$$^{228}_{90}\mathrm{Th}_{138}$$

1 Decay Scheme

Th-228 decays 100% by alpha-particle emission to various excited levels and the ground state of Ra-224.
Le thorium 228 se désintègre par émission alpha principalement vers le niveau fondamental et le niveau excité de 84,4 keV de radium 224.

2 Nuclear Data

$T_{1/2}(^{228}\mathrm{Th})$	:	698,60	(23)	d
$T_{1/2}(^{224}\mathrm{Ra})$	:	3,627	(7)	d
$Q^{\alpha}(^{228}\mathrm{Th})$	:	5520,12	(22)	keV

2.1 α Transitions

	Energy keV	Probability × 100	F
$\alpha_{0,8}$	4527,5 (3)	0,0000044 (12)	7,37
$\alpha_{0,7}$	4603,8 (3)	0,000017 (3)	6,96
$\alpha_{0,6}$	5040,9 (4)	0,000025 (5)	4370
$\alpha_{0,5}$	5087,1 (3)	0,000010 (3)	21300
$\alpha_{0,4}$	5229,76 (26)	0,036 (7)	44,1
$\alpha_{0,3}$	5269,34 (23)	0,20 (2)	13,6
$\alpha_{0,2}$	5304,14 (22)	0,38 (3)	11,5
$\alpha_{0,1}$	5435,75 (22)	26,2 (2)	0,948
$\alpha_{0,0}$	5520,12 (22)	73,2 (2)	1

2.2 Gamma Transitions and Internal Conversion Coefficients

	Energy keV	$P_{\gamma+ce}$ × 100	Multipolarity	α_K	α_L	α_M+	α_T
$\gamma_{4,2}$(Ra)	74,4 (1)	0,016 (6)	[E2]		28,9 (8)	7,89 (16)	39,5 (8)
$\gamma_{1,0}$(Ra)	84,373 (3)	26,6 (14)	E2		15,9 (3)	5,8 (1)	21,7 (4)
$\gamma_{2,1}$(Ra)	131,612 (4)	0,155 (8)	E1	0,195 (4)	0,041 (1)	0,013 (1)	0,249 (6)
$\gamma_{5,4}$(Ra)	142,7 (1)	0,0000041 (13)	[E2]	0,280 (6)	1,396 (28)	0,50 (1)	2,18 (4)
$\gamma_{3,1}$(Ra)	166,410 (4)	0,205 (16)	E2	0,225 (5)	0,704 (14)	0,256 (5)	1,185 (24)
$\gamma_{5,3}$(Ra)	182,3 (1)	0,0000056 (20)	[E1]	0,090 (2)	0,0178 (3)	0,0060 (1)	0,114 (2)
$\gamma_{4,1}$(Ra)	205,99 (4)	0,0201 (11)	[E1]	0,0676 (14)	0,0131 (3)	0,0042 (1)	0,0849 (17)
$\gamma_{2,0}$(Ra)	215,985 (4)	0,243 (22)	E1	0,0605 (12)	0,01160 (25)	0,0038 (1)	0,0759 (15)
$\gamma_{6,3}$(Ra)	228,4 (2)	0,000025 (5)	[E2]	0,125 (2)	0,182 (4)	0,065 (1)	0,372 (7)
$\gamma_{7,2}$(Ra)	700,4 (1)	0,0000029 (9)	E1	0,00508 (10)	0,00084 (2)	0,000270 (5)	0,00619 (12)
$\gamma_{8,3}$(Ra)	741,87 (1)	0,0000014 (4)	[E2]	0,0121 (2)	0,00330 (6)	0,00110 (2)	0,0165 (3)
$\gamma_{7,1}$(Ra)	832,0 (1)	0,000014 (2)	E2+M3	0,0098 (2)	0,00240 (5)	0,00090 (2)	0,0131 (3)
$\gamma_{8,1}$(Ra)	908,28 (1)	0,0000016 (5)	[M1+50%E2]	0,0203 (20)	0,0038 (4)	0,0012 (1)	0,0253 (25)
$\gamma_{8,0}$(Ra)	992,65 (6)	0,0000014 (4)	[E2]	0,00720 (15)	0,00160 (3)	0,00050 (1)	0,0093 (2)

3 Atomic Data

3.1 Ra

ω_K	:	0,968	(4)
$\bar{\omega}_L$	:	0,452	(18)
n_{KL}	:	0,801	(5)

3.1.1 X Radiations

		Energy keV		Relative probability
X_K				
	$K\alpha_2$	85,43		61,22
	$K\alpha_1$	88,47		100
	$K\beta_3$	99,432	}	
	$K\beta_1$	100,13	}	
	$K\beta_5''$	100,738	}	34,9
	$K\beta_2$	102,89	}	
	$K\beta_4$	103,295	}	11,51
	$KO_{2,3}$	103,74	}	
X_L				
	$L\ell$	10,622		
	$L\alpha$	12,196 – 12,339		
	$L\eta$	13,662		
	$L\beta$	14,236 – 15,447		
	$L\gamma$	17,848 – 18,412		

3.1.2 Auger Electrons

	Energy keV	Relative probability
Auger K		
KLL	65,15 – 72,73	100
KLX	79,72 – 88,47	58
KXY	94,27 – 103,91	8,4
Auger L	5,71 – 12,04	9050

4 α Emissions

	Energy keV	Probability × 100
$\alpha_{0,8}$	4448,0 (3)	0,0000044 (12)
$\alpha_{0,7}$	4523,0 (3)	0,000017 (3)
$\alpha_{0,6}$	4952,5 (4)	0,000025 (5)
$\alpha_{0,5}$	4997,8 (3)	0,000010 (3)
$\alpha_{0,4}$	5138,01 (26)	0,036 (7)
$\alpha_{0,3}$	5176,89 (23)	0,20 (2)
$\alpha_{0,2}$	5211,08 (22)	0,38 (3)
$\alpha_{0,1}$	5340,38 (22)	26,2 (2)
$\alpha_{0,0}$	5423,28 (22)	73,2 (2)

5 Electron Emissions

		Energy keV		Electrons per 100 disint.
e_{AL}	(Ra)	5,71 - 12,04		10,5 (4)
e_{AK}	(Ra)			0,00193 (26)
	KLL	65,15 - 72,73	}	
	KLX	79,72 - 88,47	}	
	KXY	94,27 - 103,91	}	
$ec_{1,0\ T}$	(Ra)	65,14 - 84,09		25,4 (8)
$ec_{1,0\ L}$	(Ra)	65,14 - 68,93		18,6 (6)
$ec_{1,0\ M}$	(Ra)	79,55 - 84,09		6,8 (2)
$ec_{2,0\ K}$	(Ra)	112,067 (5)		0,180 (6)
$ec_{3,1\ L}$	(Ra)	147,17 - 150,97		0,066 (2)

6 Photon Emissions

6.1 X-Ray Emissions

		Energy keV		Photons per 100 disint.	
XL	(Ra)	10,622 — 18,412		8,8 (4)	
$XK\alpha_2$	(Ra)	85,43		0,0172 (8)	} $K\alpha$
$XK\alpha_1$	(Ra)	88,47		0,0281 (12)	}
$XK\beta_3$	(Ra)	99,432	}		
$XK\beta_1$	(Ra)	100,13	}	0,0098 (5)	$K'\beta_1$
$XK\beta_5''$	(Ra)	100,738	}		
$XK\beta_2$	(Ra)	102,89	}		
$XK\beta_4$	(Ra)	103,295	}	0,00323 (16)	$K'\beta_2$
$XKO_{2,3}$	(Ra)	103,74	}		

6.2 Gamma Emissions

	Energy keV	Photons per 100 disint.
$\gamma_{4,2}$(Ra)	74,4 (1)	0,00039 (14)
$\gamma_{1,0}$(Ra)	84,373 (3)	1,17 (5)
$\gamma_{2,1}$(Ra)	131,612 (4)	0,124 (6)
$\gamma_{5,4}$(Ra)	142,7 (1)	0,0000013 (4)
$\gamma_{3,1}$(Ra)	166,410 (4)	0,094 (7)
$\gamma_{5,3}$(Ra)	182,3 (1)	0,0000050 (18)
$\gamma_{4,1}$(Ra)	205,99 (4)	0,0185 (10)
$\gamma_{2,0}$(Ra)	215,985 (4)	0,226 (20)
$\gamma_{6,3}$(Ra)	228,4 (2)	0,000018 (4)
$\gamma_{7,2}$(Ra)	700,4 (1)	0,0000029 (9)
$\gamma_{8,3}$(Ra)	741,87 (1)	0,0000014 (4)
$\gamma_{7,1}$(Ra)	832,0 (1)	0,000014 (2)
$\gamma_{8,1}$(Ra)	908,28 (1)	0,0000016 (5)
$\gamma_{8,0}$(Ra)	992,65 (6)	0,0000014 (4)

7 Main Production Modes

Th – 230(p,t)Th – 228

Th – 230(α,α2nγ)Th – 228

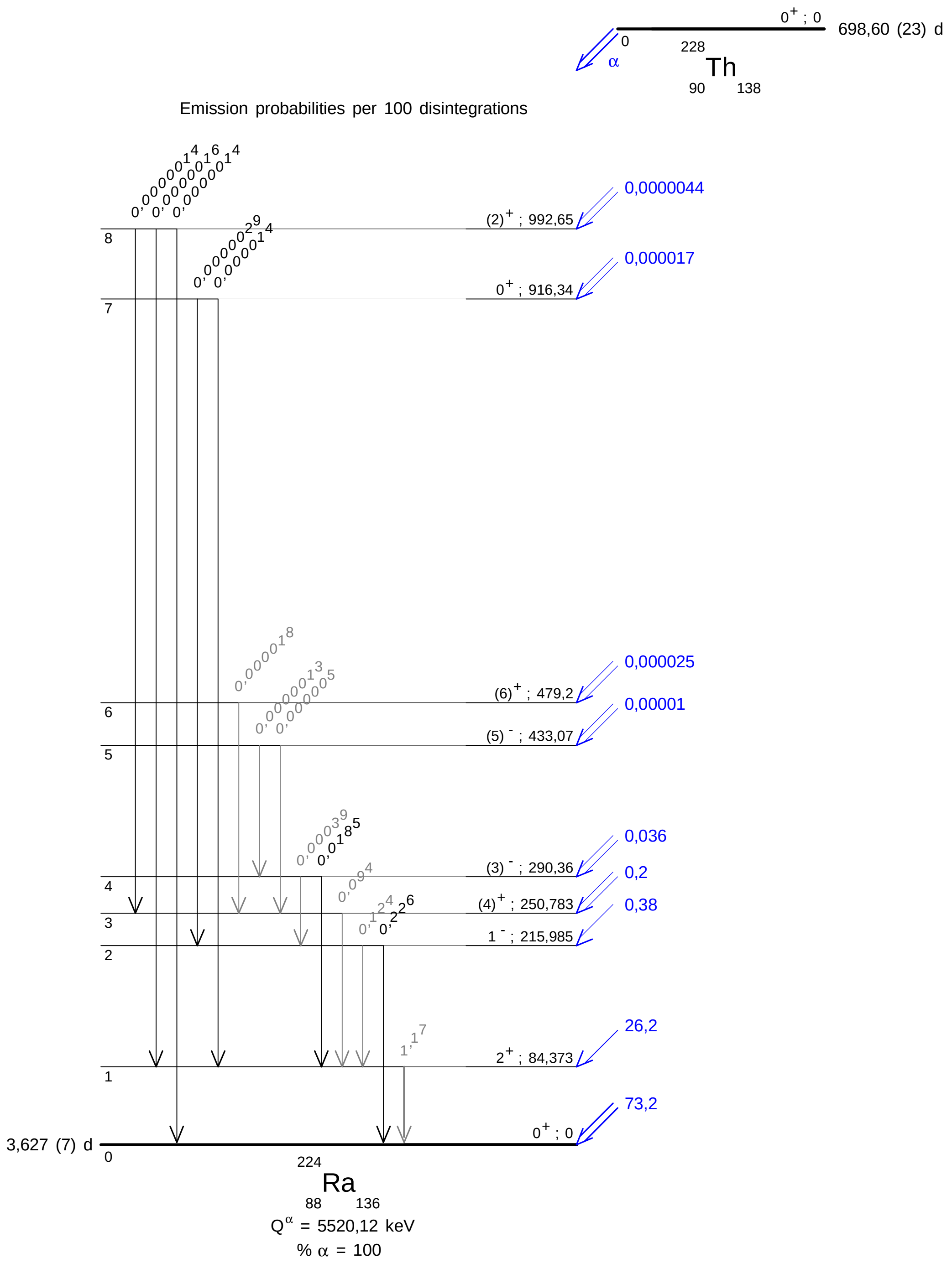
Ra – 226(α,2nγ)Th – 228

U – 232 alpha decay

8 References

- F. ASARO, F. STEPHENS, I. PERLMAN. Phys. Rev. 92 (1953) 1495
(Alpha-particle emission probabilities, gamma-ray emission probabilities, internal conversion coefficients)
- H.W. KIRBY, G.R. GROVE, D.L. TIMMA. Phys. Rev. 102 (1956) 1140
(Half-life)
- M.O. COSTA, M.R.S. GRADE. Port. Phys. 4 (1966) 267
(Conversion electrons, internal conversion coefficients)
- C.L. DUKE, W.L. TALBERT. Phys. Rev. 173 (1968) 1125
(Internal conversion coefficients)
- A. PEGHAIRE. Nucl. Instrum. Methods 75 (1969) 66
(Gamma-ray emission probabilities)
- S.A. BARANOV, V.M. SHATINSKII, V.M. KULAKOV, Y.F. RODIONOV. Sov. J. Nucl. Phys. 11 (1970) 515
(Gamma-ray emission probabilities)
- K.C. JORDAN, G.W. OTTO, R.P. RATAY. J. Inorg. Nucl. Chem. 33 (1971) 1215
(Half-life)
- J. DALMASSO. Report FRNC-TH-441 (1972)
(Gamma-ray energies)
- R.L. HEATH. Report ANCR-1000-2 (1974)
(Gamma-ray energies)
- S.A. BARANOV, A.G. ZELENKOV, V.M. KULAKOV. IAEA-186 III (1976) 249
(Alpha-particle emission probabilities)
- W. KURCEWICZ, N. KAFFRELL, N. TRAUTMANN, A. PLOCHOCKI, J. ZYLICZ, M. MATUL, K. STRYCZNIEWICZ. Nucl. Phys. A289 (1977) 1
(Gamma-ray energies Gamma-ray emission probabilities)
- W. KURCEWICZ, E. RUCHOWSKA, N. KAFFRELL, N. TRAUTMANN. Nucl. Instrum. Methods 146 (1977) 613
(Gamma-ray energies)
- F. Rösel, H.M. FRIES, K. ALDER, H.C. PAULI. At. Data Nucl. Data Tables 21 (1978) 291
(Internal conversion coefficients)
- A. RYTZ. At. Data Nucl. Data Tables 23 (1979) 507
(Alpha emission energies)
- W. KURCEWICZ, E. RUCHOWSKA, N. KAFFRELL, T. BJOERNSTAD, G. NYMAN. Nucl. Phys. A356 (1981) 15
(908.28 keV gamma-ray emission probabilities)
- S. SADASIVAN, V.M. RAGHUNATH. Nucl. Instrum. Methods 196 (1982) 561
(Gamma-ray emission probabilities)
- R.J. GEHRKE, V.J. NOVICK, J.D. BAKER. Int. J. Appl. Radiat. Isotop. 35 (1984) 581
(Gamma-ray emission probabilities)
- M.P. UNTERWEGER, D.D. HOPPES, F.J. SCHIMA. Nucl. Instrum. Methods A312 (1992) 349
(Half-life)
- T. BABELIOWSKY, G. BORTELS. Appl. Rad. Isotopes 44 (1993) 1349
(Alpha-particle emission probabilities)
- G. AUDI, A.H. WAPSTRA. Nucl. Phys. A595 (1995) 409
(Q value)
- G. ARDISSON, M. HUSSONNOIS. Radiochim. Acta 70/71 (1995) 123
(Cluster decay)
- E. SCHÖNFELD, H. Janssen. Nucl. Instrum. Methods A369 (1996) 527
(K-x ray, L-x ray, Auger electrons)
- A. ARTNA-COHEN. Nucl. Data Sheets 80 (1997) 227
(Nuclear structure, energies)

- S.P. TRETYAKOVA, V.L. MIKHEEV. Nuovo Cim. 110 (1997) 1043
  (Cluster decay)
- E. SCHÖNFELD, G. RODLOFF. Report PTB-6.11-98-1 (1998)
  (Auger electrons)
- E. SCHÖNFELD, G. RODLOFF. Report PTB-6.11-1999-1 (1999)
  (X-ray emission probabilities)


0+ ; 0
698,60 (23) d
228 Th 90 138
α
Emission probabilities per 100 disintegrations
0,0000044
(2)+ ; 992,65
0,000017
0+ ; 916,34
0,000025
(6)+ ; 479,2
0,00001
(5) - ; 433,07
0,036
(3) - ; 290,36
0,2
(4)+ ; 250,783
0,38
1 - ; 215,985
26,2
2+ ; 84,373
73,2
0+ ; 0
3,627 (7) d
224 Ra 88 136
Qα = 5520,12 keV
% α = 100