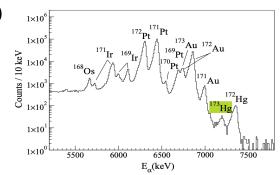
rossible two proton peak from the p-2p decay of 3711 to the ground state of  $\mathbf{x}$  [20010101, 17721/1013].



https://nucleardata.berkeley.edu/research/betap.html

#### What is included (and what is not)

- \* Targeted (and complete) references—different from NSR
  - Example:
    - $^{173}$ Hg  $\alpha$  decay- NSR lists 2009Ha42
    - <sup>173</sup>Hg only appears as a bg peak in a figure. not included



- NSR includes where nucleus is a possible daughter, but no info
  - Example: search for <sup>140</sup>Dy gives <sup>141</sup>Ho proton decay No info on <sup>140</sup>Dy
- Sometimes the reference doesn't even address that type of decay
  - Example:  $^{219}$ At search gives  $^{223}$ Fr beta decay papers. No  $\alpha$  decay.
- Only references with information relevant to particle emission from the given nucleus are included.
  - In beam studies, beta decay with no heavy particle emission, moments, etc. are not included in the references
- \* All papers with information on the given nucleus including conference proceedings and reports. (I'm getting most of my refences from NSR, IAEA, LBNL library and google scholar)

Explicit refs for  $T_{1/2}$ , Energy, BR, etc.



#### What is included (and what is not)

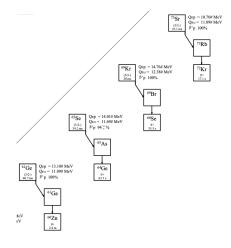
Organized by Tz = (N-Z)/2(-4 to +32, even and odd – 145 datasets!), Simple decay chain figure included for each Tz.

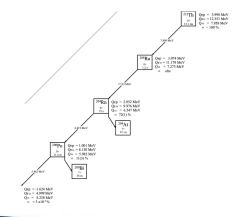
Beta-delayed emitters have similair properties across Tz chain Example: Tz = -3/2 - beta decay primarily proceeds through IAS followed by proton emission ( $^{73}$ Sr,  $^{69}$ Br,  $^{65}$ Se,  $^{61}$ Ge,  $^{57}$ Zn, etc.)

Alpha emitters decay along Tz chain

Isomers (> 1 ns) are treated separately. - only decay from "long-lived" states included, not high energy states that emit p or  $\alpha$ .

No attempt is made at adding theoretical predictions or references.



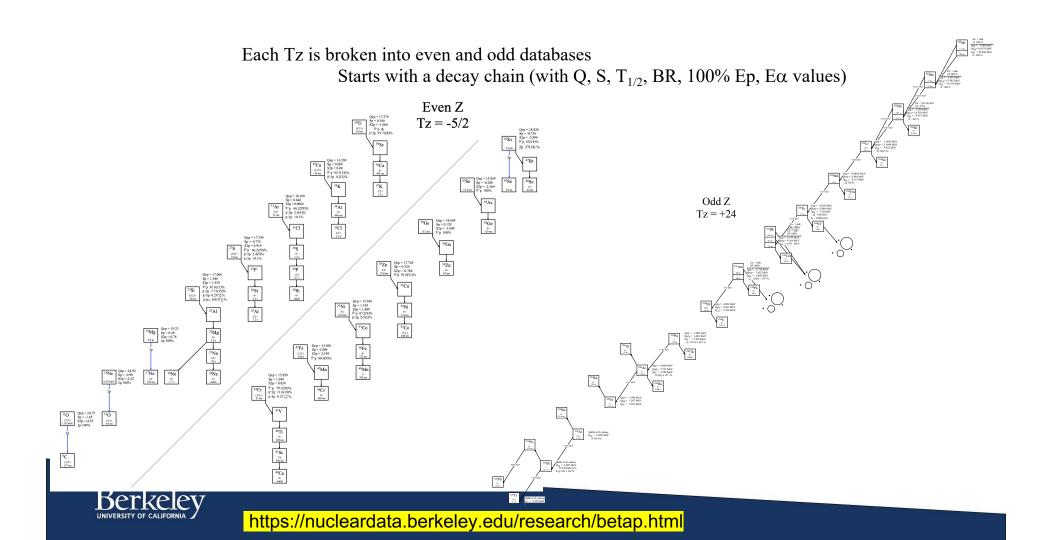




## How this is different from AME/NuBase/ENSDF?

- The AME and our work are very different animals. The main goal of the Berkeley online database is to provide experimentalists access to all the latest information on direct and beta -delayed alpha and proton emitters, all collected in one easy to access place.
- Some mass information might be derived through separation energies, but that is not the goal of this work The AME is a phenomenal work on masses of nuclei across the entire chart, but doesn't have complete information on decay transitions.
- ENSDF offers A chains based on and perfect for beta decay.
- ENSDF A chains updated every 10-20ish years.  $BE\alpha_nR$  updated ~ bi-monthly.
- $BE\alpha_pR$  contains complete list of references, allowing a more complete picture for the experimenter.
- Consistent in formatting for C.O.M. and lab frames for energy





Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\varepsilon}$	$Q_{\varepsilon_P}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	Experimental
<sup>117</sup> Te	1/2+	61(2) m	3.544(13)	-0.858(13)	_	-10.137(13)	[1961Fi05]
<sup>121</sup> Xe	$(5/2^+)$	38.8(6) m	3.765(11)	-0.408(10)	_	-7.583(12)	[1969Bu07]
<sup>125</sup> Ba	1/2+	3.3(4) m*	4.421(13)	0.709(11)		-6.304(12)	[1975Ar31, 1968Da09]
<sup>129</sup> Ce	$(5/2^+)$	3.5(3) m	5.040(40)	1.793(28)		-4.625(28)	[1993Al03]
133 Nd	$(7/2^+)$	70(10) s	5.610(50)	2.847(51)		-3.141(54)	[1977Bo02]
137Sm	(9/2-)	45(1) s	6.080(30)	3.919(31)		-1.634(31)	[1983AlZO]
<sup>141</sup> Gd	1/2+	14(4) s	6.701(23)	4.943(23)	0.3(1)%	-0.301(24)	[1989Gi06, 1986Wi15]
<sup>145</sup> Dy	$(1/2^+)$	6(2) s	8.16(11)	6.228(29)	≈50%	1.421(13)	[1993To04, 1984ScZT]
<sup>149</sup> Er	$(1/2^+)$	4(2) s	7.900(30)	6.829(29)	7(2)%	2.423(29)	[1989Fi01, 1984ScZT]
149mEr**	$(11/2^{-})$	8.9(2) s	8.642(30)	7.571(29)	0.18(7)%	3.165(29)	[1989Fi01, 1984To07, 1984ScZT]
153 Yb	7/2-	4.2(2) s	6.81(20)#	6.05(20)#	0.008(2)%	1.89(20)#	[1988Wi05]
<sup>157</sup> Hf	$(7/2^{-})$	115(1) s	7.59(20)#	7.12(20)#		3.19(20)#	[1996Pa01]
$^{161}W$		409(18) ms	8.27(20)#	8.14(20)#		4.62(20)#	[1996Pa01]
<sup>165</sup> Os	$(7/2^{-})$	21(1) ms	8.91(20)#	9.20(20)#		6.21(20)#	[1996Pa01]
<sup>169</sup> Pt	$(7/2^{-})$	7.0(2) ms	9.63(20)#	10.24(20)#		7.79(20)#	[2004Ke04]
$^{173}{ m Hg}$	(7/2-)	0.80(8) ms	10.17(20)#	11.16(20)#		9.17(20)#	[2012Od01]

<sup>\*</sup> Weighted average of 3.5(4) m [1975Ar31] and 3.0(5) m 1968Da09].

**Table 2** Particle separation and  $\beta$ - $\alpha$  emission from the even-Z,  $T_z = +13/2$  nuclei

Nuclide	$S_p$	$S_{2p}$	$Q_{\alpha}$	$BR_{\alpha}$	$Q_{\varepsilon  \alpha}$	Experimental
<sup>117</sup> Te	5.562(14)	9.640(13)	0.808(14)		1.847(13)	
<sup>121</sup> Xe	6.023(18)	9.876(13)	0.190(17)		3.734(13)	
<sup>125</sup> Ba	5.217(14)	8.999(15)	0.387(15)		4.152(12)	
<sup>129</sup> Ce	4.951(61)	8.047(30)	0.957(30)		5.377(29)	
133Nd	4.394(55)	7.202(57)	1.530(54)		6.566(51)	
137Sm	4.111(75)	6.356(34)	1.916(55)		7.521(31)	
<sup>141</sup> Gd	3.527(55)	5.422(23)	2.343(35)		8.424(24)	
<sup>145</sup> Dy	3.163(29)	4.59(20)	2.557(21)		9.258(14)	
<sup>149</sup> Er	3.039(88)	4.12(29)	2.076(29)		10.23(11)	
<sup>149m</sup> Er*	3.781(88)	4.86(29)	2.818(29)		10.97(11)	
<sup>153</sup> Yb	2.73(21)#	3.47(20)#	4.16(20)#		12.06(20)#	
<sup>157</sup> Hf	2.44(21)#	2.93(20)#	5.880(3)	94(5)%**	12.69(20)#	[1996Pa01. 1979Ho10, 1989Wo02, 1981HoZM]
						1973Ea01, 1965Ma14]
$^{161}$ W	1.972(208)#	2.23(20)#	5.923(4)	73(3)%	13.51(20)#	[1996Pa01. 1981Ho10, 1989Ho02, 1981HoZM]
165Os	1.563(208)#	1.42(21)#	6.335(6)	90(2)%	14.61(20)#	[2008Bi15, 1996Pa01. 2013Dr06, 2002Pa03
						[1997Da07, 1991Se01, 1981Ho10, 1978Ca11,
						1978CaZF, 1977Ca23]
<sup>169</sup> Pt	1.087(208)#	0.54(22)#	6.858(5)	$\approx 100\%$	15.77(20)#	[2004Ke06, 1999Se14, 2012Od01, 2009Go16]
						[2008Bi15, 1996Pa01, 1981Ho10]
<sup>173</sup> Hg	0.632(208)#	-0.23(22)#	7.378(4)	100%	17.001(20)#	[2012Od01, 2009Sa27, 2004Ke04, 1999Se14]
						[1998NiZW]

Table 1 – beta delayed particle emission info: parent  $J^{\pi},\,T_{1/2},\,Q_{\beta x}$  , BR, refs

Table 2 – Direct particle emission info: Q, S, BR, refs



<sup>\*\*</sup> Excitation energy = 741.8(2) keV [1989Fi01].

**Table 10**  $\beta$ -p emission from  ${}^{35}\text{Ca*}$ ,  ${}^{1/2}$ = 25.7(2) ms,  $BR_{\beta p}$  = 95.7(15)%\*\*.

$E_p(\text{c.m.})$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ (35K)***	$E_{daughter}(^{34}\mathrm{Ar})^{@}$	coincident γ-rays <sup>@</sup>
1.427(5)	100	48.5(13)	1.511(5)	0	
$1.909-2.647^{a}$	11(2)	5.4(9)	4.084-4.822	2.0911(3)	2.091
1.909-2.647a	2.1(8)	1.0(4)	5.280-6.018	3.2877(5)	1.197, 2.091, 3.286
1.909-2.647a	4.1(14)	2.0(7)	5.866-6.604	3873(3)	1.782, 2.091, 0.585, 1.197
2.727(13)	12.4(10)	6.0(5)	4.902(13)	2.0911(3)	2.091
2.947-3.500 <sup>a</sup>	4.5(6)	2.2(3)	5.122-5675	2.0911(3)	2.091
3.592(25)	6.2(6)	3.0(3)	3.676(25)	0	
3.822(36)	7.8(6)	3.8(3)	3.906(36)	0	
4.041(71)	6.0(6)	2.9(3)	6.216(71)	2.0911(3)	2.091
4.570(48)	6.0(6)	2.9(3)	4.654(48)	0	
4.754(38)	8.7(8)	4.2(4)	4.838(38)	0	
5.018(71)	8.0(6)	3.9(3)	5.102(71)	0	
5.294(48)	1.5(4)	0.72(18)	5.378(48)	0	
5.466(48)	1.26(31)	0.61(15)	5.550(48)	0	
5.616(37)	2.95(35)	1.43(17)	5.700(37)	0	
5.834(60)	2.9(4)	1.40(19)	5.918(60)	0	
5.983-6.649 <sup>a</sup>	2.25(35)	1.09(17)	6.067-6.733	0	
6.783(22)	7.8(4)	3.8(2)	8.958(22)	2.0911(3)	2.091
$7.131-7.887^a$	2.3(4)	1.1(2)	4.084-7.971	0	
8.802(89)	0.85(12)	0.41(6)	8.886(89)	0	

<sup>\*</sup> All values are taken from [1999Tr04], except where noted.

Table 11 β-2p emission from  ${}^{35}\text{Ca*}$ ,  $BR_{\beta 2p} = 4.2(3)\%**$ .

$E_{2p}(c.m.)$	$I_p(\text{rel})$	$I_p(abs)$	$E_{emitter}$ ( $^{35}$ K)****	$E_{daughter}(^{33}\text{Cl})$	coincident γ-rays	
4.305(26)	100	4.2(3)	9.053(27)	0		

<sup>\*</sup> All values are taken from [1999Tr04], except where noted.

If individual transitions are known for beta-delayed particles, the particle energy, initial and final states, branching, and explicit refences for each number given.



<sup>\*\*</sup> From [2016Ci05].

<sup>\*\*\*</sup> Calculated from proton energies and  $S_p$  ( $^{35}$ K) = 83.6(5) keV [2021Wa16].

<sup>&</sup>lt;sup>@</sup> Values from adopted levels in ENSDF [2012Si06].

a unresolved multiplet

<sup>\*\*</sup> From [2016Ci05].

<sup>\*\*\*</sup> Calculated from two-proton energy and  $S_{2p}$  ( $^{35}$ K) = 4747.5(6) keV [2021Hu06].

If individual transitions are known for direct particle emitters, the particle energy, initial and final states,  $J^{\pi}$ , branching, HF ( $\alpha$  only) and explicit refences for each number given.

Table 6 direct  $\alpha$  emission from  $^{171}$ Os\*,  $J^{\pi} = 5/2^{-}$ ,  $T_{1/2} = 8.3(2)$  s,  $BR_{\alpha} = 1.8(3)\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(abs)$	$\mathbf{J}^{\boldsymbol{\pi}}_f$	$E_{daughter}(^{167}\mathrm{W})$	coincident γ-rays	R <sub>0</sub> (fm)	HF	
5.290(10) 5.367(7)	5.166(10) 5.241(7)	7.0%*** 100%***	(7/2 <sup>-</sup> ) (5/2 <sup>-</sup> )	0.12(3)% 1.68(3)%	0.079 0.0	1.5721(95) 1.5721(95)	$7.7_{-2.1}^{+3.0} \\ 1.3_{-0.3}^{+0.4}$	

<sup>\*</sup> All values from [1995Hi02], except where noted.

**Table 7** direct  $\alpha$  emission from  $^{175}$ Pt\*,  $J^{\pi} = (7/2^{-})$ ,  $T_{1/2} = 2.43(4)$  s,  $BR_{\alpha} = 64.5(13)\%$ .

$E_{\alpha}$ (c.m.)	$E_{\alpha}(lab)$	$I_{\alpha}(\mathrm{rel})$	$I_{\alpha}(abs)$	$J_f^\pi$	$E_{daughter}(^{171}\mathrm{Os})$	coincident γ-rays	R <sub>0</sub> (fm)	HF
5.950(4) 5.955(4) 6.087(4) 6.162(4)	5.814(4) 5.819(4) 5.948(4) 6.021(4)	7.3(16)% 1.3(4)% 100(1)% 8.7(15)%	4.0(9)% 0.7(2)% 55.0(5)% 4.8(8)%	(7/2 <sup>-</sup> , 9/2 <sup>-</sup> ) (9/2 <sup>-</sup> ) (7/2 <sup>-</sup> ) (5/2 <sup>-</sup> )	0.2112(5) 0.2079(5) 0.0767(3) 0.0	0.2112(5), 0.1341(4), 0.0767(3) 0.2079(5), 0.1308(4), 0.0767(3) 0.0767(3)	1.5574(37) 1.5574(37) 1.5574(37) 1.5574(37)	$6.6_{-1.4}^{+2.1}$ $38_{-9}^{+16}$ $1.71(15)$ $40_{-7}^{+9}$

<sup>\*</sup> All values from [2014Pe02], except where noted.



<sup>\*\*</sup> Weighted average of 1.9(3)% [1995Hi02] and 1.7(3)% [1979Ha10].

<sup>\*\*\*</sup> Uncertainties not given in [1995Hi02].

If individual transitions are known for direct particle emitters, the particle energy, initial and final states,  $J^{\pi}$ , branching, HF ( $\alpha$  only) and explicit referces for each number given.

**Table 10** direct  $\alpha$  emission from <sup>189</sup>Po\*,  $J^{\pi} = (7/2^{-})$ ,  $T_{1/2} = 3.5(5)$  ms,  $BR_{\alpha} = 100\%$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(lab)$	$I_{\alpha}(\mathrm{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}^{\boldsymbol{\pi}}_f$	$E_{daughter}(^{173}\mathrm{Os})$	coincident γ-rays	R <sub>0</sub> (fm)	HF
7.416(15) 7.467(20) 7.695(20)	7.259(15) 7.309(20) 7.53(20)	100(21)% 15(7)% 10(8)%	80(12)% 12(5)% 8(6)%	(5/2 <sup>-</sup> ) (3/2 <sup>-</sup> )	0.280 0.226 0.0	0.280 0.226	1.4991(51) 1.4991(51) 1.4991(51)	$ \begin{array}{c c} 0.18^{+0.07}_{-0.05}*\\ 1.0_{-0.7}\\ 14^{+49}_{-7} \end{array} $

<sup>\*</sup> All values from [2005Va04].

When HF don't make sense, this is pointed out in the comments. If possible I've attempted to contact authors. (many times the values come from VERY old papers).



<sup>\*\*</sup> The reason for this unphysically low value is unknown.

## Fission - direct and $\varepsilon$ -delayed

Table 1024
Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +47/2$  nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$Q_{\alpha}$	$BR_{\alpha}$		$BR_{SF}$	BR <sub>cluste</sub>	r	type	Experimental
207 📙 🚗	9.59(30)#	0.60(20)#							
211Pb(AcB)	9.535(30)#	3.570(30)							
Po(AcB)	6.555(12)	7.526(1)	99.99977(	2)01					[1998Li53, 1971Gr17, 1950Av61, 2023Ta02, 2019Ma02,
FO(ACA)	0.030(11)	7.520(1)	99.99911(.	2)70					1996Wi27, 1979Be58, 1976Bl13, 1971Er02, 1971Gr17,
									1990W127, 1979Be38, 1970B113, 1971E102, 1971G117, 1967Da20, 1965Va10, 1962Wa18, 1961Ry02, 1961Vo06,
									1960Ry02, 1950Av61, 1942Wa04]
<sup>219</sup> Rn(An)	6.560(12)	6.9462(3)	100%						[1999Li05, 2019Ma02, 2015Co07, 2015Pi10, 1989It01,
KII(AII)	0.300(12)	0.9402(3)	100%						1979Be58, 1974Bo11, 1972NgZZ, 1970Da09, 1970Kr01,
									1970Kr01, 1970Kr08, 1967Le05, 1962Wa18, 1961Ro14,
									1961Ry02, 1960Ry02, 1960Wa16]
223Ra(AcX)	6.434(8)	5.9790(2)	100%			8.9(4)×	10-80%	<sup>14</sup> C	[1998Sh02, 1995Ho11, 1992Ar02, 1962Wa18, 1971Gr17
Ka(ACA)	0.434(8)	3.9790(2)	100%			0.9(4)×	10 %	C	2021Si11, 2019Ma02, 2016Jo02, 2015Be13, 2015Co02,
									2015Co07, 2015Ko06, 2015Pi10, 1991Ho15, 1990Hu02,
									1990Hu07,1990We01, 1989Br34, 1987Mi10, 1985Al28,
									1985Ku24, 1985Pr01, 1984Al34, 1984Ga38, 1984Ro30,
									1976Bl13, 1974Ri05, 1971Gr17, 1970Da08, 1970Kr01,
									1969Be67, 1968Br37, 1968Be37, 1967JoZX, 1965Ki05,
									1962Gi04, 1961Ry02, 1960Ry02, 1959Ro51, 1957Pi31,
									1954Ha60]
Th(RdAc)	5 703(3)	6.1466(1)	100%						[19s64Ba33, 2019Ma02, 1998Jo08, 1972He18, 2019Ko06
III(KuAC)	3.193(3)	0.1400(1)	100 /6						2019Co04, 2015Co11, 1990Br23, 1990BrZZ, 1987Mi10,
									1977Ma32, 1972HeYM, 1968Wa07, 1967JoZX, 1965Br23
									1954Ha60, 1949Pe08]
<sup>231</sup> U	5.657(4)	5.576(2)	4(1)×10			_			[1997Mu08, 1994Li12, 1949Os01]
	5.061(22)	5.951(20)	$3.0(6) \times 1$	%					[1957Th10, 1952Or03]
235mpu	2.06(20)	7.95(20)	5.0(0)///	~	100%				[1970Bu02, 1971Br39, 1972Ga42, 1969Me11]
	4.56(16)	6.54(15)	< 1×10		100%				[2008Qi03]
	4.05(23)#	7.42(10)#	obs	-					[1967Fi04, 1967Si08]
	3.44(20)#	8.258(10)	64%						[ <b>2006He27</b> , 2004HeZY, 2004He28]
	3.39(20)#	8.305(11)	88(2)%						[ <b>2006He27</b> , 2004HeZY, 2004He28]
	2.84(20)#	8.752(4)	91+9/%	-	$0.14^{+0.31}_{-10.12}\%$	_			[2006He27, 2004He25, 2022Te01, 2009Dr02, 2005KuZZ,
NO	2.04(20)#	0.732(4)	91_2270		$0.14_{-10.12}$ %				2005SuZX, 2004He28, 2004HeZY, 1999He07, 1997He29,
									1967Gh01]
251mNo	2.74(20)#	8.858(7)	100%						[2006He27, 2022Te01, 2005KuZZ, 2005SuZX, 2004He28.
140	2.74(20)#	0.030(7)	100%						2004HeZY]
255 p.c	2.61(20)#	9.055(4)	46(5)%	╟	54(5)%*				[2006He27, 2015An05, 2001He35,2020Mo11,
KI	2.01(20)#	5.055(4)	40(3)70		J+(J)70.				2008Dr05, 1997He29, 1986He06, 1984De07, 1984Og02,
									2008Dt03, 1997He29, 1986He06, 1984De07, 1984Og02, 1984Og03]
<sup>259</sup> Sg	2.278(30)#	9.765(8)	≈ 97%		3(1)%**				[2015An05, 2013An08, 2009Dr02, 2009He20, 1985Mu11,
sg	2.278(30)#	9.703(8)	≈ 91%		3(1)%***				
259m c -	2.191(20)#	9.852(22)	≈ 97%		3(1)%**				1984De07] [ <b>2015An05</b> , 2009He20]
	1.86(22)#	10.733(78)	≈ 97%	1	<8.4%				[2009Dr02, 2009He20]
	1.86(22)#	10.733(78)			< 8.4%				
		11.777(51)	≈ 100%						[1995Gh05]

Direct (129 nuclei, g.s. and isomer) and  $\beta$ -delayed fissioning (29  $\beta$ <sup>+</sup>, 2  $\beta$ <sup>-</sup>) nuclei are included in the database.

- Only half-lives, branching ratios and isomer energies are detailed.
- no attempt is made to detail fission products, ave. # of neutrons, etc.

Only refs. that detail some aspect of the fission decay are listed.

(*i.e.* papers that only detail gammas/states in a particular fission fragment are not listed.)

## Cluster emission

#### Table 994

Particle separation, Q-values, and measured values for direct particle emission of the even-Z,  $T_z = +23$  nuclei. Unless otherwise stated, all S and Q-values are taken

from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$Q_{\alpha}$	$BR_{\alpha}$	В	$BR_{cluster}$	type	imental
<sup>210</sup> Pb(RaD) <sup>214</sup> Po(RaC')		3.792(20) 7.834(0)	1.9(3)×10 <sup>-6</sup> %* 100%				W005, 1962Ka27, 1969Ho26] Ku08, 1971Gr17, 1961Ry02, 2022Be20, 2016Al28, J10, 2013Al11, 2013Be10, 2012Su11, 2011AlZX, h30, 1973BoXL, 1973BoXW, 1971Er02, 1965Le08, r22, 1961Do02, 1960Og01, 1960Ry01, 1953Ba60, 602]
<sup>218</sup> Rn	6.466(5)	7.262(2)	100%				Ko54, 1973BoXL, 2012Su11, 1971Er02, 1963Di08,
<sup>222</sup> Ra	6.246(6)	6.678(4)	100%		2.64(31)×10 <sup>-8</sup> %*	** <sup>14</sup> C	e17, 1962Di08, 1961Ru06, 1958To25, 1948St42] Ko54, 1991Hu02, 1985Ho21, 1985Pr01, 1956As38, o13, 1991Hu2Y, 1991LeZV, 1987BaZS, 1976Ka08, aZD, 1969Pe17, 1964Ba49, 1963Le17, 1961Fo08, u06, 1960Be25, 1958To25, 1958Sm88, 1948St42]
<sup>226</sup> Th	5.729(6)	6.453(1)	100%				Ma30, 1995Ko54, 1976Ku08, 2012Po13, 1987Mi10, aZD, 1974KaZM, 1969Br10, 1968GuZU, 1963Le17, v06, 1956As38, 1953AsZZ, 1948St42]
<sup>230</sup> U	5.571(5)	5.992(1)	100%		4.8(20)×10 <sup>-12</sup> %	<sup>22</sup> Ne	Ma30, 2001Bo11, 1995Ko54, 1976Ku08, 2012Po12, a54, 1999Pa22, 1996Tr10, 1974KaZM, 1969Pe17, a14, 1963Le17, 1961Ru06, 1956As38, 1953AsZZ,

22 examples of cluster emission are detailed.

- <sup>14</sup>C, <sup>20</sup>O, <sup>23</sup>F, <sup>22,24</sup>Ne, <sup>28,30</sup>Mg. <sup>32,34</sup>Si

Branching ratios and type

are listed in table 2 of each Tz

**Table 1028** 

direct <sup>14</sup>C emission from <sup>223</sup>Ra\*,  $J^{\pi} = 3/2^+$ ,  $T_{1/2} = 11.4354(17)$  d\*\*,  $Q_{14C} = 31.83$  MeV,  $BR_{14C} = 8.9(4) \times 10^{-8} \%$ \*\*\*.

$E_{14C}(\text{c.m.})$	$E_{14C}(\text{lab})$	$I_{14C}(\text{rel})$	$I_{14C}(abs)$	$J_f^{\boldsymbol{\pi} @}$	$E_{daughter}(^{209}\text{Pb})^{@}$	coincident γ-rays <sup>@</sup>
30.43 31.07 31.50	28.52 29.12 29.52	5% <sup>@@</sup> 100% <sup>@@</sup> 19% <sup>@@</sup>	$3.6 \times 10^{-9}\%$ $7.2 \times 10^{-8}\%$ $1.3 \times 10^{-8}\%$	15/2 <sup>-</sup> 11/2 <sup>+</sup> 9/2 <sup>+</sup>	1.423 0.779 0.0	0.6435, 0.7789, 1.4227 0.7789

If energies were measured, individual tables are presented.

<sup>\*</sup> All values from [1992Ar02], except where noted.

<sup>\*\* [2015</sup>Co02].

<sup>\*\*\* [1995</sup>Ho11].

<sup>@ [2015</sup>Ch30].

# • Summary tables for all types of charged particle decays have been added

Summary of known  $\beta_p$  Emitters. Detailed references for each nucleus can be found in their respective  $T_z$  tables.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\varepsilon_p}$ (MeV)	BR	other decays	$T_z$
		-,-			-	-
9C	(3/2-)	126.5(9) ms	16.680(2)	61.1(17)%	$\beta_{\alpha},\beta_{p},\alpha$	-3/2
13O	$(3/2^{-})$	8.58(5) ms	15.826(10)	11.3(20)%	$\beta_{\alpha}$	-3/2
<sup>17</sup> Ne	1/2-	109.3(6) ms	13.9485(4)	94.4(29)%	$\beta_{\alpha}$	-3/2
$^{20}$ Mg	$0^{+}$	90.4(6) ms	8.437(2)	30.0(12)%		-2
<sup>21</sup> Mg	5/2+	118.6(5) ms	10.657(1)	20.9(13)%	$\beta_{\alpha}$	-3/2
<sup>22</sup> Al	4+	91.1(5) ms	13.10(40)#	54.5(25)%	$\beta_{2p}, \beta_{\alpha}$	-2
<sup>22</sup> Si	$0^{+}$	28.6(14) ms	15.45(50)#	61.8(52)%	$\beta_{2p}$	-3
<sup>23</sup> Al	5/2+	446(6) ms	4.6406(4)	1.22(5)%	, -,	-3/2
<sup>23</sup> Si	$(5/2)^+$	42.3(4) ms	17.06(50)#	81.8(11)%	$\beta_{2p}$ , $\beta_{3p}$	-5/2
<sup>24</sup> Al	4+	2.053(4) s	2.19207(23)	0.0012(3)%	$\beta_{\alpha}$	-1
<sup>24</sup> Si	0+	141.4(15) ms	8.930(19)	33.3(16)%	,	-2
<sup>25</sup> Si	5/2+	220(3) ms	10.472(10)	35.0(20)%		-3/2
$^{26}P$	3+	43.6(3) ms	12.775(61)	33.5(20)%	$\beta_{2p}$	-2
$^{27}P$	$(5/2)^+$	260(80) ms	4.262(9)	≈0.07%	1	-3/2
<sup>27</sup> S	$(5/2^+)$	16.3(2) ms	17.34(40)#	62.2(29)%	$\beta_{2p}$	-5/2
28P	3+	270.3(5) ms	2.7600(11)	0.0013(4)%	βα	-1
<sup>28</sup> S	$0^+$	125(10) ms	9.17(16)	20.7(20)%		-2
<sup>29</sup> S	$(5/2^{+})$	187(6) ms	11.109(13)	47(5)%		-3/2
<sup>31</sup> C1	3/2+	190(1) ms	5.877(3)	2.4(2)%		-3/2
31 Ar	5/2+	15.1(3) ms	18.10(20)#	68.3(3)%	$\beta_{2p}$ , $\beta_{3p}$	-5/2
32C1	1+	298(1) ms	3.8169(6)	0.026(5)%	$\beta_{\alpha}$	-1
<sup>32</sup> Ar	0+	98(2) ms	9.553(2)	35.58(22)%		-2
<sup>33</sup> Ar	1/2+	173.0(20) ms	9.3423(4)	38.8(14)%		-3/2
$^{35}$ K	3/2+	150(25) ms	5.9782(5)	0.37(15)%		-3/2
<sup>35</sup> Ca	$(1/2^+)$	25.7(2) ms	16.28(20)#	95.7(15)%	$\beta_{2p}$	-5/2
<sup>36</sup> K	2+	342(2) ms	4 3075(3)	0.048(14)%	R	-1

Summary of known  $\beta_{\alpha}$  emitters. Detailed references for each nucleus can be found in their respective  $T_z$  tables.

<sup>114</sup> Cs	$(1^{+})$	0.57(2) s	15.115(90)	0.16(6)%	$\beta_p, \alpha$	+2	
<sup>115</sup> Cs		1.03(10) s	11.46(10)#	0.010(5)%	$\beta_p$	+5/2	
<sup>115</sup> Xe	$(5/2^{+})$	18(4) s	9.755(15)	0.0003(1)%	$\hat{\beta_p}$	+7/2	
<sup>116</sup> Cs	$(1^{+})$	0.70(4) s	13.08(10)#	0.049(25)%	$\beta_p$	+3	
<sup>116m</sup> Cs		3.85(13) s	13.18(12)#	< 0.0033%	$\beta_p$	+3	
117Ba	(3/2)	1.75(7) s	11.24(25)	0.011-0.038%	$\beta_p$	+5/2	_
<sup>118</sup> Cs	2	14(2) s	11.055(31)	< 0.0024(4)%	$\beta_p$	+4	
<sup>120</sup> Cs	2(+)	61.3(11) s	8.955(30)	0.000020(4)%	$\beta_p$	+5	
<sup>181</sup> Hg	$(1/2^{-})$	3.6(1) s	12.961(25)	9(2)X10 <sup>-6</sup> %	$\beta_p, \alpha$	+21/2	

**Table 1121** Summary of known  $\beta_{\alpha}^-$  emitters. Detailed references for each nucleus can be found in their respective  $T_z$  tables.

Nuclide	$J^{\pi}$	$T_{1/2}$	Q <sub>β</sub> - α (MeV)	BR <sub>β</sub> - α (%)	other decays	$T_z$
<sup>212m</sup> Bi	(9 <sup>-</sup> )	25.0(2) m	11.625(30)	30(1)%	$\begin{array}{c} \alpha \\ \alpha \end{array}$	+23
<sup>214</sup> Bi	1 <sup>-</sup>	19.71(2) m	11.102(11)	$3.03 \times 10^{-3}\%$		+24

 Table 1122

 Summary of known  $BR_{E_F}$  emitters. Detailed references for each nucleus can be found in their respective  $T_z$  tables.

Nuclide	$J^{\pi}$	$T_{1/2}$	$\mathrm{BR}_{arepsilon_F}$	other decays	$T_z$	
<sup>178</sup> Tl	$(4^-, 5^-)$	252(20) ms	0.15(6)%	α	+8	
180Tl	(5-)		3.2(3)X10 <sup>-3</sup> %	α	+9	
<sup>186</sup> Bi	(3 <sup>+</sup> )	14.8(8) ms	< 0.022(13)%	α	+10	
<sup>186m</sup> Bi	$(10^{-})$	9.8(4) ms	< 0.022(13)%	α	+10	
<sup>188</sup> Bi	(3+)	60(3) ms	0.46(9)%	α	+11	
$^{188m}$ Bi	$(10^{-})$	265(10) ms	≈0.11%	α	+11	
<sup>190</sup> Bi	(3 <sup>+</sup> )	6.3(1) s	$2.5(5)\times10^{-5}$	α	+12	
<sup>190m</sup> Bi	$(10^{-})$	6.2(1) s	$4.1^{+0.8}_{-1.5} \times 10^{-5}$	α	+12	
<sup>192</sup> At		11.5(6) ms	< 0.42(9)%	α	+11	
192m ∆t	(9- 10-)	88(6) ms	~0.42(9)%	ď	±11	

Summary of known direct  $\alpha$  emitters. Detailed references for each nucleus can be found in their respective  $T_z$  tables.

Nuclide	$J^{\pi}$	$T_{1/2}$	$Q_{\alpha}$	$BR_{\alpha}$ (%)	other decays	$T_z$
404						
<sup>104</sup> Te	0+	<18 ns	5.10(21)	100%		0
<sup>105</sup> Te	$(5/2^{+})$	0.62(7) μs	5.069(3)	100%		+1/2
<sup>106</sup> Te	0+	$70^{+20}_{-10}~\mu s$	4.290(9)	100%		+1
<sup>107</sup> Te	$(5/2^{+})$	3.1(1) ms	4.004(6)	70(30)%		+3/2
108I		26.4(8) ms	4.099(5)	100%		+1
<sup>108</sup> Te	0+	2.1(1) s	3.445(4)	49(4)%		+2
<sup>108</sup> Xe	0+	$58^{+106}_{-23} \mu s$	4.57(21)	100%		0
109I	1/2+	93.5(3) μs	3.918(21)	0.014(4)%	p	+3/2
109 Xe	(7/2+)	13(2) ms	4.217(7)	100%	•	+1/2
<sup>109</sup> Te	(5/2+)	4.3(1) s	3.198(6)	3.9(13)%	$\beta_p$ , $\beta_\alpha$	+5/2
110Xe	0+	93(3) ms	3.872(9)	64(35)%	.,	+1
110Te	0+	18.4(8) s	2.723(15)	≈0.00076%		+3
110I	(1 <sup>+</sup> )	664(24) ms	3.536(10)	17(4)%	$\beta_p$ , $\beta_\alpha$	+2
111 Xe	(7/2+)	0.81(20) s	3.719(10)	10.4(19)%		+3/2
112Xe	0+	2.7(8) s	3.330(6)	0.8 <sup>+1.1</sup> <sub>-0.5</sub> %		+2
112I	(1 <sup>+</sup> )	3.34(8)s	2.957(12)	≈0.0012%	$\beta_p, \beta_\alpha$	+3
113Xe	(5/2+)	2.74(8) s	3.087(8)	≈0.011%	$\beta_p, \beta_\alpha$	+5/2
114Cs	(1+)	0.57(2) s	3.360(60)	0.018(6)%	$\beta_p, \beta_\alpha$	+2
114 <b>Ba</b>	0+	380 <sup>+190</sup> ms	3.592(19)	0.9(3)%	$\beta_n$	+1



Database was finished May 2025. Datasets from -4 to +31! Li to Og!

139 datasets with 1456 delayed and direct emitters from 1241 nuclei, with 3962 discrete transitions detailed with 3962 unique references

All beta-delayed and direct p,  $\alpha$ , c and f emitters

All of these are available for download (as .pdf) individually or everything in one document.

Information on nuclei are updated as new papers come out.

Website is updated ~bi-month

Update emails are sent out every couple months.

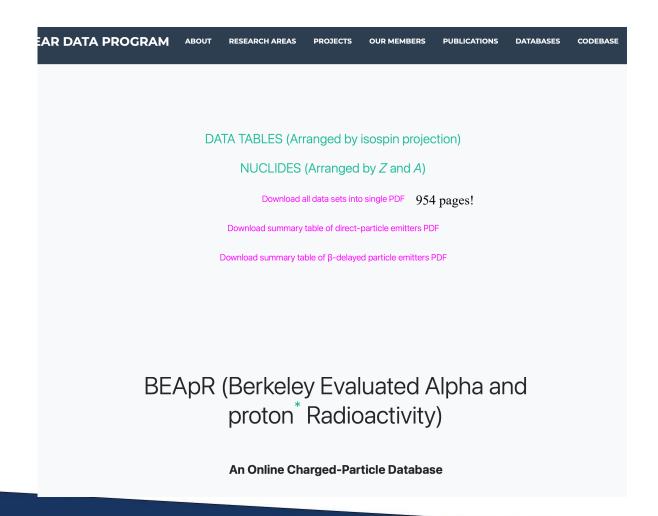


https://nucleardata.berkeley.edu/research/betap.html

## Where is the database?









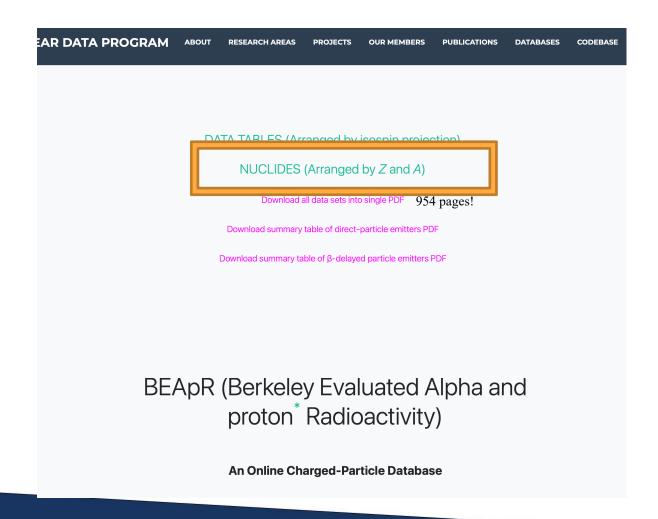


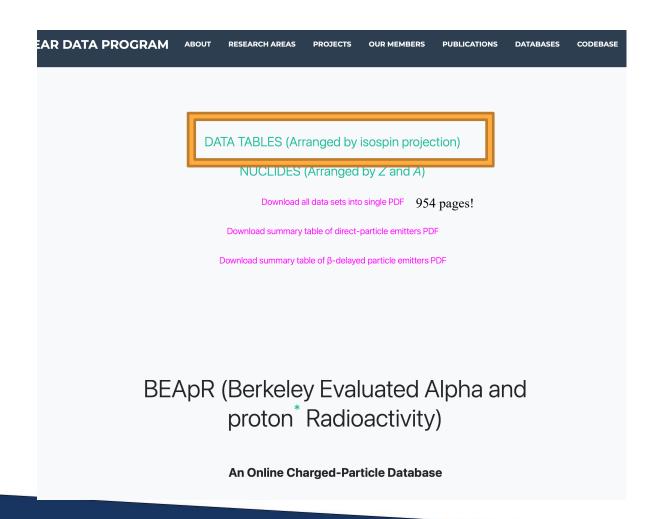


Table 1: Master list of nuclides (click on  $T_z$  to open link)

Nuclide	Decay Mode(s)	$T_z$			
<sup>4</sup> Li	p	-1 odd Z			
<sup>7</sup> B	p	-3/2 odd Z			
$^{8}\mathrm{B}$	$\beta$ -2 $\alpha$	-1 odd Z			
°C	β-p, β-α	-3/2 even Z			
<sup>10</sup> N	p	-2 odd Z			
$^{11}N$	p	-3/2 odd Z			
$^{12}N$	β-α	-1 odd Z			
<sup>11</sup> O	2p	-5/2 even Z			
12O	p	-2 even Z			
<sup>13</sup> O	β-p	-3/2 even Z			
<sup>13</sup> F	3p	-5/2 odd Z			
$^{14}F$	p	-2 odd Z			
15 <sub>E</sub>	n .	-3/2 odd 7			
<sup>287</sup> Mc	α	+57/2 odd Z			
<sup>288</sup> Mc	α	+29 odd Z			
<sup>289</sup> Mc	α	+59/2 odd Z			
<sup>290</sup> Mc	α	+30 odd Z			
<sup>289</sup> Lv	α	+57/2 even Z			
<sup>290</sup> Lv <sup>291</sup> Lv	α	+29 even Z			
<sup>291</sup> Lv <sup>292</sup> Lv	α	+59/2 even Z +30 even Z			
2893Lv	α	+30 even Z +61/2 even Z			
		TOTAL EVER Z			
$^{293}{ m Ts}$	α	+59/2 odd Z			
<sup>294</sup> Ts	α	+30 odd Z			
<sup>293</sup> Og <sup>294</sup> Og	α	+57/2 even Z			

Tz values are clickable clickable links







 $T_z = -7/2 \text{ (Even-}Z)$  $T_z = -4 \text{ (AII-Z)}$  $T_z = -7/2 \text{ (Odd-}Z)$   $T_z = -5/2 \text{ (Even-}Z)$   $T_z = -5/2 \text{ (Odd-}Z)$  $T_z = -3$  (Even-Z)  $T_z = -3$  (Odd-Z)  $T_z = -2$  (Even-Z)  $T_z = -5/2 \text{ (Odd-2)}$   $T_z = -3/2 \text{ (Even-Z)}$   $T_z = -3/2 \text{ (Odd-Z)}$   $T_z = -1/2 \text{ (Even-Z)}$   $T_z = -1/2 \text{ (Odd-Z)}$   $T_z = +1/2 \text{ (Even-Z)}$   $T_z = +1/2 \text{ (Odd-Z)}$  $T_z = -2 \text{ (Even-2)}$   $T_z = -2 \text{ (Odd-Z)}$   $T_z = -1 \text{ (Even-Z)}$   $T_z = -1 \text{ (Odd-Z)}$  $T_z = 0$  (Even-Z)  $T_z = 0$  (Odd-Z)  $T_z = +1$  (Even-Z)  $T_z = +3/2$  (Even-Z)  $T_z = +3/2$  (Odd-Z)  $T_z = +5/2$  (Even-Z)  $T_z = +1 \text{ (Odd-}Z)$   $T_z = +2 \text{ (Even-}Z)$  $T_z = +2 \text{ (Odd-}Z)$  $T_z = +5/2 \text{ (Odd-}Z\text{)}$   $T_z = +7/2 \text{ (Even-}Z\text{)}$  $T_z = +3 \text{ (Even-Z)}$   $T_z = +3 \text{ (Odd-Z)}$  $T_z = +7/2 \text{ (Odd-}Z)$  $T_z = +4 \text{ (Even-}Z)$  $T_z = +9/2 \text{ (Even-}Z)$   $T_z = +9/2 \text{ (Odd-}Z)$  $T_z = +4 \text{ (Odd-}Z)$   $T_z = +5 \text{ (Even-}Z)$  $T_z = +11/2 \text{ (Even-Z)}$  $T_z = +5 \text{ (Odd-}Z)$  $T_z = +11/2 \text{ (Odd-}Z\text{)}$   $T_z = +13/2 \text{ (Even-}Z\text{)}$  $T_z = +6 \text{ (Even-Z)}$   $T_z = +6 \text{ (Odd-Z)}$  $T_z = +13/2 \text{ (Odd-}Z)$  $T_z = +7 \text{ (Even-}Z\text{)}$  $T_z = +15/2 \text{ (Even-Z)}$   $T_z = +15/2 \text{ (Odd-Z)}$  $T_z = +7 \text{ (Odd-}Z)$   $T_z = +8 \text{ (Even-}Z)$  $T_z = +17/2 \text{ (Even-Z)}$  $T_z = +8 \text{ (Odd-}Z)$  $T_z = +17/2 \text{ (Odd-}Z)$   $T_z = +19/2 \text{ (Even-}Z)$  $T_z = +9 \text{ (Even-}Z)$   $T_z = +9 \text{ (Odd-}Z)$  $T_z = +19/2 \text{ (Odd-}Z)$  $T_z = +10 \text{ (Even-Z)}$  $T_{v} = +21/2$  (Even-Z  $T_{v} = +10 \text{ (Odd-Z)}$  $T_z = +21/2 \text{ (Odd-Z)}$  $T_z = +11 \text{ (Even-}Z)$  $T_z = +23/2 \text{ (Even-}Z\text{)}$  $T_Z = +11 \text{ (Odd-}Z)$  $T_z = +12 \text{ (Even-}Z\text{)}$   $T_z = +12 \text{ (Odd-}Z\text{)}$  $T_r = +23/2 \text{ (Odd-Z)}$  $T_z = +25/2 \text{ (Even-}Z)$  $T_z = +25/2 \text{ (Odd-}Z)$  $T_z = +13 \text{ (Even-}Z\text{)}$  $T_z = +13 \text{ (Odd-}Z)$   $T_z = +14 \text{ (Even-}Z)$  $T_z = +27/2$  (Even-Z)  $T_z = +27/2 \text{ (Odd-}Z)$  $T_z = +29/2 \text{ (Even-Z)}$   $T_z = +29/2 \text{ (Odd-Z)}$  $T_z = +14 \text{ (Odd-}Z)$   $T_z = +15 \text{ (Even-}Z)$  $T_z = +31/2 \text{ (Even-}Z)$  $T_z = +15 \text{ (Odd-}Z)$  $T_z = +31/2 \text{ (Odd-}Z)$   $T_z = +33/2 \text{ (Even-}Z)$  $T_z = +16 \text{ (Even-}Z\text{)}$  $T_z = +16 \text{ (Odd-}Z)$  $T_z = +33/2 \text{ (Odd-}Z)$  $T_z = +17 \text{ (Even-}Z)$  $T_z = +35/2$  (Even-Z)  $T_z = +35/2$  (Odd-Z)  $T_z = +17 \text{ (Odd-}Z)$   $T_z = +18 \text{ (Even-}Z)$  $T_z = +37/2$  (Even-Z)  $T_z = +18 \text{ (Odd-}Z)$  $T_z = +37/2 \text{ (Odd-}Z)$   $T_z = +39/2 \text{ (Even-}Z)$  $T_z = +19 \text{ (Even-}Z)$   $T_z = +19 \text{ (Odd-}Z)$  $T_z = +39/2 \text{ (Odd-}Z)$  $T_z = +20 \text{ (Even-}Z)$  $T_z = +20 \text{ (Odd-}Z)$   $T_z = +21 \text{ (Even-}Z)$  $T_z = +41/2$  (Even-Z)  $T_z = +41/2$  (Odd-Z)  $T_z = +43/2$  (Even-Z)  $T_z = +21 \text{ (Odd-}Z)$  $T_z = +43/2 \text{ (Odd-}Z)$   $T_z = +45/2 \text{ (Even-}Z)$  $T_z = +22 \text{ (Even-}Z)$   $T_z = +22 \text{ (Odd-}Z)$  $T_z = +45/2 \text{ (Odd-}Z)$  $T_z = +23 \text{ (Even-}Z\text{)}$  $T_z = +47/2 \text{ (Even-}Z)$   $T_z = +47/2 \text{ (Odd-}Z)$  $T_z = +23 \text{ (Odd-}Z\text{)}$   $T_z = +24 \text{ (Even-}Z\text{)}$  $T_z = +49/2 \text{ (Even-Z)}$  $T_z = +24 \text{ (Odd-}Z)$  $T_z = +49/2 \text{ (Odd-}Z)$  $T_z = +25 \text{ (Even-}Z)$   $T_z = +25 \text{ (Odd-}Z)$  $T_z = +51/2 \text{ (Even-}Z\text{)}$  $T_z = +51/2 \text{ (Odd-}Z)$  $T_z = +26 \text{ (Even-}Z)$  $T_z = +26 \text{ (Odd-}Z\text{)}$   $T_z = +27 \text{ (Even-}Z\text{)}$  $T_z = +53/2$  (Even-Z)  $T_z = +53/2 \text{ (Odd-}Z)$  $T_z = +55/2 \text{ (Even-}Z\text{)}$  $T_z = +27 \text{ (Odd-}Z)$  $T_r = +55/2 \text{ (Odd-}Z)$  $T_z = +28 \text{ (Even-Z)}$  $T_z = +57/2 \text{ (Even-}Z\text{)}$  $T_z = +28 \text{ (Odd-}Z)$  $T_z = +57/2 \text{ (Odd-}Z\text{)}$   $T_z = +59/2 \text{ (Even-}Z\text{)}$  $T_z = +29 \text{ (Even-}Z\text{)}$  $T_7 = +29 \text{ (Odd-}Z)$  $T_z = +59/2 \text{ (Odd-}Z)$  $T_z = +30 \text{ (Even-}Z)$  $T_z = +61/2 \text{ (Even-}Z\text{)}$  $T_z = +30 \text{ (Odd-}Z)$   $T_z = +31 \text{ (Even-}Z)$ 



 $T_z = -7/2 \text{ (Odd-}Z)$  $T_z = -5/2$  (Even-Z)  $T_z = -5/2 \text{ (Odd-}Z)$  $T_z = -1/2 \text{ (Odd-}Z)$  $T_{\nu} = +1/2$  (Even-Z  $T_z = +1/2 \text{ (Odd-}Z)$  $T_z = +3/2 \text{ (Even-}Z)$  $T_z = +3/2 \text{ (Odd-Z)}$  $T_z = +5/2 \text{ (Even-}Z)$  $T_z = +5/2 \text{ (Odd-}Z)$  $T_{\tau} = +7/2 \text{ (Even-Z)}$  $T_z = +7/2 \text{ (Odd-}Z)$  $T_z = +9/2 \text{ (Even-}Z)$  $T_2 = +9/2 \text{ (Odd-}Z)$  $T_z = +11/2 \text{ (Even-Z)}$  $T_z = +11/2 \text{ (Odd-}Z)$  $T_z = +13/2 \text{ (Even-}Z)$  $T_z = +13/2 \text{ (Odd-}Z)$  $T_z = +15/2$  (Even-Z  $T_z = +15/2 \text{ (Odd-}Z)$  $T_z = +17/2 \text{ (Even-Z)}$  $T_z = +17/2 \text{ (Odd-Z)}$  $T_z = +19/2 \text{ (Even-}Z\text{)}$  $T_z = +19/2 \text{ (Odd-}Z)$  $T_{\tau} = +21/2$  (Even-Z  $T_z = +21/2 \text{ (Odd-Z)}$  $T_z = +23/2 \text{ (Even-}Z\text{)}$  $T_r = +23/2 \text{ (Odd-}Z)$  $T_z = +25/2 \text{ (Even-}Z)$  $T_z = +25/2 \text{ (Odd-}Z)$  $T_z = +27/2$  (Even-Z)  $T_z = +27/2 \text{ (Odd-}Z)$  $T_z = +29/2 \text{ (Even-Z)}$  $T_{\tau} = +29/2 \text{ (Odd-Z)}$  $T_z = +31/2 \text{ (Even-}Z)$  $T_z = +31/2 \text{ (Odd-}Z)$   $T_z = +33/2 \text{ (Even-}Z)$  $T_z = +33/2 \text{ (Odd-}Z)$  $T_z = +35/2$  (Even-Z)  $T_z = +35/2$  (Odd-Z)  $T_z = +37/2 \text{ (Odd-}Z)$  $T_z = +39/2$  (Even-Z)  $T_z = +39/2 \text{ (Odd-}Z)$  $T_z = +41/2$  (Even-Z)  $T_z = +41/2$  (Odd-Z)  $T_z = +43/2 \text{ (Odd-}Z)$   $T_z = +45/2 \text{ (Even-}Z)$  $T_z = +45/2 \text{ (Odd-}Z)$  $T_{\tau} = +47/2 \text{ (Even-Z)}$  $T_z = +47/2 \text{ (Odd-Z)}$  $T_z = +49/2 \text{ (Even-Z)}$  $T_z = +49/2 \text{ (Odd-}Z)$  $T_z = +51/2 \text{ (Even-}Z\text{)}$  $T_z = +51/2 \text{ (Odd-}Z)$  $T_z = +53/2$  (Even-Z)  $T_z = +53/2 \text{ (Odd-}Z)$  $T_z = +55/2 \text{ (Even-Z)}$  $T_r = +55/2 \text{ (Odd-}Z)$  $T_z = +57/2 \text{ (Even-}Z\text{)}$  $T_z = +57/2 \text{ (Odd-}Z)$  $T_z = +59/2$  (Even-Z)  $T_z = +59/2 \text{ (Odd-}Z)$  $T_z = +61/2 \text{ (Even-}Z)$ 

 $T_z = -3$  (Even-Z)  $T_z = -3 \text{ (Odd-}Z)$   $T_z = -2 \text{ (Even-}Z)$  $T_z = -2 \text{ (Odd-}Z)$  $T_z = -1$  (Even-Z)  $T_z = -1$  (Odd-Z)  $T_z = 0$  (Even-Z)  $T_z = 0 \text{ (Odd-}Z)$  $T_z = +1$  (Even-Z)  $T_z = +1 \text{ (Odd-}Z\text{)}$   $T_z = +2 \text{ (Even-}Z\text{)}$  $T_z = +2 \text{ (Odd-}Z)$  $T_z = +3$  (Even-Z)  $T_{\tau} = +3 \; (Odd-Z)$  $T_z = +4 \text{ (Even-}Z)$  $T_z = +4 \text{ (Odd-}Z)$   $T_z = +5 \text{ (Even-}Z)$  $T_z = +5 \text{ (Odd-}Z)$  $T_z = +6 \text{ (Even-Z)}$   $T_z = +6 \text{ (Odd-Z)}$  $T_z = +7 \text{ (Odd-}Z)$   $T_z = +8 \text{ (Even-}Z)$  $T_z = +8 \text{ (Odd-}Z)$  $T_z = +9 \text{ (Even-Z)}$   $T_z = +9 \text{ (Odd-Z)}$  $T_z = +10$  (Even-Z)  $T_{\tau} = +10 \text{ (Odd-Z)}$  $T_z = +11 \text{ (Even-}Z)$  $T_z = +11 \text{ (Odd-}Z)$  $T_{\nu} = +12 \text{ (Even-Z)}$  $T_z = +12 \text{ (Odd-}Z)$  $T_z = +13 \text{ (Even-}Z\text{)}$  $T_{r} = +13 \text{ (Odd-}Z)$  $T_z = +14 \text{ (Even-}Z)$  $T_z = +14 \text{ (Odd-}Z)$  $T_z = +15 \text{ (Even-}Z)$  $T_z = +15 \text{ (Odd-}Z)$  $T_z = +16 \text{ (Even-}Z)$  $T_z = +16 \; (Odd-Z)$ T<sub>z</sub> = +17 (Odd-Z) T<sub>z</sub> = +18 (Even-Z)  $T_z = +18 \text{ (Odd-}Z)$  $T_z = +19 \text{ (Even-}Z)$   $T_z = +19 \text{ (Odd-}Z)$  $T_z = +20 \text{ (Even-}Z)$  $T_z = +20 \text{ (Odd-}Z)$   $T_z = +21 \text{ (Even-}Z)$  $T_z = +21 \text{ (Odd-}Z)$  $T_z = +22 \text{ (Even-Z)}$  $T_Z = +23 \text{ (Even-}Z)$ 

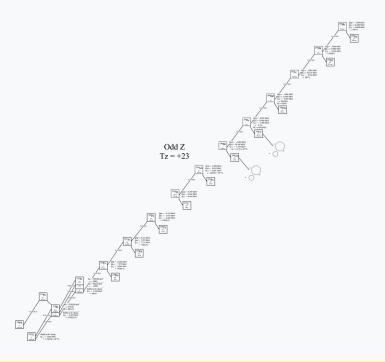
T<sub>e</sub> = +24 (Odd-Z)
T<sub>e</sub> = +25 (Even-Z)
T<sub>e</sub> = +25 (Odd-Z)
T<sub>e</sub> = +26 (Odd-Z)
T<sub>e</sub> = +26 (Odd-Z)
T<sub>e</sub> = +27 (Even-Z)
T<sub>e</sub> = +27 (Gdd-Z)
T<sub>e</sub> = +27 (Even-Z)
T<sub>e</sub> = +28 (Even-Z)
T<sub>e</sub> = +28 (Odd-Z)
T<sub>e</sub> = +28 (Odd-Z)
T<sub>e</sub> = +30 (Odd-Z)
T<sub>e</sub> = +30 (Even-Z)
T<sub>e</sub> = +30 (Even-Z)
T<sub>e</sub> = +30 (Even-Z)
T<sub>e</sub> = +30 (Even-Z)

 $T_z = +24 \text{ (Even-}Z)$ 

#### Isospin $T_z = +23$ (Odd-Z)

#### **Downloadable documentation:**

Data table (PDF)





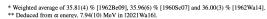
https://nucleardata.berkeley.edu/research/betap.html

Table 1 Observed and predicted  $\beta$ -delayed particle emission from the odd-Z,  $T_c$  = +23 nuclei. Unless otherwise stated, all Q-values are taken from [2021Wa16] or deduced from values therein. The  $J^{\pi}$  value for  $Z^{300}$ T1 is taken from ENSDE.

Nuclide	Ex.	$J^{\pi}$	$T_{1/2}$	$Q_{\varepsilon}$	Q <sub>β</sub> -	Q <sub>β</sub> - α	BR <sub>β</sub> - α	$\mathrm{BR}_{arepsilon F}$	Experimental
208Tl(ThC")*		5+	3.0527(33) m	-3.480(30)	4.998(2)	5.695(2)			[1971Ac02]
212Bi(ThC)		1-	60.600(43) m	-0.569(2)	2.252(2)	11.386(2)			[1961Ap03]
<sup>212m</sup> Bi	0.239(30)	$(9^{-})$	25.0(2) m	-0.340(30)	2.491(30)	11.625(30)	30(1)%		[2013Ch12, 1984Es01, 1980Le27,
									1978Ba44, 1978BaYL, 1978BaZI]
					$Q_{\varepsilon_P}$	$Q_{\varepsilon\alpha}$			
<sup>216</sup> At		1-	300(30) μs	0.474(4)	-6.662(7)	7.381(4)			[1951Me10]
216m1 At	0.048(24)	$(4^{-})$		0.522(24)	-6.614(25)	7.429(24)			[1994Li10, 1971Br13, 1965Br11]
<sup>216m2</sup> At	0.399(30)	(9-)		0.873(30)	-6.263(31)	7.780(30)			[1994Li10, 1971Br13, 1965Br11]
<sup>220</sup> Fr		1+	27.4(3) s	0.870(4)	-6.203(5)	7.275(4)			[1971Br13]
<sup>224</sup> Ac		0-	2.78(16) h**	1.408(4)	-5.437(4)	7.197(4)			[1951Me10, 1987Mi10]
<sup>228</sup> Pa		3+	19.5(4) h	2.153(4)	-4.215(5)	7.673(5)			[2021Km01]
<sup>232</sup> Np		$(4^{+})$	14.7(3) m	2.75(10)#	-3.35(10)#	8.16(10)#			[1970Ho27]
236Am		5-	3.6(2) m	3.14(12)#	-2.29(12)#	9.01(12)#			[2005As01]
<sup>240</sup> Bk			4.8(8) m	3.94(15)#	-1.02(15)#	10.34(15)#		$1.3^{+1.8}_{-0.7} \times 10^{-3}\%$	[1983Ga05, 1980Ga07, 1980GaZZ]
<sup>244</sup> Es			37(4) s	4.55(18)#	0.05(18)#	11.88(18)#		0.012(4) %	[2002Sh02, 1980Ga07, 1980GaZZ]
<sup>248</sup> Md			13 <sup>+3</sup> <sub>-2</sub> s	5.05(18)#	1.08(19)#	13.05(18)#		< 0.05%	[2024PoXY]
<sup>252</sup> Lr			$410^{+70}_{50}$ ms	5.67(19)#	2.28(19)#	14.21(19)#			[2024PoXY]
<sup>256</sup> Db			410 <sup>+70</sup> <sub>-50</sub> ms 1.4 <sup>+0.3</sup> <sub>-0.2</sub> s	6.08(19)#	3.06(19)#	15.00(19)#			[2024PoXY]
<sup>260</sup> Bh			35 <sup>+19</sup> <sub>-9</sub> ms	6.58(20)#	3.84(20)#	16.48(20)#			[2008Ne01]
						. ,			

Particle separation, Q-values, and measured values for direct particle emission of the odd-Z, T<sub>z</sub> = +23 nuclei. Unless otherwise stated, all S and Q-values are taken from [2021Wa16] or deduced from values therein.

Nuclide	$S_p$	$Q_{\alpha}$	$BR_{\alpha}$	$BR_{SF}$	Experimental
208Tl(ThC")	7.552(30)	1.22(20)			
<sup>212</sup> Bi(ThC)	4.914(3)	6.207	35.94(3) %*		[1971Gr17, 1962Be09, 1960Sc07, 1960Wa14, 1984Es01,
(,	(- )	0122.	55		1969Gr28, 1966II01, 1966KIZZ, 1963Co28, 1961Ap03,
					1961Ba12, 1961Fe04, 1960Ga15, 1960Gi07, 1960Ha19,
					1958De25, 1956Ho11, 1956Ko60, 1955We10, 1949Me54,
					1948Gh01, 1943Ka05, 1933Ru03]
$^{212m}$ Bi	4.675(30)	6.446(30)	67(1)%		[1984Es01, 1978Ba44]
216At	4.491(4)	7.950(3)	100%		[1994Li10, 1971Br13, 1965Br11, 1973BoXL, 1973BoXW,
					1964Br16, 1964Mc21, 1962Wa28, 1951Me10, 1949Me54,
					1948Gh01]
<sup>216m1</sup> At	4.443(24)	7.998(24)	obs		[1994Li10, 1971Br13, 1965Br11]
<sup>216m2</sup> At	4.092(20)	8.349(30)	obs		[1994Li10, 1971Br13, 1965Br11]
<sup>220</sup> Fr	4.636(4)	6.801(2)	99.65%		[1996Sh05, 1971Br13, 1974Ho27, 1973ChZH, 1970Br29,
					1968Ba73, 1964Br16, 1964Mc21, 1951Me10, 1949Me54,
					1948Gh01]
<sup>224</sup> Ac	4.288(4)	6.327(1)	10(2)%		[1968Le17, 1992Li31, 1951Me10, 1987Mi10, 1976MiZR,
					1973ChZH, 1970Br31, 1969LeZW, 1968Ba73, 1968Br15,
					1967Br15, 1964Mc21, 1958Hi78, 1949Me54, 1948Gh01]
<sup>228</sup> Pa	4.170(5)	6.265(1)	2.0(2)%		[1994Ah03, 1993Sh07, 1964Ge08, 1958Hi78, 1951Me10,
					1949Me54, 1948Gh01]
<sup>232</sup> Np	3.74(10)#	6.01(10)#			
<sup>236</sup> Am	3.43(12)#	6.256(64)	$4.0(10)\times10^{-3}\%$		[2004Sa05, 2002As08, 1989HaZO]
$^{240}$ Bk	2.77(21)#	7.20(19)#			
<sup>244</sup> Es	2.25(26)#	7.696(20)**	$4^{+3}_{-2}\%$		[1973Es02]
<sup>248</sup> Md	2.01(26)#	8.785(47) <sup>@</sup>	61(16)-68(22)%		[2024PoXY, 1973Es01, 2008Ne01, 1971EsZY, 1971EsZZ]
<sup>252</sup> Lr	1.60(26)#	9.132(47)@@	70-90%		[2024PoXY, 2001He35, 2008Ne01, 1999He07, 1999HeZX]
<sup>256</sup> Db	1.32(26)#	9.265(47) <sup>@@@</sup>	90(4)%	10(4)%	[2024PoXY, 2001He35, 2020Ku23, 1999He07, 1999He11,
					1999HeZX]
<sup>260</sup> Bh	0.69(27)#	10.400(59)	100%	<18%	[2008Ne01, 1983OgZX]
		* *			, , , , , , , , , , , , , , , , , , , ,





<sup>\*\*</sup> Weighted average of 2.9(2) h [1951Me10] and 2.55(28) h [1987Mi10].

#### Possible future additions

• Summary tables of values that are poorly or not known. Many of these values might be in experimental data and ignored as "background".

Examples: direct  $\alpha$  emission from  $^{234}Pu^*, J^\pi=0^+, T_{1/2}=8.7(1)~h^{***}, \textit{BR}_\alpha=\approx 6\%$ 

$E_{\alpha}$ (c.m.)	$E_{\alpha}(\text{lab})$	$I_{\alpha}(\text{rel})$	$I_{\alpha}(abs)$	$\mathbf{J}^{m{\pi}***}_f$	$E_{daughter}(^{230}\mathrm{U})^{***}$	coincident γ-rays***	$R_0$ (fm)	HF
6.130 6.252 6.304	6.025 6.145 6.196	0.6% 47% 100%	pprox 0.024% pprox 1.9% pprox 4.1%	4 <sup>+</sup> 2 <sup>+</sup> 0 <sup>+</sup>	0.1693 0.0517 0.0	0.0517, 0.1693 0.0517	1.518(27) 1.518(27) 1.518(27)	$\approx 25$ $\approx 1.1$ $\approx 0.9$

<sup>\*</sup> All values from [1964Hy02] p. 799 (based on unpublished results from R. W. Hoff, F. Asaro, I. Perlman [1960Ho18]), except where noted.

direct  $\alpha$  emission from  $^{207}$ At,  $J^{\pi} = 9/2^{-}$ ,  $T_{1/2} = 1.80(3)$  h\*,  $BR_{\alpha} = \text{obs**}$ .

$E_{\alpha}(\text{c.m.})$	$E_{\alpha}(\mathrm{lab})$	$I_{\alpha}(abs)$	$\mathbf{J}^{\boldsymbol{\pi}}_f$	$E_{daughter}(^{203}\mathrm{Bi})$	coincident γ-rays	R <sub>0</sub> (fm)]	HF
5.872(3)	5.759(3)***	obs**	9/2-	0.0		1.4651(131)	≈1.10

<sup>\*</sup> Weighted average of 1.80(5) h [1962Th08], 1.82(4) h [1969Ba69] and 1.77(5) h [1968GuZX].

<sup>\*\*</sup> Weighted average of 8.8(1) h [1973Ja06] and 8.5(1) h [1949Pe04].

<sup>\*\*\* [2012</sup>Br12].

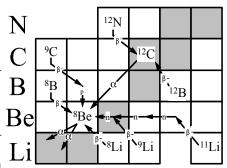
<sup>\*\* &</sup>quot;No serious attempt has been made to determine the degree of alpha-branching of  $At^{207}$ . The best estimate from the alpha-particles of  $At^{207}$  and the yield of  $Po^{207}$  is 10 percent alpha-branching." [1951Ba14].  $\approx 10\%$  is used for the branching ratio in determining the HF value. \*\*\* [1969GoZX].

Possible future additions (once datasets up to Tz = +30 are finished):

- \* p and  $\alpha$  emission from highly excited states (not populated by beta decay)?
- \* (mostly) Low Z exotic decays ( $\beta$  -  $\alpha$ , etc.) (how to handle this)?

Summary of more exotic  $\beta$  delayed charged particle emitters

Nuclide		$T_{1/2}$	decay mode	$Q_{\varepsilon x}$ (MeV)	BR (%)	other decays	ENSDF	Experimental
<sup>6</sup> He		806.7(1) ms	$eta^-$ -d	2.03245(5)	0.0000076(6)%		[2002Ti10]	[ <b>2015Pf01</b> , 1993Bo24]
<sup>8</sup> He		119.1(12) ms	$eta^-$ -t $lpha$ n	6.16364(9)	0.9(1)%	$oldsymbol{eta}^-$ -n	*	[ <b>1996Ba66</b> , 1993Bo24, 1986Bo41]
<sup>8</sup> Li	$2^{+}$	839.9(9) ms	$eta^-$ -2 $lpha$	16.09597(5)	100%		*	[2013Li12, 1986Wa01, 1974Tr01]
								[1970Sc34, 1971Wi05]
$^{8}B$	$2^+$	770(3) ms	$eta^+$ -2 $lpha$	18.072(1)	100%		*	[1964Ma35, 1971Wi05]
<sup>9</sup> Li	3/2-	178.3(4) ms	$\beta^-$ -n2 $\alpha$	12.03375(19)	50.0(18)%		[2004Ti06]	[ <b>1991Re02</b> , 1992Te03, 1970Ch07]
<sup>11</sup> Li	$3/2^{-}$	8.75(4) ms	$\beta^-$ -n $\alpha$	12.6400(6)	0.29(4)%	$\beta^-$ -n, $\beta^-$ -2n	[2012Ke01]	[2008Ma34]
			$\beta^-$ -d	2.6377(6)	0.0130(13)%			[ <b>2008Ra23</b> , 1996Mu19]
			$\beta^-$ -t	4.832.7(6)	0.000093(8)%			[2009Ma72]
			$\beta^-$ -3n2 $\alpha$	11.6645(6)	1.4(2)%			[2008Ma34]
			$\beta^-$ - $\alpha$ n	12.6400(6)	0.29(4)%			[2008Ma34]
<sup>11</sup> Be		13.76(7) s	$eta^- lpha$	2.84515(24)	3.1(5)%		[2012Ke01]	[1971Al07,1981Al03, <b>1982Mi08</b> ]
$^{12}\mathbf{B}$		20.20(2) ms	$\beta^{-}3\alpha$	6.0946(13)	1.58(30)%		[1990Aj01]	[2009Hy01, <b>2009Hy02</b> , 2010Hy01, 1990Aj01]
$^{12}N$	1+	11.000(16) ms	$\beta^+$ -3 $\alpha$	10.063(1)	3.5(5)%		[1990Aj01]	[2009Hy01, <b>2009Hy02</b> , 2010Hy01, 1990Aj01]
$^{16}N$	$2^{-}$	7.13(2) s	$eta^-$ - $lpha$	3.259(2)	0.00106(10)%		[1993Ti07]	[2016Re01, 1993Zh13, 1974Ne10]
<sup>17</sup> Ne	1/2-	109.2(6) ms	$\beta^+$ -p $\alpha$	6.7866(4)	0.0016(4)%	β-p, β-α	[1993Ti07]	[2002Ch61]
$^{18}N$	-	624(12) ms	$eta^-$ - $lpha$	7.668(19)	12.2(6)%	$\beta^-$ -n	[1995Ti07]	[ <b>2007Bu01</b> , 1995ReZZ]
$^{21}$ Mg	5/2+	122(3) ms	$oldsymbol{eta}^+$ -p $oldsymbol{lpha}$	5.937(16)	0.016(3)%	$\beta$ - $\alpha$	[2015Fi05]	[2015Lu13]
$^{212m}$ Bi	$(8^-, 9^-)$	25.0(2) m	$\beta^-$ - $\alpha$	11.456(2)	30(1)%	α	[2005Br03]	[ <b>1984Es01</b> , 1978Ba44]



<sup>\*</sup> J. H. Kelley, J. L. Godwin, C. G. Sheu, ENSDF Jan. 2018, http://www.nndc.bnl.gov/ensdf/

Possible future additions (once datasets up to Tz = +30 are finished):

- \* p and  $\alpha$  emission from highly excited states (not populated by beta decay)?
- \* Low Z exotic decays ( $\beta$  -  $\alpha$ , etc.) (how to handle this)?
- \* Links to theory papers?



#### A BIG thank you to all those who have given me suggestions, commented, etc!

Several experimental colleagues (Rykaczewski, Liddick, Schatz, Sun, Hardy, etc.) have offered suggestions/corrections

Any corrections, additions, or suggestions to improve this database?

new (or old) papers/thesis that I missed?

Please let me know so I can fix it

What else would be useful???

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## Thank you for your attention!

**Evaluation/compilation (UC Berkeley) – Jon Batchelder** 

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