Table of Alpha-Disintegration Energies of the Heavy Elements

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THIS compilation is a revision of the "Table of Alpha-Disintegration Energies of the Heavy Elements" published in 1954.[1] Included are new alpha emitters and revisions concerning those previously listed. The basis for inclusion in Table II of a previously listed alpha emitter is the availability of additional data which would change the alpha-disintegration energy by more than 1 kev from that listed in Table I.[1] Polonium-211 (0.52 sec) is included but not the 25-sec isomer because it is now certain that the alpha group belonging to the 0.52-sec nuclide represents the transition between ground states.

The only references given are those relevant to the energy determinations. The decay energies are the Q values for the alpha transitions and can be transformed into mass differences by including the atomic mass of He^4.

COLUMN 1

This column indicates the alpha emitter and its product as well as the half-life which is given solely for purposes of further identification. These are the measured half-lives and not the partial alpha-decay half-lives for those cases in which there is more than one mode of decay. Since this table is not a compilation of general decay properties, references are not given for the half-lives cited.

COLUMNS 2 AND 3

In a large fraction of the cases the "highest-energy group" of column 3 is either known to be that of the ground-state transition or is assumed to be so in the absence of information regarding a complex spectrum for the purpose of calculating the disintegration energy of column 2. The Q values, unless otherwise stated under "comments," were calculated by adding to the energy of column 2 the recoil energy, $4E/(A\text{-}4)$, where E is the alpha-particle energy and A is the mass number of the emitter. The Q values were rounded off to values consistent with the precision of the energy measurements.

COLUMN 4

The absence of a notation under "intensity" means that no high-resolution instrument has been used to obtain evidence on complex structure. Otherwise the entry indicates the intensity of the group believed to represent the ground-state transition. The designation "$\sim$100" means that a careful search has been made for other groups and either none has been found or that the intensities of lower-energy groups are low.

[1] F. Asaro and I. Perlman, Revs. Modern Phys. **26**, 456 (1954).

COLUMN 5

This column refers to the method of energy determination.

ion ch	ionization chamber coupled with some form of pulse-height analyzer.
range air	range determination in air.
range emuls	range of alpha tracks in a photographic emulsion.
spect	magnetic spectrograph.

COLUMN 6

References are given for the energy measurements selected.

COLUMN 7

These letter ratings give the estimated degree of certainty of the isotopic assignments according to the following code:

A Element and mass number certain;
B Element certain and mass number probable;
C Element probable and mass number certain or probable;
D Element certain and mass number not well established.

COLUMN 8

The comments in this column for the most part reinforce the decision on the decay energy.

ins evid	Insufficient evidence to know whether or not the alpha energy measured is that of the ground-state transition.
e-e	No direct evidence, but since the nucleus is of the even-even type it can be assumed that the measured energy is that of the ground-state transition.
α-γ coinc	This designation indicates that coincidences have been observed between alpha particles and gamma rays (or conversion electrons) which show some doubt that the highest-energy alpha group is the ground-state transition. Where the evidence is not sufficiently definite to deduce a decay energy based on anything other than the highest-energy alpha group, this is reflected by the values in columns 2 and 3 differing only by the recoil energy. Where the evidence is sufficiently definite to deduce the decay energy, it will be found that columns 2 and 3 differ by more than the recoil energy.

TABLE II.

Reaction	Adopted Q (Mev)	Highest energy group measured (Mev)	Intensity (%)	Method	Energy ref.	Identification	Comments
$Bi^{210} \longrightarrow Tl^{206}$ 2.6×10^{6} y	5.03	4.935 4.97		ion ch ion ch	2 2a	A	
$Bi^{211} \longrightarrow Tl^{207}$ 2.16 m	6.745	6.617 6.620	82.6	spect spect	2b 3	A	
$Po^{197} \longrightarrow Pb^{193}$ ~4 m	6.165	6.040		spect	4	D	ins evid
$Po^{198} \longrightarrow Pb^{194}$ ~6 m	6.057	5.935		spect	4	D	e-e
$Po^{199} \longrightarrow Pb^{195}$ 11 m	5.966	5.846 5.84		spect ion ch	4 4a	B	ins evid
$Po^{200} \longrightarrow Pb^{196}$ ~8 m	5.888	5.770		spect	4	B	e-e
$Po^{201} \longrightarrow Pb^{197}$ 18 m	5.786	5.671 5.70		spect ion ch	4 4b	B	ins evid
$Po^{202} \longrightarrow Pb^{198}$ 51 min	5.689	5.575 5.57 5.61 5.59		spect ion ch ion ch ion ch	4 5 6 7	B	e-e
$Po^{204} \longrightarrow Pb^{200}$ 3.8 h	5.477	5.370 5.37		spect ion ch	4 7	B	e-e
$Po^{211} \longrightarrow Pb^{207}$ 0.52 s	7.58	7.442 7.434	99	spect range air	8 9	A	
$Po^{213} \longrightarrow Pb^{209}$ 4.2×10^{-6} s	8.51	8.35 8.336	~100	spect ion ch	11 13	A	ins evid
$Po^{215} \longrightarrow Pb^{211}$ 1.83×10^{-3} s	7.50	7.360 7.365 7.383	~100	spect range air spect	2b 9 13a	A	
$At^{209} \longrightarrow Bi^{205}$ 5.5 h	5.752	5.642 5.65	~100	spect ion ch	14, 15 17	B	ins evid
$At^{217} \longrightarrow Bi^{213}$ 0.018 s	7.18	7.05 7.02 7.00	~100	spect ion ch ion ch	18 13 19	A	
$Em^{204} \longrightarrow Po^{200}$ 3 m	6.41	6.28		ion ch	5	D	e-e
$Em^{206} \longrightarrow Po^{202}$ 6.2 m	6.37	6.25 6.25		ion ch ion ch	5 6	B	e-e
$Em^{207} \longrightarrow Po^{203}$ 11 m	6.24	6.12 6.09		ion ch ion ch	5 6	B	ins evid
$Em^{208} \longrightarrow Po^{204}$ 23 m	6.261	6.141	~100	spect	20	B	e-e
$Em^{209} \longrightarrow Po^{205}$ 30 m	6.155	6.037		spect	20	B	ins evid
$Em^{210} \longrightarrow Po^{206}$ 2.7 h	6.155	6.037		spect	20	A	
$Em^{212} \longrightarrow Po^{208}$ 23 m	6.384	6.264	~100	spect	20	A	
$Em^{221} \longrightarrow Po^{217}$ 25 m	6.1	6.0		ion ch	21	A	ins evid
$Em^{219} \longrightarrow Po^{215}$ 3.92 s	6.940	6.813 6.807	83	spect spect	2b 21b	A	
$Fr^{212} \longrightarrow At^{208}$ 19.3 m	6.534	6.411	37	spect	20	A	ins evid
$Fr^{221} \longrightarrow At^{217}$ 4.8 m	6.449	6.332 6.30	84	spect ion ch	18 13, 21a	A	

TABLE II.—*Continued.*

Reaction	Adopted Q (Mev)	Highest energy group measured (Mev)	Intensity (%)	Method	Energy ref.	Identification	Comments
$Fr^{223} \longrightarrow At^{219}$ 21 m	5.44	5.34		range emuls	22	A	ins evid
$Ra^{223} \longrightarrow Em^{219}$ 11.2 d	5.974	5.867 5.860	0.9	spect spect	2b 22a	A	
$Ra^{222} \longrightarrow Em^{218}$ 38 s	6.671	6.551	96	spect	23	A	
$Ac^{225} \longrightarrow Fr^{221}$ 10.0 d	5.923	5.818 5.80	56	spect ion ch	24 21a, 13	A	
$Th^{226} \longrightarrow Ra^{222}$ 30.9 m	6.444	6.330	79	spect	23	A	
$Th^{227} \longrightarrow Ra^{223}$ 18.6 d	6.144	6.036 6.030	23	spect spect	2b 22a	A	
$Th^{232} \longrightarrow Ra^{228}$ 1.4×10^{10} y	4.077	4.007 4.006		ion ch range emuls	25 26	A	
$Pa^{231} \longrightarrow Ac^{227}$ 3.43×10^{4} y	5.138	5.049 5.046 5.042	8.7	spect spect spect	27 28 29	A	
$U^{230} \longrightarrow Th^{226}$ 20.8 d	5.988	5.884	67.2	spect	23	A	
$U^{233} \longrightarrow Th^{229}$ 1.62×10^{5} y	4.900	4.816 4.823	83.5	spect ion ch	30 13	A	
$U^{234} \longrightarrow Th^{230}$ 2.48×10^{5} y	4.851	4.768 4.768 4.763	72	spect ion ch ion ch	27 25 31	A	
$U^{235} \longrightarrow Th^{231}$ 7.13×10^{8} y	4.63	4.552 4.58	7	spect ion ch	2b 31a	A	
$U^{238} \longrightarrow Th^{234}$ 4.51×10^{9} y	4.267	4.195	77	ion ch	25	A	
$Np^{235} \longrightarrow Pa^{231}$ 410 d	5.23	5.06		ion ch	32	A	α-γ(33)
$Np^{237} \longrightarrow Pa^{233}$ 2.2×10^{6} y	4.950	4.866 4.872	3	spect ion ch	34 35	A	
$Pu^{233} \longrightarrow U^{229}$ 20 m	6.41	6.30		ion ch	36	B	ins evid
$Pu^{236} \longrightarrow U^{232}$ 2.7 y	5.862	5.763	68.9	spect	37	A	
$Pu^{237} \longrightarrow U^{233}$ 44 d	5.75	5.65	21	ion ch	36	A	ins evid
$Pu^{238} \longrightarrow U^{234}$ 89.6 y	5.589	5.495 5.491	72	spect spect	38 27	A	
$Pu^{239} \longrightarrow U^{235}$ 24,360 y	5.235	5.147 5.147 5.150	72.5	spect spect spect	27 39 40	A	isomeric state less than 1 kev 38a, b
$Pu^{240} \longrightarrow U^{236}$ 6580 y	5.246	5.159 5.162	75.5	spect spect	30 40	A	
$Am^{239} \longrightarrow Np^{235}$ 12 h	5.90	5.75		ion ch	41	A	α-γ(42)
$Am^{241} \longrightarrow Np^{237}$ 461 y	5.628	5.535 5.541	0.42	spect spect	43 27	A	
$Am^{243} \longrightarrow Np^{239}$ 7.9×10^{3} y	5.428	5.339	0.17	spect	44	A	ins evid
$Cm^{238} \longrightarrow Pu^{234}$ 2.4 h	6.63	6.52 6.50		ion ch ion ch	41 45	B	e-e

TABLE II.—*Continued.*

Reaction	Adopted Q (Mev)	Highest energy group measured (Mev)	Intensity (%)	Method	Energy ref.	Identification	Comments
$Cm^{240} \longrightarrow Pu^{236}$ 26.8 d	6.38	6.27 6.25		ion ch ion ch	46 47	A	e-e
$Cm^{241} \longrightarrow Pu^{237}$ 35 d	6.20	5.95		ion ch	46	A	α-γ(47a)
$Cm^{243} \longrightarrow Pu^{239}$ 35 y	6.159	6.003 5.777	1 78	spect spect	48 83	A	(49)
$Cm^{245} \longrightarrow Pu^{241}$ 1×10^4 y	5.62	5.45 5.36 5.4	~10 ~82	ion ch ion ch ion ch	50 51 52	A	α-γ(48)
$Cm^{246} \longrightarrow Pu^{242}$ 5×10^3 y	5.46	5.373 5.37 5.39 5.4		ion ch ion ch ion ch ion ch	53 50 54 52	A	e-e
$Cm^{248} \longrightarrow Pu^{244}$ 4.7×10^5 y	5.14	5.054		ion ch	53	A	e-e
$Bk^{244} \longrightarrow Am^{240}$ 4.35 h	6.78	6.67		ion ch	55	B	ins evid
$Bk^{245} \longrightarrow Am^{241}$ 4.95 d	6.48	6.37 6.35 6.33	33	ion ch ion ch ion ch	56 55 57	A	ins evid
$Bk^{247} \longrightarrow Am^{243}$ ~10^4 y	5.85	5.67	~40	ion ch	55	B	α-γ(58)
$Bk^{249} \longrightarrow Am^{245}$ 280 d	5.53	5.40 5.4 5.4	~94	ion ch ion ch ion ch	55 59 60	A	α-γ(58)
$Cf^{244} \longrightarrow Cm^{240}$ ~25 m	7.29	7.17		ion ch	61	A	e-e
$Cf^{245} \longrightarrow Cm^{241}$ 44 m	7.23	7.11 7.15		ion ch ion ch	61 62	A	
$Cf^{249} \longrightarrow Cm^{245}$ 5×10^2 y	6.29	6.19 6.19	~3	ion ch ion ch	63 64	A	
$Cf^{250} \longrightarrow Cm^{246}$ 10 y	6.122	6.024 6.025 6.033 6.05 6.03	83	spect ion ch ion ch ion ch ion ch	66 66a 65 67 59	A	
$Cf^{252} \longrightarrow Cm^{248}$ 2.2 y	6.211	6.112 6.119 6.117 6.15 6.12	84.5	spect ion ch ion ch ion ch ion ch	66 66a 65 67 59	A	
$E^{246} \longrightarrow Bk^{242}$ 7.3 m	7.4	7.3		ion ch	68	D	ins evid
$E^{248} \longrightarrow Bk^{244}$ 25 m	6.98	6.87		ion ch	72	B	ins evid
$E^{249} \longrightarrow Bk^{245}$ 2 h	6.87	6.76		ion ch	73	B	ins evid
$E^{251} \longrightarrow Bk^{247}$ 1.5 d	6.58	6.48		ion ch	73	B	ins evid
$E^{252} \longrightarrow Bk^{248}$ ~140 d	6.75	6.64		ion ch	73	B	ins evid
$E^{253} \longrightarrow Bk^{249}$ 20.03 d	6.740	6.633 6.636 6.63 6.61	90.2	spect ion ch ion ch ion ch	74 75 67 76	A	

TABLE II.—*Continued.*

Reaction	Adopted Q (Mev)	Highest energy group measured (Mev)	Intensity (%)	Method	Energy ref.	Identification	Comments
$E^{254} \longrightarrow Bk^{250}$ ~300 d	6.52	6.42 6.44		ion ch ion ch	75 77	A	ins evid
$Fm^{250} \longrightarrow Cf^{246}$ 30 m	7.55	7.43 7.7		ion ch ion ch	78 79	B	e-e
$Fm^{251} \longrightarrow Cf^{247}$ 7 h	7.00	6.89		ion ch	78	B	ins evid
$Fm^{252} \longrightarrow Cf^{248}$ 23 h	7.16	7.05 7.04		ion ch ion ch	78 80	B	e-e
$Fm^{253} \longrightarrow Cf^{249}$ 4.5 d	7.05	6.94 6.85		ion ch ion ch	81 80	B	ins evid
$Fm^{254} \longrightarrow Cf^{250}$ 3.24 h	7.32	7.20 7.22 7.17		ion ch ion ch ion ch	75 82 76	A	
$Fm^{255} \longrightarrow Cf^{251}$ 21.5 h	7.2	7.08 7.1		ion ch ion ch	75 82	B	ins evid

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