$^{231}_{91}\mathrm{Pa}_{140}$

1 Decay Scheme

Pa-231 is a member of the natural U-235 decay chain. Pa-231 disintegrates by alpha emission to various excited levels and the ground state of Ac-227.
Le protactinium 231 se désintègre par émissions alpha vers des niveaux excités et le niveau fondamental de l'actinium 227.

2 Nuclear Data

$T_{1/2}(^{231}\mathrm{Pa})$	:	32670	(260)	a
$T_{1/2}(^{227}\mathrm{Ac})$	:	21,772	(3)	a
$Q^{\alpha}(^{231}\mathrm{Pa})$	:	5149,9	(8)	keV

2.1 α Transitions

	Energy keV	Probability × 100	F
$\alpha_{0,25}$	4493,5 (9)	0,0021 (5)	43
$\alpha_{0,24}$	4587,1 (8)	0,0036 (3)	126
$\alpha_{0,23}$	4612,9 (8)	0,00076 (20)	930
$\alpha_{0,22}$	4648,6 (9)	0,008 (4)	160
$\alpha_{0,21}$	4680,6 (8)	0,015 (7)	146
$\alpha_{0,20}$	4711,9 (8)	0,078 (21)	47
$\alpha_{0,19}$	4714,7 (8)	0,0504 (11)	75,8
$\alpha_{0,18}$	4724,3 (8)	0,080 (6)	56
$\alpha_{0,17}$	4762,6 (8)	1,8 (3)	4,6
$\alpha_{0,16}$	4795,4 (8)	1,20 (22)	11,7
$\alpha_{0,15}$	4819,8 (8)	8,4 (4)	2,46
$\alpha_{0,14}$	4845,1 (8)	0,0032 (9)	9600
$\alpha_{0,12}$	4878,6 (8)	0,040 (15)	1300
$\alpha_{0,11}$	4939,1 (8)	1,40 (15)	94
$\alpha_{0,8}$	4989,9 (22)	0,002 (1)	141000
$\alpha_{0,7}$	5023,0 (8)	2,9 (3)	160

	Energy keV	Probability × 100	F
$\alpha_{0,6}$	5039,9 (8)	22,5 (5)	26,5
$\alpha_{0,5}$	5065,3 (8)	0,4 (1)	2160
$\alpha_{0,4}$	5075,7 (8)	1,6 (2)	629
$\alpha_{0,3}$	5103,5 (8)	25,3 (5)	59,5
$\alpha_{0,2}$	5119,9 (8)	20 (2)	95
$\alpha_{0,1}$	5122,5 (8)	2,8 (3)	707
$\alpha_{0,0}$	5149,9 (8)	11,7 (5)	250

2.2 Gamma Transitions and Internal Conversion Coefficients

	Energy keV	$P_{\gamma+ce}$ × 100	Multipolarity	α_K	α_L	α_M	α_T
$\gamma_{3,2}$(Ac)	16,370 (14)	2,12 (9)	E1		5,06 (7)	2,68 (4)	8,58 (12)
$\gamma_{3,1}$(Ac)	18,980 (14)	42 (4)	M1		2,35 (4)	82,7 (12)	113,2 (16)
$\gamma_{11,9}$(Ac)	23,46 (6)	1,16 (15)	M1		182 (3)	44,1 (7)	241 (4)
$\gamma_{16,15}$(Ac)	24,46 (4)	1,05 (21)	M1		161,3 (24)	39,0 (6)	214 (4)
$\gamma_{6,5}$(Ac)	25,390 (22)	18,3 (14)	M1		144,6 (21)	34,9 (5)	191 (3)
$\gamma_{1,0}$(Ac)	27,37 (1)	59 (7)	E1		3,3 (4)	0,87 (13)	4,5 (6)
$\gamma_{2,0}$(Ac)	29,98 (1)	26 (3)	M1+E2		202 (21)	52 (6)	270 (30)
$\gamma_{6,4}$(Ac)	35,800 (22)	0,045 (3)	E1		1,313 (19)	0,327 (5)	1,746 (25)
$\gamma_{5,3}$(Ac)	38,200 (14)	13 (3)	M1+E2		66 (14)	17 (4)	89 (19)
$\gamma_{4,2}$(Ac)	44,160 (14)	2,11 (16)	M1		28,3 (4)	6,79 (10)	37,4 (6)
$\gamma_{3,0}$(Ac)	46,35 (1)	0,357 (19)	E1		0,663 (10)	0,1634 (23)	0,879 (13)
$\gamma_{20,17}$(Ac)	50,73 (5)	0,057 (21)	M1		18,8 (3)	4,52 (7)	24,9 (4)
$\gamma_{7,4}$(Ac)	52,720 (22)	1,77 (10)	M1		16,81 (24)	4,03 (6)	22,2 (4)
$\gamma_{5,2}$(Ac)	54,570 (14)	0,110 (6)	E1		0,430 (6)	0,1053 (15)	0,569 (8)
$\gamma_{15,13}$(Ac)	56,90 (3)	0,18 (4)	M1+E2		28 (5)	7,1 (12)	37 (6)
$\gamma_{5,1}$(Ac)	57,180 (14)	4,6 (5)	E2		108,6 (16)	29,6 (5)	148,1 (21)
$\gamma_{17,15}$(Ac)	57,190 (22)	0,7 (3)	E2		108,5 (16)	29,6 (5)	148,0 (21)
$\gamma_{9,7}$(Ac)	60,46 (4)	0,0076 (10)	E1		0,327 (5)	0,0800 (12)	0,433 (7)
$\gamma_{6,3}$(Ac)	63,590 (22)	3,99 (16)	E2		65,1 (10)	17,8 (3)	88,8 (13)
$\gamma_{(-1,1)}$(Ac)	70,49 (5)	0,0051 (8)					
$\gamma_{10,7}$(Ac)	71,85 (5)	0,019 (7)	M1		6,79 (10)	1,630 (23)	8,98 (13)
$\gamma_{12,10}$(Ac)	72,58 (7)	0,029 (7)	M1		6,59 (10)	1,582 (23)	8,71 (13)
$\gamma_{4,0}$(Ac)	74,14 (1)	0,97 (4)	E2		31,2 (5)	8,53 (12)	42,6 (6)
$\gamma_{9,6}$(Ac)	77,38 (4)	0,50 (4)	M1		5,47 (8)	1,313 (19)	7,23 (11)
$\gamma_{7,2}$(Ac)	96,880 (22)	1,10 (4)	E2		8,81 (13)	2,41 (4)	12,02 (17)
$\gamma_{11,6}$(Ac)	100,84 (5)	0,248 (10)	E2		7,30 (11)	2,00 (3)	9,97 (15)
$\gamma_{9,5}$(Ac)	102,77 (3)	0,20 (4)	E2		6,69 (10)	1,83 (3)	9,12 (13)
$\gamma_{10,4}$(Ac)	124,57 (4)	0,0217 (20)	E2	0,285 (4)	2,75 (4)	0,752 (11)	4,04 (6)
$\gamma_{12,7}$(Ac)	144,43 (6)	0,037 (3)	E2	0,263 (4)	1,407 (20)	0,384 (6)	2,18 (3)
$\gamma_{13,4}$(Ac)	199,00 (3)	0,0030 (12)					
$\gamma_{14,4}$(Ac)	230,59 (5)	0,0017 (8)					
$\gamma_{(-1,2)}$(Ac)	242,18 (8)	0,0099 (10)					
$\gamma_{13,2}$(Ac)	243,16 (3)	0,065 (11)	M1+E2	0,56 (16)	0,176 (10)	0,0445 (16)	0,80 (17)
$\gamma_{15,5}$(Ac)	245,490 (14)	0,042 (3)	M2	3,70 (6)	1,143 (16)	0,293 (5)	5,24 (8)
$\gamma_{13,1}$(Ac)	245,77 (3)	0,013 (4)	E1	0,0455 (7)	0,00867 (13)	0,00208 (3)	0,0570 (8)
$\gamma_{15,4}$(Ac)	255,900 (14)	0,134 (3)	E2	0,0992 (14)	0,1216 (17)	0,0327 (5)	0,264 (4)
$\gamma_{14,3}$(Ac)	258,38 (5)	0,0015 (4)					

	Energy keV	$P_{\gamma+ce}$ × 100	Multipolarity	α_K	α_L	α_M	α_T
$\gamma_{17,7}$(Ac)	260,37 (3)	0,282 (21)	M1+E2	0,37 (10)	0,133 (7)	0,0340 (13)	0,55 (11)
$\gamma_{13,0}$(Ac)	273,14 (3)	0,101 (7)	M1+E2	0,57 (10)	0,131 (8)	0,0323 (15)	0,74 (11)
$\gamma_{17,6}$(Ac)	277,29 (3)	0,10 (6)	E1+M2	0,4 (7)	0,11 (19)	0,03 (5)	0,5 (9)
$\gamma_{15,3}$(Ac)	283,690 (14)	1,72 (3)	E1	0,0329 (5)	0,00614 (9)	0,001468 (21)	0,0410 (6)
$\gamma_{(-1,3)}$(Ac)	286,58 (10)	0,0104 (5)					
$\gamma_{15,2}$(Ac)	300,060 (14)	4,25 (10)	M1+E2	0,613 (15)	0,1146 (20)	0,0275 (5)	0,764 (17)
$\gamma_{15,1}$(Ac)	302,670 (14)	2,4 (3)	E1	0,0285 (4)	0,00527 (8)	0,001260 (18)	0,0355 (5)
$\gamma_{17,5}$(Ac)	302,680 (22)	0,22 (10)	E1	0,0285 (4)	0,00527 (8)	0,001260 (18)	0,0355 (5)
$\gamma_{(-1,4)}$(Ac)	310,0 (1)	0,00092 (20)					
$\gamma_{17,4}$(Ac)	313,090 (22)	0,129 (9)	M1+E2	0,22 (8)	0,070 (8)	0,0177 (16)	0,31 (9)
$\gamma_{16,1}$(Ac)	327,13 (4)	0,0372 (11)	E1	0,0240 (4)	0,00440 (7)	0,001050 (15)	0,0298 (5)
$\gamma_{15,0}$(Ac)	330,04 (1)	2,09 (5)	M1+E2	0,430 (16)	0,0836 (20)	0,0202 (5)	0,541 (19)
$\gamma_{17,3}$(Ac)	340,880 (22)	0,196 (7)	E1+M2	0,081 (22)	0,020 (6)	0,0050 (15)	0,11 (3)
$\gamma_{18,4}$(Ac)	351,45 (3)	0,0029 (12)	E1	0,0206 (3)	0,00373 (6)	0,000891 (13)	0,0255 (4)
$\gamma_{16,0}$(Ac)	354,50 (4)	0,1094 (23)	M1+E2	0,0855 (12)	0,0386 (6)	0,01003 (14)	0,1375 (20)
$\gamma_{17,2}$(Ac)	357,250 (22)	0,240 (18)	M1+E2	0,34 (9)	0,066 (10)	0,0159 (21)	0,43 (10)
$\gamma_{17,1}$(Ac)	359,860 (22)	0,0085 (3)					
$\gamma_{20,4}$(Ac)	363,82 (4)	0,0080 (3)					
$\gamma_{(-1,5)}$(Ac)	374,95 (10)	0,0045 (3)					
$\gamma_{18,3}$(Ac)	379,24 (3)	0,066 (6)	M1+E2	0,25 (10)	0,052 (11)	0,0125 (24)	0,32 (11)
$\gamma_{21,5}$(Ac)	384,69 (6)	0,00365 (22)					
$\gamma_{17,0}$(Ac)	387,23 (2)	0,00032 (11)	E2	0,0430 (6)	0,0254 (4)	0,00667 (10)	0,0773 (11)
$\gamma_{20,3}$(Ac)	391,61 (4)	0,00687 (22)	E1	0,01636 (23)	0,00293 (5)	0,000697 (10)	0,0202 (3)
$\gamma_{18,2}$(Ac)	395,61 (3)	0,00230 (22)	E1	0,01601 (23)	0,00286 (4)	0,000682 (10)	0,0198 (3)
$\gamma_{18,1}$(Ac)	398,22 (3)	0,0095 (3)					
$\gamma_{19,1}$(Ac)	407,820 (22)	0,0475 (11)	M1	0,269 (4)	0,0496 (7)	0,01187 (17)	0,334 (5)
$\gamma_{20,1}$(Ac)	410,59 (4)	0,00183 (22)	E1	0,01482 (21)	0,00264 (4)	0,000628 (9)	0,0183 (3)
$\gamma_{22,4}$(Ac)	427,14 (7)	0,0007 (4)					
$\gamma_{19,0}$(Ac)	435,19 (2)	0,00294 (17)					
$\gamma_{20,0}$(Ac)	437,96 (4)	0,0045 (3)					
$\gamma_{(-1,6)}$(Ac)	438,72 (10)	0,0013 (4)					
$\gamma_{24,4}$(Ac)	488,66 (10)	0,00165 (17)					
$\gamma_{23,3}$(Ac)	490,65 (10)	0,0004 (1)					
$\gamma_{22,0}$(Ac)	501,28 (7)	0,00076 (18)					
$\gamma_{23,1}$(Ac)	509,63 (10)	0,00036 (17)					
$\gamma_{24,3}$(Ac)	516,45 (10)	0,00137 (15)					
$\gamma_{24,1}$(Ac)	535,43 (10)	0,00061 (12)					
$\gamma_{25,6}$(Ac)	546,5 (3)	0,00083 (13)					
$\gamma_{25,5}$(Ac)	571,9 (3)	0,00048 (20)					
$\gamma_{25,4}$(Ac)	582,3 (3)	0,00031 (17)					
$\gamma_{25,3}$(Ac)	610,1 (3)	0,0005 (4)					

3 Atomic Data

3.1 Ac

ω_K : 0,969 (4)
$\bar{\omega}_L$: 0,464 (18)
n_{KL} : 0,799 (5)

3.1.1 X Radiations

		Energy keV		Relative probability
X_K				
	$K\alpha_2$	87,768		61,52
	$K\alpha_1$	90,885		100
	$K\beta_3$	102,101	}	
	$K\beta_1$	102,841	}	
	$K\beta_5''$	103,462	}	35,26
	$K\beta_2$	105,679	}	
	$K\beta_4$	106,098	}	11,74
	$KO_{2,3}$	106,563	}	
X_L				
	$L\ell$	10,8701		
	$L\alpha$	12,5002 – 12,6505		
	$L\eta$	14,0807		
	$L\beta$	14,6024 – 15,9311		
	$L\gamma$	17,813 – 18,9228		

3.1.2 Auger Electrons

	Energy keV	Relative probability
Auger K		
KLL	66,769 – 74,715	100
KLX	81,775 – 90,882	58,2
KXY	96,76 – 106,75	8,47
Auger L	5,87 – 19,69	

4 α Emissions

	Energy keV	Probability × 100
$\alpha_{0,25}$	4415,6 (9)	0,0021 (5)
$\alpha_{0,24}$	4507,6 (8)	0,0036 (3)
$\alpha_{0,23}$	4533,0 (8)	0,00076 (20)
$\alpha_{0,22}$	4568,1 (9)	0,008 (4)
$\alpha_{0,21}$	4599,6 (8)	0,015 (7)
$\alpha_{0,20}$	4630,3 (8)	0,078 (21)
$\alpha_{0,19}$	4633,0 (8)	0,0504 (11)
$\alpha_{0,18}$	4642,5 (8)	0,080 (6)
$\alpha_{0,17}$	4680,1 (8)	1,8 (3)
$\alpha_{0,16}$	4712,3 (8)	1,20 (22)
$\alpha_{0,15}$	4736,3 (8)	8,4 (4)
$\alpha_{0,14}$	4761,2 (8)	0,0032 (9)
$\alpha_{0,12}$	4794,1 (8)	0,040 (15)
$\alpha_{0,11}$	4853,5 (8)	1,40 (15)
$\alpha_{0,8}$	4903,4 (22)	0,002 (1)
$\alpha_{0,7}$	4936,0 (8)	2,9 (3)
$\alpha_{0,6}$	4952,6 (8)	22,5 (5)
$\alpha_{0,5}$	4977,6 (8)	0,4 (1)
$\alpha_{0,4}$	4987,8 (8)	1,6 (2)
$\alpha_{0,3}$	5015,1 (8)	25,3 (5)
$\alpha_{0,2}$	5031,2 (8)	20 (2)
$\alpha_{0,1}$	5033,8 (8)	2,8 (3)
$\alpha_{0,0}$	5060,7 (8)	11,7 (5)

5 Electron Emissions

		Energy keV	Electrons per 100 disint.
e_{AL}	(Ac)	5,87 - 19,69	52,6 (15)
e_{AK}	(Ac)		0,078 (11)
	KLL	66,769 - 74,715	}
	KLX	81,775 - 90,882	}
	KXY	96,76 - 106,75	}

6 Photon Emissions

6.1 X-Ray Emissions

		Energy keV		Photons per 100 disint.	
XL	(Ac)	10,8701 — 18,9228		44,3 (13)	
XKα_2	(Ac)	87,768		0,715 (23)	} Kα
XKα_1	(Ac)	90,885		1,16 (4)	}
XKβ_3	(Ac)	102,101	}		
XKβ_1	(Ac)	102,841	}	0,410 (15)	K$'\beta_1$
XKβ''_5	(Ac)	103,462	}		
XKβ_2	(Ac)	105,679	}		
XKβ_4	(Ac)	106,098	}	0,136 (6)	K$'\beta_2$
XKO$_{2,3}$	(Ac)	106,563	}		

6.2 Gamma Emissions

	Energy keV	Photons per 100 disint.
$\gamma_{3,2}$(Ac)	16,370 (14)	0,221 (9)
$\gamma_{3,1}$(Ac)	18,980 (14)	0,37 (3)
$\gamma_{11,9}$(Ac)	23,46 (6)	0,0048 (6)
$\gamma_{16,15}$(Ac)	24,46 (4)	0,0049 (10)
$\gamma_{6,5}$(Ac)	25,390 (22)	0,095 (7)
$\gamma_{1,0}$(Ac)	27,37 (1)	10,8 (4)
$\gamma_{2,0}$(Ac)	29,98 (1)	0,097 (4)
$\gamma_{6,4}$(Ac)	35,800 (22)	0,0163 (10)
$\gamma_{5,3}$(Ac)	38,200 (14)	0,144 (6)
$\gamma_{4,2}$(Ac)	44,160 (14)	0,055 (4)
$\gamma_{3,0}$(Ac)	46,35 (1)	0,19 (1)
$\gamma_{20,17}$(Ac)	50,73 (5)	0,0022 (8)
$\gamma_{7,4}$(Ac)	52,720 (22)	0,076 (4)
$\gamma_{5,2}$(Ac)	54,570 (14)	0,070 (4)
$\gamma_{15,13}$(Ac)	56,90 (3)	0,0047 (7)
$\gamma_{5,1}$(Ac)	57,180 (14)	0,031 (3)
$\gamma_{17,15}$(Ac)	57,190 (22)	0,0046 (21)
$\gamma_{9,7}$(Ac)	60,46 (4)	0,0053 (7)
$\gamma_{6,3}$(Ac)	63,590 (22)	0,0446 (17)
$\gamma_{(-1,1)}$(Ac)	70,49 (5)	0,0051 (8)
$\gamma_{10,7}$(Ac)	71,85 (5)	0,0019 (7)

	Energy keV	Photons per 100 disint.
$\gamma_{12,10}$(Ac)	72,58 (7)	0,0030 (7)
$\gamma_{4,0}$(Ac)	74,14 (1)	0,0223 (9)
$\gamma_{9,6}$(Ac)	77,38 (4)	0,061 (4)
$\gamma_{7,2}$(Ac)	96,880 (22)	0,084 (3)
$\gamma_{11,6}$(Ac)	100,84 (5)	0,0226 (9)
$\gamma_{9,5}$(Ac)	102,77 (3)	0,019 (4)
$\gamma_{10,4}$(Ac)	124,57 (4)	0,0043 (4)
$\gamma_{12,7}$(Ac)	144,43 (6)	0,0115 (9)
$\gamma_{13,4}$(Ac)	199,00 (3)	0,0030 (12)
$\gamma_{14,4}$(Ac)	230,59 (5)	0,0017 (8)
$\gamma_{(-1,2)}$(Ac)	242,18 (8)	0,0099 (10)
$\gamma_{13,2}$(Ac)	243,16 (3)	0,036 (5)
$\gamma_{15,5}$(Ac)	245,490 (14)	0,0067 (5)
$\gamma_{13,1}$(Ac)	245,77 (3)	0,012 (4)
$\gamma_{15,4}$(Ac)	255,900 (14)	0,1059 (22)
$\gamma_{14,3}$(Ac)	258,38 (5)	0,0015 (4)
$\gamma_{17,7}$(Ac)	260,37 (3)	0,182 (4)
$\gamma_{13,0}$(Ac)	273,14 (3)	0,0579 (12)
$\gamma_{17,6}$(Ac)	277,29 (3)	0,0680 (15)
$\gamma_{15,3}$(Ac)	283,690 (14)	1,65 (3)
$\gamma_{(-1,3)}$(Ac)	286,58 (10)	0,0104 (5)
$\gamma_{15,2}$(Ac)	300,060 (14)	2,41 (5)
$\gamma_{15,1}$(Ac)	302,670 (14)	2,3 (3)
$\gamma_{17,5}$(Ac)	302,680 (22)	0,21 (10)
$\gamma_{(-1,4)}$(Ac)	310,0 (1)	0,00092 (20)
$\gamma_{17,4}$(Ac)	313,090 (22)	0,0987 (20)
$\gamma_{16,1}$(Ac)	327,13 (4)	0,0361 (11)
$\gamma_{15,0}$(Ac)	330,04 (1)	1,36 (3)
$\gamma_{17,3}$(Ac)	340,880 (22)	0,177 (4)
$\gamma_{18,4}$(Ac)	351,45 (3)	0,0028 (12)
$\gamma_{16,0}$(Ac)	354,50 (4)	0,0962 (20)
$\gamma_{17,2}$(Ac)	357,250 (22)	0,168 (4)
$\gamma_{17,1}$(Ac)	359,860 (22)	0,0085 (3)
$\gamma_{20,4}$(Ac)	363,82 (4)	0,0080 (3)
$\gamma_{(-1,5)}$(Ac)	374,95 (10)	0,0045 (3)
$\gamma_{18,3}$(Ac)	379,24 (3)	0,0498 (11)
$\gamma_{21,5}$(Ac)	384,69 (6)	0,00365 (22)
$\gamma_{17,0}$(Ac)	387,23 (2)	0,0003 (1)
$\gamma_{20,3}$(Ac)	391,61 (4)	0,00673 (22)
$\gamma_{18,2}$(Ac)	395,61 (3)	0,00226 (22)
$\gamma_{18,1}$(Ac)	398,22 (3)	0,0095 (3)
$\gamma_{19,1}$(Ac)	407,820 (22)	0,0356 (8)
$\gamma_{20,1}$(Ac)	410,59 (4)	0,00180 (22)
$\gamma_{22,4}$(Ac)	427,14 (7)	0,0007 (4)
$\gamma_{19,0}$(Ac)	435,19 (2)	0,00294 (17)
$\gamma_{20,0}$(Ac)	437,96 (4)	0,0045 (3)
$\gamma_{(-1,6)}$(Ac)	438,72 (10)	0,0013 (4)

	Energy keV	Photons per 100 disint.
$\gamma_{24,4}$(Ac)	488,66 (10)	0,00165 (17)
$\gamma_{23,3}$(Ac)	490,65 (10)	0,0004 (1)
$\gamma_{22,0}$(Ac)	501,28 (7)	0,00076 (18)
$\gamma_{23,1}$(Ac)	509,63 (10)	0,00036 (17)
$\gamma_{24,3}$(Ac)	516,45 (10)	0,00137 (15)
$\gamma_{24,1}$(Ac)	535,43 (10)	0,00061 (12)
$\gamma_{25,6}$(Ac)	546,5 (3)	0,00083 (13)
$\gamma_{25,5}$(Ac)	571,9 (3)	0,00048 (20)
$\gamma_{25,4}$(Ac)	582,3 (3)	0,00031 (17)
$\gamma_{25,3}$(Ac)	610,1 (3)	0,0005 (4)

7 Main Production Modes

$\mathrm{Th-232(n,\,2n)Th-231}$

$\mathrm{Th-231}(\beta^-)\mathrm{Pa-231}$

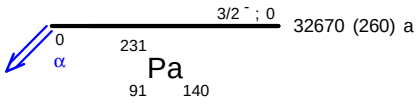
U – 235 decay chain

8 References

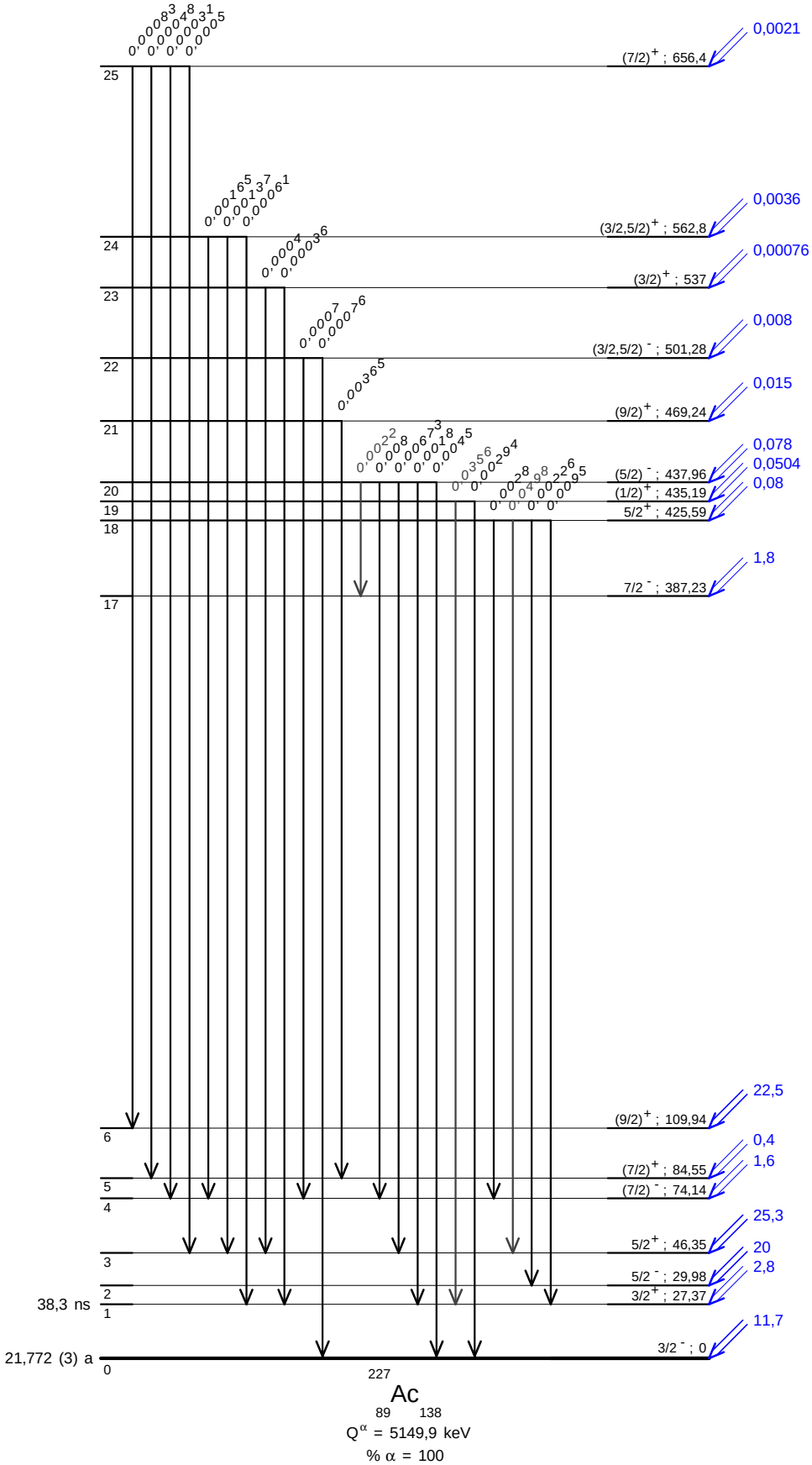
- A.V.GROSSE. Naturwissensch. 20 (1932) 505
  (Half-life)
- Q.VAN WINKLE, R.G.LARSON, L.I.KATZIN. J. Am. Chem. Soc. 71 (1949) 2585
  (Half-life)
- P. FALK-VAIRANT, M.RIOU. J. Phys. Radium 14,2 (1953) 65
  (Gamma-ray emission probabilities and energies)
- J.P.HUMMEL. Thesis, Uni. Calif. (1956)
  (Alpha-particle emission probabilities)
- F.ASARO, F.S.STEPHENS,J.M.HOLLANDER,I.PERLMAN. Phys. Rev. 117, 2 (1960) 492
  (L- and M-shell conversion coefficients)
- R.FOUCHER. Comp. Rend. Acad. Sci. (Paris) 250 (1960) 1249
  (Gamma-ray emission probabilities)
- F.BRAGANCA GIL, G.Y.PETIT. J. Phys. Radium 22 (1961) 680
  (Spin and parity, mixing ratio, half-life excited level)
- H.W.KIRBY. J. Inorg. Nucl. Chem. 18 (1961) 8
  (Half-life)
- S.BARANOV, V.M.KULAKOV,P.S.SAMOILOV,A.G.ZELENKOV,Y.F.RODIONOV,S.V.PIROZHKOV. Sov. Phys. - JETP 14, 5 (1961) 1053
  (Alpha-particle emission energies and probabilities, experimental conversions)
- V.B.SUBRAHMANYAM. Thesis, Uni. Calif. (1963)
  (Alpha-particle emission probabilities)
- H.ABOU-LEILA, R.FOUCHER, A.G.DE PINHO, N.PERRIN, M.VALADARES. J. Phys. (Paris) 24 (1963) 857
  (Spin and parity, multipolarities)
- G.BASTIN, C.F.LEANG, R.J.WALES. Comp. Rend. Acad. Sci. (Paris) T.262 (1966) 89
  (Alpha-particle emission energies)
- D.BROWN, S.N.DIXON, K.M.GLOVER, F.J.G.ROGERS. J. Inorg. Nucl. Chem. 30 (1968) 19
  (Half-life)

- S.BARANOV, V.M.KULAKOV,V.M.SHATINSKII. Sov. J. Nucl. Phys. 7,4 (1968) 442
  (Alpha-particle emission energies)
- G.R.HAGEE, R.C.LANGE,A.G.BARNETT, A.R.CAMPBELL, C.R. COTHERN, D.F. GRIFFING, H.J. HENNECKE. Nucl. Phys. A115 (1968) 157
  (Spin and parity, conversion electron emission probabilities)
- A.G.BARNETT, A.R.CAMPBELL, G.R.HAGEE. J. Inorg. Nucl. Chem. 31 (1969) 1553
  (Multipolarities, conversion electron emission probabilities, mixing ratio)
- R.C.LANGE, G.R.HAGEE. Nucl. Phys. A124 (1969) 412
  (Gamma-ray emission energies and probabilities)
- J.ROBERT, C.F.MIRANDA, R.MUXART. Radiochim. Acta 11 (1969) 104
  (Half-life)
- A.G.DE PINHO, E.F.DA SILVEIRA, N.L.DA COSTA. Phys. Rev.C 2,2 (1970) 572
  (Gamma-ray emission energies and probabilities, ICC)
- C.F.LEANG. J. Phys. (Paris) 31 (1970) 269
  (Gamma-ray emission energies and probabilities)
- C.F.LEANG. J. Phys. (Paris) 32,2-3 (1971) 95
  (Spin and parity)
- R.K.GARG, S.D.CHAUHAN, S.SANYAL, S.C. PANCHOLI, S.L.GUPTA, N.K.SAHA. Z. Physik 257 (1972) 124
  (Half-life of excited level)
- A.G.DE PINHO, L.T.AULER, A.G.DA SILVA. Phys. Rev.C 9,5 (1974) 2056
  (X-ray emission probabilities, gamma-ray emission probabilities, ICC)
- S.A.BARANOV. Sov.J.At.Energ. 41 (1976) 342
  (Alpha-particle emission energies and probabilities)
- S.A.BARANOV, A.G.ZELENKOV, V.M.KULAKOV. Proc. Advisory Group Meeting on Transactinium Nucl. Data, Karlsruhe. IAEA-186 Vol III (1976) 249
  (Alpha-particle emission energies and probabilities)
- W.TEOH, R.D.CONNOR, R.H.BETTS. Nucl. Phys. A319 (1979) 122
  (Gamma-ray emission energies and probabilities, Multipolarities, ICC)
- H.G.BORNER, G.BARREAU, W.F.DAVIDSON, P.JEUCH, T.VON EGIDY, J.ALMEIDA, D.H.WHITE. Nucl. Instrum. Methods 166 (1979) 251
  (Gamma-ray emission energies)
- I.ANICIN, I.BIKIT, C.GIRIT, H.GUVEN, W.D.HAMILTON, A.A.YOUSIF. Nucl. Phys. 8 (1982) 369
  (Gamma-ray emission probabilities)
- M.F.BANHAM, R.JONES. Int. J. Appl. Radiat. Isotop. 34, 8 (1983) 1225
  (Gamma-ray emission probabilities)
- T.ISHII, I.AHMAD, J.E.GINDLER,A.M.FRIEDMAN, R.R.CHASMAN, S.B.KAUFMAN. Nucl. Phys. A444 (1985) 237
  (half-life first excited state)
- IAEA Technical Reports Series, N°261 (1986)
  (Gamma-ray emission energies and probabilities, alpha-particle emission energies and probabilities.)
- N.E.HOLDEN. Pure & Appl. Chem. 62,5 (1990) 941
  (Half-life)
- A.RYTZ. At. Data Nucl. Data Tables 47 (1991) 205
  (Evaluated alpha-particle emission energies and probabilities)
- Y.A.AKOVALI. Nucl. Data Sheets 84 (1998) 1
  (R0, radius parameter)
- E.BROWNE. Nucl. Data Sheets 93 (2001) 763
  (Spin, parity, energy levels, multipolarities)
- G.AUDI, A.H.WAPSTRA, C.THIBAULT. Nucl. Phys. A729 (2003) 337
  (Q value)
- T.KIBEDI, T.W.BURROWS, M.B.TRZHASKOVSKAYA, P.M.DAVISON, C.W.NESTOR JR.. Nucl. Instrum. Methods Phys. Res. A589 (2008) 202
  (Theoretical ICC)

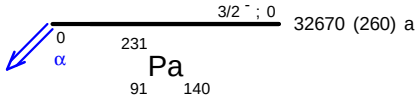
$^{231}_{91}Pa_{140}$



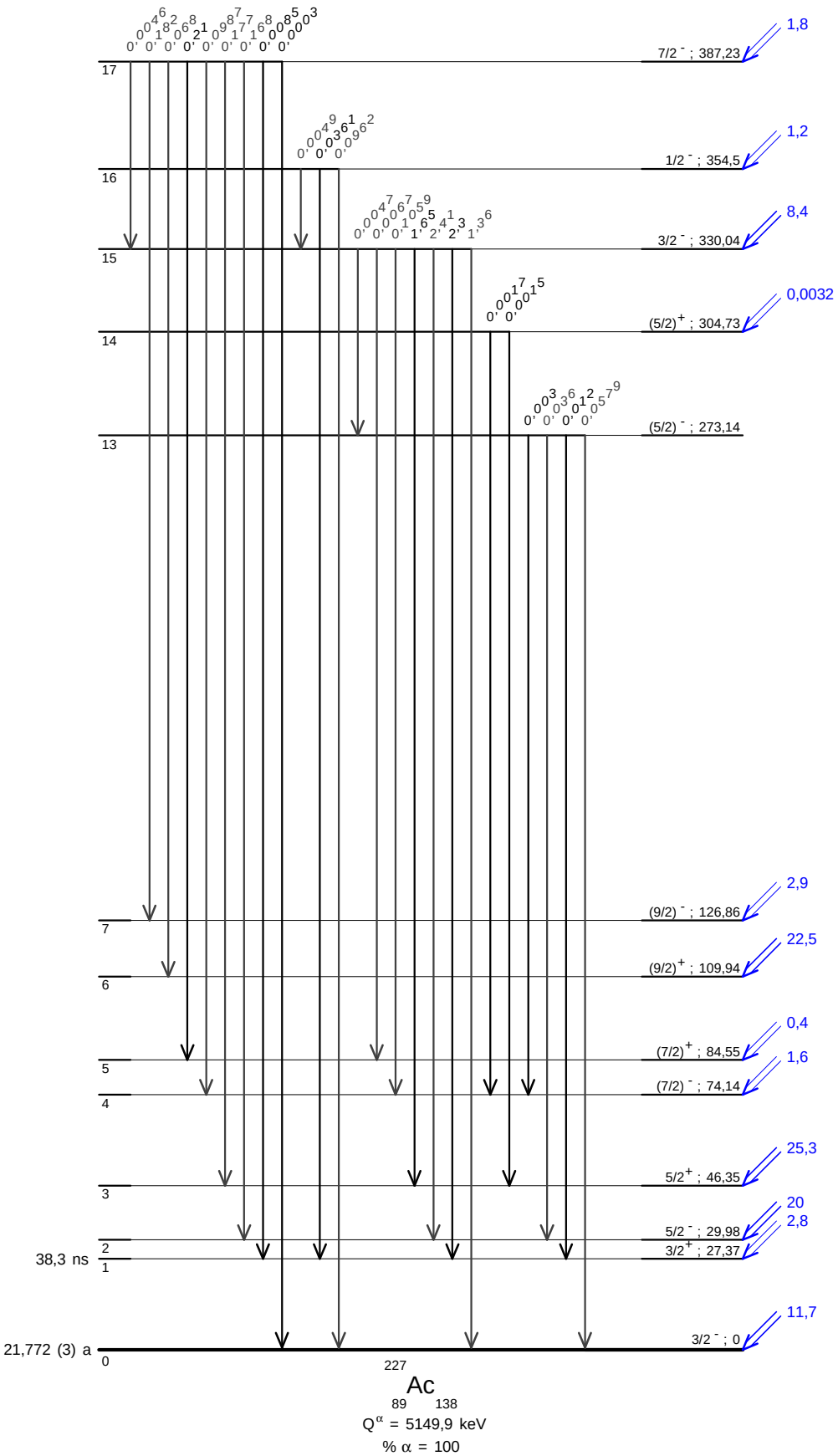
γ Emission intensities per 100 disintegrations



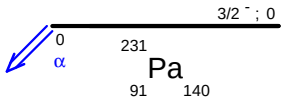
$^{231}_{91}Pa_{140}$



γ Emission intensities per 100 disintegrations



$^{231}_{91}Pa_{140}$



γ Emission intensities per 100 disintegrations