Update on the (nearly finished) Berkeley Evaluated Alpha & proton Radioactivity (BEApR*) An Online Global Heavy Charged Particle Database/Horizontal Evaluation

(a work in progress)

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Aaron Hurst
Yun-Hsuan "Abby" Lee (former undergraduate)
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* The p is silent like pterodactyl.

Talk Outline

1. Intro/Purpose of Evaluation (who benefits from this work)
    - Experimenters & Evaluators
    - Teaching tool

2. Contents of current version
3. The website
4. Future plans

Purpose of this horizontal evaluation/database

Provides an up to date database of relevant information on nuclei that decay by heavy charged particles
- It will be updated as new results are published.

Currently known: > 1300 nuclei

β –delayed emitters
200 ß-p emitters
15 ß-2p emitters
5 ß-3p emitters
2 β-αp or β-pα emitters
23 ß-α emitters
~30 ß-fission emitters

Direct emitters
80 direct proton emitters
10 direct 2p emitters (many inferred from $T_{1/2}$)
~850 direct alpha emitters
~110 Spontaneous fission
~20 cluster (^{14}C, ^{24}Ne, etc.) emitters

+ many, many more to be discovered!

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 E and BR
- Competition between different decay modes

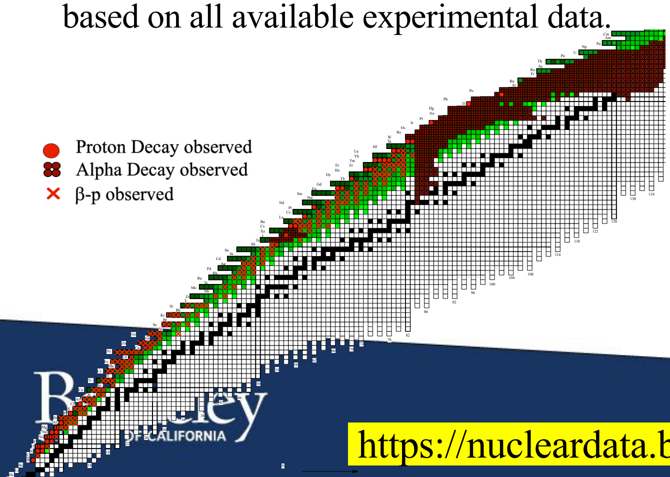
- Involves the entire chart of the nuclides, provides a comprehensive overview of the topic.

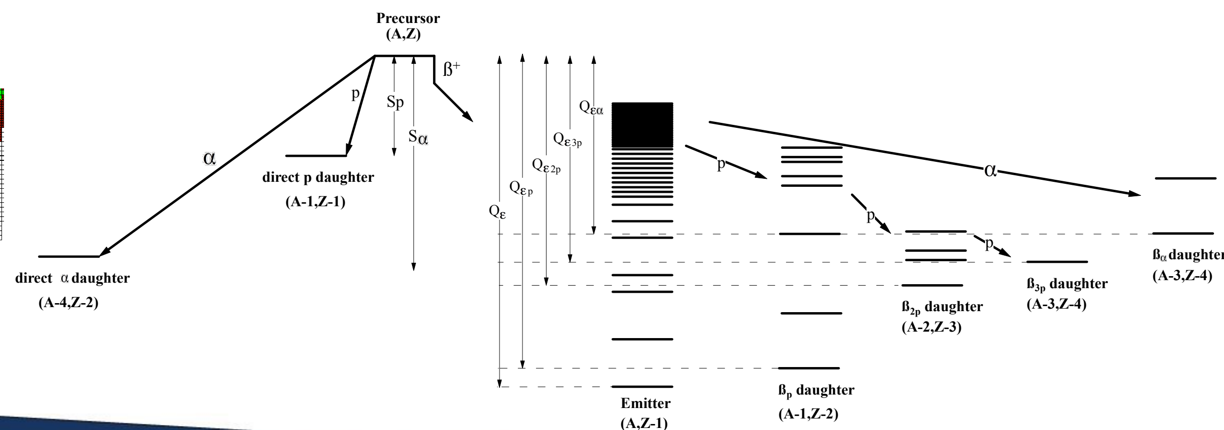
- Evaluates and gives recommended values based on all available experimental data.

- Is being kept up to date as new papers come out Anything published is out of date.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.

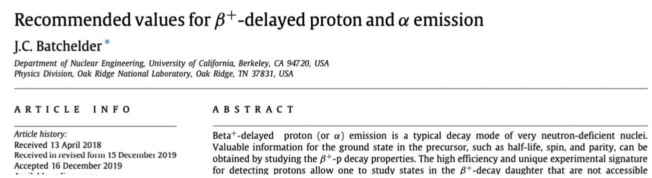




https://nucleardata.berkeley.edu/research/betap.html

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 β^+-delayed proton and α emission

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ABSTRACT

Beta$^+$-delayed proton (or α) emission is a typical decay mode of very neutron-deficient nuclei. Valuable information for the ground state in the precursor, such as half-life, spin, and parity, can be obtained by studying the β^+-p decay properties. The high efficiency and unique experimental signature for detecting protons allow one to study states in the β^+-decay daughter that are not accessible

Greatly expanding it to include all beta delayed and direct p, α and f 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:

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

Purp

Builds on ADNDT art

Uses the latest mass e

2021Wa16 M. Wang,
unless a more accurat

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.

Nuclide	S_p	S_{2p}	Q_α	BR_α	Experimental
^{135}Ce	6.687(22)	11.641(10)	-0.362(10)		
^{139}Nd	6.177(29)	10.676(28)	0.174(29)		
^{143}Sm	5.665(24)	9.904(4)	0.075(28)		
^{147}Gd	5.528(6)	9.283(1)	1.735(2)		
^{151}Dy	4.936(8)	8.203(4)	4.180(3)	5.6(4)%	[**1974To07, 1982Bo04, 1978MoZH, 1973Bi06, 1965Ma51, 1964Ma19**, 1990KaZM, 1989KaYU, 1988KaZK, 1987KaZI, 1985Ne09, 1982De11, 1981HoZM, 1979Ho10, 1978AfZZ, 1976ToZT, 1974ToZN, 1974ToZQ, 1974ToZU, 1973BoXL, 1972OkZZ, 1968Go13, 1967Go32, 1960Ma47]
^{155}Er	4.859(10)	7.644(7)	4.118(5)	<0.022(7)%	[**1974To07**, 1990Po13, 1990KaZM, 1978AfZZ, 1975ToZT, 1974PeZS, 1970Ma23, 1969To06]
^{159}Yb	4.419(31)	6.998(32)	3.951(18)	<0.0001%***	[**1995Hi12**]
^{163}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**]
^{171}Os	2.682(22)	3.957(24)	5.371(4)	1.8(3)%*	[**1995Hi02, 1979Ha10**, 2004GoZZ, 1996Pa01, 1978Sc26, 1976HoZD, 1972To06, 1972ToZC, 1972ToZL, 1972ToZO, 1972ToZW]
^{175}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, 1970Ha18, 1966Si08]
^{179}Hg	1.919(30)	2.140(33)	6.430(4)**	75(4)%	[**2012Ve04, 2002Ko09, 1979Ho10**, 2002Ro17, 1996Pa01, 1982HeZM, 1971Ha03, 1971Ho17, 1970Ha18, 1969NaZT, 1968De01]
^{183}Pb	1.542(31)#	1.497(33)#	6.928(7)	obs@	[**2002Je09, 1989To01**, 2012Ve04, 1987To09, 1986Ke03, 1980Sc09]
^{183m}Pb	1.463(31)#	1.418(33)#	7.007(9)	obs@	[**2002Je09, 1989To01**, 1987To09, 1986Ke03, 1984ScZQ, 1980Sc09]
^{187}Po	1.320(37)	0.213(36)	7.979(15)	100%	[**2006An11**, 2007An19, 2005An17, 2005AnZY]

1979Ha10].
** Deduced from α energy, 6.351(31) in [2021Wa16].
@ Not measured, expected to be 80-90% based on half-life.

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Purpose of this horizontal evaluation/database

Builds on ADNDT article for beta-delayed p and α emitters. Greatly expanding it to include direct p, α, c, and f 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 – examples:

						1984Gr14, 1975Ca06, 1973Ga08, 1968Si01]
^{181}Tl	-0.999(14)		1.552(15)	6.322(4)	8.6(6)%	[**2018Cu04, 2009An14, 1998To14**, 1993BoZK 1992BoZO, 1992BlZW,1984ScZQ]
^{181m}Tl	0.163(14)		2.388(15)	7.158(4)	0.40(6)%	[**2009An14**, 1998To14, 1984ScZQ]
^{185}Bi	-1.592(5)	91(2)%^{a}	0.226(82)#	8.207(15)^{b}	9(2)%^{c}	[**2021Do08, 2004An07**, 2001Po05, 2000PoZY, 1996Da06, 1995DaZX]

* Weighted average of 15.8(14)% [1978Ja14] and 22.6(23)% [1968Ch30].
** Weighted average of 0.020(4)% [1973Bi06] and 0.0225(25)% [1964Ma14].
*** Weighted average of 0.034(17)% and 0.051(25)% [1974ToZN].
@ Weighted average of 0.12(5)% and 0.18(8)% [1974ToZN].
@@ Weighted average of 7(2)% [1996Pa01], 12(1)% [1992Sc16] and 14(3)% [2004GoZZ].
@@@ Weighted average of 40(6)% [2009An14] and 64(5)%5 [2021Ha32].
[a] Weighted average of 92(2)% [2021Do08], and 90(2)% [2004An07].
[b] Deduced from α and p energies; S_p = -1.527(81)#, and Q_α = 8.138(81)# in [2021Wa16]. Combining the p energy and the mass excess of ^{184}Pb gives -2.171(14) MeV for the mass excess of ^{185}Bi. The α energy and mass excess of ^{181}Tl gives -2.167(17) MeV, resulting in a weighted average of -2.169(11) MeV; -2.240(80)# in [2021Wa16].
[c] Weighted average of 8(2)% [2021Do08], and 10(2)% [2004An07].

Positive Comments/Feedback from the community

From: "Brown, Alex" <brown@frib.msu.edu>
Subject: Re: BEApR Online Charged Particle Database Newsletter (1/19/2024)
Date: January 22, 2024 at 10:33:20 AM PST
To: Jon Charles Batchelder <batchelder@berkeley.edu>

Jon
Thanks for the great compilation.
If there a ascii text file of some info available.
Alex

From: MINATO FUTOSHI <minato.futoshi@phys.kyushu-u.ac.jp>
Subject: Re: BEApR_talk
Date: December 3, 2023 at 8:04:36 PM PST
To: Jon Charles Batchelder <batchelder@berkeley.edu>

Dear Batchelder,

Hi, I'm Futoshi. Let me explain more about my question. Sometimes we want to make figures reading from tables in PDF. Copy and Paste from the tables is the easiest way. But text-style file resulting from Copy and Paste often becomes messy because PDF and text file are not inconsistent. Therefore, it is helpful if we could have a text-style table in PDF files.
Best regards,
Futoshi

On Dec 11, 2015, at 10:43 AM, John Hardy <hardy@comp.tamu.edu> wrote:
Hi Batch,
There are two published sources -- one rather obscure -- for these measurements on 81Zr and 85Mo. The first (obscure) one is J.C. Hardy, J.A. Macdonald, H. Schmeing, T. Faestermann, H.R. Andrews, J.S. Geiger, R.L.Graham and K.P. Jackson in Proc. Int. School Seminar on Reactions of Heavy Ions with Nuclei and Synthesis of New Elements, Dubna report D7-9734 (1976) 197. In it we state that these two decays have been "provisionally" identified but we show proton spectra from both. The second source is J. Cerny and J.C. Hardy, Ann Rev. Nucl. Sci. 1977. 27:333-51, in which 81Zr appears with half-life and energy in Table 2 attributed to "J.C. Hardy unpublished"; there is no mention of 85Mo.

On Jun 26, 2023, at 9:57 AM, Hardy, John C <hardy@comp.tamu.edu> wrote:

Hi Batch,
Thanks for sending the updated database. I see that you added four of the five references I sent you in an email some time ago. The one you didn't include was the one I listed as the first observation of delayed proton decay, without noting that they had conclusively identified 25Si as the precursor. That's my fault.
The discovery paper by Barton et al is actually not easy to access so I've attached a copy produced at my request by the TAMU interlibrary service. As stated in the abstract, the authors positively identified 25Si and tentatively claimed 13O, 17Ne and 21Mg. I think you should definitely list this reference against 25Si. I leave it to you to decide whether you think it should appear against the other three.
Best wishes

From: "Rykaczewski, Krzysztof" <rykaczewskik@ornl.gov>
Subject: RE: [EXTERNAL] BEApR Online Charged Particle Database Newsletter (1/19/2024)
Date: January 21, 2024 at 7:06:58 PM PST
To: Jon Charles Batchelder <batchelder@berkeley.edu>

Hi Batch,
Good to hear about BEA(p)RS getting updated…
I have mentioned this data base in my recent letter.

Bertram Blank: "
the Berkeley Evaluated Alpha and proton Database BEApR. The collection, evaluation and easy-to-access presentation of a huge amount of decay data is first of all a very tedious and irksome work, which means scanning through the literature of more than 60 years from the first observation of beta-delayed proton emission to the latest work. Needless to say that this involves reading hundreds of paper and trying to get the information searched for out of these papers. Nevertheless, this work is now the standard work for information on the decay of proton-rich nuclei and therefore an extremely nice piece of work"

On Dec 7, 2021, at 8:07 AM, Liddick, Sean <liddick@nscl.msu.edu> wrote:

Hi Batch,

Good to hear from you! Thanks for sending this along and giving a preview.
I took a quick look and what about including the beta-p energy window for the beta-p branches?
The only other comment I had was that my brain was desperately trying to use the diagonal as proton=neutron and look for mirror pair matches between the left and right hand sides of the picture (it didn't work well, ha). I don't know if there is anything that you can do about that but I thought I'd let you know.

What is included (and what is not)

All available measured and predicted $Q_{\varepsilon x}$, Q_{α}, 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^{π}, initial and final states)

Complete listing of relevant references for all direct and beta delayed α, 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
β-p emission from ^{39}Ti*, $T_{1/2}$ = 28.5(9) ms, $BR_{\beta p}$ = 93.7(28)%**.

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

* All values taken from [2007Do17], except where noted.
** Mixture of β-p and β-2p [2007Do17], β-xp is expected to be 100% as ^{39}Sc is unbound to proton emission S_p = -597(24) keV [2021Hu06].
*** Note that there is considerable disagreement between the published works in this nucleus, and many β-p transitions are unknown.
[a] Possible two proton peak from the β-2p decay of 39Ti to the ground state of ^{37}K [2001Gi01, 1992Mo15].

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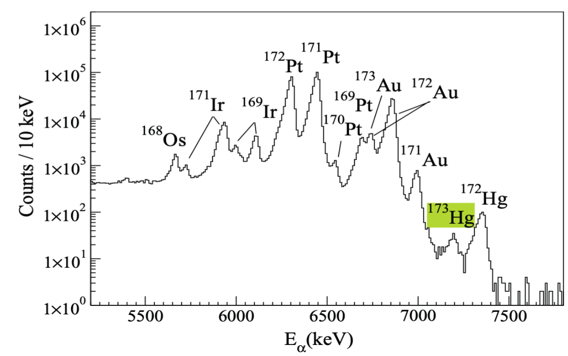
What is included (and what is not)

PHYSICAL REVIEW C **80**, 064310 (2009)



* Targeted (and complete) references– different from NSR

– Example:

^{173}Hg α decay- NSR lists 2009Ha42

^{173}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 ^{140}Dy gives ^{141}Ho proton decay – No info on ^{140}Dy
- Sometimes the reference doesn't even address that type of decay

  Example: ^{219}At search gives ^{223}Fr beta decay papers. – No α 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)

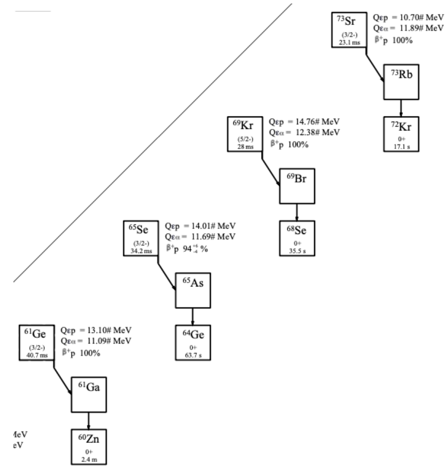
Explicit refs for $T_{1/2}$, Energy, BR, etc.

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

What is included (and what is not)

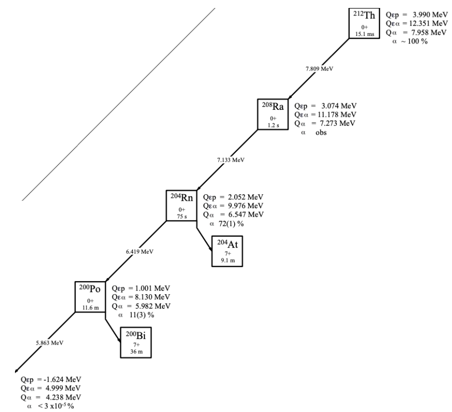
Organized by Tz = (N-Z)/2
(-4 to +32, even and odd – 145 datasets!),
Simple decay chain figure included for each Tz.

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 (> 10 ns) are treated separately.
- only decay from "long-lived" states included,
not high energy states that emit p or α.



No attempt is made at adding theoretical predictions or references.

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How this is different from AME/NuBase?

- 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.
- A semi random example is ^{141}Ho and ^{141m}Ho.

From BEApR Tz =+7/2, odd Z:

Table 3
direct p emission from ^{141}Ho*, J^{π} = $T_{1/2}$ =4.1(1) ms, BR_p = 100%.

E_p(c.m.)	E_p(lab)	I_p(rel)	I_p(absb)	J^{π}_f	$E_{daughter}$(^{140}Dy)	coincident γ-rays
0.975(10)	0.968(10)	0.9(2)%	0.9(2)%	(2$^+$)	0.202(2)	0.202(2)
1.177(8)	1.169(8)	100%	99.1(2)%	0$^+$	0.0	—

* All values from [2008Ka16]

Table 4
direct p emission from ^{141m}Ho*, Ex = 66(12) keV, J^{π} = $T_{1/2}$ = 7.4(3) μs, BR_p = 100%.

E_p(c.m.)	E_p(lab)	I_p(rel)	I_p(absb)	J^{π}_f	$E_{daughter}$(^{140}Dy)	coincident γ-rays
1.037(10)	1.030(10)	≈1%	≈1%	(2$^+$)	0.202(2)	0.202(2)
1.244(9)	1.235(9)	100%	≈99%	0$^+$	0.0	—

* All values from [2008Ka16].

4 total proton transitions
Fine Structure from both isomers

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Table III. Nuclear-reaction and separation energies (continued, Explanation of Table on p. 030003-102)

A	Elt.	*Z*	*S*(n)		*S*(p)		*Q*(4β⁻)		*Q*(d,α)		*Q*(p,α)		*Q*(n,α)	
141	Sb	51	3220#	780#	12340#	580#	34940#	500#	10480#	640#	10830#	640#	*	
	Te	52	2370#	400#	13570#	720#	29060#	400#	10090#	570#	8840#	500#	490#	570#
	I	53	4392	20	10848	21	23003	16	10989	16	10633	16	370#	300#
	Xe	54	3282	4	11880	12	17234	3	10984	5	8647	7	3145	5
	Cs	55	5499	12	8780	9	11537	9	11878	9	10359	10	3149	11
	Ba	56	4536	9	9972	10	4459	6	11679	6	8019	11	5886	6
	La	57	6689	4	6951	9	−2407	15	12695	4	10196	4	5604	10
	Ce	58	5428.15	0.10	8408.0	1.3	−9497	9	12502.1	1.3	5946.4	1.4	8477.2	1.3
	Pr	59	9400	6	5229.3	1.2	−16089	13	11654.0	2.5	6415.4	1.6	6145.3	1.6
	Nd	60	8006	5	6794	7	−20967	20	11348	5	3801	11	9021	3
	Pm	61	10382	28	3555	14	−25980	110	12200	30	6358	18	8252	17
	Sm	62	8549	15	5011	26	−30550#	300#	12278	16	3844	14	11730	14
	Eu	63	11010	50	1759	18	−35560#	400#	13165	17	6436	17	10635	17
	Gd	64	9510	30	3530	60	*		12885	24	3390	30	13920	23
	Tb	65	12130	810	50	110	*		13800#	220#	5980#	230#	12860	110
	Dy	66	10620#	500#	[illegible]	[illegible]	*		13460#	420#	3080#	420#	15920#	360#
	Ho	67	13120#	640#	−1177	7	*		14050#	640#	5430#	640#	14880#	500#

2021Ko07

Table I. The NUBASE2020 table (Explanation of Table on page 030001-16)

Nuclide	Mass excess (keV)		Excitation Energy (keV)		Half-life		J^π	Ens	Reference	Year of discovery	Decay modes and intensities (%)
^{141}Ho	−34360#	400#			4.1 ms	0.1	(7/2⁻)	14		1998	p≈100;β⁺ ?;β⁺p ?
^{141}Ho^m	−34290#	400#	66	2	7.3 μs	0.3	(1/2⁺)	14		1998	p=100

2021Hu06

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Table I. Comparison of input data and adjusted values (continued, Explanation of Table on page 030002-30)

Item	Input value		Adjusted value		v_i	Dg	Signf.	Main infl.	Lab	*F*	Reference
^{141}Ho(p)^{140}Dy	1177.4	8.	1177	7	−0.1	3			98Da03		
	1172.9	20.			0.2	3			99Ry04		

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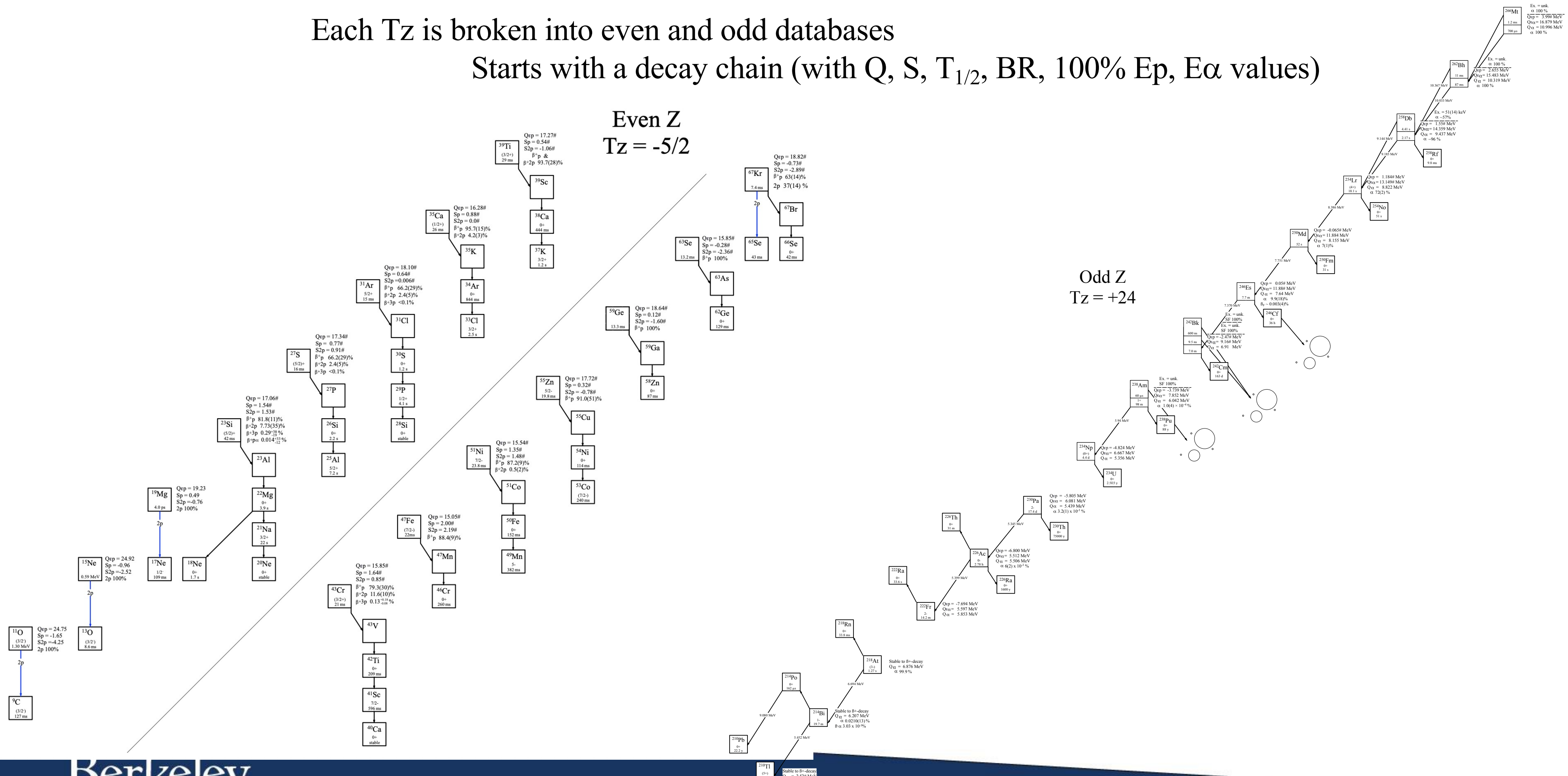
How is this different from ENSDF/NuDat?

- From NNDC website "evaluations of experimentally measured nuclear quantities that span nuclei across mass chains."
- ENSDF offers A chains – based on and perfect for beta decay.
- ENSDF A chains updated every 10ish years.

  BEApR updated approximently once a month.
- BEApR 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

Each Tz is broken into even and odd databases

Starts with a decay chain (with Q, S, $T_{1/2}$, BR, 100% Ep, Eα values)



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

Nuclide	J^{π}	$T_{1/2}$	Q_{ε}	$Q_{\varepsilon p}$	$BR_{\beta p}$	$Q_{\varepsilon 2p}$	Experimental
^{117}Te	$1/2^+$	61(2) m	3.544(13)	-0.858(13)	—	-10.137(13)	[**1961Fi05**]
^{121}Xe	$(5/2^+)$	38.8(6) m	3.765(11)	-0.408(10)	—	-7.583(12)	[**1969Bu07**]
^{125}Ba	$1/2^+$	3.3(4) m*	4.421(13)	0.709(11)		-6.304(12)	[**1975Ar31, 1968Da09**]
^{129}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**]
^{137}Sm	$(9/2^-)$	45(1) s	6.080(30)	3.919(31)		-1.634(31)	[**1983AlZO**]
^{141}Gd	$1/2^+$	14(4) s	6.701(23)	4.943(23)	0.3(1)%	-0.301(24)	[**1989Gi06**, 1986Wi15]
^{145}Dy	$(1/2^+)$	6(2) s	8.16(11)	6.228(29)	≈50%	1.421(13)	[**1993To04**, 1984ScZT]
^{149}Er	$(1/2^+)$	4(2) s	7.900(30)	6.829(29)	7(2)%	2.423(29)	[**1989Fi01**, 1984ScZT]
^{149m}Er**	$(11/2^-)$	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**]
^{157}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**]
^{165}Os	$(7/2^-)$	21(1) ms	8.91(20)#	9.20(20)#		6.21(20)#	[**1996Pa01**]
^{169}Pt	$(7/2^-)$	7.0(2) ms	9.63(20)#	10.24(20)#		7.79(20)#	[**2004Ke04**]
^{173}Hg	$(7/2^-)$	0.80(8) ms	10.17(20)#	11.16(20)#		9.17(20)#	[**2012Od01**]

* Weighted average of 3.5(4) m [1975Ar31] and 3.0(5) m 1968Da09].
** Excitation energy = 741.8(2) keV [1989Fi01].

Table 2
Particle separation and β-α emission from the even-Z, T_z = +13/2 nuclei

Nuclide	S_p	S_{2p}	Q_{α}	BR_{α}	$Q_{\varepsilon\alpha}$	Experimental
^{117}Te	5.562(14)	9.640(13)	0.808(14)		1.847(13)	
^{121}Xe	6.023(18)	9.876(13)	0.190(17)		3.734(13)	
^{125}Ba	5.217(14)	8.999(15)	0.387(15)		4.152(12)	
^{129}Ce	4.951(61)	8.047(30)	0.957(30)		5.377(29)	
^{133}Nd	4.394(55)	7.202(57)	1.530(54)		6.566(51)	
^{137}Sm	4.111(75)	6.356(34)	1.916(55)		7.521(31)	
^{141}Gd	3.527(55)	5.422(23)	2.343(35)		8.424(24)	
^{145}Dy	3.163(29)	4.59(20)	2.557(21)		9.258(14)	
^{149}Er	3.039(88)	4.12(29)	2.076(29)		10.23(11)	
^{149m}Er*	3.781(88)	4.86(29)	2.818(29)		10.97(11)	
^{153}Yb	2.73(21)#	3.47(20)#	4.16(20)#		12.06(20)#	
^{157}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]
^{165}Os	1.563(208)#	1.42(21)#	6.335(6)	90(2)%	14.61(20)#	[**2008Bi15, 1996Pa01**. 2013Dr06, 2002Pa03 [1997Da07, 1991Se01, 1981Ho10, 1978Ca11, 1978CaZF, 1977Ca23]
^{169}Pt	1.087(208)#	0.54(22)#	6.858(5)	≈ 100%	15.77(20)#	[**2004Ke06, 1999Se14**, 2012Od01, 2009Go16] [2008Bi15, 1996Pa01, 1981Ho10]
^{173}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^{π}, $T_{1/2}$, $Q_{\beta x}$, BR, refs

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

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

E_p(c.m.)	I_p(rel)	I_p(abs)	$E_{emitter}$ (^{35}K)***	$E_{daughter}$(^{34}Ar)[@]	coincident γ-rays[@]
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
1.909-2.647[a]	2.1(8)	1.0(4)	5.280-6.018	3.2877(5)	1.197, 2.091, 3.286
1.909-2.647[a]	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[a]	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[a]	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	——

* All values are taken from [1999Tr04], except where noted.
** From [2016Ci05].
*** Calculated from proton energies and S_p (^{35}K) = 83.6(5) keV [2021Wa16].
[@] Values from adopted levels in ENSDF [2012Si06].
[a] unresolved multiplet

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

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

* All values are taken from [1999Tr04], except where noted.
** From [2016Ci05].
*** Calculated from two-proton energy and S_{2p} (^{35}K) = 4747.5(6) keV [2021Hu06].

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

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

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

E_{α}(c.m.)	E_{α}(lab)	I_{α}(abs)	J^{π}_{f}	$E_{daughter}(^{167}W)$	coincident γ-rays	R_0 (fm)	HF
5.290(10)	5.166(10)	7.0%***	(7/2⁻)	0.12(3)%	0.079	1.5721(95)	$7.7^{+3.0}_{-2.1}$
5.367(7)	5.241(7)	100%***	(5/2⁻)	1.68(3)%	0.0	1.5721(95)	$1.3^{+0.4}_{-0.3}$

* All values from [1995Hi02], except where noted.
** Weighted average of 1.9(3)% [1995Hi02] and 1.7(3)% [1979Ha10].
*** Uncertainties not given in [1995Hi02].

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

E_{α}(c.m.)	E_{α}(lab)	I_{α}(rel)	I_{α}(abs)	J^{π}_{f}	$E_{daughter}(^{171}Os)$	coincident γ-rays	R_0 (fm)	HF
5.950(4)	5.814(4)	7.3(16)%	4.0(9)%	(7/2⁻, 9/2⁻)	0.2112(5)	0.2112(5), 0.1341(4), 0.0767(3)	1.5574(37)	$6.6^{+2.1}_{-1.4}$
5.955(4)	5.819(4)	1.3(4)%	0.7(2)%	(9/2⁻)	0.2079(5)	0.2079(5), 0.1308(4), 0.0767(3)	1.5574(37)	38^{+16}_{-9}
6.087(4)	5.948(4)	100(1)%	55.0(5)%	(7/2⁻)	0.0767(3)	0.0767(3)	1.5574(37)	1.71(15)
6.162(4)	6.021(4)	8.7(15)%	4.8(8)%	(5/2⁻)	0.0	—	1.5574(37)	40^{+9}_{-7}

* All values from [2014Pe02], except where noted.

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

If there are a large number of coincident gammas, The 100% peak decaying from $E_{daughter}$ (i.e. the state that the particle populated) is marked in ***bolditalic***, and peaks 10% or larger of the aforementioned peak are marked in **bold**. – this is to identify the largest coincident peaks for the experimenter.

						217.4, **228.6**, **234.8**	
4.919(10)	≈4.833@	0.45%	0.253%	$(3/2^+,5/2,7/2^+)$	0.2486	11.1, **17.3**, 23.6, **25.4**, 29.9, 31.4, 37.8, 42.4, **42.8**, 44.0, 51.0, 55.2, 59.3, 65.0, 68.1, **68.8**, 77.6, 86.3, 89.1, 94.7, 94.8, ***98.9***, 110.3, **107.1**, 118.1, **124.6**, **137.0**, 148.2, 149.9, **154.3**, 179.8	310
4.9241(10)	4.838(2)	8.90%	5%	$7/2^+$	0.2435	**11.1**, **17.3**, 23.6, **25.4**, 29.9, **31.4**, **37.8**, 42.4, **42.8**, **44.0**, 51.0, 55.2, 59.3, 63.7, 65.0, 68.1, **68.8**, **75.2**, 77.6, 86.3, 89.1, 94.7, 94.8, 110.3, 107.1, 118.1, 123.2, 124.6, ***131.9***, 137.0, **142.9**, 148.2, 149.9, 154.3, 174.1, 179.8, 200.8, **218.2**	17
4.9313(10)	4.845(2)	100.00%	56.2%	$5/2^+$	0.2363	11.1, **17.3**, 23.6, **25.4**, 29.9, **31.4**, **37.8**, 42.4, **42.8**, **44.0**, 51.0, 55.2, **56.5**, 59.3, 65.0, 68.1, 68.8, 77.6, ***86.3***, 89.1, 94.7, 94.8, 110.3, **107.1**, 115.9, 118.1, **124.6**, **137.0**, 148.2, 149.9, **154.3**, 166.9, 179.8, **193.5**, 204.7,**210.9**, 236.3	1.7
4.9407(10)	≈4.852@	0.053%	0.03%	$(11/2^+)$	0.2269	**25.4**, **31.4**, 37.8, 44.0, **75.2**, ***126.5***	3.6×10^3
4.9425(10)	4.856**	0.023%	0.013%	$3/2^-$	0.2251	**17.3**, **23.6**, **25.4**, **31.4**, **42.8**, **55.2**, **75.2**, 94.7, **107.1**, 118.1, **124.6**, 149.9, **169.2**, ***182.1***, **193.5**, **225.3**	8.5×10^3
4.947(10)	4.860(2)	0.50%	0.28%	$(7/2^+,9/2^+)$	0.2206	11.1, **17.3**, **25.4**, **31.4**, **37.8**, 42.4, **42.8**, **44.0**, **49.7**, ***68.8***, **75.2**, **86.3**, **101,6**, **109.1**, **120.1**, **126.1**, 151.6, **194.9**	420
4.9513(10)	≈4.865@	0.073%	0.041%	$(13/2^+)$	0.2163	**25.4**, **31.4**, **37.8**, **44.0**, **75.2**, ***115.9***	3.1×10^3
4.9641(10)	≈4.878@	0.14%	0.077%	$(9/2^-)$	0.2035	**25.4**, **31.4**, **37.8**, **44.0**, ***134.2***	2.0×10^3
4.9879(10)	4.901(2)	18.15%	10.2%	$5/2^+$	0.1797	**11.1**, **17.3**, 23.6, **25.4**, 29.9, **31.4**, **37.8**, 42.4, **42.8**, **44.0**, 51.0, 55.2, 59.3, 65.0, **68.1**, 68.8, **75.2**, 77.6, **86.3**, 89.1, 94.7, 94.8, 110.3, 107.1, 118.1, 124.6, ***137.0***, **148.2**, 149.9, **154.3**, 179.8	21
5.0182(10)	4.930(2)	0.28%	0.16%	$3/2^+$	0.1499	**17.3**, 23.6, **25.4**, 31.4, **42.8**, 55.2, 94.7, ***107.1***, 118.1, **124.6**, 149.9	2.1×10^3
5.056(10)	4.968(2)	10.62%	5.97%	$7/2^+$	0.1116	***11.1***, **17.3**, **25.4**, **31.4**, **37.8**, **44.0**, 42.4, **42.8**, **68.8**, **75.2**, **86.3**	99
5.0671(10)	4.979(2)	5.64%	3.17%	$(9/2)^+$	0.1005	**25.4**, **31.4**, **37.8**, **44.0**, ***75.2***	220
5.0982(10)	5.009(2)	0.16%	0.09%	$(7/2)^-$	0.0694	**25.4**, **31.4**, ***37.8***, **44.0**	1.2×10^4
5.1124(10)	5.023(2)	0.02%	0.009%	$(1/2^-)$	0.0552	***23.6***, **31.4**, 55.2	1.5×10^5
5.1249(10)	5.036(2)	0.43%	0.24%	$3/2^+$	0.0427	***17.3***, **25.4**, **42.8**	6.6×10^3
5.136(10)	5.046**	0.36%	0.2%	$3/2^-$	0.0316	***31.4***	9.1×10^3
5.1422(10)	5.053(2)	11.74%	6.6%	$5/2^+$	0.254	***25.4***	310
5.1676(10)	5.077(2)	0.089%	0.05%	$1/2^+$	0.0	—	5.8×10^4

Example: ^{229}Th

42 α's

204 γ's

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

Table 10
direct α emission from ^{189}Po*, J^{π} = (7/2⁻), $T_{1/2}$ = 3.5(5) ms, BR_{α} =100%.

E_{α}(c.m.)	E_{α}(lab)	I_{α}(rel)	I_{α}(abs)	J^{π}_{f}	$E_{daughter}(^{173}Os)$	coincident γ-rays	R_0 (fm)	HF
7.416(15)	7.259(15)	100(21)%	80(12)%	($5/2^-$)	0.280	0.280	1.4991(51)	$0.18^{+0.07}_{-0.05}$*
7.467(20)	7.309(20)	15(7)%	12(5)%		0.226	0.226	1.4991(51)	$1.8_{-0.7}$
7.695(20)	7.53(20)	10(8)%	8(6)%	($3/2^-$)	0.0	—	1.4991(51)	14^{+49}_{-7}

* All values from [2005Va04].
** The reason for this unphysically low value is unknown.

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).

Fission - direct and ε-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_α	BR_α	BR_{SF}	$BR_{cluster}$	type	Experimental
^{207}Hg	9.59(30)#	0.60(20)#					
^{211}Pb(AcB)	8.535(12)	3.570(30)					
^{215}Po(AcA)	6.630(11)	7.526(1)	99.99977(2)%				[**1998Li53, 1971Gr17, 1950Av61**, 2023Ta02, 2019Ma02, 1996Wi27, 1979Be58, 1976Bl13, 1971Er02, 1971Gr17, 1967Da20, 1965Va10, 1962Wa18, 1961Ry02, 1961Vo06, 1960Ry02, 1950Av61, 1942Wa04]
^{219}Rn(An)	6.560(12)	6.9462(3)	100%				[**1999Li05**, 2019Ma02, 2015Co07, 2015Pi10, 1989It01, 1979Be58, 1974Bo11, 1972NgZZ, 1970Da09, 1970Kr01, 1970Kr01, 1970Kr08, 1967Le05, 1962Wa18, 1961Ro14, 1961Ry02, 1960Ry02, 1960Wa16]
^{223}Ra(AcX)	6.434(8)	5.9790(2)	100%		8.9(4)×10^{-8}%	^{14}C	[**1998Sh02, 1995Ho11, 1992Ar02, 1962Wa18, 1971Gr17**, 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]
^{227}Th(RdAc)	5.793(3)	6.1466(1)	100%				[**19s64Ba33, 2019Ma02, 1998Jo08, 1972He18**, 2019Ko06, 2019Co04, 2015Co11, 1990Br23, 1990BrZZ, 1987Mi10, 1977Ma32, 1972HeYM, 1968Wa07, 1967JoZX, 1965Br23, 1954Ha60, 1949Pe08]
^{231}U	5.657(4)	5.576(2)	4(1)×10				[**1997Mu08, 1994Li12**, 1949Os01]
^{235}Pu	5.061(22)	5.951(20)	3.0(6)×1 %				[**1957Th10**, 1952Or03]
^{235m}Pu	2.06(20)	7.95(20)		100%			[**1970Bu02, 1971Br39**, 1972Ga42, 1969Me11]
^{239}Cm	4.56(16)	6.54(15)	< 1×10				[**2008Qi03**]
^{243}Cf	4.05(23)#	7.42(10)#	obs				[**1967Fi04, 1967Si08**]
^{247}Fm	3.44(20)#	8.258(10)	64%				[**2006He27**, 2004HeZY, 2004He28]
^{247m}Fm	3.39(20)#	8.305(11)	88(2)%				[**2006He27**, 2004HeZY, 2004He28]
^{251}No	2.84(20)#	8.752(4)	91^{+9}_{-22}%	$0.14^{+0.31}_{-10.12}$%			[**2006He27, 2001He35**, 2022Te01, 2009Dr02, 2005KuZZ, 2005SuZX, 2004He28, 2004HeZY, 1999He07, 1997He29, 1967Gh01]
^{251m}No	2.74(20)#	8.858(7)	100%				[**2006He27**, 2022Te01, 2005KuZZ, 2005SuZX, 2004He28, 2004HeZY]
^{255}Rf	2.61(20)#	9.055(4)	46(5)%	54(5)%*			[**2006He27, 2015An05, 2001He35**,2020Mo11, 2008Dr05, 1997He29, 1986He06, 1984De07, 1984Og02, 1984Og03]
^{259}Sg	2.278(30)#	9.765(8)	≈ 97%	3(1)%**			[**2015An05**, 2013An08, 2009Dr02, 2009He20, 1985Mu11, 1984De07]
^{259m}Sg	2.191(20)#	9.852(22)	≈ 97%	3(1)%**			[**2015An05**, 2009He20]
^{263}Hs	1.86(22)#	10.733(78)	100%	<8.4%			[**2009Dr02**, 2009KaZU, 1984Og02]
^{267}Ds	1.08(23)#	11.777(51)	≈ 100%				[**1995Gh05**]

* Weighted average of 58(9)% [2015An05] and
** Combination of ground state and isomer.

Only branching ratios and refs. are given.

No attempt has been made to list fission products, energy, etc.

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_α	BR_α	Bl	$BR_{cluster}$	type	imental
^{210}Pb(RaD)	8.373(6)	3.792(20)	$1.9(3)\times10^{-6}$%*				**Wo05, 1962Ka27**, 1969Ho26]
^{214}Po(RaC')	6.527(5)	7.834(0)	100%				**Ku08, 1971Gr17, 1961Ry02**, 2022Be20, 2016Al28, l110, 2013Al11, 2013Be10, 2012Su11, 2011AlZX, h30, 1973BoXL, 1973BoXW, 1971Er02, 1965Le08, r22, 1961Do02, 1960Og01, 1960Ry01, 1953Ba60, o02]
^{218}Rn	6.466(5)	7.262(2)	100%				**Ko54, 1973BoXL**, 2012Su11, 1971Er02, 1963Di08, e17, 1962Di08, 1961Ru06, 1958To25, 1948St42]
^{222}Ra	6.246(6)	6.678(4)	100%		$2.64(31)\times10^{-8}$%**	^{14}C	**Ko54, 1991Hu02, 1985Ho21, 1985Pr01, 1956As38**, o13, 1991HuZY, 1991LeZV, 1987BaZS, 1976Ka08, aZD, 1969Pe17, 1964Ba49, 1963Le17, 1961Fo08, u06, 1960Be25, 1958To25, 1956Sm88, 1948St42]
^{226}Th	5.729(6)	6.453(1)	100%				**Ma30, 1995Ko54, 1976Ku08**, 2012Po13, 1987Mi10, aZD, 1974KaZM, 1969Br10, 1968GuZU, 1963Le17, y06, 1956As38, 1953AsZZ, 1948St42]
^{230}U	5.571(5)	5.992(1)	100%		$4.8(20)\times10^{-12}$%	^{22}Ne	**Ma30, 2001Bo11, 1995Ko54, 1976Ku08**, 2012Po12, a54, 1999Pa22, 1996Tr10, 1974KaZM, 1969Pe17, a14, 1963Le17, 1961Ru06, 1956As38, 1953AsZZ,

Branching ratios and type are listed in table 2 of each Tz

Table 1028
direct ^{14}C emission from ^{223}Ra*, $J^\pi = 3/2^+$, $T_{1/2}$ = 11.4354(17) d**, Q_{14C} = 31.83 MeV, $BR_{14C} = 8.9(4)\times10^{-8}$%***.

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

If energies were measured, individual tables are presented.

* All values from [1992Ar02], except where noted.
** [2015Co02].
*** [1995Ho11].
@ [2015Ch30].

Timeline

Datasets from -4 to +49/2 done!   (>85% finished!)

115 datasets with 1156 delayed and direct emitters from 1013 nuclei, with 3195 discrete transitions detailed in 1139 tables with 2978 unique references

All beta-delayed and direct proton emitters

Most of the rest are alpha and cluster emitters (and fission)

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

Should be finished by the end of 2024 – after that only updates/corrections.

Information on nuclei are updated as new papers come out.

Website is updated each month

Update emails are sent out every couple months.

Timeline

- To be added to the website soon: Summary tables for all types of charged particle decays

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

Nuclide	J^π	$T_{1/2}$	$Q_{\varepsilon p}$ (MeV)	BR	other decays	T_z
^{9}C	(3/2-)	126.5(9) ms	16.680(2)	61.1(17)%	β_α,β_p, α	-3/2
^{13}O	$(3/2^-)$	8.58(5) ms	15.826(10)	11.3(20)%	β_α	-3/2
^{17}Ne	$1/2^-$	109.3(6) ms	13.9485(4)	94.4(29)%	β_α	-3/2
^{20}Mg	0^+	90.4(6) ms	8.437(2)	30.0(12)%		-2
^{21}Mg	$5/2^+$	118.6(5) ms	10.657(1)	20.9(13)%	β_α	-3/2
^{22}Al	4^+	91.1(5) ms	13.10(40)#	54.5(25)%	β_{2p}, β_α	-2
^{22}Si	0^+	28.6(14) ms	15.45(50)#	61.8(52)%	β_{2p}	-3
^{23}Al	$5/2^+$	446(6) ms	4.6406(4)	1.22(5)%		-3/2
^{23}Si	$(5/2)^+$	42.3(4) ms	17.06(50)#	81.8(11)%	β_{2p}, β_{3p}	-5/2
^{24}Al	4^+	2.053(4) s	2.19207(23)	0.0012(3)%	β_α	-1
^{24}Si	0^+	141.4(15) ms	8.930(19)	33.3(16)%		-2
^{25}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)%	β_{2p}	-2
^{27}P	$(5/2)^+$	260(80) ms	4.262(9)	≈0.07%		-3/2
^{27}S	$(5/2^+)$	16.3(2) ms	17.34(40)#	62.2(29)%	β_{2p}	-5/2
^{28}P	3^+	270.3(5) ms	2.7600(11)	0.0013(4)%	β_α	-1
^{28}S	0^+	125(10) ms	9.17(16)	20.7(20)%		-2
^{29}S	$(5/2^+)$	187(6) ms	11.109(13)	47(5)%		-3/2
^{31}Cl	$3/2^+$	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)%	β_{2p}, β_{3p}	-5/2
^{32}Cl	1^+	298(1) ms	3.8169(6)	0.026(5)%	β_α	-1
^{32}Ar	0^+	98(2) ms	9.553(2)	35.58(22)%		-2
^{33}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
^{35}Ca	$(1/2^+)$	25.7(2) ms	16.28(20)#	95.7(15)%	β_{2p}	-5/2
^{36}K	2^+	342(2) ms	4.3075(3)	0.048(14)%	β_α	-1

Summary of known β_α emitters. Detailed references for each nucleus can be found in their respective T_z tables.

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

Table 1121
Summary of known β_α^- emitters. Detailed references for each nucleus can be found in their respective T_z tables.

Nuclide	J^π	$T_{1/2}$	$Q_{\beta^-\alpha}$ (MeV)	$BR_{\beta^-\alpha}$ (%)	other decays	T_z
^{212m}Bi	(9^-)	25.0(2) m	11.625(30)	30(1)%	α	+23
^{214}Bi	1^-	19.71(2) m	11.102(11)	3.03×10^{-3}%	α	+24

Table 1122
Summary of known BR_{ε_F} emitters. Detailed references for each nucleus can be found in their respective T_z tables.

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

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

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

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Timeline

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

- 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 α emission from ^{234}Pu*, $J^{\pi} = 0^{+}$, $T_{1/2}$ = 8.7(1) h***, $BR_{\alpha} = \approx 6\%$

E_{α}(c.m.)	E_{α}(lab)	I_{α}(rel)	I_{α}(abs)	J^{π}_{f}***	$E_{daughter}$(^{230}U)***	coincident γ-rays***	R_0 (fm)	HF
6.130	6.025	0.6%	≈ 0.024%	4^{+}	0.1693	0.0517, 0.1693	1.518(27)	≈ 25
6.252	6.145	47%	≈1.9%	2^{+}	0.0517	0.0517	1.518(27)	≈ 1.1
6.304	6.196	100%	≈ 4.1%	0^{+}	0.0	—–	1.518(27)	≈ 0.9

* All values from [1964Hy02] p. 799 (based on unpublished results from R. W. Hoff, F. Asaro, I. Perlman [1960Ho18]), except where noted.
** Weighted average of 8.8(1) h [1973Ja06] and 8.5(1) h [1949Pe04].
*** [2012Br12].

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

E_{α}(c.m.)	E_{α}(lab)	I_{α}(abs)	J^{π}_{f}	$E_{daughter}$(^{203}Bi)	coincident γ-rays	R_0 (fm)]	HF
5.872(3)	5.759(3)***	obs**	$9/2^{-}$	0.0	—-	1.4651(131)	≈1.10

* Weighted average of 1.80(5) h [1962Th08], 1.82(4) h [1969Ba69] and 1.77(5) h [1968GuZX].
** "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]. ≈ 10% is used for the branching ratio in determining the HF value.
*** [1969GoZX].

Timeline

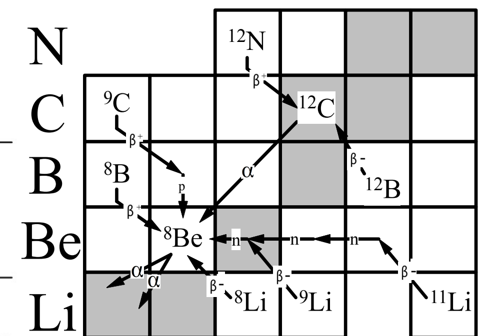
Possible future additions (once datasets up to Tz = +30 are finished):

*   p and α emission from highly excited states (not populated by beta decay)?

*   (mostly) Low Z exotic decays (β^- - α, etc.) – (how to handle this)?

Summary of more exotic β delayed charged particle emitters

Nuclide	J^π	$T_{1/2}$	decay mode	$Q_{\varepsilon x}$ (MeV)	BR (%)	other decays	ENSDF	Experimental
^{6}He	0^+	806.7(1) ms	β^--d	2.03245(5)	0.0000076(6)%		[2002Ti10]	[**2015Pf01**, 1993Bo24]
^{8}He	0^+	119.1(12) ms	β^--tαn	6.16364(9)	0.9(1)%	β^--n	*	[**1996Ba66**, 1993Bo24, 1986Bo41]
^{8}Li	2^+	839.9(9) ms	β^--2α	16.09597(5)	100%		*	[2013Li12, 1986Wa01, 1974Tr01]
								[1970Sc34, 1971Wi05]
^{8}B	2^+	770(3) ms	β^+-2α	18.072(1)	100%		*	[1964Ma35, 1971Wi05]
^{9}Li	$3/2^-$	178.3(4) ms	β^--n2α	12.03375(19)	50.0(18)%		[2004Ti06]	[**1991Re02**, 1992Te03, 1970Ch07]
^{11}Li	$3/2^-$	8.75(4) ms	β^--nα	12.6400(6)	0.29(4)%	β^--n, β^--2n	[2012Ke01]	[**2008Ma34**]
			β^--d	2.6377(6)	0.0130(13)%			[**2008Ra23**, 1996Mu19]
			β^--t	4.832.7(6)	0.000093(8)%			[**2009Ma72**]
			β^--3n2α	11.6645(6)	1.4(2)%			[**2008Ma34**]
			β^--αn	12.6400(6)	0.29(4)%			[2008Ma34]
^{11}Be	$1/2^+$	13.76(7) s	$\beta^-\alpha$	2.84515(24)	3.1(5)%		[2012Ke01]	[1971Al07,1981Al03, **1982Mi08**]
^{12}B	1^+	20.20(2) ms	$\beta^-3\alpha$	6.0946(13)	1.58(30)%		[1990Aj01]	[2009Hy01, **2009Hy02**, 2010Hy01, 1990Aj01]
^{12}N	1^+	11.000(16) ms	β^+-3α	10.063(1)	3.5(5)%		[1990Aj01]	[2009Hy01, **2009Hy02**, 2010Hy01, 1990Aj01]
^{16}N	2^-	7.13(2) s	β^--α	3.259(2)	0.00106(10)%		[1993Ti07]	[**2016Re01**, 1993Zh13, 1974Ne10]
^{17}Ne	$1/2^-$	109.2(6) ms	β^+-pα	6.7866(4)	0.0016(4)%	β-p, β-α	[1993Ti07]	[**2002Ch61**]
^{18}N	1^-	624(12) ms	β^--α	7.668(19)	12.2(6)%	β^--n	[1995Ti07]	[**2007Bu01**, 1995ReZZ]
^{21}Mg	$5/2^+$	122(3) ms	β^+-pα	5.937(16)	0.016(3)%	β-α	[2015Fi05]	[**2015Lu13**]
^{212m}Bi	$(8^-, 9^-)$	25.0(2) m	β^--α	11.456(2)	30(1)%	α	[2005Br03]	[**1984Es01**, 1978Ba44]



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

Timeline

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

* p and α emission from highly excited states (not populated by beta decay)?

* Low Z exotic decays (β^- - α, etc.) – (how to handle this)?

* Links to theory papers?

Where is the database?

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

nucleardata.berkeley.edu

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DATA TABLES (Arranged by isospin projection)

NUCLIDES (Arranged by Z and A)

Download all data sets into single PDF

700 pages

Global Heavy Charged-Particle Decay Database

Jon Batchelder, Aaron M. Hurst, Sanjana Goyal, Yun-Hsuan Lee

Last updated: June 11, 2024

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Explanation of tables

T_z = -7/2 (Even-Z)	T_z = -4 (All-Z)
T_z = -7/2 (Odd-Z)	T_z = -3 (Even-Z)
T_z = -5/2 (Even-Z)	T_z = -3 (Odd-Z)
T_z = -5/2 (Odd-Z)	T_z = -2 (Even-Z)
T_z = -3/2 (Even-Z)	T_z = -2 (Odd-Z)
T_z = -3/2 (Odd-Z)	T_z = -1 (Even-Z)
T_z = -1/2 (Even-Z)	T_z = -1 (Odd-Z)
T_z = -1/2 (Odd-Z)	T_z = 0 (Even-Z)
T_z = +1/2 (Even-Z)	T_z = 0 (Odd-Z)
T_z = +1/2 (Odd-Z)	T_z = +1 (Even-Z)
T_z = +3/2 (Even-Z)	T_z = +1 (Odd-Z)
T_z = +3/2 (Odd-Z)	T_z = +2 (Even-Z)
T_z = +5/2 (Even-Z)	T_z = +2 (Odd-Z)
T_z = +5/2 (Odd-Z)	T_z = +3 (Even-Z)
T_z = +7/2 (Even-Z)	T_z = +3 (Odd-Z)
T_z = +7/2 (Odd-Z)	T_z = +4 (Even-Z)
T_z = +9/2 (Even-Z)	T_z = +4 (Odd-Z)
T_z = +9/2 (Odd-Z)	T_z = +5 (Even-Z)
T_z = +11/2 (Even-Z)	T_z = +5 (Odd-Z)
T_z = +11/2 (Odd-Z)	T_z = +6 (Even-Z)
T_z = +13/2 (Even-Z)	T_z = +6 (Odd-Z)
T_z = +13/2 (Odd-Z)	T_z = +7 (Even-Z)
T_z = +15/2 (Even-Z)	T_z = +7 (Odd-Z)
T_z = +15/2 (Odd-Z)	T_z = +8 (Even-Z)
T_z = +17/2 (Even-Z)	T_z = +8 (Odd-Z)
T_z = +17/2 (Odd-Z)	T_z = +9 (Even-Z)

^{141}Dy	β-p	+9/2 even Z
^{142}Dy	β-p	+5 even Z
^{143}Dy	β-p	+11/2 even Z
^{144}Dy	β-p	+6 even Z
^{145}Dy	β-p	+13/2 even Z
^{147}Dy	β-p	+15/2 even Z
^{150}Dy	α	+9 even Z
^{151}Dy	α	+19/2 even Z
^{152}Dy	α	+10 even Z
^{153}Dy	α	+21/2 even Z
^{154}Dy	α	+11 even Z
^{140}Ho	p	+3 odd Z

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Conversion to JSON format after evaluation finished

- JSON documents for all charged-particle-decay datasets will be available.
- Software implemented in Python to handle data.
- Developing methods for access, manipulation, and analysis of decay data.
- Bundled with suite of unit tests driving development.

- Project (software and all datasets) is currently maintained in a private repo on GitHub.

- Hope to make publicly available in the near future (mid 2025).

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???

batchelder@berkeley.edu

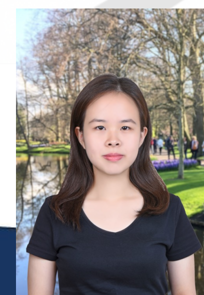
Thank you for your attention!

JSON development team (UC Berkeley)

Aaron Hurst

Sanjana Goyal (undergraduate)

Yun-Hsuan "Abby" Lee (undergraduate)



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