^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Ictp-2014 Workshop Group	NDS 132,257 (2016)	15-Jan-2016

Parent: ^{231}Pa: E=0.0; $J^\pi=3/2^-$; $T_{1/2}=3.276\times10^4$ y *11*; Q(α)=5150.0 *8*; %α decay=100

^{231}Pa-J^π,$T_{1/2}$: From ^{231}Pa Adopted Levels.

^{231}Pa-Q(α): From 2012Wa38.

Main references:

1986BaYK (see also previous publication 1983Ba77 by the same authors and 1986LoZT evaluation): measured Iγ.

Note: results from 1986BaYK were not included in the 2001 (and 1992) Nuclear Data Sheets publications of A=227 nuclides. 1984BaYS reference in connection with the work of 1983Ba77 cited in the DDEP evaluation of Feb 2010 by A. Arinc is an incorrect citation.

1982An02: measured Iγ, $\gamma\gamma(\theta)$, $\gamma(\theta$,H,t) for oriented nuclei, TDPAC. Deduced levels, J, π, multipolarity, mixing ratios. Energies of γ transitions were taken from previous studies.

1979Te02: Eγ, Iγ, ce, x-rays, $\gamma\gamma$-coin. Deduced levels, conversion coefficients, multipolarity.

1970De19: Eγ, Iγ, ce, $\gamma\gamma$-coin. Deduced levels, conversion coefficients, multipolarity. 1974De11 from the same group measured Ac L-, K-x-rays, $\gamma\gamma$-, γ(x ray) coin.

1970Le11, 1971Le10: measured Eγ, Iγ, $\alpha\gamma$-coin, Eα, Iα. Deduced levels, J, π, multipolarity. 1971Le10 from the same group: measured $\alpha\gamma(\theta)$.

1961Ba42: measured Eα, Iα, ce. In 1976Ba68 energies and intensities of five α groups are reported. See also 1976BaZZ.

Others:

1979Bo30: measured precise Eγ values for 13 γ rays using a curved-crystal spectrometer.

Additional information 1.

1972Ga39: measured $\alpha\gamma$(t); deduced half-life of a level in ^{227}Ac.

1969Ba20: measured Eγ, Iγ, I(ce), α. Deduced levels, J, π, mixing ratios.

1969La04: measured Eγ, Iγ, Eα, Iα, $\alpha\gamma$-coin. Deduced levels, J, π.

1968Ha22: measured Eγ, I(ce), α. Deduced levels, J, π.

1968Ba25, 1966Ba14, 1963Su10, 1956Hu96: measured Eα, Iα.

1963Ab04: measured Eγ, Iγ, ce.

1960As02: measured L- and M-shell conversion coefficients.

1960Fo05: measured Eγ, Iγ.

1953Fa08: measured Eγ, Iγ.

Evaluated data published in 2011BeZW (DDEP) has also been consulted.

^{227}Ac Levels

E(level)†	J^π‡	$T_{1/2}$	Comments
0.0	$3/2^-$	21.772 y *3*	
27.365 *11*	$3/2^+$	38.3 ns *3*	$T_{1/2}$: from $\alpha\gamma$(t) in ^{231}Pa α decay (1985Is03). Others: 41.0 ns *11* (1972Ga39), 43.0 ns (1963Su10), 42.0 ns *10* (1961Br32), 37.0 ns (1956Fo21), 37.0 ns (1953Mo74), 42.0 ns (1953Te08).
29.975 *11*	$5/2^-$		
46.349 *13*	$5/2^+$		
74.147 *17*	$7/2^-$		
84.539 *14*	$7/2^+$		
109.989 *21*	$9/2^+$		
126.845 *22*	$9/2^-$		
160 *2*			
187.34 *3*	$11/2^+$		
198.69 *6*	$11/2^-$		
210.84 *7*	$13/2^+$		
271.32 *7*	$(13/2^-)$		
273.16 *4*	$(5/2)^-$		
304.78 *10*	$(5/2^+)$		

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^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

^{227}Ac Levels (continued)

E(level)[†]	Jπ[‡]	$T_{1/2}$	Comments
330.037 *10*	3/2$^-$	<70 ps	$T_{1/2}$: from α(ce)(t) in ^{231}Pa α decay (1963Ab04).
354.50 *4*	1/2$^-$		
387.197 *16*	7/2$^-$		
425.60 *5*	5/2$^+$		
435.16 *3*	1/2$^+$		
437.94 *5*	(5/2$^-$)		
469.26 *9*	9/2$^+$		
501.16 *10*	(3/2$^-$,5/2$^-$)		
537.3 *6*	(3/2$^+$)		
560.98 *3*	(3/2$^+$,5/2)		
656.3 *5*	(7/2$^+$)		

† From least-squares fit by evaluators to Eγ data.
‡ From Adopted Levels. See also Adopted Levels for band structures, Nilsson assignments and parity doublet bands.

α radiations

Eα[†]	E(level)	Iα[†‡a]	HF[#]	Comments
4410[&] *10*	656.3	0.0127[&] *5*	6.9 *3*	Iα deduced by evaluators from γ-ray transition balance. Other: ≈0.001 (1961Ba42).
4508 *2*	560.98	0.00365 *25*	125 *9*	Iα deduced by evaluators from γ-ray transition balance. Other: 0.003 (1961Ba42).
4522	537.3	0.0029 *7*	235 *57*	Iα deduced by evaluators from γ-ray transition balance. No α transition reported by 1961Ba42.
4566 *2*	501.16	0.0019 *4*	6.6×10^2 *14*	Iα deduced by evaluators from γ-ray transition balance. Other: 0.008 (1961Ba42).
4599 *2*	469.26	0.0153 *18*	139 *17*	Iα deduced by evaluators from γ-ray transition balance. Other: 0.015 (1961Ba42).
4632 *2*	437.94	0.075 *9*	47 *6*	Iα deduced by evaluators from γ-ray transition balance. Other: ≈0.1 (1961Ba42). Possible doublet populates the 435 and/or 438 levels.
4624	435.16	0.0503 *11*	74 *2*	Iα deduced by evaluators from γ-ray transition balance. No α transition reported by 1961Ba42.
4643 *2*	425.60	0.082 *7*	53 *5*	Iα deduced by evaluators from γ-ray transition balance. Other: ≈0.1 (1961Ba42).
4681 *2*	387.197	1.5	5.4	Iα=1.50 *10*, deduced by evaluators from γ-ray transition balance.
4713 *2*	354.50	1.268 *21*	10.8 *2*	Iα deduced by evaluators from γ-ray transition balance. Other: ≈1 (1961Ba42).
4736.0[@] *8*	330.037	8.4[@]	2.4	Iα=9.0 *4*, deduced by evaluators from γ-ray transition balance.
4754	304.78	0.0064 *11*	4.69×10^3 *81*	Iα deduced by evaluators from γ-ray transition balance. No α transition reported by 1961Ba42.
4795 *2*	273.16	0.183 *13*	268 *20*	Iα deduced by evaluators from γ-ray transition balance. Other: 0.04 (1961Ba42). Eα: possible doublet populates 271 and/or 273 levels.
4788	271.32	0.065 *8*	7.8×10^2 *10*	Iα deduced by evaluators from γ-ray transition balance. No α transition reported by 1961Ba42.
4853 *2*	210.84	1.4	91	Iα=1.40 *24*, deduced by evaluators from γ-ray transition balance.
4900 *2*	160	0.002	137748	Iα=0, deduced by evaluators from γ-ray transition balance.
4934 *2*	126.845	3.0	150	Iα=2/53 *12*, deduced by evaluators from γ-ray transition balance.
4951.3[@] *14*	109.989	22.8[@]	25	Iα=26 *3*, deduced by evaluators from γ-ray transition balance.
4975 *2*	84.539	0.4	2105	Iα=−4 *6*, deduced by evaluators from γ-ray transition balance.
4986 *2*	74.147	1.4	700	Iα=1.0 *2*, deduced by evaluators from γ-ray transition balance.
5013.8[@] *14*	46.349	25.4[@]	58	Iα=23 *13*, deduced by evaluators from γ-ray transition balance.
5028.4[@] *10*	29.975	20.0[@]	93	Iα=16 *5*, deduced by evaluators from γ-ray transition balance.
5032[b] *2*	27.365	≈2.5	≈772	Iα=10 *13*, deduced by evaluators from γ-ray transition balance.
5058.6[@] *15*	0.0	11.0[@]	260	Iα=13 *8*, deduced by evaluators from γ-ray transition balance.

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^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

α radiations (continued)

† From 1961Ba42 unless otherwise specified.
‡ γ-ray transition intensity balances at each level are consistent with measured α-particle intensities.
# Using $r_0(^{227}Ac)$=1.5310 *9*; interpolation (or unweighted) average of $r_0(^{226}Ra)$=1.5331 *13* and $r_0(^{228}Th)$=1.5289 *5* (1998Ak04).
@ From 1991Ry01.
& From 1969La04.
a Absolute intensity per 100 decays.
b Existence of this branch is questionable.

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

$\gamma(^{227}Ac)$

Iγ normalization: From measurement of absolute intensity of 0.01649 *27* for 283.7γ (1986BaYK). Other: 0.0169 *8* (1970De19), 0.0182 *18* (deduced by evaluators from summed transition intensity to ground state=89.0% *5*, with Iα(to g.s.)=11.0% *5*).
NRM=normalized residual method for weighted averaging.
Total measured intensity of L-x rays=46 *5*/100 decays of ^{231}Pa (1974De11).
The following radiations reported in different studies are identified as Ac L- and K-x rays:
11.0 (1961Ba42), 10.9 *5* (1969La04), 10.9 *1* (1970De19).
12.4 *5* (1969La04), 12.7 (1970Le11), 12.65 *1* (1970De19).
14.1 *1* (1970De19). E(Lη x ray)=14.08.
15.5 *5* (1969La04), 15.7 (1970Le11), 15.7 (1970De19).
18.2 *5* (1969La04), 18.4 (1970Le11), 18.5 (1970De19).
19.6 (1961Ba42): strong x rays could be mixed with a γ transition.
87.5 *5* (1969La04), 87.67 *2* (1970De19).
90.7 *5* (1969La04), 90.88 *2* (1970De19).
106.0 *5* (1969La04), 105.7 *1* (1970De19).
Conversion coefficients from 1979Te02 are based on absolute intensity measurements of photons and conversion electrons. Others: 1970De19, 1968Ha22.

Measured intensities of Ac x rays
(from 1983Ba77 as quoted in 1986LoZT)

x ray	Energy	Intensity
L1	10.87	108.0 *20*
Lα1,α2	12.63	1725 *35*
Lη	14.08	21.1 *8*
Lβ	15.70	973 *19*
Lγ1	18.39	184.6 *37*
Lγ3,γ6	18.95	76.7 *15*
Lγ4	19.67	18.4 *7*
Kβ1	102.93	0.9 *2*

Values are relative to 100.0 *8* for 283.7γ

Relative intensities of Ac K- and L-x rays (1974De11)
Each group is normalized separately to 100 for
the most intense x-ray line in that group.

x ray	Energy	Intensity
KL_2	87.672	60.5 *16*
KL_3	90.886	100
KM_2	102.097	10.7 *5*
KM_3	102.837	22.8 *10*
$KM_{4,5}$	103.47	0.9 *1*
KN_2	105.643	2.8 *2*
$KN_{3,4,5}$	105.84	7.0 *5*
$KO_{2,3}$	106.56	2.3 *2*

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L_1L_3	3.97	10 *2*
L_1M_2	15.191	100
L_1M_3	15.931	92 *8*
L_1M_4	16.480	4.4 *6*
L_1M_5	16.631	6.8 *8*
L_1N_2	18.737	28.0 *20*
L_1N_3	18.926	30.5 *25*
$L_1N_{4,5}$	19.20	2.0 *6*
$L_1O_{2,3}$	19.66	14.0 *12*
L_2M_1	14.083	3.3 *5*
L_2M_4	15.715	100
$L_2N_{1,3}$	17.82	1.1 *5*
L_2N_4	18.409	23.5 *20*
L_2O_4	19.002	4.3 *5*
L_3M_1	10.869	6.4 *4*
$L_3M_{4,5}$	12.65	100
L_3N_1	14.601	2.4 *4*
L_3N_5	15.230	20.0 *25*
$L_3O_{4,5}$	15.79	3.0 *8*

E_γ [†]	I_γ [‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α [b]	$I_{(\gamma+ce)}$ [c]	Comments
16.5 *1*	13.4 *5*	46.349	$5/2^+$	29.975	$5/2^-$	[E1]	8.58 *12*		α: BrIcc code cannot be used for this transition since its energy is within 1 keV of L_3 electronic shell binding energy. The total conversion coefficient listed here is taken from the DDEP evaluation of Feb 2010 by A. Arinc, where it was calculated by T. Kibedi using the RAINE code, giving conversion coefficient of 5.06 *7* for the L_3 shell. Eγ from 1970De19, Iγ from 1986BaYK. Eγ=16.5 *1* (1970De19). Iγ=13.4 *5* (1986BaYK) for a 16.56γ.
19.6	21 *6*	46.349	$5/2^+$	27.365	$3/2^+$	[M1]	112.8	2.41×10^{3} [#] *71*	ce(L)/(γ+ce)=0.0206 *4*; ce(M)/(γ+ce)=0.725 *8* ce(N)/(γ+ce)=0.192 *4*; ce(O)/(γ+ce)=0.0447 *9*; ce(P)/(γ+ce)=0.00828 *17*; ce(Q)/(γ+ce)=0.000738 *15* α(L)=2.34 *4*; α(M)=82.5 *12*; α(N)=21.9 *3*; α(O)=5.09 *8*; α(P)=0.942 *14*; α(Q)=0.0840 *12* I_γ: from I(γ+ce) and α. Eγ=?19 (1970De19), 19.6 (1961Ba42): mixed with strong x rays.
^{x}22.7 [@] (23.6)	0.28 *6*	210.84	$13/2^+$	187.34	$11/2^+$	[M1]	237	70 *14*	ce(L)/(γ+ce)=0.752 *8*; ce(M)/(γ+ce)=0.182 *4*

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^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

$\gamma(^{227}Ac)$ (continued)

E_γ [†]	I_γ [‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	δ	α [b]	$I_{(\gamma+ce)}$ [c]	Comments
										ce(N)/(γ+ce)=0.0483 *10*; ce(O)/(γ+ce)=0.01123 *22*; ce(P)/(γ+ce)=0.00208 *5*; ce(Q)/(γ+ce)=0.000185 *4* α(L)=179 *3*; α(M)=43.3 *6* α(N)=11.50 *16*; α(O)=2.67 *4*; α(P)=0.495 *7*; α(Q)=0.0441 *7* $I_{(\gamma+ce)}$: from γ-ray intensity balance at 211 level. I_γ: from I(γ+ce) and α.
24.5 *1*	≈0.3	354.50	1/2$^-$	330.037	3/2$^-$	[M1]		213 *4*	≈68	ce(L)/(γ+ce)=0.752 *10*; ce(M)/(γ+ce)=0.182 *5* ce(N)/(γ+ce)=0.0482 *13*; ce(O)/(γ+ce)=0.0112 *3*; ce(P)/(γ+ce)=0.00207 *6*; ce(Q)/(γ+ce)=0.000185 *5* α(L)=161 *3*; α(M)=38.8 *8* α(N)=10.29 *20*; α(O)=2.39 *5*; α(P)=0.443 *9*; α(Q)=0.0395 *8* $I_{(\gamma+ce)}$: from γ-ray intensity balance at 354 level. I_γ: from I(γ+ce) and α. Others: Iγ=0.7 *3* (1979Te02), ≈0.6 (1970De19).
25.48 *6*	7.2 *8*	109.989	9/2$^+$	84.539	7/2$^+$	[M1]		189		α(L)=143.1 *23*; α(M)=34.5 *6* α(N)=9.16 *15*; α(O)=2.13 *4*; α(P)=0.394 *7*; α(Q)=0.0351 *6* Eγ=25.3 *5* (1969La04), 25.2 *2* (1970Le11), 25.54 *6* (1970De19), 25.36 *8* (1979Te02). Iγ=≈19 (1970Le11), 7.6 *12* (1974De11, ≈6 in 1970De19), 6.9 *10* (1979Te02), 16.5 *9* (1986BaYK) for a 25.28γ. Values in 1970Le11 and 1986BaYK seem discrepant and not used in averaging; these values are also inconsistent in intensity balance.
^{x}27.0 [@a]										
27.36 *2*	634 *25*	27.365	3/2$^+$	0.0	3/2$^-$	E1(+M2)	<0.0020	4.5 *4*		α(L)=3.3 *3*; α(M)=0.87 *8* α(N)=0.226 *20*; α(O)=0.048 *5*; α(P)=0.0073 *8*; α(Q)=0.00031 *6* I_γ: unweighted average. 1974De11 give absolute I(γ+ce)=52% *8*. Eγ=27.3 *5* (1969La04), 27.3 *2* (1970Le11), 27.35 *2* (1970De19), 27.38 *2* (1979Te02). Iγ=440 *140* (1970Le11), 588 *21* (1970De19,1974De11), 640 *50* (1979Te02), 673 *10* (1986BaYK). Value from 1970Le11 is not included in averaging. Mult.: from α(L)exp=3.7 *3*, ce(L1):ce(L2):ce(L3) exp=84 *16*:138 *20*:126 *25* (1974De11). Other values: α(L)exp=2.8 *3*, ce(M1):ce(M2):ce(M3):ce(M4)+ce(M5) exp=9:5:10:6 (1960As02). ce(L):ce(M):ce(N) exp=31:10:1.7 (1961Ba42). Other: 1970De19. Experimental value of α(L)exp=3.3 *3* (from weighted average of 2.8 *3* (1960As02), 3.6 *4* (1961Ba42) and 3.7 *3* (1974De11, 3.0 *3* in 1970De11)). α: from experimental value of α(L)exp=3.3 *3* (weighted

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γ(^{227}Ac) (continued)

E_γ [†]	I_γ [‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	δ	α [b]	Comments
									average of 2.8 *3* (1960As02), 3.6 *4* (1961Ba42) and 3.7 *3* (1974De11, 3.0 *3* in 1970De11)). α(theory, E1)=3.55, using BrIcc code. Anomalous E1 transition as suggested by experimental conversion data. δ: estimated by evaluators from RUL for M2 transition. Others: 0.0070 *13* from α(L)exp=3.3 *3* is too large to be consistent with RUL=1 for B(M2)(W.u.); +0.23 *10* from γγ(θ) (1982An02) is inconsistent with the experimental conversion coefficients as well as with RUL=1 for B(M2)(W.u.).
29.97 *2*	5.87 *30*	29.975	5/2$^-$	0.0	3/2$^-$	M1+E2	0.22 *3*	2.7×10^2 *5*	α(L)=2.0×10^2 *4*; α(M)=52 *9* α(N)=13.8 *23*; α(O)=3.1 *5*; α(P)=0.52 *8*; α(Q)=0.0213 *4* Eγ=29.8 *5* (1969La04), 29.9 *2* (1970Le11), 29.95 *2* (1970De19), 30.01 *3* (1979Te02). Iγ=6.3 *21* (1970Le11), 5.88 *31* (1974De11, 5.8 *6* in 1970De19), 6.5 *5* (1979Te02), 5.63 *30* (1986BaYK). Mult.,δ: from α(L)exp=203 *20*; ce(L1):ce(L2):ce(L3) exp=82 *15*:74 *12*:47 *9* (1974De11).
[x]30.92 *6*	0.59 *15*								Eγ=31.54 *5* (1970De19), 31.55 *5* (1979Te02).
[x]31.54 *5*	0.41 *14*								
[x]34.0[@]									
35.83 *3*	0.98 *6*	109.989	9/2$^+$	74.147	7/2$^-$	[E1]		1.742	α(L)=1.310 *19*; α(M)=0.327 *5* α(N)=0.0843 *12*; α(O)=0.0179 *3*; α(P)=0.00268 *4*; α(Q)=0.0001001 *15* Eγ=35.6 *5* (1969La04), 35.8 *3* (1970Le11), 35.82 *3* (1970De19), 35.86 *4* (1979Te02). Iγ=0.9 *3* (1970Le11), 1.15 *10* (1974De11, 1.00 *17* in 1970De19), 0.94 *5* (1979Te02); γ not listed in 1986BaYK.
38.20 *2*	8.8 *3*	84.539	7/2$^+$	46.349	5/2$^+$	M1+E2	0.19 *9*	92 *38*	α(L)=69 *28*; α(M)=17.4 *76* α(N)=4.6 *20*; α(O)=1.04 *44*; α(P)=0.180 *67*; α(Q)=0.0104 *3* I_γ: (nrm) weighted average. Eγ=38.0 *5* (1969La04), 38.1 *2* (1970Le11), 38.20 *2* (1970De19), 38.19 *2* (1979Te02). Iγ=6.3 *21* (1970Le11), 8.6 *7* (1974De11, 9.4 *11* in 1970De19), 9.4 *5* (1979Te02), 8.59 *33* (1986BaYK). Mult.,δ: from α(L)exp=70 *12* (1970De19).
[x]39.65 *8*	0.10 *5*								Eγ=39.57 *4* (1970De19), 39.73 *3* (1979Te02). Iγ=0.09 *5* (1970De19), 0.14 *10* (1979Te02).
[x]39.98 *2*	1.0 *2*								Eγ=39.97 *2* (1970De19), 40.00 *3* (1979Te02). Iγ=0.77 *15* (1970De19, not reported in 1974De11), 1.22 *6* (1979Te02), 6.48 *30* (1986BaYK). Note large difference in intensities in the three studies which suggests that it is a sum line, possibly of 27.36γ with x rays.
[x]42.44 *4*	0.35 *8*								Eγ=42.48 *5* (1970De19), 42.41 *4* (1979Te02). Iγ=0.36 *8* (1970De19), 0.3 *1* (1979Te02).

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γ(^{227}Ac) (continued)

E_γ [†]	I_γ [‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α [b]	Comments
[x]43.07 *4*	0.41 *11*							Eγ=43.05 *5* (1970De19), 43.08 *4* (1979Te02). Iγ=0.41 *12* (1970De19), 0.41 *11* (1979Te02).
44.14 *2*	3.36 *26*	74.147	7/2$^-$	29.975	5/2$^-$	[M1]	37.4	α(L)=28.3 *4*; α(M)=6.80 *10* α(N)=1.80 *3*; α(O)=0.420 *6*; α(P)=0.0777 *11*; α(Q)=0.00691 *10* Eγ=43.9 *5* (1969La04), 44.1 *2* (1970Le11), 44.16 *2* (1970De19), 44.13 *2* (1979Te02). Iγ=2.8 *9* (1970Le11), 3.41 *26* (1974De11, 3.8 *6* in 1970De19), 3.77 *40* (1979Te02), 2.7 *5* (1986BaYK).
46.34 *2*	11.3 *6*	46.349	5/2$^+$	0.0	3/2$^-$	(E1)	0.880	α(L)=0.663 *10*; α(M)=0.1635 *23* α(N)=0.0424 *6*; α(O)=0.00914 *13*; α(P)=0.001418 *20*; α(Q)=5.89×10^{-5} *9* I_γ: nrm weighted average. Eγ=46.1 *5* (1969La04), 46.2 *2* (1970Le11), 46.37 *2* (1970De19), 46.32 *2* (1979Te02). Iγ=8.1 *25* (1970Le11), 11.1 *6* (1974De11, 13.2 *13* in 1970De19), 12.97 *64* (1979Te02), 10.6 *7* (1986BaYK). Uncertainty of 0.2 in 1970De19 seems a misprint, it is likely to be 2.0. δ: δ(Q/D)=+0.11 *10* from γγ(θ) (1982An02) consistent with pure E1.
50.83 *15*	0.12 *2*	437.94	(5/2$^-$)	387.197	7/2$^-$	[M1]	24.7	α(L)=18.7 *3*; α(M)=4.49 *8* α(N)=1.192 *20*; α(O)=0.277 *5*; α(P)=0.0513 *9*; α(Q)=0.00456 *8* E_γ: unweighted average. Eγ=50.98 *5* (1970De19), 50.68 *6* (1979Te02). Iγ=0.12 *3* (1974De11, 0.09 *4* in 1970De19), 0.3 *1* (1979Te02).
52.71 *3*	4.65 *27*	126.845	9/2$^-$	74.147	7/2$^-$	[M1]	22.2	α(L)=16.82 *24*; α(M)=4.04 *6* α(N)=1.071 *16*; α(O)=0.249 *4*; α(P)=0.0461 *7*; α(Q)=0.00410 *6* Eγ=52.4 *5* (1969La04), 52.6 *2* (1970Le11), 52.74 *2* (1970De19), 52.66 *3* (1979Te02). Iγ=3.8 *14* (1970Le11), 4.41 *27* (1974De11, 5.4 *6* in 1970De19), 4.85 *34* (1979Te02), 5.4 *6* (1986BaYK).
54.60 *2*	4.25 *24*	84.539	7/2$^+$	29.975	5/2$^-$	[E1]	0.569	α(L)=0.429 *6*; α(M)=0.1052 *15* α(N)=0.0273 *4*; α(O)=0.00594 *9*; α(P)=0.000940 *14*; α(Q)=4.17×10^{-5} *6* Eγ=54.8 *5* (1969La04), 54.5 *2* (1970Le11), 54.61 *2* (1970De19), 54.56 *3* (1979Te02). Iγ=3.8 *14* (1970Le11), 4.12 *24* (1974De11, 5.1 *6* in 1970De19), 4.33 *35* (1979Te02), 4.44 *32* (1986BaYK).
[x]56.78 *4*	0.29 *4*							Eγ=56.76 *4* (1970De19), 56.79 *4* (1979Te02). Iγ=0.31 *5* (1974De11, 0.35 *7* in 1970De19), 0.27 *4* (1979Te02).
57.19[d] *3*	1.99[d] *13*	84.539	7/2$^+$	27.365	3/2$^+$	(E2)	148.0	α(L)=108.5 *16*; α(M)=29.6 *5* α(N)=7.87 *12*; α(O)=1.709 *25*; α(P)=0.266 *4*; α(Q)=0.000688 *10* I_γ: from intensity balance at 330 and 387 levels, Iγ=0.17 *3* is assigned from 387 level and main intensity of 1.99 *13* from the 84.5 level. Other: 1.58 *16* from 84 level and 0.96 *10* from 387 level (1979Te02).

$^{227}_{89}Ac_{138}$-8

γ(^{227}Ac) (continued)

E_γ [†]	I_γ [‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α[b]	Comments
								Eγ=57.0 *2* (1970Le11), 57.19 *3* (1970De19), 57.19 *3* (1979Te02) for the doublet. Iγ=1.9 *7* (1970Le11), 1.94 *13* (1974De11, 2.5 *3* in 1970De19), 2.54 *26* (1979Te02), 2.34 *15* (1986BaYK) for the doublet. Weighted averaged intensity of the doublet is 2.16 *13*.
57.19[d] *3*	0.17[d] *3*	387.197	7/2$^-$	330.037	3/2$^-$	(E2)	148.0	α(L)=108.5 *16*; α(M)=29.6 *5* α(N)=7.87 *12*; α(O)=1.709 *25*; α(P)=0.266 *4*; α(Q)=0.000688 *10* Mult.: from α(L)exp=105 *18* for the doublet (1970De19).
60.50 *3*	0.32 *4*	187.34	11/2$^+$	126.845	9/2$^-$	[E1]	0.433	α(L)=0.327 *5*; α(M)=0.0798 *12* α(N)=0.0208 *3*; α(O)=0.00454 *7*; α(P)=0.000726 *11*; α(Q)=3.35×10^{-5} *5* Eγ=59.4 *5* (1969La04), 60.2 *3* (1970Le11), 60.50 *3* (1970De19), 60.47 *8* (1979Te02). Iγ=0.19 *13* (1970Le11), 0.36 *4* (1974De11), 0.41 *7* (1970De19), 0.3 *1* (1979Te02), 0.29 *5* (1986BaYK).
63.64 *3*	2.70 *9*	109.989	9/2$^+$	46.349	5/2$^+$	E2	88.4	α(L)=64.8 *10*; α(M)=17.7 *3* α(N)=4.70 *7*; α(O)=1.023 *15*; α(P)=0.1592 *23*; α(Q)=0.000437 *7* Eγ=63.3 *5* (1969La04), 63.5 *2* (1970Le11), 63.67 *3* (1970De19), 63.60 *4* (1979Te02). Iγ=1.9 *7* (1970Le11), 2.82 *24* (1974De11, 3.2 *3* in 1970De19), 2.7 *3* (1979Te02), 2.70 *9* (1986BaYK). Mult.: from α(L)exp=76 *13* (1970De19).
[x]70.49 *5*	0.31 *5*							Eγ=70.50 *5* (1970De19), 70.45 *8* (1979Te02). Iγ=0.29 *6* (1974De11, 0.41 *7* in 1970De19), 0.6 *2* (1979Te02), 0.30 *5* (1986BaYK).
71.9 *1*	0.12 *4*	198.69	11/2$^-$	126.845	9/2$^-$	[M1]	8.96	α(L)=6.78 *10*; α(M)=1.626 *24* α(N)=0.432 *7*; α(O)=0.1004 *15*; α(P)=0.0186 *3*; α(Q)=0.001650 *24* Eγ=71.9 *1* (1970De19,1979Te02). Iγ=0.12 *4* (1974De11, 0.12 *6* in 1970De19), 0.1 *1* (1979Te02),
72.67 *6*	0.18 *4*	271.32	(13/2$^-$)	198.69	11/2$^-$	[M1]	8.68	α(L)=6.57 *10*; α(M)=1.577 *23* α(N)=0.418 *6*; α(O)=0.0973 *14*; α(P)=0.0180 *3*; α(Q)=0.001599 *23* Eγ=72.5 *1* (1970De19), 72.78 *8* (1979Te02). Iγ=0.18 *4* (1974De11, 0.24 *12* in 1970De19), 0.2 *1* (1979Te02).
74.15 *4*	1.35 *5*	74.147	7/2$^-$	0.0	3/2$^-$	[E2]	42.5	α(L)=31.2 *5*; α(M)=8.52 *13* α(N)=2.27 *4*; α(O)=0.493 *7*; α(P)=0.0768 *11*; α(Q)=0.000234 *4* Eγ=74.1 *3* (1970Le11), 74.18 *4* (1970De19), 74.08 *6* (1979Te02). Iγ=1.3 *6* (1970Le11), 1.41 *13* (1974De11, 1.6 *3* in 1970De19), 1.24 *20* (1979Te02), 1.35 *5* (1986BaYK).
77.34 *3*	3.47 *10*	187.34	11/2$^+$	109.989	9/2$^+$	[M1]	7.24	α(L)=5.48 *8*; α(M)=1.315 *19* α(N)=0.349 *5*; α(O)=0.0811 *12*; α(P)=0.01501 *21*; α(Q)=0.001334 *19* I_γ: nrm weighted average. Eγ=77.1 *5* (1969La04), 77.2 *2* (1970Le11), 77.36 *3* (1970De19), 77.30 *4* (1979Te02). Iγ=2.5 *7* (1970Le11), 3.53 *27* (1974De11, 4.3 *6* in 1970De19), 4.31 *20* (1979Te02), 3.45 *7* (1986BaYK).
[x]96.0[@a]								

$^{227}_{89}$Ac$_{138}$-9

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

$\gamma(^{227}Ac)$ (continued)

E_γ [†]	I_γ [‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α [b]	Comments
96.84 *3*	5.08 *13*	126.845	$9/2^-$	29.975	$5/2^-$	E2	12.04	α(L)=8.83 *13*; α(M)=2.41 *4* α(N)=0.642 *9*; α(O)=0.1399 *20*; α(P)=0.0219 *3*; α(Q)=8.55×10^{-5} *12* Eγ=96.7 *2* (1970Le11), 96.88 *3* (1970De19), 96.80 *3* (1979Te02). Iγ=4.1 *11* (1970Le11), 5.5 *5* (1974De11, 5.6 *7* in 1970De19), 5.62 *28* (1979Te02), 5.00 *7* (1986BaYK). Mult.: from α(L)exp=9.8 *16* (1970De19).
100.85 *6*	1.38 *5*	210.84	$13/2^+$	109.989	$9/2^+$	[E2]	9.96	α(L)=7.30 *11*; α(M)=2.00 *3* α(N)=0.531 *8*; α(O)=0.1157 *17*; α(P)=0.0181 *3*; α(Q)=7.42×10^{-5} *11* Eγ=100.5 *5* (1970Le11), 100.92 *4* (1970De19), 100.77 *4* (1979Te02). Iγ=0.75 *32* (1970Le11), 1.35 *13* (1974De11, 2.0 *3* in 1970De19), 1.66 *25* (1979Te02), 1.38 *4* (1986BaYK).
102.6 *5*	<0.8	187.34	$11/2^+$	84.539	$7/2^+$	[E2]	9.20 *25*	α(L)=6.74 *19*; α(M)=1.84 *5* α(N)=0.490 *14*; α(O)=0.107 *3*; α(P)=0.0167 *5*; α(Q)=6.99×10^{-5} *16* Iγ: intensity difficult to obtain since the line is strongly mixed with K-x rays. Values here are from 1979Te02. Eγ=102.5 *4* (1970Le11), ≈103 (1970De19), 102.6 *5* (1979Te02); also mixed with Ac x rays. Iγ=2.8 *10* (1970Le11), 1.35 *25* (1974De11, ≈1 in 1970De19), <0.8 (1979Te02), 0.9 *2* (1986BaYK); mixed with Ac x rays.
124.58 *8*	0.261 *24*	198.69	$11/2^-$	74.147	$7/2^-$	[E2]	4.04	α(K)=0.285 *4*; α(L)=2.75 *4*; α(M)=0.752 *11* α(N)=0.200 *3*; α(O)=0.0436 *7*; α(P)=0.00686 *10*; α(Q)=3.71×10^{-5} *6* Eγ=124.4 *5* (1970Le11), 124.6 *1* (1970De19), 124.56 *8* (1979Te02). Iγ=0.13 *7* (1970Le11), 0.29 *12* (1970De19), 0.29 *9* (1979Te02), 0.23 *13* (1982An02), 0.259 *24* (1986BaYK). Value from 1970Le11 is not included.
144.40 *8*	0.70 *6*	271.32	$(13/2^-)$	126.845	$9/2^-$	[E2]	2.18	α(K)=0.263 *4*; α(L)=1.408 *20*; α(M)=0.384 *6* α(N)=0.1023 *15*; α(O)=0.0223 *4*; α(P)=0.00353 *5*; α(Q)=2.38×10^{-5} *4* Eγ=144.4 *5* (1970Le11), 144.5 *1* (1970De19), 144.33 *8* (1979Te02). Iγ=0.25 *14* (1970Le11), 0.76 *25* (1970De19), 0.64 *30* (1979Te02), 0.70 *6* (1982An02), 0.69 *6* (1986BaYK). Value from 1970Le11 seems discrepant, and not included in averaging.
161.0[e] *10*		271.32	$(13/2^-)$	109.989	$9/2^+$	[M2]		Eγ: only from $\gamma\gamma$-coin (1979Te02). Evaluators treat this γ as questionable due to implied high multipolarity.
198.89 *10*	0.254 *24*	273.16	$(5/2)^-$	74.147	$7/2^-$	[M1+E2]	1.5 *9*	Eγ=198.7 *6* (1970Le11), 199 *1* (1970De19), 198.89 *10* (1979Te02). Iγ=0.06 *4* (1970Le11), 0.35 *13* (1970De19), 0.23 *10* (1979Te02), 0.28 *5* (1982An02), 0.246 *24* (1986BaYK). Value from 1970Le11 seems discrepant, and not included in averaging.
(219.90 *15*)	0.015	304.78	$(5/2^+)$	84.539	$7/2^+$	[M1+E2]	1.1 *7*	Eγ,Iγ: from Adopted Gammas.
(228.00 *10*)	0.019	501.16	$(3/2^-,5/2^-)$	273.16	$(5/2)^-$			Eγ,Iγ: from Adopted Gammas.
230.0[&] *10*	0.10[&] *5*	304.78	$(5/2^+)$	74.147	$7/2^-$			
(232.20 *10*)	0.048	537.3	$(3/2^+)$	304.78	$(5/2^+)$	[M1+E2]	1.0 *6*	Eγ,Iγ: from Adopted Gammas.

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

$\gamma(^{227}Ac)$ (continued)

E_γ[†]	I_γ[‡][c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	δ	α[b]	Comments
[x]242.18 *8*	0.57 *6*								I_γ: NRM weighted average. Eγ=242.2 *1* (1970De19), 242.16 *8* (1979Te02). Iγ=0.53 *7* (1970De19), 0.5 *2* (1979Te02), 0.44 *8* (1982An02), 0.70 *4* (1986BaYK).
243.08 *9*	2.04 *14*	273.16	(5/2)$^-$	29.975	5/2$^-$	M1+E2	1.1 *3*	0.80 *17*	α(K)=0.56 *16*; α(L)=0.176 *10*; α(M)=0.0445 *16* α(N)=0.0118 *5*; α(O)=0.00268 *12*; α(P)=0.00046 *3*; α(Q)=2.60×10^{-5} *70* I_γ: NRM weighted average. Eγ=243.0 *5* (1969La04), 242.9 *4* (1970Le11), 243.0 *1* (1970De19), 243.15 *9* (1979Te02). Iγ=5.7 (1969La04), 2.5 *7* (1970Le11), 2.18 *20* (1970De19), 2.97 *24* (1979Te02), 2.51 *43* (1982An02), 1.87 *4* (1986BaYK). Mult.,δ: from α(K)exp=0.57 *14* (1979Te02).
245.60 *13*	0.407 *32*	330.037	3/2$^-$	84.539	7/2$^+$	[M2]		5.23	α(K)=3.70 *6*; α(L)=1.141 *17*; α(M)=0.293 *5* α(N)=0.0787 *12*; α(O)=0.0182 *3*; α(P)=0.00331 *5*; α(Q)=0.000268 *4* Eγ=245.3 *5* (1970Le11), 245.4 *1* (1970De19), 245.77 *9* (1979Te02). Iγ=0.44 *14* (1970Le11), 0.47 *7* (1970De19), 0.48 *12* (1979Te02), 0.44 *8* (1982An02), 0.382 *32* (1986BaYK).
246.04 *9*	0.70 *20*	273.16	(5/2)$^-$	27.365	3/2$^+$	[E1]		0.0568	α(K)=0.0454 *7*; α(L)=0.00864 *13*; α(M)=0.00207 *3* α(N)=0.000544 *8*; α(O)=0.0001237 *18*; α(P)=2.18×10^{-5} *3*; α(Q)=1.515×10^{-6} *22* Eγ=246.0 *2* (1970De19), 246.05 *9* (1979Te02). Iγ= <0.06 (1970De19), 0.7 *2* (1979Te02), 0.70 *20* (1982An02).
255.78 *7*	6.42 *6*	330.037	3/2$^-$	74.147	7/2$^-$	E2		0.265	α(K)=0.0993 *14*; α(L)=0.1218 *18*; α(M)=0.0328 *5* α(N)=0.00872 *13*; α(O)=0.00192 *3*; α(P)=0.000310 *5*; α(Q)=5.37×10^{-6} *8* Eγ=256.1 *5* (1969La04), 255.9 *3* (1970Le11), 255.78 *7* (1970De19), 255.76 *8* (1979Te02). Iγ=6.3 (1969La04), 8.1 *16* (1970Le11), 6.4 *5* (1970De19), 6.34 *41* (1979Te02), 7.00 *48* (1982An02), 6.41 *6* (1986BaYK). Mult.: from α(K)exp=0.098 *10*, ce(K)/ce(L) exp=0.70 *26* (1979Te02).
258.44 *10*	0.142 *25*	304.78	(5/2$^+$)	46.349	5/2$^+$				Eγ=258.4 *1* (1970De19), 258.54 *15* (1979Te02). Iγ=0.15 *4* (1970De19), 0.15 *5* (1979Te02), 0.13 *4* (1982An02), 0.06 *2* (1986BaYK). Value from 1983Ba77 is not included in averaging.
260.19 *8*	11.01 *13*	387.197	7/2$^-$	126.845	9/2$^-$	M1+E2	1.5 *3*	0.53 *10*	α(K)=0.35 *9*; α(L)=0.131 *7*; α(M)=0.0338 *12* α(N)=0.0090 *3*; α(O)=0.00202 *8*; α(P)=0.000345 *19*; α(Q)=1.6×10^{-5} *4* Eγ=260.2 *5* (1969La04), 260.2 *3* (1970Le11), 260.14 *8* (1970De19), 260.23 *8* (1979Te02). Iγ=19 (1969La04), 11.3 *24* (1970Le11), 10.9 *7* (1970De19), 11.39 *57* (1979Te02), 11.03 *14* (1982An02), 10.97 *13* (1986BaYK). Mult.,δ: from α(K)exp=0.35 *7*, ce(K)/ce(L) exp=2.9 *12* (1979Te02).
273.15 *6*	3.50 *5*	273.16	(5/2)$^-$	0.0	3/2$^-$	M1+E2	0.7 *3*	0.74 *15*	α(K)=0.57 *14*; α(L)=0.131 *11*; α(M)=0.0323 *21* α(N)=0.0086 *6*; α(O)=0.00197 *15*; α(P)=0.00035 *4*; α(Q)=2.6×10^{-5} *6*

$^{227}_{89}Ac_{138}$-11

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

$\gamma(^{227}Ac)$ (continued)

E_γ [†]	I_γ [‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	δ	α [b]	Comments
277.22 *7*	4.12 *6*	387.197	7/2$^-$	109.989	9/2$^+$	(E1+M2)	0.40 *5*	0.52 *11*	Eγ=273.5 *5* (1969La04), 273.2 *3* (1970Le11), 273.08 *9* (1970De19), 273.15 *9* (1979Te02), 273.237 *117* (1979Bo30). Iγ=0.27 (1969La04), 4.4 *11* (1970Le11), 3.65 *22* (1970De19), 3.48 *24* (1979Te02), 3.48 *18* (1982An02), 3.50 *5* (1986BaYK). Mult.,δ: from α(K)exp=0.58 *8* (1979Te02). α(K)=0.37 *8*; α(L)=0.107 *23*; α(M)=0.027 *6* α(N)=0.0073 *16*; α(O)=0.0017 *4*; α(P)=0.00031 *7*; α(Q)=2.5×10^{-5} *6*
(277.39 *10*)	0.21	304.78	(5/2$^+$)	27.365	3/2$^+$				Eγ=277.7 *5* (1969La04), 277.2 *3* (1970Le11), 276.99 *9* (1970De19), 277.10 *9* (1979Te02), 277.322 *13* (1979Bo30). Iγ=0.065 (1969La04), 5.0 *11* (1970Le11), 4.24 *28* (1970De19), 3.88 *25* (1979Te02), 4.59 *58* (1982An02), 4.12 *6* (1986BaYK). Mult.,δ: from α(K)exp=0.37 *7* (1979Te02). δ(E2/M1)=1.2 *+3−2* is also consistent with α(K)exp; but ΔJ^π requires E1+M2. Eγ,Iγ: from Adopted Gammas.
283.682 *16*	100	330.037	3/2$^-$	46.349	5/2$^+$	E1		0.0410	α(K)=0.0329 *5*; α(L)=0.00614 *9*; α(M)=0.001468 *21* α(N)=0.000386 *6*; α(O)=8.81×10^{-5} *13*; α(P)=1.561×10^{-5} *22*; α(Q)=1.117×10^{-6} *16* Iγ: absolute Iγ=0.01649 *27* deduced from source strength (1986BaYK). Other: 0.0169 *8* (1970De19) is in agreement. Eγ=283.9 *5* (1969La04), 283.7 *3* (1970Le11), 283.56 *6* (1970De19), 283.65 *5* (1979Te02), 283.690 *13* (1979Bo30). Iγ=100.0 *8* in 1986BaYK. Mult.: from α(K)exp=0.04 *1*, ce(K)/ce(L)(exp)=5.7 *22* (1979Te02). δ: δ(Q/D)=−0.040 *+10−14* from $\gamma\gamma(\theta)$ (1982An02); uncertainty of 0.01 listed in the adopted value in table 5 of 1982An02 is a misprint. (284γ)[19γ](27γ)(θ): A_2=+0.034 *21*, A_4=+0.019 *21* or A_2=+0.025 *18* when A_4 is set to zero (1982An02). (284γ)(47γ)(θ): A_2=+0.051 *65*, A_4=+0.026 *68* or A_2=+0.056 *47* when A_4 is set to zero (1982An02). Anisotropy=0.2% *5* in $\gamma(\theta$,H,t) (1982An02).
[x]286.58 *10*	0.629 *30*								Eγ=286.55 *10* (1970De19), 286.60 *10* (1979Te02). Iγ=0.59 *6* (1970De19), 0.8 *3* (1979Te02), 0.68 *10* (1982An02), 0.632 *30* (1986BaYK).
300.066 *10*	146.1 *18*	330.037	3/2$^-$	29.975	5/2$^-$	M1+E2	−0.12 *7*	0.764 *17*	α(K)=0.613 *15*; α(L)=0.1146 *20*; α(M)=0.0275 *5* α(N)=0.00728 *12*; α(O)=0.00169 *3*; α(P)=0.000313 *6*; α(Q)=2.75×10^{-5} *7* Eγ=300.5 *5* (1969La04), 300.1 *2* (1970Le11), 299.94 *6* (1970De19), 300.02 *5* (1979Te02), 300.069 *8* (1979Bo30). Iγ=230 for 300.5+303.2 (1969La04), 144 *22* (1970Le11), 144 *10*

$^{227}_{89}Ac_{138}$-12

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

γ(^{227}Ac) (continued)

E_γ [†]	I_γ [‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	δ	α[b]	Comments
									(1970De19), 149.6 *75* (1979Te02), 143.2 *55* (1982An02), 146.3 *18* (1986BaYK). Mult.: from α(K)exp=0.34 *1* (1979Te02). δ: from γγ(θ) and γ(θ,H,t) (1982An02). Other: 1.0 *4* from α(K)exp (1979Te02). Mult.: from α(K)exp=0.34 *1* (1979Te02). If E1+M2, δ=−0.12 *7* gives α(K)(theory)=0.06 *4* in disagreement with measured value of 0.34 *11*. Anisotropy=0.3% *4* in γ(θ,H,t) (1982An02).
302.667[d] *9*	138[d] *20*	330.037	3/2−	27.365	3/2+	E1		0.0355	α(K)=0.0285 *4*; α(L)=0.00527 *8*; α(M)=0.001260 *18* α(N)=0.000331 *5*; α(O)=7.56×10^{-5} *11*; α(P)=1.344×10^{-5} *19*; α(Q)=9.74×10^{-7} *14* Iγ: split intensity ratio of 302.7 doublet based on 138 *20* from 302 level and 10.6 *26* from 387 level taken from 1982An02 which is consistent with the data in ^{227}Ra to ^{227}Ac decay. Eγ=303.2 *5* (1969La04), 302.7 *2* (1970Le11), 302.52 *6* (1970De19), 302.65 *5* (1979Te02), 302.669 *6* (1979Bo30). Iγ=230 for 300.5+302.6 (1969La04), 144 *22* (1970Le11), 148 *10* (1970De19, 294 *8* in 1974De11 for 300.1+302.7 doublet), 140 *11* (1979Te02), 149 *20* (1982An02), 149.6 *18* (1986BaYK) for 302.7 doublet. Weighted average for the 302.7 doublet is 149.3 *18*. 1979Te02 give split intensity of 100 *10* from 330 level and 40 *5* from 387 level; whereas 1982An02 give 138 *20* from 330 level and 10.6 *26* from 387 level. Mult.: from α(K)exp=0.037 *10* for the doublet (1979Te02). δ: δ(Q/D)=+0.20 *1* from γγ(θ), γγ(θ,H,t) (1982An02). (303γ)(27γ)(θ): A_2=+0.064 *13*, A_4=+0.003 *14* or A_2=+0.067 *12* when A_4 is set to zero (1982An02). Anisotropy=2.3% *4* in γ(θ,t) (1982An02).
302.667[d] *9*	10.6[d] *26*	387.197	7/2−	84.539	7/2+	E1		0.0355	α(K)=0.0285 *4*; α(L)=0.00527 *8*; α(M)=0.001260 *18* α(N)=0.000331 *5*; α(O)=7.56×10^{-5} *11*; α(P)=1.344×10^{-5} *19*; α(Q)=9.74×10^{-7} *14*
[x]310.0 *1*	0.056 *12*								Eγ=310.0 *1* (1970De19), 310.0 *5* (1979Te02). Iγ=0.09 *3* (1970De19), 0.07 *3* (1979Te02), 0.03 *2* (1982An02), 0.058 *12* (1986BaYK).
312.92 *5*	5.98 *7*	387.197	7/2−	74.147	7/2−	M1+E2	1.5 *+9−5*	0.31 *11*	α(K)=0.216 *94*; α(L)=0.070 *10*; α(M)=0.0178 *19* α(N)=0.0047 *5*; α(O)=0.00107 *13*; α(P)=0.00018 *3*; α(Q)=1.00×10^{-5} *42* Eγ=313.0 *5* (1969La04), 312.9 *3* (1970Le11), 312.88 *8* (1970De19), 312.94 *5* (1979Te02). Iγ=4.1 (1969La04), 6.9 *16* (1970Le11), 6.0 *5* (1970De19), 7.05 *56*

$^{227}_{89}Ac_{138}$-13

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

$\gamma(^{227}Ac)$ (continued)

E_γ [†]	I_γ [‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	δ	α [b]	Comments
									(1979Te02), 5.93 *17* (1982An02), 5.97 *7* (1986BaYK). Mult.,δ: from α(K)exp=0.22 *8*. Measured ce(K)/ce(L) exp=1.1 *5* (1979Te02) is not in good agreement with δ=1.5 *+9–5* which gives K/L(theory)=3.1 *14*.
[x]318.1 *7*	0.13 *8*								E_γ,I_γ: from 1970Le11.
327.14 *7*	2.18 *4*	354.50	1/2$^-$	27.365	3/2$^+$	(E1)		0.0298	α(K)=0.0240 *4*; α(L)=0.00440 *7*; α(M)=0.001050 *15* α(N)=0.000276 *4*; α(O)=6.32×10^{-5} *9*; α(P)=1.125×10^{-5} *16*; α(Q)=8.28×10^{-7} *12* Eγ=327.2 *4* (1970Le11), 327.02 *10* (1970De19), 327.26 *10* (1979Te02), 327.130 *188* (1979Bo30). Iγ=2.5 *13* (1970Le11), 1.88 *14* (1970De19), 2.27 *28* (1979Te02), 2.19 *44* (1982An02), 2.22 *4* (1986BaYK).
330.055 *15*	82.3 *10*	330.037	3/2$^-$	0.0	3/2$^-$	M1+E2	+0.36 *7*	0.540 *21*	α(K)=0.430 *19*; α(L)=0.0836 *22*; α(M)=0.0202 *5* α(N)=0.00535 *13*; α(O)=0.00124 *3*; α(P)=0.000228 *6*; α(Q)=1.93×10^{-5} *8* Eγ=330.2 *5* (1969La04), 330.0 *2* (1970Le11), 329.89 *6* (1970De19), 330.06 *5* (1979Te02), 330.057 *15* (1979Bo30). Uncertainty was doubled to 0.12 keV in the averaging procedure. Iγ=34 (1969La04), 81 *16* (1970Le11), 82.4 *40* (1974De11, 82.4 *48* in 1970De19), 81.9 *65* (1979Te02), 82.1 *12* (1982An02), 82.4 *10* (1986BaYK). Mult.: from α(K)exp=0.28 *7*, K/L(exp)=5.3 *24*. Other values: α(K)exp=0.41 *5*, K/L1(exp)=3.85 *38* (1968Ha22). δ: from $\gamma\gamma(\theta)$ (1982An02). Other: 0.66 *22* from ce data, but not using K/L1 ratio from 1968Ha22. Anisotropy=2.8% *6* in $\gamma(\theta$,H,t) (1982An02).
340.71 *6*	10.72 *13*	387.197	7/2$^-$	46.349	5/2$^+$	E1+M2	0.23 *4*	0.115 *31*	α(K)=0.086 *23*; α(L)=0.0215 *62*; α(M)=0.0054 *16* α(N)=0.00144 *42*; α(O)=3.32×10^{-4} *97*; α(P)=6.0×10^{-5} *18*; α(Q)=4.9×10^{-6} *15* Eγ=341.0 *5* (1969La04), 340.8 *2* (1970Le11), 340.61 *7* (1970De19), 340.77 *6* (1979Te02). Iγ=3.7 (1969La04), 10.0 *28* (1970Le11), 10.5 *7* (1970De19), 10.9 *13* (1979Te02), 10.62 *16* (1982An02), 10.80 *13* (1986BaYK). Mult.,δ: from α(K)exp=0.084 *20* (1979Te02). Measured ce(K)/ce(L) exp=0.76 *30* is inconsistent with δ=0.23 *4* which gives K/L(theory)=4.0 *16*.
351.5 *1*	0.23 *7*	425.60	5/2$^+$	74.147	7/2$^-$	[E1]		0.0255	α(K)=0.0206 *3*; α(L)=0.00373 *6*; α(M)=0.000890 *13* α(N)=0.000234 *4*; α(O)=5.36×10^{-5} *8*; α(P)=9.57×10^{-6} *14*; α(Q)=7.14×10^{-7} *10* I_γ: unweighted average.

$^{227}_{89}Ac_{138}$-14

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

$\gamma(^{227}Ac)$ (continued)

E_γ[†]	I_γ[‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	δ	α[b]	Comments
354.48 *5*	5.83 *8*	354.50	1/2$^-$	0.0	3/2$^-$	M1+E2	2.8 *+14−6*	0.143 *24*	Eγ=351.4 *1* (1970De19), 351.6 *1* (1979Te02). Iγ=0.22 *3* (1970De19), 0.15 *6* (1979Te02), 0.44 *7* (1982An02), 0.102 *4* (1986BaYK). Discrepant data. α(K)=0.090 *21*; α(L)=0.0391 *24*; α(M)=0.0101 *5* α(N)=0.00269 *14*; α(O)=0.00060 *4*; α(P)=0.000102 *7*; α(Q)=4.2×10^{-6} *9*
357.11 *8*	10.16 *12*	387.197	7/2$^-$	29.975	5/2$^-$	M1(+E2)	<0.8	0.40 *8*	Eγ=354.6 *2* (1970Le11), 354.38 *8* (1970De19), 354.57 *8* (1979Te02), 354.474 *75* (1979Bo30). Iγ=6.00 *42* (1970Le11), 6.3 *15* (1970De19), 5.07 *56* (1979Te02), 5.92 *16* (1982An02), 5.81 *8* (1986BaYK). Mult.,δ: from α(K)exp=0.09 *2* (1979Te02). α(K)=0.32 *7*; α(L)=0.064 *8*; α(M)=0.0155 *16* α(N)=0.0041 *5*; α(O)=0.00095 *11*; α(P)=0.000174 *21*; α(Q)=1.4×10^{-5} *3*
359.33 *15*	0.511 *15*	469.26	9/2$^+$	109.989	9/2$^+$	[M1+E2]		0.28 *19*	Eγ=356.6 *5* (1969La04), 357.2 *2* (1970Le11), 356.96 *7* (1970De19), 357.21 *6* (1979Te02). Iγ=9.4 *22* (1970Le11), 10.9 *7* (1970De19), 9.67 *82* (1979Te02), 10.35 *46* (1982An02), 10.14 *12* (1986BaYK). Mult.,δ: from α(K)exp=0.36 *10* (1979Te02). Eγ: NRM weighted average.
363.84 *10*	0.483 *13*	437.94	(5/2$^-$)	74.147	7/2$^-$	[M1+E2]		0.27 *19*	Eγ=358.6 *4* (1970Le11), 359.25 *10* (1970De19), 359.57 *10* (1979Te02). Iγ=0.38 *21* (1970Le11), 0.57 *6* (1970De19), 0.41 *18* (1979Te02), 0.42 *8* (1982An02), 0.512 *15* (1986BaYK). Eγ=364.2 *5* (1969La04), 363.9 *4* (1970Le11), 363.74 *10* (1970De19), 363.93 *10* (1979Te02). Iγ=0.38 *21* (1970Le11), 0.47 *5* (1970De19), 0.42 *15* (1979Te02), 0.45 *5* (1982An02), 0.488 *14* (1986BaYK).
[x]374.96 *10*	0.269 *15*								Eγ=374.9 *4* (1970Le11), 374.9 *1* (1970De19), 375.01 *10* (1979Te02). Iγ=0.19 *7* (1970Le11), 0.29 *3* (1970De19), 0.24 *10* (1979Te02), 0.21 *3* (1982An02), 0.282 *15* (1986BaYK).
379.35 *7*	3.01 *5*	425.60	5/2$^+$	46.349	5/2$^+$	M1(+E2)	<1.1	0.32 *9*	α(K)=0.250 *78*; α(L)=0.051 *10*; α(M)=0.0125 *20* α(N)=0.0033 *6*; α(O)=0.00076 *13*; α(P)=0.00014 *3*; α(Q)=1.12×10^{-5} *34* Eγ: NRM weighted average. Eγ=379.5 *5* (1969La04), 379.2 *3* (1970Le11), 379.09 *8* (1970De19), 379.41 *6* (1979Te02). Iγ=0.65 (1969La04), 2.5 *10* (1970Le11), 3.12 *26* (1970De19), 2.89 *23* (1979Te02), 2.96 *10* (1982An02), 3.03 *5* (1986BaYK). Mult.,δ: from α(K)exp=0.27 *10*; measured ce(K)/ce(L) exp=4.6 *24* (1979Te02).

$^{227}_{89}Ac_{138}$-15

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

γ(^{227}Ac) (continued)

E_γ [†]	I_γ [‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	δ	α [b]	Comments
384.7 *1*	0.221 *12*	469.26	9/2$^+$	84.539	7/2$^+$	[M1+E2]		0.24 *16*	Eγ=384.8 *3* (1970Le11), 384.7 *1* (1970De19), 384.7 *1* (1979Te02). Iγ=0.13 *7* (1970Le11), 0.259 *26* (1970De19), 0.18 *4* (1979Te02), 0.18 *5* (1982An02), 0.221 *12* (1986BaYK).
387.0 *1*	0.018 *6*	387.197	7/2$^-$	0.0	3/2$^-$	[E2]		0.0774	α(K)=0.0430 *6*; α(L)=0.0254 *4*; α(M)=0.00669 *10* α(N)=0.001778 *25*; α(O)=0.000396 *6*; α(P)=6.58×10^{-5} *10*; α(Q)=2.09×10^{-6} *3* Eγ: from 1970De19. Iγ=0.029 *12* (1970De19), 0.01 *1* (1982An02), 0.018 *6* (1986BaYK).
391.61 *9*	0.408 *12*	437.94	(5/2$^-$)	46.349	5/2$^+$	[E1]		0.0202	α(K)=0.01636 *23*; α(L)=0.00293 *5*; α(M)=0.000697 *10* α(N)=0.000184 *3*; α(O)=4.21×10^{-5} *6*; α(P)=7.54×10^{-6} *11*; α(Q)=5.74×10^{-7} *8* Eγ=392.5 *5* (1969La04), 391.7 *3* (1970Le11), 391.5 *1* (1970De19), 391.67 *9* (1979Te02). Iγ=0.70 (1969La04), 0.31 *13* (1970Le11), 0.43 *5* (1970De19), 0.52 *8* (1979Te02), 0.35 *5* (1982An02), 0.408 *12* (1986BaYK).
395.50 *10*	0.141 *10*	425.60	5/2$^+$	29.975	5/2$^-$	[E1]		0.0198	α(K)=0.01602 *23*; α(L)=0.00287 *4*; α(M)=0.000682 *10* α(N)=0.000180 *3*; α(O)=4.12×10^{-5} *6*; α(P)=7.38×10^{-6} *11*; α(Q)=5.62×10^{-7} *8* Eγ=395.7 *4* (1970Le11), 395.5 *1* (1970De19), 395.49 *10* (1979Te02). Iγ=0.06 *3* (1970Le11), 0.165 *19* (1970De19), 0.11 *2* (1979Te02), 0.12 *2* (1982An02), 0.148 *11* (1986BaYK). Value from 1970Le11 not used in averaging.
398.14 *8*	0.571 *15*	425.60	5/2$^+$	27.365	3/2$^+$				Eγ=398.4 *5* (1969La04), 398.1 *3* (1970Le11), 398.10 *8* (1970De19), 398.19 *9* (1979Te02). Iγ=0.075 (1969La04), 0.44 *20* (1970Le11), 0.59 *6* (1970De19), 0.49 *9* (1979Te02), 0.49 *12* (1982An02), 0.574 *15* (1986BaYK).
407.806 *28*	2.154 *30*	435.16	1/2$^+$	27.365	3/2$^+$	M1		0.334	α(K)=0.269 *4*; α(L)=0.0496 *7*; α(M)=0.01187 *17* α(N)=0.00315 *5*; α(O)=0.000732 *11*; α(P)=0.0001354 *19*; α(Q)=1.200×10^{-5} *17* Eγ=408.1 *5* (1969La04), 407.7 *3* (1970Le11), 407.71 *6* (1970De19), 407.80 *5* (1979Te02), 407.829 *28* (1979Bo30). Iγ=0.34 for 408.1+410.5 (1969La04), 1.3 *7* (1970Le11), 2.29 *20* (1970De19), 2.13 *18* (1979Te02), 2.07 *16* (1982An02), 2.156 *30* (1986BaYK). Mult.: from α(K)exp=0.4 *1*; measured ce(K)/ce(L) exp=7.5 *23* (1979Te02); deduced δ(E2/M1)=0.0 *4*.
410.30 *12*	0.109 *13*	437.94	(5/2$^-$)	27.365	3/2$^+$	[E1]		0.0183	α(K)=0.01484 *21*; α(L)=0.00264 *4*; α(M)=0.000629 *9* α(N)=0.0001656 *24*; α(O)=3.80×10^{-5} *6*; α(P)=6.81×10^{-6} *10*; α(Q)=5.22×10^{-7} *8* Eγ=410.5 *5* (1969La04), 410.3 *10* (1970Le11), 410.5 *1* (1970De19), 410.1 *1* (1979Te02).

$^{227}_{89}Ac_{138}$-16

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

$\gamma(^{227}Ac)$ (continued)

E_γ [†]	I_γ [‡c]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α [b]	Comments
								Iγ=0.06 *3* (1970Le11), 0.118 *12* (1970De19), 0.19 *4* (1979Te02), 0.21 *6* (1982An02), 0.099 *11* (1986BaYK).
427.0[&] *1*	0.04[&] *2*	501.16	(3/2⁻,5/2⁻)	74.147	7/2⁻			
435.0 *1*	0.177 *10*	435.16	1/2⁺	0.0	3/2⁻			Eγ=434.9 *8* (1970Le11), 435.1 *1* (1970De19), 435.0 *1* (1979Te02). Iγ=0.13 *6* (1970Le11), 0.212 *25* (1970De19), 0.12 *3* (1979Te02), 0.18 *1* (1982An02), 0.177 *10* (1986BaYK).
438.01 *9*	0.274 *16*	437.94	(5/2⁻)	0.0	3/2⁻	[M1+E2]	0.17 *11*	Eγ=437.9 *5* (1969La04), 437.9 *8* (1970Le11), 437.9 *1* (1970De19), 438.10 *9* (1979Te02). Iγ=0.048 (1969La04), 0.25 *14* (1970Le11), 0.259 *26* (1970De19), 0.20 *6* (1979Te02), 0.28 *3* (1982An02), 0.283 *16* (1986BaYK).
[x]438.7 *1*	0.08 *2*							Eγ=438.7 *1* (1970De19), 438.8 *2* (1979Te02). Iγ=0.094 *25* (1970De19), 0.07 *2* (1979Te02).
(471.3 *5*)	0.012	501.16	(3/2⁻,5/2⁻)	29.975	5/2⁻			E_γ,I_γ: from Adopted Gammas.
(478.4 *4*)	0.0071	560.98	(3/2⁺,5/2)	84.539	7/2⁺			E_γ,I_γ: from Adopted Gammas.
486.827 *23*	0.094 *9*	560.98	(3/2⁺,5/2)	74.147	7/2⁻			Eγ=487.2 *5* (1969La04), 486.6 *10* (1970Le11), 486.7 *3* (1970De19), 486.8 *10* (1979Te02), 486.827 *23* (1979Bo30). Iγ=0.063 *31* (1970Le11), 0.112 *24* (1970De19), 0.15 *5* (1979Te02), 0.10 (1982An02), 0.091 *9* (1986BaYK). Other: <0.02 (1969La04).
491.0 *6*	0.024 *6*	537.3	(3/2⁺)	46.349	5/2⁺			Eγ=491 *2* (1970Le11), 491.0 *6* (1970De19), 491.0 *10* (1979Te02). Iγ=0.006 (1970Le11), 0.029 (1970De19), <0.04 (1979Te02), 0.04 *2* (1982An02), 0.023 *6* (1986BaYK).
501.4 *5*	0.047 *11*	501.16	(3/2⁻,5/2⁻)	0.0	3/2⁻			Eγ=501 *1* (1970Le11), 501.6 *5* (1970De19), 501.0 *10* (1979Te02). Iγ=0.013 (1970Le11), 0.035 *13* (1970De19), 0.05 *2* (1979Te02), 0.07 *7* (1982An02), 0.053 *11* (1986BaYK).
509.7 *10*	0.056 *24*	537.3	(3/2⁺)	27.365	3/2⁺			Eγ=512.2 *5* (1969La04), 510 *1* (1970Le11), 509 *1* (1970De19), 510.0 *10* (1979Te02). Value from 1969La04 is not used in averaging. Iγ=0.031 (1970Le11), 0.018 *7* (1970De19), 0.05 *2* (1979Te02), 0.10 *4* (1982An02). Other: <0.02 (1969La04).
516.2 *5*	0.083 *9*	560.98	(3/2⁺,5/2)	46.349	5/2⁺			E_γ: poor fit. level-energy difference=514.6; Eγ not used in the fitting procedure. Eγ=516.2 *5* (1969La04), 516 *1* (1970Le11), 516.2 *6* (1970De19), 516.1 *10* (1979Te02). Iγ=0.050 (1970Le11), 0.082 *20* (1970De19), 0.06 *2* (1979Te02), 0.06 *2* (1982An02), 0.093 *9* (1986BaYK). Other: <0.02 (1969La04).
535.6 *7*	0.037 *7*	560.98	(3/2⁺,5/2)	27.365	3/2⁺			Eγ=535 *1* (1970Le11), 535.3 *7* (1970De19), 536.6 *10* (1979Te02). 1986BaYK give two γ rays near this energy: 535.3 with Iγ=0.038 *7* and 536.00 with Iγ=0.020 *7*, the latter is questionable. Iγ=0.031 (1970Le11), 0.029 *13* (1970De19), 0.05 *2* (1979Te02), 0.04 *2* (1982An02), 0.038 *7* for 535.3γ (1986BaYK).
546.5 *7*	0.050 *8*	656.3	(7/2⁺)	109.989	9/2⁺			Eγ=546 *1* (1970Le11), 546.6 *7* (1970De19), 546.6 *10* (1979Te02). Iγ=0.025 (1970Le11), 0.035 *13* (1970De19), 0.04 *2* (1979Te02), 0.06 *2* (1982An02), 0.056 *8* (1986BaYK).

$^{227}_{89}Ac_{138}$-17

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42 (continued)

$\gamma(^{227}Ac)$ (continued)

E_γ [†]	I_γ [‡ c]	E_i(level)	J_i^π	E_f	J_f^π	Comments
571.6 *8*	0.030 *13*	656.3	$(7/2^+)$	84.539	$7/2^+$	Eγ=571 *2* (1970Le11), 572.1 *8* (1970De19), 571.0 *10* (1979Te02). Iγ=0.019 (1970Le11), 0.029 *13* (1970De19), 0.04 *2* (1979Te02), 0.02 *2* (1982An02).
583 *2*	0.26 *1*	656.3	$(7/2^+)$	74.147	$7/2^-$	Eγ from 1970Le11, Iγ from 1982An03. Other: Iγ=0.019 (1970Le11).
609 *2*	0.43 *2*	656.3	$(7/2^+)$	46.349	$5/2^+$	Eγ from 1970Le11, Iγ from 1982An03. Other: Iγ=0.031 (1970Le11).

† Weighted average from 1979Te02, 1979Bo30, 1970De19, 1970Le11 (also 1971Le10), and 1969La04 unless otherwise specified. Others: 1969Ba20, 1963Ab04, 1961Ba42, 1960As02.

‡ Weighted averages from 1986BaYK (see also 1983Ba77,1986LoZT), 1982An02, 1979Te02, 1970De19 (also 1974De11), and 1970Le11 (also 1971Le10), unless otherwise specified. All values are relative to 100 for 283.7γ. Note that values listed in the above mentioned papers were normalized as follows: to 1000 for 27.36γ and to 170 *6* for 283.7γ in 1974De11 (169 *8* in 1970De19); per 100 α and to 1.6 *2* for 283.7γ in 1970Le11; to 100 for 283.7γ in 1979Te02, 1982An02, and 1983Ba77.

From I(γ+ce)(19γ)/I(γ+ce)(16γ)=18 *5* (1974De11) and γ-ray transition intensity balance at 46 level.

@ From 1961Ba42.

& From 1979Te02.

a Uncertain γ ray.

b From BrIcc v2.3b (16-Dec-2014) 2008Ki07, "Frozen Orbitals" appr.

c For absolute intensity per 100 decays, multiply by 0.01649 *27*.

d Multiply placed with intensity suitably divided.

e Placement of transition in the level scheme is uncertain.

x γ ray not placed in level scheme.

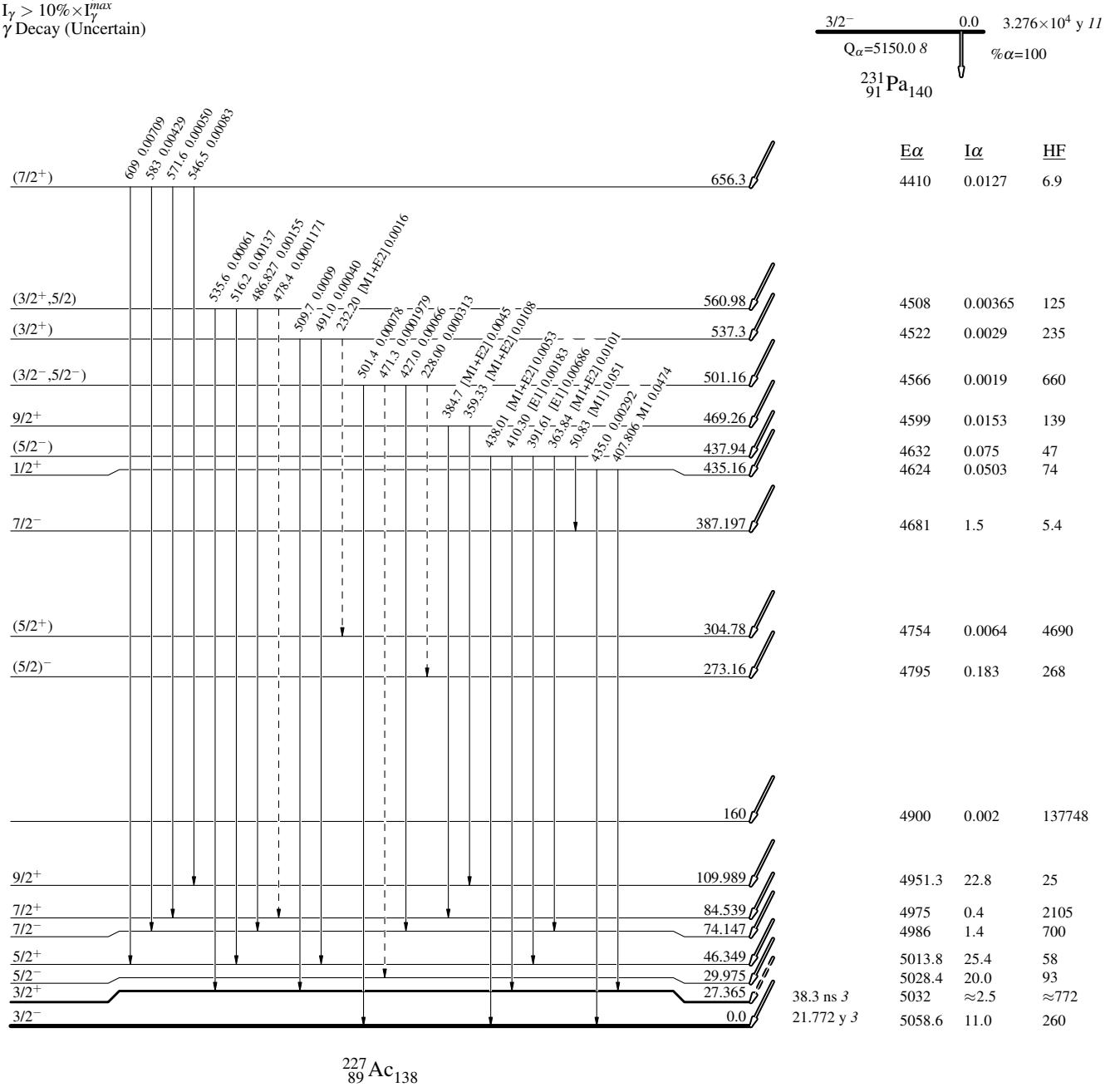
$^{227}_{89}Ac_{138}$-18

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42

Decay Scheme

Intensities: $I_{(\gamma+ce)}$ per 100 parent decays

Legend
- $I_\gamma < 2\% \times I_\gamma^{max}$
- $I_\gamma < 10\% \times I_\gamma^{max}$
- $I_\gamma > 10\% \times I_\gamma^{max}$
- γ Decay (Uncertain)



	Eα	Iα	HF
656.3	4410	0.0127	6.9
560.98	4508	0.00365	125
537.3	4522	0.0029	235
501.16	4566	0.0019	660
469.26	4599	0.0153	139
437.94	4632	0.075	47
435.16	4624	0.0503	74
387.197	4681	1.5	5.4
304.78	4754	0.0064	4690
273.16	4795	0.183	268
160	4900	0.002	137748
109.989	4951.3	22.8	25
84.539	4975	0.4	2105
74.147	4986	1.4	700
46.349	5013.8	25.4	58
29.975	5028.4	20.0	93
27.365	5032	≈2.5	≈772
0.0	5058.6	11.0	260

$^{227}_{89}Ac_{138}$

^{231}Pa α decay (3.276×10^4 y) 1986BaYK,1979Te02,1961Ba42

Decay Scheme (continued)

Intensities: $I_{(\gamma+ce)}$ per 100 parent decays
@ Multiply placed: intensity suitably divided

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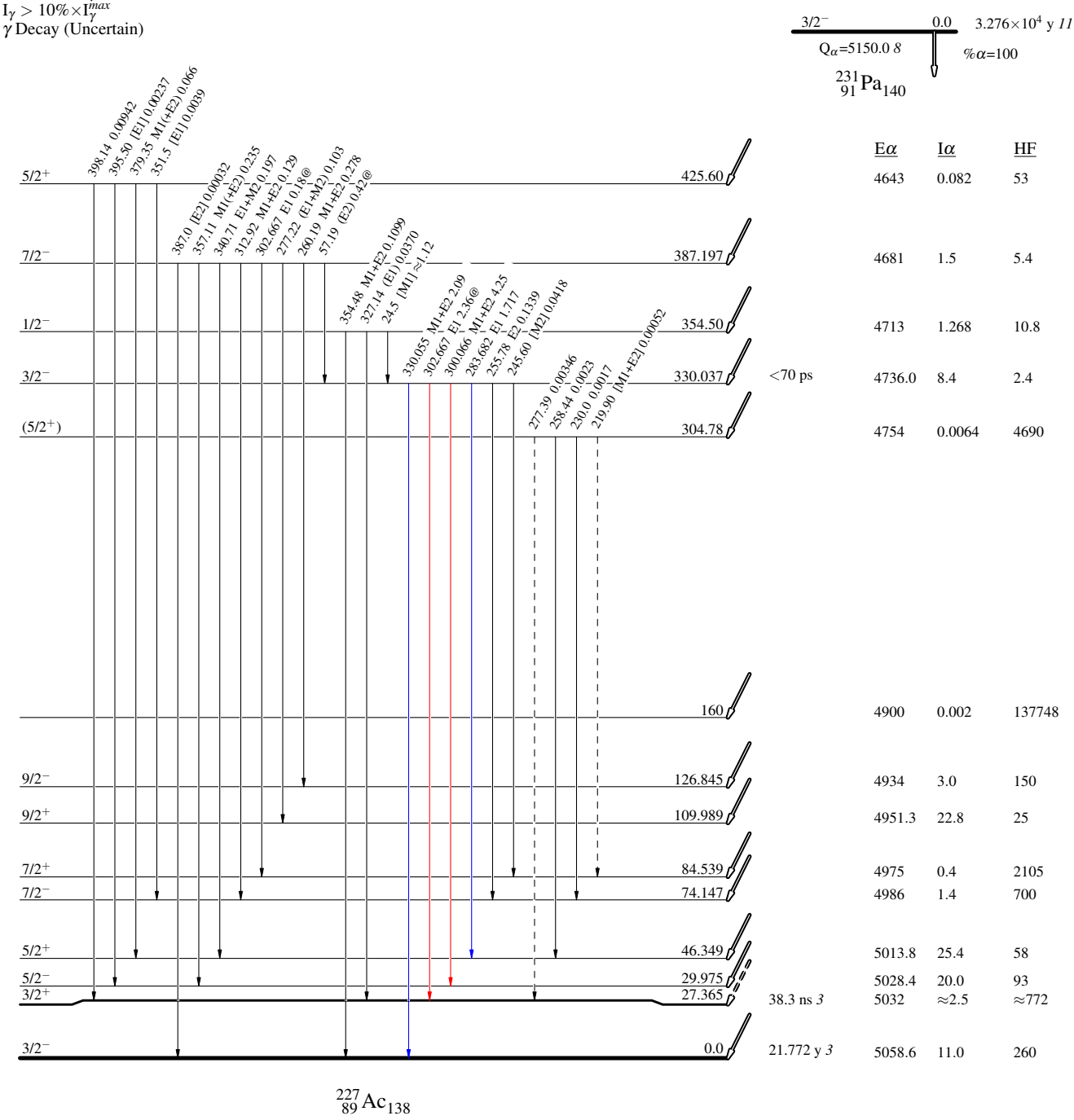

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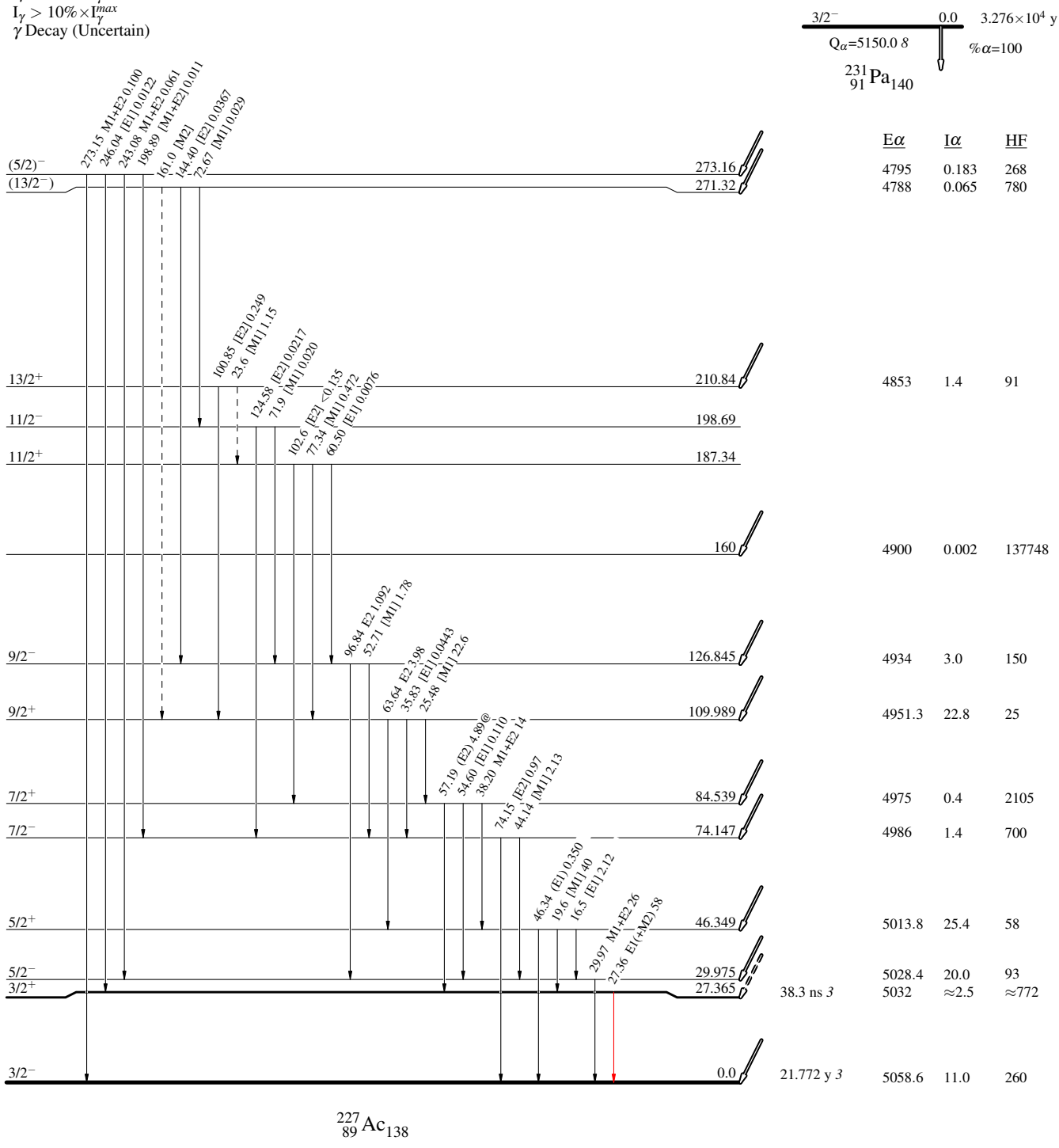

$^{227}_{89}Ac_{138}$