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TABLE OF ALPHA-DISINTEGRATION ENERGIES OF THE HEAVY ELEMENTS

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July, 1957

This compilation is a revision of the "Table of Alpha-Disintegration Energies of the Heavy Elements" published in this journal 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 will be 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, no references are 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, $4E/(A-4)$, 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 "~100" means that careful search has been made for other groups and either none has been found or that the intensities of lower-energy groups are low.

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 α (Mev)	Highest-energy group measured (Mev)	Intensity (%)	Method	Energy ref.	Ident-ification	Comments
$Bi^{210} \rightarrow Tl^{206}$ 2.6×10^{6} y	5.03	4.935		ion ch	2	A	
		4.97		ion ch	2a		
$Bi^{211} \rightarrow Tl^{207}$ 2.16 m	6.745	6.617	82.6	spect	2b	A	
		6.620		spect	3		
$Po^{197} \rightarrow Pb^{193}$ ~4 m	6.165	6.040		spect	4	D	ins evid
$Po^{198} \rightarrow Pb^{194}$ ~6 m	6.057	5.935		spect	4	D	e-e
$Po^{199} \rightarrow Pb^{195}$ 11 m	5.966	5.846		spect	4	B	ins evid
		5.84		ion ch	4a		
$Po^{200} \rightarrow Pb^{196}$ ~8 m	5.888	5.770		spect	4	B	e-e
$Po^{201} \rightarrow Pb^{197}$ 18 m	5.786	5.671		spect	4	B	ins evid
		5.70		ion ch	4b		
$Po^{202} \rightarrow Pb^{198}$ 51 min	5.689	5.575		spect	4	B	e-e
		5.60		ion ch	5		
		5.61		ion ch	6		
		5.59		ion ch	7		
$Po^{204} \rightarrow Pb^{200}$ 3.8 h	5.477	5.370		spect	4	B	e-e
		5.37		ion ch	7		
$Po^{211} \rightarrow Pb^{207}$ 0.52 s	7.58	7.442	99	spect	8	A	
		7.434		range air	9		
$Po^{213} \rightarrow Pb^{209}$ 4.2×10^{-6} s	8.51	8.35	~100	spect	11	A	ins evid
		8.336		ion ch	13		
$Po^{215} \rightarrow Pb^{211}$ 1.83×10^{-3} s	7.50	7.360	~100	spect	2b	A	
		7.365		range air	9		
		7.383		spect	13a		
$At^{209} \rightarrow Bi^{205}$ 5.5 h	5.752	5.642	~100	spect	14,15	B	ins evid
		5.65		ion ch	17		
$At^{217} \rightarrow Bi^{213}$ 0.018 s	7.18	7.05	~100	spect	18	A	
		7.02		ion ch	13		
		7.00		ion ch	19		
$Rn^{204} \rightarrow Po^{200}$ 3 m	6.41	6.28		ion ch	5	D	e-e
$Rn^{206} \rightarrow Po^{202}$ 6.2 m	6.37	6.25		ion ch	5	B	e-e
		6.25		ion ch	6		
$Rn^{207} \rightarrow Po^{203}$ 11 m	6.24	6.12		ion ch	5	B	ins evid
		6.09		ion ch	6		

Reaction	Adopted Q (Mev)	Highest-energy group measured (Mev)	Intensity (%)	Method	Energy ref.	Ident-ification	Comments
$Em^{208} \xrightarrow[23\ m]{} Po^{204}$	6.261	6.141	~100	spect	20	B	e-e
$Em^{209} \xrightarrow[30\ m]{} Po^{205}$	6.155	6.037		spect	20	B	ins evid
$Em^{210} \xrightarrow[2.7\ h]{} Po^{206}$	6.155	6.037		spect	20	A	
$Em^{212} \xrightarrow[23\ m]{} Po^{208}$	6.384	6.264	~100	spect	20	A	
$Em^{221} \xrightarrow[25\ m]{} Po^{217}$	6.1	6.0		ion ch	21	A	ins evid
$Em^{219} \xrightarrow[3.92\ s]{} Po^{215}$	6.940	6.813 6.807	83	spect spect	2b 21b	A	
$Fr^{212} \xrightarrow[19.3\ m]{} At^{208}$	6.534	6.411	37	spect	20	A	ins evid
$Fr^{221} \xrightarrow[4.8\ m]{} At^{217}$	6.449	6.332 6.30	84	spect ion ch	18 13,21a	A	
$Fr^{223} \xrightarrow[21\ m]{} At^{219}$	5.44	5.34		range emuls	22	A	ins evid
$Ra^{223} \xrightarrow[11.2\ d]{} Em^{219}$	5.974	5.867 5.860	0.9	spect spect	2b 22a	A	
$Ra^{222} \xrightarrow[38\ s]{} Em^{218}$	6.671	6.551	96	spect	23	A	
$Ac^{225} \xrightarrow[10.0\ d]{} Fr^{221}$	5.923	5.818 5.80	56	spect ion ch	24 21a,13	A	
$Th^{226} \xrightarrow[30.9\ m]{} Rn^{222}$	6.444	6.330	79	spect	23	A	
$Th^{227} \xrightarrow[18.6\ d]{} Ra^{223}$	6.144	6.036 6.030	23	spect spect	2b 22a	A	
$Th^{232} \xrightarrow[1.4\times10^{10}\ y]{} Ra^{228}$	4.077	4.007 4.006		ion ch range emuls	25 26	A	
$Pa^{231} \xrightarrow[3.43\times10^{4}\ y]{} Ac^{227}$	5.138	5.049 5.046 5.042	8.7	spect spect spect	27 28 29	A	
$U^{230} \xrightarrow[20.8\ d]{} Th^{226}$	5.988	5.884	67.2	spect	23	A	
$U^{233} \xrightarrow[1.62\times10^{5}\ y]{} Th^{229}$	4.900	4.816 4.823	83.5	spect ion ch	30 13	A	
$U^{234} \xrightarrow[2.48\times10^{5}\ y]{} Th^{230}$	4.851	4.768 4.768 4.763	72	spect ion ch ion ch	27 25 31	A	
$U^{235} \rightarrow Th^{231}$	4.63	4.552 4.58	7	spect ion ch	2b 31a	A	
$U^{238} \xrightarrow[4.51\times10^{9}\ y]{} Th^{234}$	4.267	4.195	77	ion ch	25	A	

Reaction	Adopted α (Mev)	Highest-energy group measured (Mev)	Intensity (%)	Method	Energy ref.	Ident-ification	Comments
$Np^{235}_{410\ d} \rightarrow Pa^{231}$	5.23	5.06		ion ch	32	A	α-γ(33)
$Np^{237}_{2.2\times10^6\ y} \rightarrow Pa^{233}$	4.950	4.866	3	spect	34	A	
		4.872		ion ch	35		
$Pu^{233}_{20\ m} \rightarrow U^{229}$	6.41	6.30		ion ch	36	B	ins evid
$Pu^{236}_{2.7\ y} \rightarrow U^{232}$	5.862	5.763	68.9	spect	37	A	
$Pu^{237}_{44\ d} \rightarrow U^{233}$	5.75	5.65	21	ion ch	36	A	ins evid
$Pu^{238}_{89.6\ y} \rightarrow U^{234}$	5.589	5.495	72	spect	38	A	
		5.491		spect	27		
$Pu^{239}_{24,360\ y} \rightarrow U^{235}$	5.235	5.147	72.5	spect	27	A	isomeric state less than 1 kev
		5.147		spect	39		
		5.150		spect	40		38a,b
$Pu^{240}_{6580\ y} \rightarrow U^{236}$	5.246	5.159	75.5	spect	30	A	
		5.162		spect	40		
$Am^{239}_{12\ h} \rightarrow Np^{235}$	5.90	5.75		ion ch	41	A	α-γ(42)
$Am^{241}_{461\ y} \rightarrow Np^{237}$	5.628	5.535	0.42	spect	43	A	
		5.541		spect	27		
$Am^{243}_{7.9\times10^3\ y} \rightarrow Np^{239}$	5.428	5.339	0.17	spect	44	A	ins evid
$Cm^{238}_{2.4\ h} \rightarrow Pu^{234}$	6.63	6.52		ion ch	41	B	e-e
		6.50		ion ch	45		
$Cm^{240}_{26.8\ d} \rightarrow Pu^{236}$	6.38	6.27		ion ch	46	A	e-e
		6.25		ion ch	47		
$Cm^{241}_{35\ d} \rightarrow Pu^{237}$	6.20	5.95		ion ch	46	A	α-γ(47a)
$Cm^{243}_{35\ y} \rightarrow Pu^{239}$	6.159	6.003	1	spect	48	A	(49)
		5.777	78	spect	48		
$Cm^{245}_{1\times10^4\ y} \rightarrow Pu^{241}$		5.45	~10	ion ch	50	A	
	5.62	5.36	~82	ion ch	51		α-γ(48)
		5.4		ion ch	52		
$Cm^{246}_{5\times10^3\ y} \rightarrow Pu^{242}$	5.46	5.373		ion ch	53	A	e-e
		5.37		ion ch	50		
		5.39		ion ch	54		
		5.4		ion ch	52		
$Cm^{248}_{4.7\times10^5\ y} \rightarrow Pu^{244}$	5.14	5.054		ion ch	53	A	e-e
$Bk^{244}_{4.35\ h} \rightarrow Am^{240}$	6.78	6.67		ion ch	55	B	ins evid
$Bk^{245}_{4.95\ d} \rightarrow Am^{241}$	6.48	6.37	33	ion ch	56	A	ins evid
		6.35		ion ch	55		
		6.33		ion ch	57		
$Bk^{247}_{\sim10^4\ y} \rightarrow Am^{243}$	5.85	5.67	~40	ion ch	55	B	α-γ(58)

Reaction	Adopted E_α (Mev)	Highest-energy group measured (Mev)	Intensity (%)	Method	Energy ref.	Ident-ification	Comment
$Bk^{249} \xrightarrow[280\ d]{} Am^{245}$	5.53	5.40	~94	ion ch	55	A	α-γ(58)
		5.4		ion ch	59		
		5.4		ion ch	60		
$Cf^{244} \xrightarrow[\sim 25\ m]{} Cm^{240}$	7.29	7.17		ion ch	61	A	e-e
$Cf^{245} \xrightarrow[44\ m]{} Cm^{241}$	7.23	7.11		ion ch	61	A	
		7.15		ion ch	62		
$Cf^{249} \xrightarrow[5\times10^2\ y]{} Cm^{245}$	6.29	6.19	~3	ion ch	63	A	
		6.19		ion ch	64		
$Cf^{250} \xrightarrow[10\ y]{} Cm^{246}$	6.122	6.024	83	spect	66	A	
		6.025		ion ch	66a		
		6.033		ion ch	65		
		6.05		ion ch	67		
		6.03		ion ch	59		
$Cf^{252} \xrightarrow[2.2\ y]{} Cm^{248}$	6.211	6.112	84.5	spect	66	A	
		6.119		ion ch	66a		
		6.117		ion ch	65		
		6.15		ion ch	67		
		6.12		ion ch	59		
$E^{246} \xrightarrow[7.3\ m]{} Bk^{242}$	7.4	7.3		ion ch	68	D	ins evid
$E^{248} \xrightarrow[25\ m]{} Bk^{244}$	6.98	6.87		ion ch	72	B	ins evid
$E^{249} \xrightarrow[2\ h]{} Bk^{245}$	6.87	6.76		ion ch	73	B	ins evid
$E^{251} \xrightarrow[1.5\ d]{} Bk^{247}$	6.58	6.48		ion ch	73	B	ins evid
$E^{252} \xrightarrow[\sim 140\ d]{} Bk^{248}$	6.75	6.64		ion ch	73	B	ins evid
$E^{253} \xrightarrow[20.03\ d]{} Bk^{249}$	6.740	6.633	90.2	spect	74	A	
		6.636		ion ch	75		
		6.63		ion ch	67		
		6.61		ion ch	76		
$E^{254} \xrightarrow[\sim 300\ d]{} Bk^{250}$	6.52	6.42		ion ch	75	A	ins evid
		6.44		ion ch	77		
$Fm^{250} \xrightarrow[30\ m]{} Cf^{246}$	7.55	7.43		ion ch	78	B	e-e
		7.7		ion ch	79		
$Fm^{251} \xrightarrow[7\ h]{} Cf^{247}$	7.00	6.89		ion ch	78	B	ins evid
$Fm^{252} \xrightarrow[23\ h]{} Cf^{248}$	7.16	7.05		ion ch	78	B	e-e
		7.04		ion ch	80		
$Fm^{253} \xrightarrow[4.5\ d]{} Cf^{249}$	7.05	6.94		ion ch	81	B	ins evid
		6.85		ion ch	80		

Reaction	Adopted α (Mev)	Highest-energy group measured (Mev)	Intensity (%)	Method	Energy ref.	Ident-ification	Comments
$Fm^{254} \xrightarrow[3.24\ h]{} Cf^{250}$	7.32	7.20		ion ch	75	A	
		7.22		ion ch	82		
		7.17		ion ch	76		
$Fm^{255} \xrightarrow[21.5\ h]{} Cf^{251}$	7.2	7.08		ion ch	75	B	ins evid
		7.1		ion ch	82		

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