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SPECIFIC ACTIVITIES OF NUCLIDES, $Z > 87$

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Basis of Calculation:

The specific activity of an isotope is expressed as the product of its decay constant and the number of atoms per unit weight. In these calculations the units of specific activity are disintegrations per minute per microgram (d/min/ μ g).

For example, if the half-life is known in minutes:

$$\text{Specific Activity} = \frac{0.69315}{\text{Half-life}} \times \frac{(10^{-6})(6.025 \times 10^{23})}{\text{Atomic Weight}}$$

or

$$(\text{Specific Activity}) \times (\text{Half-life}) \times (\text{Atomic Weight})$$

$$= \text{constant}$$

$$= (0.69315)(10^{-6})(6.025 \times 10^{23})$$

$$= 4.176 \times 10^{17}$$

Appropriate constants can be calculated for half-lives in different units. Results are tabulated below:

<u>Units of Half-life</u>	<u>Appropriate Constant</u>
Seconds (s)	2.506×10^{19}
Minutes (m)	4.176×10^{17}
Hours (h)	6.960×10^{15}
Days (d)	2.900×10^{14}
Years (y)	7.940×10^{11}

Method of Calculation:

The appropriate constant was divided by a product of the half-life and the mass number to yield specific activities in d/min/ μ g. Specific activities in counts per minute per microgram (cpm/ μ g) were calculated for all known alpha emitters on the basis of a 52% geometry.

Method of Tabulation:

In the first column the mass numbers are listed. ("m" is used to indicate the metastable isomer of an isotope.) The calculated specific activities are recorded in the second column (d/min/ μ g) and in the third column (cpm/ μ g). A value is entered in the third column only if the isotope is a known alpha emitter which has either no or negligible other modes of decay. Information on the modes of decay is listed in the fourth column. In the fifth column are the half-lives.

It should be noted that each specific activity is calculated on the assumption of a single mode of decay. When a nuclide has several modes of decay, the actual specific activity associated with one of its modes is equal to the product of the percentage fraction of the decay occurring by that mode (see the fourth column) and of the value listed in the second column.

Data for the fourth and fifth columns, except where noted, were secured from the Table of Isotopes by D. Strominger, J. M. Hollander, and G. T. Seaborg [Rev. Mod. Phys., 30, 585-904 (1958)].

Acknowledgment

We would like to thank P. R. Fields for his useful suggestions.

RADIUM 88

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
213	7.26×10^{14}	3.78×10^{14}	α	2.7 m
219	$\sim 1.14 \times 10^{20}$	$\sim 5.95 \times 10^{19}$	α	$\sim 10^{-3}$ s
220	3.80×10^{18}	1.97×10^{18}	α	0.03 s
221	3.78×10^{15}	1.97×10^{15}	α	30 s
222	2.97×10^{15}	1.54×10^{15}	α, γ	38 s
223	1.11×10^{11}	5.79×10^{10}	α, γ	11.68 d
224	3.56×10^{11}	1.85×10^{11}	α, γ	3.64 d
225	8.71×10^{10}		β^-, γ ; no α ($<0.01\%$)	14.8 d
226	2.23×10^6	1.16×10^6	α, γ	1577 y*
227	4.47×10^{13}		β^-, γ	41.2 m
228	5.20×10^8		β^-, γ ; no α ($<2 \times 10^{-6}\%$)	6.7 y
229	-		$[\beta^-]$	short
230	3.03×10^{13}		β^-	1 h

* G. V. Gorshkov, Z. G. Gritchenko, and N. S. Shimanskia, Soviet Phys. JETP, 7, 519-20 (1958).

ACTINIUM 89

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
221	-	-	α	
222	2.05×10^{16}	1.07×10^{16}	α	5.5 s
223	8.51×10^{14}		$\alpha(99\%); \text{EC}(1\%)$	2.2 m
224	1.07×10^{13}		$\text{EC}(\sim 90\%), \gamma; \alpha(\sim 10\%)$	2.9 h
225	1.29×10^{11}	6.70×10^{10}	α, γ	10.0 d
226	1.06×10^{12}		$\beta^-(\sim 80\%), \gamma; \text{EC}(\sim 20\%), \gamma$	29 h
227	1.62×10^8		$\beta^-(\sim 99\%); \alpha(1.2\%)$	21.6 y
228	4.98×10^{12}		β^-, γ	6.13 h
229	2.76×10^{13}		β^-	66 m
230	$>1.82 \times 10^{15}$		β^-	<1 m

THORIUM 90

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
223	1.25×10^{17}	6.49×10^{16}	α	0.9 s*
224	1.07×10^{17}	5.54×10^{16}	α	1.05 s*
225	2.32×10^{14}		α (~90%); EC(~10%)	8.0 m
226	5.98×10^{13}	3.11×10^{13}	α, γ	30.9 m
227	7.03×10^{10}	3.66×10^{10}	α, γ	18.17 d
228	1.82×10^9	9.48×10^8	α, γ	1.910 y
229	4.72×10^5	2.46×10^5	α, γ	7340 y
230	4.32×10^4	2.24×10^4	α, γ	8.0×10^4 y
231	1.18×10^{12}		β^-, γ	25.52 h**
232	0.246	0.128	α, γ	1.39×10^{10} y
233	8.10×10^{13}		β^-, γ	22.12 m
234	5.14×10^{10}		β^-, γ ; no α ($<10^{-4}\%$)	24.10 d
235	-		$[\beta^-]$	$<<10$ m

* P. A. Tove, Arkiv Fysik, 13, 549-78 (1958).

** M. J. Cabell, Can. J. Phys., 36, 989-96 (1958).

PROTACTINIUM 91

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
225	5.57×10^{16}	2.90×10^{16}	α	2.0 s
226	1.03×10^{15}	5.34×10^{14}	α	1.8 m
227	4.80×10^{13}		α (~85%); EC(~15%)	38.3 m
228	1.39×10^{12}		EC(~98%), γ ; α (~2%), γ	22 h
229	8.44×10^{11}		EC(99+%), γ ; α (0.25%), γ	1.5 d
230	7.12×10^{10}		EC(~85%), γ ; β^- (~15%), γ ; β^+ (?~0.03%); α (~0.003%)	17.7 d
231	1.00×10^5	5.21×10^4	α, γ	3.43×10^4 y
232	9.54×10^{11}		β^-, γ ; no EC(<2%)	1.31 d
233	4.61×10^{10}		β^-, γ	27.0 d
234 ^m	1.52×10^{15}		$\beta^-(99+%), \gamma$; IT(0.63%); no α ($<10^{-4}\%$)	1.175 m
234	4.47×10^{12}		β^-, γ	6.66 h
235	7.50×10^{13}		β^-	23.7 m
237	1.60×10^{14}		β^-	11 m

URANIUM 92

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
227	1.41×10^{15}	7.34×10^{14}	α	1.3 m
228	1.97×10^{14}		α (~80%); EC (~20%)	9.3 m
229	3.14×10^{13}		EC (~80%); α (~20%)	58 m
230	6.06×10^{10}	3.15×10^{10}	α, γ	20.8 d
231	2.92×10^{11}		EC (99+%;); α (0.0055%), γ	4.3 d
232	4.62×10^7	2.40×10^7	α, γ ; SF $\sim 8 \times 10^{13}$ y	74 y
233	2.10×10^4	1.09×10^4	α, γ	1.626×10^5 y*
234	1.37×10^4	7.11×10^3	α, γ ; SF 2×10^{16} y	2.48×10^5 y
235m			IT, γ	26.5 m
235	4.76	2.47	α, γ ; SF 1.9×10^{17} y	7.1×10^8 y
236	1.41×10^2	7.32×10^1	α, γ ; SF 2×10^{16} y	2.39×10^7 y
237	1.81×10^{11}		β^-, γ	6.75 d
238	0.740	0.385	α, γ ; SF 8.0×10^{15} y	4.51×10^9 y
239	7.42×10^{13}		β^-, γ	23.54 m
240	2.06×10^{12}		$\beta^-,$ (no γ)	14.1 h

* Ya. P. Dokuchayev and I. S. Osipov, Atomnaya Energiya, 6, 73 (1959).

NEPTUNIUM 93

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
231	$\sim 3.62 \times 10^{13}$	$\sim 1.88 \times 10^{13}$	α	~ 50 m
232	$\sim 1.38 \times 10^{14}$		EC, γ	~ 13 m
233	5.12×10^{13}		EC (99+%;); α ($\sim 10^{-3}$ %)	35 m
234	2.82×10^{11}		EC (L/K ~ 1); no α (< 0.01 %); β^+ (~ 0.05 %), γ	4.40 d
235	3.01×10^9		EC (L/K = 36.7, M/L = 0.46); α (1.6×10^{-3} %), γ^*	410 d
236m**	-		Beta half-life $> 5 \times 10^3$ y	
236	1.34×10^{12}		EC (L/K ≤ 0.3 , 43%), γ ; β^- (57%), γ	22 h
237	1.52×10^3	7.92×10^2	α, γ	2.20×10^6 y
238	5.80×10^{11}		β^-, γ ; no EC (< 1 %)	2.10 d
239	5.17×10^{11}		β^-, γ	2.346 d
240m	2.38×10^{14}		β^-, γ	7.3 m
240	2.90×10^{13}		β^-, γ	60 m
241†	$\sim 8.25 \times 10^{12}$			~ 3.5 h

* J. E. Gindler, J. R. Huizenga, and D. W. Engelkemeir, Phys. Rev., 109, 1263-7 (1958).

** There is no experimental evidence as to which isomer (236m or 236) represents the lower energy state.

† R. M. Lessler and M. C. Michel, UCRL-8141, 74 (1957).

PLUTONIUM 94

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
232	5.00×10^{13}	6.14×10^8	EC($\leq 98\%$); $\alpha(\geq 2\%)$	36 m
233	8.96×10^{13}		EC($99^{+}\%$); $\alpha(0.1\%)$	20 m
234	3.30×10^{12}		EC(94% , L/K = 0.3); $\alpha(6\%)$	9.0 h
235	6.83×10^{13}		EC($99^{+}\%$); $\alpha(0.003\%)$	26 m
236	1.18×10^9		α , γ ; SF 3.5×10^9 y	2.85 y
237m	2.68×10^{10}		IT, γ	0.18 s
237			EC($99^{+}\%$, K/L = 1.33)*; $\alpha(0.0033\%)$	45.6 d
238	3.72×10^7	1.93×10^7	α , γ ; SF 3.8×10^{10} y	89.6 y**
239	1.36×10^5	7.08×10^4	α , γ ; SF 5.5×10^{15} y	2.441×10^4 y [†]
240	5.03×10^5	2.61×10^5	α , γ ; SF 1.22×10^{11} y	6.58×10^3 y
241	2.53×10^8	4.50×10^3	β^{-} ($99^{+}\%$); $\alpha(0.004\%)$, γ	13.0 y
242	8.66×10^3		α , γ ; SF 7.1×10^{10} y	3.79×10^5 y
243	5.75×10^{12}		β^{-} , γ	4.98 h
244	$\sim 4.28 \times 10^1$		α ; SF 2.5×10^{10} y	$\sim 7.6 \times 10^7$ y
245	2.81×10^{12}		β^{-}	10.1 h
246	1.08×10^{11}		β^{-} , γ	10.85 d

* D. C. Hoffman and B. J. Dropesky, Phys. Rev., 109, 1282-90 (1958).

** A. H. Jaffey and J. Lerner, ANL-4411, 9-10 (1950).

[†] T. L. Markin, J. Inorg. Nucl. Chem., 9, 320-2 (1959).

AMERICIUM 95

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
237	$\sim 2.26 \times 10^{13}$	3.74×10^6	EC($99^{+}\%$); $\alpha(0.005\%)$	~ 1.3 h
238	1.54×10^{13}		EC, γ ; no $\alpha(<0.0003\%)$	1.9 h
239	2.43×10^{12}		EC($99^{+}\%$), γ ; $\alpha(0.004\%), \gamma$	12 h
240	5.69×10^{11}		EC, γ ; no $\alpha(<0.2\%)$	51 h
241	7.19×10^6		α , γ	458 y
242m	1.80×10^{12}		$\beta^{-}(84\%), \gamma$; EC(16%), γ ;* no IT ($<6\%$)	16.01 h
242**	2.16×10^7	2.14×10^5	$\beta^{-}(83.6\%); \text{EC}(15.9\%);$ $\alpha(0.476\%)$	152 y
243	4.11×10^5		α , γ	7.95×10^3 y
244	6.58×10^{13}		$\beta^{-}(99^{+}\%); \text{EC}(0.039\%)$	26 m
245	1.43×10^{13}		β^{-} , γ	1.98 h
246	6.79×10^{13}		β^{-} , γ	25.0 m

* R. W. Hoff, E. K. Hulet, and M. C. Michel, J. Nucl. Energy, 8, 224-8 (1959).

** R. F. Barnes, D. J. Henderson, A. L. Harkness, and H. Diamond, J. Inorg. Nucl. Chem. 9, 105-7 (1959).

CURIUM 96

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
238	1.17×10^{13}	2.34×10^{10}	EC(<90%); α (>10%)	2.5 h
239	9.88×10^{12}		EC, γ ; no α (<0.1%)	2.9 h
240	4.51×10^{10}		α ; no EC(<0.5%); SF 7.9×10^5 y	26.8 d
241	3.44×10^{10}	3.83×10^9	EC(99+ %); α (0.96%), γ	35 d
242	7.37×10^9		α , γ ; SF 7.2×10^6 y	162.5 d
243	1.17×10^8		α , γ ; EC(0.26%)	28 y*,**
244	1.85×10^8	9.62×10^7	α , γ ; SF 1.4×10^7 y	17.59 y [†]
245	4.05×10^5	2.11×10^5	α , γ	8×10^3 y
246	4.89×10^5	2.54×10^5	α ; SF 2.0×10^7 y	6.6×10^3 y
247			alpha half-life $> 4 \times 10^7$ y	
248	6.81×10^3		α (89%); SF (11%) 4.6×10^6 y	4.7×10^5 y
249	2.62×10^{13}		β^-	64 m
250	-		SF $\sim 2 \times 10^4$ y	

* G. R. Choppin and S. G. Thompson, J. Inorg. Nucl. Chem., 7, 197-8 (1958).

** Value from above reference recalculated using better value for half-life of Cm²⁴⁴ (see reference below).

[†] W. T. Carnall and S. Fried, private communication (July, 1959).

BERKELIUM 97

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
243	6.36×10^{12}	$\sim 1.67 \times 10^5$	EC(99+ %), γ ; α (0.15%), γ	4.5 h
244	6.48×10^{12}		EC(99+ %), γ ; α (0.006%)	4.4 h
245	2.38×10^{11}		EC(99+ %), γ ; α (0.11%), γ	4.98 d
246	6.55×10^{11}		EC, γ	1.8 d
247	$\sim 3.21 \times 10^5$		α , γ ; no EC	$\sim 10^4$ y
248	1.75×10^{12}		β^- (70%); EC(30%, (L + M)/K ~ 1)	16 h
249	3.71×10^9		β^- (99+ %); α (2.2×10^{-3} %), γ ; SF 6×10^8 y	314 d
250	8.64×10^{12}		β^- , γ	193.3 m*

* S. E. Vandenbosch, H. Diamond, R. K. Sjolom, and P. R. Fields, Phys. Rev., to be published (1959); see Phys. Rev. Lett., 3, 120 (1959).

CALIFORNIUM 98

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
244	6.85×10^{13}	3.56×10^{13}	α	25 m
245	3.87×10^{13}		EC(70%); α (30%)	44 m
246	7.93×10^{11}	4.12×10^{11}	α, γ ; SF 2.1×10^3 y	35.7 h
247	1.13×10^{13}		EC, γ	2.5 h
248	4.68×10^9	2.43×10^9	α ; SF $\geq 1.5 \times 10^6$ y	250 d
249	8.86×10^6	4.61×10^6	α, γ ; SF $\geq 1.5 \times 10^9$ y	360 y
250	2.91×10^8	1.52×10^8	α, γ ; SF $\sim 1.5 \times 10^4$ y	10.9 y
251	$\sim 3.95 \times 10^6$	$\sim 2.06 \times 10^6$	α, γ	~ 800 y
252	1.24×10^9		α (97%), γ ; SF (3%) 82 y	2.55 y*
253	6.74×10^{10}		β^-, γ	17 d
254	2.03×10^{10}		SF	56.2 d**

* T. A. Eastwood, et al., Phys. Rev., 107, 1635-8 (1957).

** J. R. Huizenga and H. Diamond, Phys. Rev., 107, 1087-90 (1957).

EINSTEINIUM 99

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
246	2.33×10^{14}		α ; EC(?)	7.3 m
248	6.74×10^{13}		EC(99 ⁺ %); α ($\sim 0.3\%$)	25 m
249	1.40×10^{13}		EC(99 ⁺ %); α (0.13%)	2 h
250	3.48×10^{12}		EC	8 h
251	7.70×10^{11}		EC(99 ⁺ %); α (0.53%)	1.5 d
252	$\sim 8.22 \times 10^9$	$\sim 4.27 \times 10^9$	α ; no β ($< 3\%$); no EC	~ 140 d
253	5.72×10^{10}	2.98×10^{10}	α, γ ; SF $\sim 7 \times 10^5$ y	20.03 d
254	2.38×10^9	1.24×10^9	α ; no β ($< 1\%$)	480 d
254m	7.41×10^{11}		$\beta^-(99^+\%), \gamma$; EC($\sim 0.1\%$); SF > 10 y	37 h
255	4.74×10^{10}		β^-	24 d
256	-		β^-	short

FERMIUM 100

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
248*	2.81×10^{15}	1.46×10^{15}	α	0.6 m
250	5.57×10^{13}		α ; EC	30 m
251	3.96×10^{12}		EC($\sim 99\%$); α ($\sim 1\%$)	7 h
252	1.22×10^{12}	6.33×10^{11}	α ; SF > 8 y	22.7 h
253	$\sim 2.55 \times 10^{11}$		EC(89%); α (11%)	~ 4.5 d
254	8.46×10^{12}	4.40×10^{12}	α , γ ; SF 246 d	3.24 h
255	1.27×10^{12}	6.60×10^{11}	α ; SF > 60 y	21.5 h
256	1.02×10^{13}		SF	160 m**

* A. Ghiorso, et al., Phys. Rev. Lett., 1, 18-21 (1958).

** L. Phillips, et al., Phys. Rev. Lett., 1, 215-7 (1958).

MENDELEVIUM 101

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
255*	$\sim 5.46 \times 10^{13}$		EC	$\sim \frac{1}{2}$ h
256*	$\sim 1.81 \times 10^{13}$		EC	~ 1.5 h

* L. Phillips, et al., Phys. Rev. Lett., 1, 215-7 (1958).

NOBELIUM 102

Mass Number	Specific Activity		Modes of Decay Branching Ratios, etc.	Half-life
	d/min/ μ g	cpm/ μ g		
251 } 253 }	-	-	α	~ 10 m*
254	3.29×10^{16}	1.71×10^{16}	α	3 s

*P. R. Fields, et al., Phys. Rev., 107, 1460-2 (1957).