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HINDRANCE FACTORS FOR ALPHA DECAY

Helen V. Michel

May, 1960

-2-

HINDRANCE FACTORS FOR ALPHA DECAY*

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Berkeley, California

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The theoretical half lives for alpha emission have been calculated for nearly all of the complex alpha spectra. The spin independent ($l=0$) equations of Preston¹ were used for the calculations. The nuclear radius for the even-even nuclei was determined with the assumption that the alpha transition to the ground state is unhindered; i.e., the hindrance factor = 1. For odd mass nuclides the average of the nuclear radii of the adjacent even-even nuclides was used. For odd-odd nuclides the average of the nuclear radii of the adjacent odd mass nuclides of the same atomic number was used.

Table I contains the experimental data and results for the even-even nuclides and Table II has those for the odd mass and odd-odd nuclides. No references are included for the experimental data since many of the alpha groups are somewhat uncertain.

Column 1 specifies the alpha emitting nuclide and the energy of the excited state in the daughter nucleus.

In Column 2 is the alpha particle energy of the highest energy group (in a few cases the most intense group) which has been observed.

Column 3 contains the total alpha decay energy for the group listed in column 2. This includes the alpha particle energy, the nuclear recoil energy, and a correction for the rearrangement of the electron orbitals during the passage of the alpha particle through the coulomb barrier. This latter quantity is dependent on Z and varies from 34 kev for Rn to 42.5 kev for Fm.

Column 4 contains the measured half life. If there are other modes of decay, column 4 also contains the percent of alpha branching and the partial half life for alpha emission.

* This work was done under the auspices of the U.S. Atomic Energy Commission

-3-

Column 5 contains the measured relative alpha particle abundance.

Column 6 shows the calculated half life for each alpha group.

Column 7 and column 8 indicate the nuclear radius used in the calculation.

Column 9 contains the hindrance factor for the alpha decay for each observed alpha group. This is simply the ratio of the experimental partial half life for a given group to the calculated value. The experimental partial half life for any alpha group can be determined from columns 4 and 5.

¹M. A. Preston, Phys. Rev. 71, 865 (1947).

Table I

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	$R/A^{1/3}$ (fermis)	Hindrance factor
Fm^{254} α 0	7.20	7.3578	3.24 h	85	3.814 h	9.355	1.4850	1.00
α 42				14	5.722 h			4.0
α 139				0.9	14.13 h			30
Cf^{252} α 0	6.112	6.2518	2.2 yr	84.5	2.599 y	9.50144	1.5123	1.033
α 43.4			97% α $T_{1/2} \alpha = 2.27$ y	15.5	4.301 y			3.40
α 146				0.28	14.43 y			56
Cf^{250} α 0	6.024	6.1631	11 y	83	13.26 y	9.3489	1.4920	1.00
α 44				17	22.38 y			2.9
α 142				0.32	73.29 y			47
Cf^{246} α 0	6.753	6.9057	35.7 h	78	45.01 h	9.306	1.4933	1.02
α 42.12				22	68.29 h			2.4
α 140				0.16	183.7 h			1.2×10^2
α 291				0.015	879.5 h			2.7×10^2
Cm^{244} α 0	5.798	5.9347	19 y	76.7	24.77 y	9.314	1.4987	1.000
α 42.88				23.3	41.98 y			1.94
α 141.8				0.016	145.4 y			8.2×10^2
α 292				4×10^{-3}	993.2 y			5×10^2

Table I (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	$R/A^{1/3}$ (fermis)	Hindrance factor
$\text{Cm}^{242}_{\alpha 0}$	6.110	6.2528	162.5 d	73.7	2.205×10^2 d	9.3088	1.5021	1.000
$\alpha 44.11$				26.3	3.638×10^2 d			1.698
$\alpha 146$				0.035	1.182×10^3 d			3.9×10^2
$\alpha 303.7$				6×10^{-3}	7.788×10^3 d			3.5×10^2
$\alpha 514$				3×10^{-5}	1.092×10^5 d			5×10^3
$\alpha 605$				3.2×10^{-4}	3.592×10^5 d			141
$\alpha 941.4$				1.4×10^{-4}	3.788×10^7 d			3.1
$\alpha \sim 1010$				2×10^{-5}	1.054×10^8 d			8
$\text{Pu}^{242}_{\alpha 0}$	4.898	5.0194	3.76×10^5 y	74	5.081×10^5 y	9.38406	1.5142	1.00
$\alpha 45$				26	1.030×10^6 y			1.40
$\text{Pu}^{240}_{\alpha 0}$	5.162	5.2885	6580 y	75.5	8.707×10^3 y	9.396	1.5204	1.001
$\alpha 45$				24.5	1.668×10^4 y			1.610
$\alpha 151$				0.085	7.959×10^4 y			97
$\text{Pu}^{238}_{\alpha 0}$	5.495	5.6279	89.6 y	72	1.238×10^2 y	9.2973	1.5087	1.00
$\alpha 43.5$				28	2.187×10^2 y			1.46
$\alpha 143.31$				0.095	8.300×10^2 y			114
$\alpha 296.4$				0.004	6.905×10^3 y			3.2×10^2
$\alpha 499$				7×10^{-6}	1.327×10^5 y			9.6×10^3

Table I (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	$R/A^{1/3}$ (fermis)	Hindrance factor
Pu^{238} (cont'd.)								
α 810				1.2×10^{-4}	1.798×10^7 y			4.2
Pu^{236} α 0	5.763	5.9014	2.7 y	68.9	3.92 y	9.30266	1.5139	1.00
α 47.5				30.9	6.98 y			1.252
α 156				0.18	26.84 y			56
α 321				0.002	225 y			6×10^2
Pu^{234} α 0	6.17	6.3164	9 hr	67.6	9.76 d	9.3636	1.5283	0.997
α 51.67			5.7% α $T_{1/2} \alpha = 6.6$ d	32	17.18 d			1.20
α 174				0.41	67.21 d			2.39
U^{238} α 0	4.182	4.2906	4.49×10^9 y	77	5.82×10^9 y	9.5342	1.5472	1.00
α 48				23	1.488×10^{10} y			1.31
α 160				0.23	1.413×10^{11} y			13.8
U^{236} α 0	4.499	4.6136	2.39×10^7 y	73	3.274×10^7 y	9.347	1.5211	1.00
α 49				27	7.695×10^7 y			1.15
α 163				~ 0.5	5.953×10^8 y			8

Table I (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	$R/A^{1/3}$ (fermis)	Hindrance factor
U^{234} $\alpha 0$ $\alpha 52.4$ $\alpha 170$ $\alpha 505$ $\alpha 630$	4.768	4.8885	2.48×10^5 y	72 28 0.3 2.5×10^{-5} 1×10^{-5}	3.440×10^5 y 7.94×10^5 y 5.45×10^6 y 2.043×10^9 y 2.227×10^{10} y	9.3475	1.5256	1.00 1.11 15 4.9×10^2 1×10^2
U^{232} $\alpha 0$ $\alpha 57.5$ $\alpha 186.1$ $\alpha 326$	5.318	5.4484	73.6 y	68 32 0.32 0.01	1.083×10^2 y 2.349×10^2 y 1.393×10^3 y 1.046×10^4 y	9.3269	1.5267	1.00 0.98 16.5 7×10^1
U^{230} $\alpha 0$ $\alpha 72.13$ $\alpha 226.4$ $\alpha 230$	5.884	6.0257	20.8 d	67.2 32.1 0.4 0.3	30.76 d 70.67 d 441.2 d 460.8 d	9.3338	1.5323	1.006 0.917 12 15
U^{228} $\alpha 0$ $\alpha 93$ $\alpha 246$ $\alpha 280$	6.68	6.8369	9.1 m $> 95\% \alpha$ $T_{1/2} \alpha = 9.6$ m	70 29 ~ 0.6 ~ 0.5	13.34 m 32.15 m 142.3 m 199.7 m	9.261	1.5249	1.02 1.03 11 10

Table I (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	$R/A^{1/3}$ (fermis)	Hindrance factor
$\text{Th}_{\alpha 0}^{232}$	3.994	4.1001	1.39×10^{10} y	76	1.835×10^{10} y	9.4700	1.5501	1.00
$\alpha 59$				24	6.144×10^{10} y			0.94
$\alpha 185$				0.2	8.923×10^{11} y			8
$\text{Th}_{\alpha 0}^{230}$	4.682	4.8010	8.0×10^4 y	74	1.079×10^5 y	9.3330	1.5322	1.00
$\alpha 67.62$				26	3.193×10^5 y			0.96
$\alpha 210$				0.2	3.410×10^6 y			12
$\alpha 253$				0.03	7.126×10^6 y			4×10^1
$\alpha 320$				0.001	2.298×10^7 y			3×10^1
$\alpha 416$				8×10^{-6}	1.292×10^8 y			8×10^3
$\alpha 445$				8×10^{-6}	2.199×10^8 y			4.5×10^3
$\text{Th}_{\alpha 0}^{228}$	5.421	5.5541	1.90 y	71	2.699 y	9.310	1.5329	0.99
$\alpha 84.47$				28	7.969 y			0.85
$\alpha 217$				0.4	45.84 y			10
$\alpha 253$				0.2	74.75 y			13
$\alpha 289$				0.03	122.4 y			5×10^1
$\text{Th}_{\alpha 0}^{226}$	6.330	6.4802	30.9 m	78	39.38 m	9.339	1.5423	1.01
$\alpha 111.1$				20	120.3 m			1.28
$\alpha 242$				1.7	468.3 m			3.9
$\alpha 309$				0.6	953.7 m			5

Table I (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	$R/A^{1/3}$ (fermis)	Hindrance factor
Th^{224}_{90}	7.17	7.3365	1 s	79	1.241 s	9.2973	1.5401	1.02
α 177				19	5.397 s			0.98
α 410				~1.5	41.04 s			1.6
α 475				~0.5	73.61 s			2.7
Ra^{226}_{88}	4.777	4.8982	1622 y	94.3	1.715×10^3 y	9.3452	1.5434	1.003
α 187				5.7	3.103×10^4 y			0.92
α 448				0.0115	2.496×10^6 y			5.65
α 610				0.0017	4.425×10^7 y			2.2
Ra^{224}_{88}	5.681	5.8194	3.64 d	95.1	3.827 d	9.3206	1.5440	1.000
α 241				4.9	66.73 d			1.11
α 530				0.01	2.691×10^3 d			1×10^1
α 650				0.01	1.369×10^4 d			3
Ra^{222}_{88}	6.551	6.7063	38 s	96.8	39.92 s	9.2984	1.5450	0.983
α 324.6				3.2	883.9 s			1.34
α 650				0.10	2.557×10^4 s			15
α 800				0.032	1.330×10^5 s			0.89
α 850				0.002	2.341×10^5 s			8

Table I (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	$R/A^{1/3}$ (fermis)	Hindrance factor
$\text{Ra}_{\alpha 0}^{220}$ $\alpha 465$	7.45	7.6231	0.023 s	99 1	0.02328 s 0.8980 s	9.259	1.5432	1.00 2.6
$\text{Rn}_{\alpha 0}^{222}$ $\alpha 510$	5.486	5.6208	3.825 d	99.9 ~0.07	3.899 d 2.577×10^3 d	9.323	1.5491	0.982 2.1
$\text{Rn}_{\alpha 0}^{220}$ $\alpha 545$	6.282	6.4324	54.5 s	99.7 0.3	54.46 s 1.446×10^4 s	9.3519	1.5586	1.003 1.3
$\text{Rn}_{\alpha 0}^{218}$ $\alpha 609$	7.127	7.2944	0.030 s	99.8 0.2	0.02995 s 4.895 s	9.3704	1.5666	1.004 3.06
$\text{Rn}_{\alpha 0}^{216}$	8.04	8.2259	4.5×10^{-5} s	100	4.504×10^{-5} s	9.3444	1.5671	0.999
$\text{Rn}_{\alpha 0}^{212}$	6.264	6.4185	23 m	~100	22.9 m	8.5076	1.4359	1.00
$\text{Rn}_{\alpha 0}^{210}$	6.037	6.1844	2.7 h 97% α $T_{1/2} \alpha = 2.8$ h	~100	2.784 h	8.5847	1.4536	1.01

Table II

Alpha emitter	Alpha particle energy (Mev) +	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Fm^{255}	7.03	7.1846	21.5 h	90	18.68 h	9.3614	1.28
$\text{E}^{253}_{\alpha 0}$	6.633	6.7817	20.03 d	90	11.53 d	9.42822	1.93
$\alpha 41.7$				7.7	17.70 d		14.7
$\alpha 82.7$				0.8	27.12 d		9×10^1
$\alpha 94.3$				0.9	30.61 d		73
$\alpha 138.3$				0.25	48.76 d		164
$\alpha 156.8$				0.1	59.34 d		3×10^2
$\alpha 207.2$				0.1	101.8 d		2×10^2
$\alpha 390$				0.04	763.1 d		7×10^1
$\alpha 431$				0.05	1215 d		33
$\alpha 475$				0.02	2008 d		5×10^1
$\text{Cf}^{251}_{\alpha 0 (+?)}$	5.843	5.9790	3.1×10^3 y		91.03 y	9.42517	34
$\alpha 179 (+?)$			3.2×10^3 y		880.8 y	9.3810	3.6×10^3
$\text{Cf}^{249}_{\alpha 0}$	6.194	6.3365	360 ± 40 y	1.94	1.879 y	9.3359	9.88×10^3
$\alpha 56$				1.12	3.559 y		8.9×10^3
$\alpha 124$				0.40	7.807 y		1.15×10^4

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Cf^{249}	(cont'd.)						
α 207				0.08	20.77 y		2.2×10^4
α 257				3.25	37.77 y		293
α 301				2.97	64.52 y		188
α 357				1.21	128.4 y		232
α 394				83.72	203.3 y		2.115
α 422				0.52	289.1 y		239
α 450				4.36	412.2 y		20.03
α 511				0.43	897.7 y		93
Bk^{249}	---		$314 \pm 3\%$	---	8.404×10^3 y	9.3359	---
α 0			$2.2 \times 10^{-3} \%$	---	1.458×10^4 y		2.85
α ~40	5.40	5.5288	$T_{1/2} = 3.91 \times 10^4$ y	94	2.383×10^6 y		0.27
α ~390				6			
Bk^{247}	---		$\sim 10^4$ y	--	1.262×10^2 y	9.3314	---
α 0					3.666×10^2 y		74
α 84.3	5.67	5.8062		~40	3.939×10^3 y		4.4
α 265				~60	5.862×10^4 y		3.4
α ~460				~5			

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Bk ²⁴⁵ α 0	6.37	6.5165	4.98 d	32	.09733 y	9.310	4.0×10^2
α 206			0.11% α	41	.9327 y		32.4
α 480			$T_{1/2} \alpha = 12.4$ y	27	22.75 y		2.0
Bk ²⁴³ α 0	6.72	6.8731	4.5 h	30	.9069 d	9.3114	4.6×10^2
α 192			0.15% α	53	6.246 d		37.8
α 550			$T_{1/2} \alpha = 125$ d	17	291.9 d		2.5
Cm ²⁴⁵ α 0	---		8×10^3 y	---	7.685×10^2 y	9.3269	---
α ~80	5.45	5.5805		~15	2.236×10^3 y		24
α 172				~77	7.867×10^3 y		1.32
α ~230				~8	1.766×10^4 y		6
Cm ²⁴³ α 0	6.061	6.2025	35 y	1.0	1.049 y	9.3114	3.3×10^3
α 7.12			99.7% α	4.8	1.137 y		6.4×10^2
α 56.94			$T_{1/2} \alpha = 35.1$ y	1.2	2.019 y		1.4×10^3
α 75.23				6.1	2.500 y		230
α 163.69				0.15	7.080 y		3.3×10^3
α 195.51				0.70	10.33 y		484
α 285.7				73	31.10 y		1.54
α 330.44				11.5	54.07 y		5.62

-13-

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Cm^{243}	(cont'd.)						
α 387.38				1.6	110.6 y		20
α 391.44				0.18	116.4 y		1.7×10^2
α 434.15				0.15	200.4 y		1.2×10^2
α 460				0.02	279.2 y		6×10^2
α 485				0.05	386.0 y		1.8×10^2
Am^{243}	5.339	5.4674	7.95×10^3 y	0.17	2.882×10^3 y	9.34903	1.6×10^3
α 0				0.16	4.421×10^3 y		1.12×10^3
α 31				86.9	8.061×10^3 y		1.127
α 74				11.5	1.48×10^4 y		4.64
α 117				1.3	3.314×10^4 y		18
α 173							
Am^{242}	---		152 y	---	---	9.35071	---
α 0			0.48% α				
α 350	5.196	5.3147	$T_{1/2} = 3.17 \times 10^4$ y		2.182×10^4 y		1.45
Am^{241}	5.535	5.6679	461 y	0.39	193.4 y	9.3524	6.1×10^2
α 0				0.24	298.8 y		6.4×10^2
α 33.2				85	423.3 y		1.28
α 59.57				12.8	752.8 y		4.78
α 103.0				1.7	1595 y		17
α 158.6							

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Am ²⁴¹	(cont'd.)						
α 225				1.5×10^{-2}	3970 y		7.7×10^2
α 267.4				2×10^{-3}	7167 y		3×10^3
Pu ²⁴¹	---		$T_{1/2} \alpha = 6.4 \times 10^5$ y	---	5.853×10^4 y	9.39003	---
α 0							
α 145	4.893	5.0149		75	5.314×10^5 y		1.61
α 191				25	1.094×10^6 y		2.3
Pu ²³⁹	---		2.4360×10^4 y	---	1.306×10^4 y	9.347	---
α 0							
α .07	5.147	5.2736		72	1.306×10^4 y		2.59
α 13.2				16.8	1.578×10^4 y		9.19
α 46.5				---	2.562×10^4 y		---
α 52				10.7	2.772×10^4 y		8.21
α 84				0.037	4.440×10^4 y		1.48×10^3
α 104.3				---	5.997×10^4 y		---
α 151				0.013	1.205×10^5 y		1.6×10^3
α 172				0.005	1.657×10^5 y		2.9×10^3
α 234				0.005	4.275×10^5 y		1.1×10^3
α 373				0.002	3.829×10^6 y		3×10^2
α 426				0.005	9.081×10^6 y		5×10^1
α 497				0.0015	2.950×10^7 y		55

-15-

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Pu ²³⁷ α 0 α 290	5.65	5.786	45.6 d $3.3 \times 10^{-3} \% \alpha$ $T_{1/2} = 3780$ y	21 79	16.36 y 702.7 y	9.300	1.10×10^3 6.8
Np ²³⁷ α 0 α 6 α 56 α 69 α 86 α 103 α 108 α 140 α 157 α 162 α 171 α 177 α 200 α 205 α 228 α 273 α 293 α 360	4.872	4.9927	2.20×10^6 y	3.1 ~1 1.4 1.5 42 28 5 0.8 0.7 1.5 0.4 1.2 1.5 4.0 6.0 0.35 0.5 0.02	2.663×10^5 y 2.923×10^5 y 6.393×10^5 y 7.842×10^5 y 1.028×10^6 y 1.347×10^6 y 1.459×10^6 y 2.443×10^6 y 3.221×10^6 y 3.491×10^6 y 4.047×10^6 y 4.464×10^6 y 6.518×10^6 y 7.073×10^6 y 1.037×10^7 y 2.208×10^7 y 3.093×10^7 y 9.811×10^7 y	9.3222	2.7×10^2 8×10^2 2.5×10^2 1.9×10^2 5.1 5.8 30 1.1×10^2 10×10^1 42 1.4×10^2 41 23 7.8 3.54 28 14 1.1×10^2

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
U^{235} $\alpha 0$ $\alpha 40$ $\alpha 95$ $\alpha 191$ $\alpha 204$ $\alpha 224$ $\alpha 390$	4.559	4.6755	7.13×10^8 y	6.7 2.7 0.9 29 43 12 5.8	1.130×10^7 y 2.236×10^7 y 5.803×10^7 y 3.197×10^8 y 4.051×10^8 y 5.839×10^8 y 1.329×10^{10} y	9.34725	9.4×10^2 1.18×10^3 1.4×10^3 7.7 4.1 10 0.92
U^{233} $\alpha 0$ $\alpha 42.8$ $\alpha 98.9$ $\alpha 120$ $\alpha 146$ $\alpha 164$ $\alpha 164$ $\alpha 211$ $\alpha 245$ $\alpha 285$ $\alpha 321$ $\alpha 367$	4.816	4.9377	1.62×10^5 y	84.2 13.7 1.95 ~.02 ~.01 0.04 ~.01 ~.02 ~.01 ~.01 0.04 ~.004	1.650×10^5 y 3.228×10^5 y 7.883×10^5 y 1.108×10^6 y 1.692×10^6 y 2.256×10^6 y 2.256×10^6 y 4.942×10^6 y 8.747×10^6 y 1.722×10^7 y 3.197×10^7 y 7.130×10^7 y	9.3372	1.166 3.66 10.5 7×10^2 1×10^3 1.8×10^2 7×10^2 2×10^2 2×10^2 9×10^1 13 6×10^1

-17-

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
U^{229}	6.355	6.5051	58 min	64	.2042 d	9.2974	1.54
$\alpha 0$			20% α	20	.2741 d		3.7
$\alpha 29$			$T_{1/2} \alpha = .201$ d	11	.3959 d		4.6
$\alpha 65$				1	.5799 d		3×10^1
$\alpha 102$				3	.8444 d		8
$\alpha 138$				1	1.278 d		2×10^1
$\alpha 178$							
Pa^{231}	5.046	5.1719	3.43×10^4 y	10	1.431×10^3 y	9.330	2.4×10^2
$\alpha 0$				23	2.196×10^3 y		68
$\alpha 29$				24	2.806×10^3 y		51
$\alpha 46$				2.3	4.353×10^3 y		3.4×10^2
$\alpha 76$				22	7.180×10^3 y		22
$\alpha 110$				2.8	9.236×10^3 y		1.3×10^2
$\alpha 127$				1.4	3.278×10^4 y		75
$\alpha 211$				11	2.059×10^5 y		1.5
$\alpha 329$				1.4	3.167×10^5 y		7.7
$\alpha 356$				2.1	5.254×10^5 y		3.1
$\alpha 387$							
Pa^{229}	5.665	5.8027	1.5 d	19.1	140.7 d	9.3219	22.3
$\alpha 0$			0.25% α	9.8	228.8 d		26.8
$\alpha 40.5$			$T_{1/2} \alpha = 600$ d	13.4	277.8 d		16.1
$\alpha 56.3$							

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Pa ²²⁹	(cont'd.)						
α 80.6				4.7	372.6 d		34
α 91.9				36.8	428.9 d		3.80
α 107.3				3.9	517.9 d		30
α 136.7				8.9	745.3 d		9.0
α 155.9				0.60	948.8 d		105
α 172.1				0.74	1159 d		70
α 194.1				1.77	1529 d		22.2
α 252.4				0.07	3216 d		2.7×10^2
α 263.7				0.15	3716 d		1.1×10^2
α 356				0.05	12363 d		1.0×10^2
Pa ²²⁸	6.138	6.2846	22 h	2.5	.6523 d	9.31095	2.8×10^3
α 0			2% α	10.5	.8415 d		518
α 24			$T_{1/2} = 45.8$ d	12.0	.9770 d		391
α 38.1				2.3	1.135 d		1.8×10^3
α 52.1				20.7	1.321 d		168
α 66.3				1.0	1.486 d		3.1×10^3
α 77.2				2.3	1.959 d		1.02×10^3
α 102.8				9.0	2.270 d		224
α 116.4				0.8	2.738 d		2.1×10^3

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (femis)	Hindrance factor
Pa ²²⁸	(cont'd.)						
α 146.2				0.3	3.137 d		5×10^3
α 155.8				1.1	3.488 d		1.2×10^3
α 163.3				2.8	3.791 d		4.3×10^2
α 170.0				2.7	4.081 d		4.2×10^2
α 198.8				0.6	5.608 d		1.4×10^3
α 204.6				0.5	5.987 d		1.5×10^3
α 224.4				0.8	7.457 d		8×10^2
α 239.5				1.1	8.840 d		4.7×10^2
α 272.6				1.4	12.83 d		2.6×10^2
α 289.6				0.3	15.55 d		1.0×10^3
α 304.3				0.4	18.38 d		6×10^2
α 343.2				7.3	28.71 d		21.9
α 349.4				11.3	30.90 d		13.1
α 369.9				1.4	39.13 d		84
α 383.7				2.0	45.96 d		50
α 388.4				1.4	48.51 d		67
α 393.5				2.5	51.48 d		36
α 439.4				1.0	88.38 d		52

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Pa^{227}	6.526	6.6801	38.3 m	2.3	18.29 m	9.300	107
α 0			85% α				
α 10.7			$T_{1/2} \alpha = 45.1$ m	0.3	20.30 m		7×10^2
α 67.3				49.5	35.06 m		2.60
α 109.7				11.5	53.06 m		7.38
α 117.8				14.8	57.49 m		5.30
α 132.0				9.3	66.12 m		7.3
α 157.9				2.6	85.61 m		20
α 177.6				7.8	104.0 m		5.6
α 198.6				0.7	128.5 m		50
α 208.6				0.4	142.1 m		8×10^1
α 235.6				0.8	186.7 m		30
Th^{229}	5.040	5.1659	7340 y	8	4.691×10^2 y	9.3215	2.0×10^2
α 0							
α 77				10	1.415×10^3 y		52
α 153				12	4.326×10^3 y		14
α 210				60	1.016×10^4 y		1.20
α 240				10	1.603×10^4 y		4.6
Th^{227}	6.036	6.1806	18.17 d	23	.6338 d	9.3245	125
α 0							
α 30.0				2.8	.8753 d		7.4×10^2
α 61.5				24	1.231 d		62

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Th^{227}	(cont'd.)						
α 79.9				3.5	1.504 d		3.5×10^2
α 124.2				0.9	2.449 d		8×10^2
α 174.4				3.0	4.279 d		142
α 234.9				1.0	8.463 d		2.1×10^2
α 247.1				0.3	9.729 d		6×10^2
α 280.0				0.3	14.19 d		4×10^2
α 286.1				21	15.21 d		5.7
α 329.8				5.0	25.27 d		14.4
α 334.2				8.7	26.57 d		7.9
α 342.6				4.0	29.34 d		15.5
α 350.4				1.5	32.17 d		38
α 376.0				1.9	43.42 d		22
Th^{225}	6.79	6.9490	8 m	9	.5197 m	9.318	1.8×10^2
α 0			$> 95\% \alpha$	7	.8493 m		1.4×10^2
α 55			$T_{1/2} \alpha = 8.4 \text{ m}$	2	1.253 m		3×10^2
α 98				3	2.035 m		1.4×10^2
α 151				3	2.517 m		1.1×10^2
α 174				14	8.297 m		7.3
α 301				43	10.35 m		1.89
α 324							

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Th ²²⁵	(cont'd.)						
α 361				15	14.75 m		3.8
α 460				2	38.93 m		11
α 494				2	54.58 m		8
Ac ²²⁵	5.818	5.9594	10.0 d	54	2.322 d	9.3298	8.0
α 0				27.9	3.491 d		10.26
α 36.3				9.5	7.130 d		14.8
α 98.8				2.6	7.818 d		49
α 107				0.8	12.72 d		1.0×10^2
α 149				3.8	21.71 d		12.1
α 194.5				0.6	30.39 d		55
α 223				0.7	42.94 d		33
α 252				0.07	60.22 d		2.4×10^2
α 280							
Ra ²²³	5.867	6.009	11.68 d	0.96	.4761 d	9.3095	2.56×10^3
α 0				---	.5007 d		---
α 4.8				0.3	.5566 d		7×10^3
α 14.4				0.05	.7214 d		3.2×10^4
α 38.0				10.5	1.945 d		57.2
α 127				50.4	2.796 d		8.29
α 158.9							

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Ra ²²³	(cont'd.)						
α 269.6				23.6	10.05 d		4.93
α 338.5				10.3	22.71 d		4.99
α 376.5				0.86	35.92 d		37.8
α 445.6				2.4	83.37 d		5.8
α 515.6				0.20	199.1 d		29
α 541.8				0.07	277.5 d		60
α 589.6				0.03	509.7 d		8×10^1
α 594.6					544.0 d		
Ra ²²¹	6.75	6.9095	30 s	30	6.945 s	9.2787	14.4
α 0				20	15.52 s		9.7
α 91				37	26.63 s		3.0
α 151				8	32.85 s		11
α 174				3	35.93 s		3×10^1
α 184				0.4	106.1 s		7×10^1
α 301				0.3	187.3 s		5×10^1
α 361				0.7	713.4 s		6
α 499				0.3	1973 s		5
Fr ²²¹	6.332	6.4833	4.8 m	84	1.742 m	9.32515	3.28
α 0				16	15.12 m		2.0
α 220							

Table II (cont'd.)

Alpha emitter	Alpha particle energy (Mev)	Total alpha decay energy (Mev)	Experimental half-life α -branching α half-life	Relative abundance (%)	Calculated half-life	Radius (fermis)	Hindrance factor
Rn^{219} α 0 α 271.6 α 401	6.813	6.9739	3.92 s	82 13 5	.4149 s 4.356 s 14.11 s	9.3612	11.5 6.9 6
Rn^{217} α 0	7.735	7.9144	5.4×10^{-4} s	100	3.388×10^{-4} s	9.3574	1.59
Rn^{211} α 0 α 68.8 α 239	5.847	5.9941	16 h 26% α $T_{1/2} \alpha = 2.56$ d	33.5 64.5 2	1.031 d 2.177 d 14.68 d	8.5461	7.41 1.823 9

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