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

1 Decay Scheme

Th-228 decays 100 % by alpha-particle emission to various excited levels and the ground state of Ra-224, and by a small O-20 cluster-decay branch of 1.13 (22) 10^{-11} %.
Le thorium 228 se désintègre par émission alpha principalement vers le niveau fondamental et le niveau excité de 84,4 keV du radium 224.

2 Nuclear Data

$T_{1/2}(^{228}\mathrm{Th})$	:	698,55	(32)	d
$T_{1/2}(^{224}\mathrm{Ra})$	:	3,631	(2)	d
$Q^{\alpha}(^{228}\mathrm{Th})$	:	5520,08	(22)	keV

2.1 α Transitions

	Energy keV	Probability × 100	F
$\alpha_{0,8}$	4527,43 (23)	0,0000045 (7)	7,2
$\alpha_{0,7}$	4603,74 (23)	0,000017 (3)	7
$\alpha_{0,6}$	5040,9 (3)	0,000024 (5)	4600
$\alpha_{0,5}$	5087,01 (24)	0,000010 (2)	21400
$\alpha_{0,4}$	5229,72 (22)	0,036 (6)	44
$\alpha_{0,3}$	5269,30 (22)	0,218 (4)	12,5
$\alpha_{0,2}$	5304,10 (22)	0,408 (7)	10,7
$\alpha_{0,1}$	5435,71 (22)	26,0 (5)	0,958
$\alpha_{0,0}$	5520,08 (22)	73,4 (5)	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)	74,38 (4)	0,015 (5)	[E2]		28,3 (4)	7,71 (11)	38,6 (6)
$\gamma_{1,0}$(Ra)	84,373 (3)	26,4 (7)	E2		15,57 (22)	4,24 (6)	21,2 (3)
$\gamma_{2,1}$(Ra)	131,612 (5)	0,158 (3)	E1	0,194 (3)	0,0406 (6)	0,00977 (14)	0,247 (4)
$\gamma_{5,4}$(Ra)	142,71 (11)	0,0000041 (13)	[E2]	0,279 (4)	1,368 (20)	0,372 (6)	2,14 (3)
$\gamma_{3,1}$(Ra)	166,410 (4)	0,217 (4)	E2	0,225 (4)	0,691 (10)	0,187 (3)	1,164 (17)
$\gamma_{5,3}$(Ra)	182,29 (10)	0,0000057 (20)	[E1]	0,0894 (13)	0,01757 (25)	0,00421 (6)	0,1126 (16)
$\gamma_{4,1}$(Ra)	205,99 (4)	0,0204 (5)	[E1]	0,0671 (10)	0,01292 (18)	0,00309 (5)	0,0841 (12)
$\gamma_{2,0}$(Ra)	215,985 (4)	0,265 (4)	E1	0,0600 (9)	0,01148 (16)	0,00274 (4)	0,0752 (11)
$\gamma_{6,3}$(Ra)	228,42 (18)	0,000025 (6)	[E2]	0,1244 (18)	0,178 (3)	0,0479 (7)	0,366 (6)
$\gamma_{7,2}$(Ra)	700,36 (7)	0,000003 (1)	E1	0,00502 (7)	0,000834 (12)	0,000196 (3)	0,00611 (9)
$\gamma_{8,3}$(Ra)	741,87 (6)	0,0000014 (4)	[E2]	0,01196 (17)	0,00322 (5)	0,000803 (12)	0,01625 (23)
$\gamma_{7,1}$(Ra)	831,97 (10)	0,000014 (2)	E2	0,00970 (14)	0,00240 (4)	0,000594 (9)	0,01289 (18)
$\gamma_{8,1}$(Ra)	908,28 (6)	0,0000017 (5)	[M1+50%E2]	0,0190 (24)	0,0036 (4)	0,00087 (9)	0,024 (3)
$\gamma_{8,0}$(Ra)	992,65 (6)	0,0000014 (4)	[E2]	0,00705 (10)	0,001569 (22)	0,000384 (6)	0,00913 (13)

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
	$K\alpha_1$	88,47		100
	$K\beta_3$	99,432	}	
	$K\beta_1$	100,13	}	
	$K\beta_5''$	100,738	}	35,1
	$K\beta_2$	102,89	}	
	$K\beta_4$	103,295	}	11,5
	$KO_{2,3}$	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	65,149 – 72,729	100
KLX	79,721 – 88,466	57
KXY	94,27 – 103,91	8,4
Auger L	5,71 – 12,04	852500

4 α Emissions

	Energy keV	Probability × 100
$\alpha_{0,8}$	4448,00 (23)	0,0000045 (7)
$\alpha_{0,7}$	4522,97 (23)	0,000017 (3)
$\alpha_{0,6}$	4952,5 (3)	0,000024 (5)
$\alpha_{0,5}$	4997,76 (24)	0,000010 (2)
$\alpha_{0,4}$	5137,97 (22)	0,036 (6)
$\alpha_{0,3}$	5176,86 (22)	0,218 (4)
$\alpha_{0,2}$	5211,05 (22)	0,408 (7)
$\alpha_{0,1}$	5340,35 (22)	26,0 (5)
$\alpha_{0,0}$	5423,24 (22)	73,4 (5)

5 Electron Emissions

		Energy keV	Electrons per 100 disint.
e_{AL}	(Ra)	5,71 - 12,04	10,4 (4)
e_{AK}	(Ra)		0,0020 (3)
	KLL	65,149 - 72,729 }	
	KLX	79,721 - 88,466 }	
	KXY	94,27 - 103,91 }	
$ec_{3,1\ K}$	(Ra)	62,497 (4)	0,023 (1)
$ec_{1,0\ T}$	(Ra)	65,14 - 84,36	25,2 (7)
$ec_{1,0\ L}$	(Ra)	65,14 - 68,93	18,5 (5)
$ec_{1,0\ M}$	(Ra)	79,55 - 81,27	5,0 (2)
$ec_{1,0\ N+}$	(Ra)	83,17 - 84,36	1,65 (5)

		Energy keV	Electrons per 100 disint.
$ec_{2,0\ K}$	(Ra)	112,072 (4)	0,015 (6)
$ec_{3,1\ L}$	(Ra)	147,17 - 150,97	0,069 (2)
$ec_{3,1\ M}$	(Ra)	161,59 - 166,40	0,025 (1)

6 Photon Emissions

6.1 X-Ray Emissions

		Energy keV		Photons per 100 disint.	
XL	(Ra)	10,622 — 18,412		8,6 (4)	
$XK\alpha_2$	(Ra)	85,43		0,0180 (3)	} Kα
$XK\alpha_1$	(Ra)	88,47		0,0295 (5)	}
$XK\beta_3$	(Ra)	99,432	}		
$XK\beta_1$	(Ra)	100,13	}	0,01034 (21)	$K'\beta_1$
$XK\beta_5''$	(Ra)	100,738	}		
$XK\beta_2$	(Ra)	102,89	}		
$XK\beta_4$	(Ra)	103,295	}	0,00339 (9)	$K'\beta_2$
$XKO_{2,3}$	(Ra)	103,74	}		

6.2 Gamma Emissions

	Energy keV	Photons per 100 disint.
$\gamma_{4,2}$(Ra)	74,38 (4)	0,00039 (14)
$\gamma_{1,0}$(Ra)	84,373 (3)	1,19 (3)
$\gamma_{2,1}$(Ra)	131,612 (5)	0,127 (2)
$\gamma_{5,4}$(Ra)	142,71 (11)	0,0000013 (4)
$\gamma_{3,1}$(Ra)	166,410 (4)	0,1004 (14)
$\gamma_{5,3}$(Ra)	182,29 (10)	0,0000051 (18)
$\gamma_{4,1}$(Ra)	205,99 (4)	0,0188 (5)
$\gamma_{2,0}$(Ra)	215,985 (4)	0,246 (4)
$\gamma_{6,3}$(Ra)	228,42 (18)	0,000018 (4)
$\gamma_{7,2}$(Ra)	700,36 (7)	0,000003 (1)
$\gamma_{8,3}$(Ra)	741,87 (6)	0,0000014 (4)

	Energy keV	Photons per 100 disint.
$\gamma_{7,1}$(Ra)	831,97 (7)	0,000014 (2)
$\gamma_{8,1}$(Ra)	908,28 (6)	0,0000017 (5)
$\gamma_{8,0}$(Ra)	992,65 (6)	0,0000014 (4)

7 Main Production Modes

$\mathrm{Th-230(p,t)Th-228}$

$\mathrm{Th-230}(\alpha,\alpha 2\mathrm{n}\gamma)\mathrm{Th-228}$

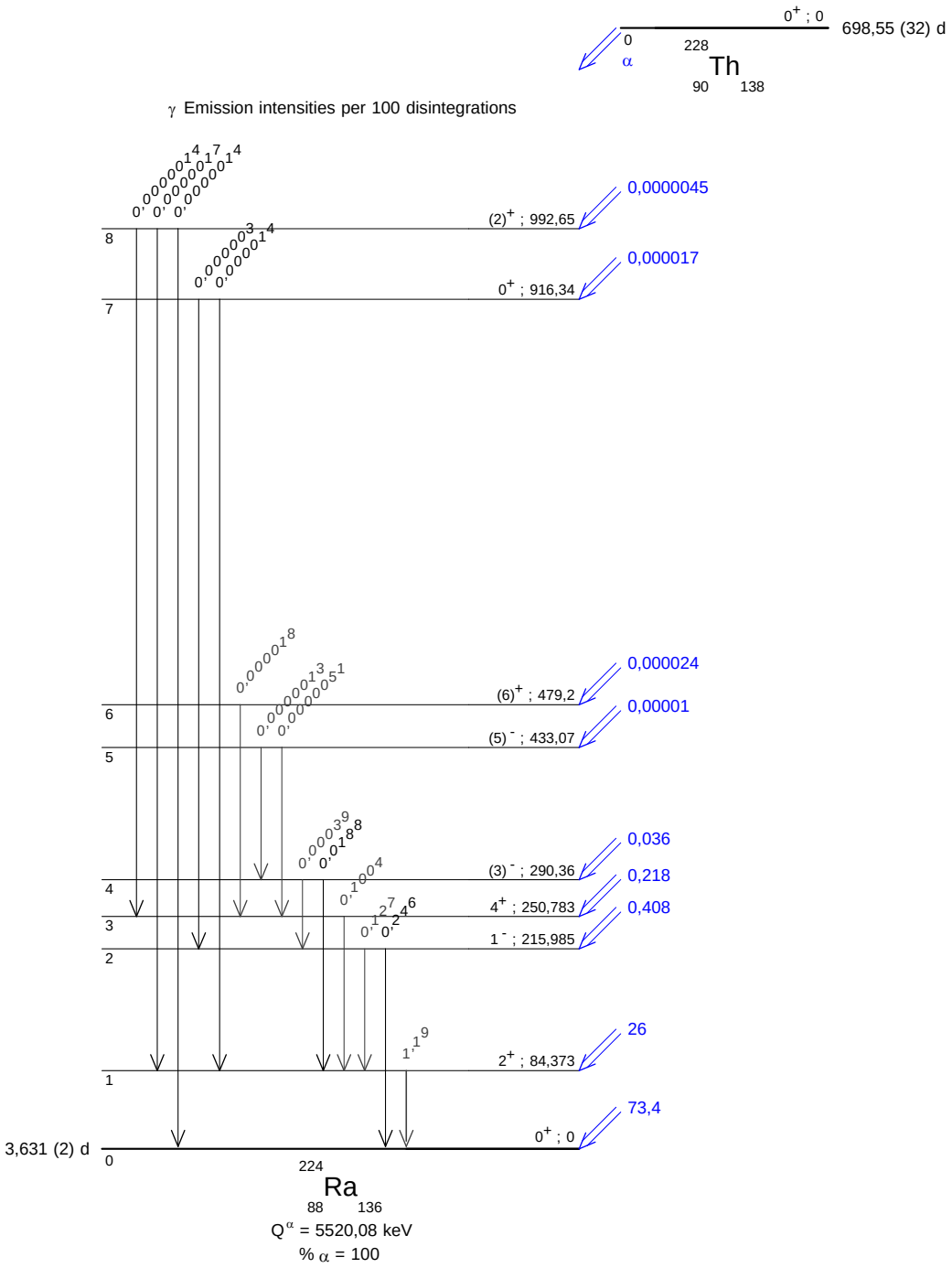
$\mathrm{Ra-226}(\alpha,2\mathrm{n}\gamma)\mathrm{Th-228}$

$\mathrm{U-232}(\alpha)$

8 References

- L. MEITNER. Phys. Zeitschr. 19 (1918) 257
  (Half-life)
- F. ASARO, F. STEPHENS JR., I. PERLMAN. Phys. Rev. 92 (1953) 1495
  (Alpha-particle energies, 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)
- C.W. MAYS, D.R. ATHERTON, R.D. LLOYD, D.O. CLARK. COO-225 (1962) 90
  (Half-life)
- M.O. COSTA, M.R.S. GRADE. Port. Phys. 4 (1966) 267
  (Conversion-electron emission probabilities, internal conversion coefficients)
- J. DALMASSO, C. MARSOL. C.R. Acad. Sci. (Paris) 267B (1968) 1366
  (Gamma-ray energies)
- C.L. DUKE, W.L. TALBERT JR. Phys. Rev. 173 (1968) 1125
  (Internal conversion coefficients)
- A. PEGHAIRE. Nucl. Instrum. Methods 75 (1969) 66
  (Alpha-particle emission probabilities, gamma-ray emission probabilities, internal conversion coefficients)
- S.A. BARANOV, V.M. SHATINSKII, V.M. KULAKOV, Y.F. RODIONOV. Sov. J. Nucl. Phys. 11 (1970) 515
  (Alpha-particle energies, alpha-particle emission probabilities)
- D.L. SPENNY, A.A. BARTLETT. COO-535-620 (1970) 102
  (L- and M-subshell ratios)
- K.C. JORDAN, G.W. OTTO, R.P. RATAY. J. Inorg. Nucl. Chem. 33 (1971) 1215
  (Half-life)
- B. GRENNBERG, A. RYTZ. Metrologia 7 (1971) 65
  (Alpha-particle energies)
- S.A. BARANOV, A.G. ZELENKOV, V.M. KULAKOV. IAEA-186 III (1976) 249
  (Alpha-particle energies, alpha-particle emission probabilities)
- F.P. LARKINS. At. Data Nucl. Data Tables 20 (1977) 311
  (Auger-electron energies)

- 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)
- W. KURCEWICZ, E. RUCHOWSKA, N. KAFFRELL, T. BJOERNSTAD, G. NYMAN. Nucl. Phys. A356 (1981) 15
  (908.28-keV gamma-ray emission probability)
- 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. Isot. 35 (1984) 581
  (Gamma-ray emission probabilities)
- A. RTYZ. At. Data Nucl. Data Tables 47 (1991) 205
  (Alpha-particle energies, alpha-particle emission probabilities)
- M.P. UNTERWEGER, D.D. HOPPES, F.J. SCHIMA. Nucl. Instrum. Methods Phys. Res. A312 (1992) 349
  (Half-life)
- R. BONETTI, C. CHIESA, A. GUGLIELMETTI, C. MIGLIORINO, A. CESANA, M. TERRANI. Nucl. Phys. A556 (1993) 115
  (Cluster decay)
- T. BABELIOWSKY, G. BORTELS. Appl. Radiat. Isot. 44 (1993) 1349
  (Alpha-particle emission probabilities)
- G. ARDISSON, M. HUSSONNOIS. Radiochim. Acta 70/71 (1995) 123
  (Cluster decay)
- E. SCHÖNFELD, H. JANSSEN. Nucl. Instrum. Methods Phys. Res. 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. 110A (1997) 1043
  (Cluster decay)
- Y.A. AKOVALI. Nucl. Data Sheets 84 (1998) 1
  (Alpha decay, r0 parameter)
- 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)
- M.P. UNTERWEGER. Appl. Radiat. Isot. 56 (2002) 125
  (Half-life)
- I.M. BAND, M.B. TRZHASKOVSKAYA, C.W. NESTOR JR., P.O. TIKKANEN, S. RAMAN. At. Data Nucl. Data Tables 81 (2002) 1
  (Theoretical ICC)
- S. RAMAN, C.W.NESTOR JR., A. ICHIHARA, M.B. TRZHASKOVSKAYA. Phys. Rev. C66 (2002) 044312
  (Theoretical ICC)
- G. AUDI, A.H. WAPSTRA, C. THIBAULT. Nucl. Phys. A729 (2003) 337
  (Q value)
- M.-M.BÉ, V.P. CHECHEV, R. DERSCH, O.A.M. HELENE, R.G. HELMER, M. HERMAN, S. HLAVÁC, A. MARCINKOWSKI, G.L. MOLNÁR, A.L. NICHOLS, E. SCHÖNFELD, V.R. VANIN, M.J. WOODS. IAEA Scientific and Technical Report STI/PUB/1287 (2007)
  (Half-life)
- T. KIBEDI, T.W. BURROWS, M.B. TRZHASKOVSKAYA, P.M. DAVIDSON, C.W. NESTOR JR. Nucl. Instrum. Methods Phys. Res. A589 (2008) 202
  (Theoretical ICC)


0+ ; 0
698,55 (32) d
0
α
228
Th
90
138
γ Emission intensities per 100 disintegrations
0,0000045
(2)+ ; 992,65
0,000017
0+ ; 916,34
0,000024
(6)+ ; 479,2
0,00001
(5)- ; 433,07
0,036
(3)- ; 290,36
0,218
4+ ; 250,783
0,408
1- ; 215,985
26
2+ ; 84,373
73,4
0+ ; 0
3,631 (2) d
224
Ra
88
136
Q α = 5520,08 keV
% α = 100