^{231}Th β^- decay (25.57 h) 1999Ch12,1975Ho14,1973Br12

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh, Jagdish K. Tuli, and Edgardo Browne	NDS 185, 560 (2022)	31-Aug-2022

Parent: ^{231}Th: E=0.0; J$^\pi$=5/2$^+$; $T_{1/2}$=25.57 h *8*; Q(β^-)=391.5 *15*; %β^- decay=100.0
^{231}Th-J$^\pi$,$T_{1/2}$: From ^{231}Th Adopted Levels, Gammas.
^{231}Th-Q(β^-): From 2021Wa16.
1999Ch12 (also 1992Ch23): measured relative γ-intensities of 52 γ rays, including absolute intensity of 84-keV γ ray.
1977Ba72: measured Eγ and Iγ for 52 γ rays; Ge, Ge(Li) detectors.
1975Ho14: measured Eγ, Iγ, $\gamma\gamma$-coin, x rays, ce, level half-lives by γ(ce)(t), Eβ, (217.9γ)(102.3γ)(θ) using Ge(Li) and NaI(Tl) detectors for γ and x rays. The conversion electrons were detected using Aarhus six-gap β-ray spectrometer, and with a Si(Li) detector in a zero-dispersion magnetic β-ray spectrometer. The β spectrum was measured using the Swierk zero-dispersion β-ray spectrometer. Total of 45 γ rays were reported. Conversion coefficients were measured for 14 γ rays up to 301 keV. Authors give absolute (per 100 decays of the parent) values for the intensities of γ rays and conversion electrons from the given decay scheme and associated intensity balances, by assigning Iβ(to g.s. and 9.2 level)=0.022% *7*.
1973Br12 (also 1970BrZX, 1969Br12): measured Eγ and Iγ for 41 γ rays, and $\gamma\gamma$-coin.
Other measurements for selected γ rays:
2017Le03: measured absolute and relative intensities of nine γ rays, and K- and L-x rays by first measuring source activity by α-counting method. Values compared with those in the DDEP evaluation (2010BeZQ). Corrected relative-intensity data received March 5, 2021 from the first author of 2017Le03 (from M.-C. Lépy as a private communication, as the evaluators enquired about some issues with the published values).
1984He12: measured Eγ values for 25.5 and 84.2 γ rays, and %Iγ for the 84.2γ.
1982Va04: measured absolute intensities of 25.5 and 84.2 γ rays.
1975Va11: measured energies and intensities of x rays and 25.65γ.
1973Te06: measured Eγ and Iγ for ten γ rays.
1971Ko48: measured relative γ-ray intensities for 11 γ rays.
1969To07: measured (89.9γ+93.0γ)(ce 84.2γ)(θ).
1967Ba69, 1966Ca18, 1966Gi02, 1966TrZZ: measured ce for 25.6, 58.5 and 84.2 γ rays.
1966CaZZ: measured Eβ, Iβ, ce.
1966PeZZ: measured Eγ, Iγ.
1961Ho29, 1957Ho07: data from private communications from J.M. Hollander listed in 1978LeZA.
1960Ba57: measured Eβ, Eγ, Iγ, $\gamma\gamma$-coin, ce.
1960As02: measured %Iγ and ce for 25.6 and 84.2 transitions.
1957Ju30: measured Eβ, Iβ.
1956Ph61: measured Eγ of 25.6-keV transition, half-life of ^{231}Th decay, production σ in ^{232}Th(n,2n),E(n)=14 MeV reaction.
1953Fr37: measured Eβ, Iβ, Eγ, Iγ.
Other Eβ, Iβ, and ce measurements: 1963Na06, 1956Mi25, 1951St41, 1951Ja17, 1949Kn09.
Evaluators′ note about the decay scheme: spectral information for a few low-energy transitions (9.18, 17.19, 44.08, 53.2 keV) is limited and makes the decay scheme somewhat incomplete in that respect.

^{231}Pa Levels

E(level)[†]	J$^\pi$[‡]	$T_{1/2}$[#]	Comments
0.0[@]	3/2$^-$	32570 y *130*	$T_{1/2}$: from the Adopted Levels.
9.21[@] *3*	1/2$^-$		
58.570[@] *3*	7/2$^-$	274 ps *10*	$T_{1/2}$: measured by 1975Ho14 from (25.6γ)(ce(L) for 58.6γ)(t).
77.694[@] *17*	5/2$^-$		
84.2153[&] *20*	5/2$^+$	45.1 ns *13*	$T_{1/2}$: from 1975Ho14 (β(84γ ce)(t)). Others: 43.7 ns *5* (1972Mc29, a time interval distribution method); 41 ns *4* (1955St88, (25.6γ)β(t) and (84.2γ)β(t)). There could be an unobserved 6.5-keV γ from the 5/2$^+$, 84.2 level to the 77.7 level. See discussion in 1973Br12 about intensity estimate for such a transition. Calculated wave function amplitudes (1975Ho14): 0.786 π3/2[651], 0.598 π5/2[642].

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^{231}Th β^- decay (25.57 h) 1999Ch12,1975Ho14,1973Br12 (continued)

^{231}Pa Levels (continued)

E(level)[†]	Jπ[‡]	$T_{1/2}$[#]	Comments
101.408[&] *4*	7/2+	0.7 ns *2*	$T_{1/2}$: combined half-life for 101.4+102.3 levels, measured by 1975Ho14 from (ce(M) for 81.2γ+82.1γ)(ce for 25.6γ+18.1γ+17.2γ)(t). Calculated wave function amplitudes (1975Ho14): 0.753 π3/2[651], 0.647 π5/2[642].
102.2685[&] *21*	3/2+	0.7 ns *2*	$T_{1/2}$: combined half-life for 101.4+102.3 levels, measured by 1975Ho14 from (ce(M) for 81.2γ+82.1γ)(ce for 25.6γ+18.1γ+17.2γ)(t). Calculated wave function amplitude (1975Ho14): 0.996 π3/2[651].
111.648[&] *12*	(9/2+)		Calculated wave function amplitudes (1975Ho14): 0.753 π3/2[651], 0.600 π5/2[642].
174.160 *5*	(5/2−)		Proposed configuration=π5/2[523] (1975Ho14).
183.4955[a] *25*	5/2+	≤0.19 ns	$T_{1/2}$: measured by 1975Ho14 from β(ce(M) for 81.2γ+82.1γ)(t). Calculated wave function amplitude (1975Ho14): 0.801 π5/2[642].
218.244 *13*	(7/2−)		
247.320[a] *6*	7/2+		Calculated wave function amplitude (1975Ho14): 0.758 π5/2[642].
317.95 *4*	(3/2+)	0.07 ns +*11*−*3*	$T_{1/2}$: from the Adopted Levels, where it was deduced from Coulomb excitation data.
320.211 *20*	3/2−		Jπ: 3/2 based on γγ(θ), A_2=+0.27 *7* (1975Ho14). Proposed configuration=π3/2[532] or π3/2[521] (1975Ho14).
351.86 *4*	(5/2−)		

† Deduced from least-squares fit to Eγ values.
‡ From the Adopted Levels.
\# For excited states, values are from 1975Ho14 in delayed coincidence experiments as detailed in comments. The same values are given in the Adopted Levels.
@ Proposed member of configuration=π1/2[530] (1973Br12).
& Proposed member of dominant configuration=π3/2[651] (1973Br12).
a Proposed member of dominant configuration=π5/2[642] (1973Br12).

β^- radiations

E(decay)	E(level)	Iβ−[†‡]	Log *ft*	Comments
(39.6 *15*)	351.86	0.0033 *2*	7.31 *6*	av Eβ=10.03 *41*
(71.3 *15*)	320.211	0.067 *2*	6.78 *3*	av Eβ=18.29 *40*
(73.5 *15*)	317.95	0.00088 *7*	8.70 *5*	av Eβ=18.89 *40*
(144.2 *15*)	247.320	2.9 *5*	6.1 *1*	av Eβ=38.05 *42*
(173.3 *15*)	218.244	0.34 *24*	7.3 *3*	av Eβ=46.20 *44*
(208.0 *15*)	183.4955	11.4 *6*	6.0 *3*	av Eβ=56.12 *44*
(217.3 *15*)	174.160	1.35 *24*	7.0 *1*	av Eβ=58.82 *44*
(289.2 *15*)	102.2685	14 *8*	6.3 *3*	av Eβ=80.08 *46*
(290.1 *15*)	101.408	42 *16*	5.9 *2*	av Eβ=80.34 *46*
305 *2*	84.2153	25 *18*	6.2 *4*	av Eβ=85.54 *46*
(313.8 *15*)	77.694	0.53 *8*	7.9 *1*	av Eβ=87.52 *46* If a 6.5-keV γ from the 5/2+, 84.2 level to the 77.7 level exists, it would decrease the β feeding. See discussion in 1973Br12 about intensity estimate for such a transition.
(332.9[#] *15*)	58.570	<0.33	>8.2	av Eβ=93.37 *47* Iβ−: determined from β− Kurie plot (1975Ho14). From the present level scheme Iβ=−1 *3*, consistent with almost no β feeding to the 58.5 level.
(382.3 *15*)	9.21	<0.022	>9.4[1u]	av Eβ=115.13 *46* I(β− feeding to g.s. and 9.2 level)=0.022% *7* (1975Ho14), estimated from β− spectrum and Kurie plot.
(391.5 *15*)	0.0	<0.022	>9.6	av Eβ=111.60 *48* I(β− feeding to g.s. and 9.2 level)=0.022% *7* (1975Ho14), estimated from β−

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^{231}Th β^- decay (25.57 h) 1999Ch12,1975Ho14,1973Br12 (continued)

β^- radiations (continued)

E(decay)	E(level)	Comments
		spectrum and Kurie plot. From the present level scheme Iβ=3 *4*, consistent with almost no β feeding to the g.s.

† From γ-ray transition intensity balance, unless stated otherwise.
‡ Absolute intensity per 100 decays.
# Existence of this branch is questionable.

γ(^{231}Pa)

Iγ normalization: From %Iγ(84γ)=6.79 *10*; weighted average of measured values of 6.98 *36* (2017Le03), 6.60 *25* (1999Ch12), 6.84 *10* (1984He12), 6.6 *3* (1982Va04). Other: 0.0694 *20* from intensity balance in the present decay scheme, using measured Iβ(g.s.+9.2 level)=0.022% *7* (1975Ho14) is consistent with γ-normalization factor of 0.0680 *10* from the adopted value of %Iγ(84γ) from several directly measured values.

Measured intensities of x rays (2017Le03), absolute intensities (per 100 decays of ^{231}Th) are determined from %Iγ=0.576 *7*, for the 185.72-keV transition in ^{235}U decay:

Pa L_l x-rays: 1.663 *38* (absolute).

Pa L_α x-rays: 29.4 *6* (absolute).

Pa L_β x-rays: 28.8 *6* (absolute).

Pa L_γ x-rays: 4.93 *11* (absolute).

Pa total L x-rays: 64.8 *14* (absolute).

Pa $K_{\alpha 2}$ x-rays: 0.231 *12* (absolute).

Pa $K_{\beta' 1}$ x-ray (108.36γ in priv comm): 0.116 *6* (absolute).

Experimental Pa K x ray intensities: 0.38 *3* (Kα_2 x ray), 0.64 *4* (Kα_1 x ray), and 0.23 *2* (Kβ x ray) (weighted averages of values from 1999Ch12 and 1973Br12) compare with 0.36 *4* (Kα_2 x ray), 0.58 *7* (Kα_1 x ray), and 0.28 *4* (Kβ x ray), respectively, calculated by evaluators (using the computer code RADLST) from γ-ray intensities and K-conversion coefficients presented here, and using a K-fluorescence yield of 0.970 *4* (1996Sc06). This agreement shows that most γ rays with energies greater than 112.6 keV (the K-binding energy in Pa) have accurate intensities and correct multipolarities.

The $\gamma\gamma$-coin information is from 1973Br12.

Q(β^-)=391.5 *15* (2021Wa16) compares with a total average radiation energy of 377 keV, calculated by evaluators using the computer program RADLST, and separately adding the contribution (17 keV) from low-energy strongly converted γ-ray transitions of 9.2-, 10.2-, 17.2-, 18.0-, and 19.1 keV. These results support the consistency and completeness of the decay scheme.

Experimental conversion coefficients are from ce data in 1975Ho14, with values listed in Table 2, adjusted by evaluators for revised α(L3)(theory)(for 58.6γ)=47.0 instead of 50.9 in 1975Ho14 and for revised adopted %Iγ values. For the 25.6 and 84.2 transitions, ce data from 1960As02 and other authors are also listed.

1973Br12 discussed a possible 19.1-keV transition from 77.7 level to the 58.6 level, based on a reported electron line observed by 1960Ba57 corresponding to a 19.8-keV γ ray, but no electron intensity was given in this work. 1973Br12 also mentioned that unassigned conversion lines in 1961Ho29 (an unpublished work) could be assigned to M1, O1 and N1 lines of a 19.14-keV transition, and deduced limits >0.5% if the M1 line was correctly assigned, and >4.5% if O1 was correctly assigned, and <16% from intensity balance in the decay scheme. No such internal conversion line was reported by 1975Ho14, based on which, evaluators have not included this transition in the present decay scheme or the Adopted dataset. In 2013Br04 evaluation, a theoretical I(γ+ce)=3.7, relative to Iγ(84γ)=100 was reported from Coulomb excitation work of 1992De51. As the branching ratio cited in 1992De51 is highly model dependent, and as no firm experimental evidence for this transition is available, evaluators have discarded this transition.

Following γ rays with Eγ(Iγ) reported by 1977Ba72 only are not confirmed in other studies: 26.55 *5* (8.32 *9*), 29.30 *5* (0.55 *2*), 32.73 *5* (1.121 *3*), 33.32 *5* (0.455 *19*), 38.90 *5* (1.71 *4*), 41.55 *5* (0.250 *14*), 42.22 *5* (0.796 *25*), 45.34 *5* (0.527 *20*), 82.02 *5* (4.68 *7*), 85.80 *5* (0.089 *9*), 97.55 *5* (0.353 *20*), 99.33 *5* (1.56 *4*), 173.0 *1* (0.704 *21* for a doublet), 216.0 and 217.6 (0.96 *3* for a triplet), 224.1 *1* (0.137 *11*), 237.8 *1* (1.47 *3* for a doublet), 312.30 *25*.

$^{231}_{91}$Pa$_{140}$-4

γ(^{231}Pa) (continued)

E_γ	I_γ [#a]	E_i(level)	J^π_i	E_f	J^π_f	Mult. [@]	δ	α [b]	$I_{(\gamma+ce)}$ [a]	Comments
(9.183)		9.21	1/2$^-$	0.0	3/2$^-$				7.6 *4*	E_γ: from the Adopted Gammas. $I_{(\gamma+ce)}$: from intensity balance at 9.2 level. α(theory)=845 for M1, 2.65×10^5 for E2, with assumed uncertainty of 0.1 keV in transition energy.
17.195 *21*	4.1 *14*	101.408	7/2$^+$	84.2153	5/2$^+$	(M1)		166 *3*	68×10^1 *23*	%Iγ=0.28 *10* α(L)=1.4; α(M)=122.6 *18*; α(N)=32.7 *5*; α(O)=7.75 *12*; α(P)=1.505 *22*; α(Q)=0.144 *2* I_γ: 4.1 *14* from I(γ+ce) and α. E_γ: from level-energy difference. $I_{(\gamma+ce)}$: 44 *15* per 100 decays (1975Ho14), from ce and x-ray data, converted to intensity relative to 100 for Iγ(84.2γ). α: assuming 0.1 keV uncertainty in Eγ.
18.055 *18*	1.4 *5*	102.2685	3/2$^+$	84.2153	5/2$^+$	M1+E2	0.040 *+18−0*	218 *28*	31×10^1 *11*	%Iγ=0.095 *34* α(M3)exp≥8 (1975Ho14) α(L)=45 *15*; α(M)=128 *8* α(N)=34 *2*; α(O)=8.1 *4*; α(P)=1.55 *5*; α(Q)=0.124 *1* E_γ: from level-energy difference. Theoretical α(M3)=0.74 for M1 and 4683 for E2. E_γ: transition seen in ce spectrum 1975Ho14. In γ data, value is listed as %Iγ≤0.33 implying relative Iγ≤4.9. $I_{(\gamma+ce)}$: 20 *7* per 100 decays (1975Ho14), from ce and x-ray data, converted to intensity relative to 100 for Iγ(84.2γ). I_γ: 1.4 *5* from I(γ+ce) and α. α: assuming 0.1 keV uncertainty in Eγ. Mult.: from ce measurements (1975Ho14). Authors give %E2 as 2 *+5−1* implying δ(E2/M1)=0.14 *+12−4*. Using α(M3)exp=8 *+8−0* i.e. assuming 100% uncertainty on the lower limit, evaluators deduce δ(E2/M1)=0.040 *+18−0*, inconsistent with δ=0.14 *+12−4* from 1975Ho14.
25.65 *2*	202 *3*	84.2153	5/2$^+$	58.570	7/2$^-$	E1		4.37 *6*		%Iγ=13.74 *29* α(L3)exp=1.6 *3*; α(M1)exp+α(M2)exp=0.44 *6*; α(M3)exp=0.32 *5*; α(M4)exp+α(M5)exp=0.17 *4*; α(N)exp=0.25 *4* α(O)exp=0.05 *2* L12/L3=1.1 *2*; L2/L1=2.2 *2*; L3/L1=3.0 *3* (1966Ca18) M1/M3=0.50 *1*; M2/M3=0.80 *1*; M4/M3=0.27 *3*; M5/M3=0.36 *3* (1966Ca18) α(exp)=4.8 *10* (1960As02) M1/M3=0.45; M2/M3=0.83; M4/M3=0.23; M5/M3=0.22 (1961Ho29)

From ENSDF

γ(^{231}Pa) (continued)

E_γ	I_γ[#a]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[@]	α[b]	$I_{(\gamma+ce)}$[a]	Comments
									M1/M3=0.69; M2/M3=0.74; M4/M3=0.3; M5/M3=0.3 (1957Ju30) α(L)=3.26 *5*; α(M)=0.843 *12* α(N)=0.219 *4*; α(O)=0.0471 *7*; α(P)=0.00673 *10*; α(Q)=0.000196 *3* E_γ: weighted average of 25.64 *5* (1977Ba72), 25.65 *2* (1975Va11), 25.64 *2* (1975Ho14). Others: 25.509 *9* (1984He12; fits poorly in the decay scheme); 25.6 *1* (1956Ph61). I_γ: weighted average: 202 *20* (1973Br12), 228 *15* (1975Ho14), 210 *10* (1999Ch12), 200.3 *26* (2017Le03). Other: 331.9 *6* (1977Ba72). Measured %Iγ=13.95 *18* (2017Le03), 14.5 *3* (1982Va04), 12.5 *2* (1960As02). Other: %Iγ=5.8 *6*, relative to %Iγ=54% for 185.7γ from the decay of ^{235}U (1975Va11). I(ce)/100 decays: Ice(L3)=23.6, Ice(M1+M2)=6.6, Ice(M3)=5.0, Ice(M4+M5)=2.6, Ice(N)=3.9, Ice(O)=0.7 (1975Ho14). M-subshell ratios are quoted by 1960As02 from 1957Ho07 also 1961Ho29) (first set from ^{231}Th, second set from ^{231}U) and from 1957Ju30 (from ^{231}Th decay).
42.81 *5*	0.89 *2*	101.408	7/2$^+$	58.570	7/2$^-$	[E1]	1.136 *16*		%Iγ=0.0605 *16* α(L)=0.854 *13*; α(M)=0.213 *4* α(N)=0.0558 *9*; α(O)=0.01240 *19*; α(P)=0.00194 *3*; α(Q)=7.08$\times10^{-5}$ *11* E_γ: weighted average of 42.80 *5* (1977Ba72), 42.86 *7* (1975Ho14), 42.80 *6* (1973Br12). I_γ: weighted average: 0.87 *10* (1973Br12), 0.89 *6* (1975Ho14), 0.89 *2* (1999Ch12). Other: 0.469 *19* (1977Ba72).
44.08[†] *17*	0.011 *4*	218.244	(7/2$^-$)	174.160	(5/2$^-$)	[M1+E2]	3.3$\times10^2$ *29*		%Iγ=0.00075 *27* α(L)=2.4$\times10^2$ *21*; α(M)=66 *58* α(N)=18 *16*; α(O)=4.0 *35*; α(P)=0.65 *55*; α(Q)=0.0057 *29* E_γ: other:44.1 *3* (1973Br12, from $\gamma\gamma$-coin). I_γ: weighted average: 0.06 *4* (1973Br12), 0.011 *3* (1975Ho14).
53.2 *8*		111.648	(9/2$^+$)	58.570	7/2$^-$	[E1]	0.64 *3*	11.6 *13*	α(L)=0.483 *21*; α(M)=0.119 *6* α(N)=0.0313 *14*; α(O)=0.0070 *3*; α(P)=0.00114 *5*; α(Q)=4.53$\times10^{-5}$ *16* E_γ: from the Adopted Gammas. $I_{(\gamma+ce)}$: from intensity balance.
58.5700[‡] *27*	6.93 *20*	58.570	7/2$^-$	0.0	3/2$^-$	E2	155.5 *22*		%Iγ=0.471 *14*

γ(^{231}Pa) (continued)

E_γ	I_γ[#a]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[@]	δ	α[b]	Comments
									α(L1)exp+α(L2)exp=59 *5*; α(M1)exp+α(M2)exp=15.0 *18*; α(M3)exp=11.9 *18*; α(N)exp=6.5 *11*; α(O)exp=1.6 *4* L12/L3=1.23 *1*; L/M=3.40 *11* (1966Gi02) α(L)=113.6 *16*; α(M)=31.3 *5* α(N)=8.43 *12*; α(O)=1.90 *3*; α(P)=0.306 *5*; α(Q)=0.000818 *12* E_γ: statistical uncertainty=0.0024 keV (1979Bo30). Others: 58.54 *5* (1977Ba72), 58.57 *2* (1975Ho14), 58.47 *5* (1973Br12). I_γ: weighted average: 7.2 *7* (1973Br12), 7.4 *3* (1975Ho14), 6.8 *2* (1999Ch12), 6.5 *4* (2017Le03). Other: 8.75 *8* (1977Ba72). Measured %Iγ=0.452 *25* (2017Le03). I(ce)/100 decays: Ice(L1+L2)=31.4, Ice(L3)=24.4, Ice(M1+M2)=8.0, Ice(M3)=6.4, Ice(N)=3.5, Ice(O)=0.9 (1975Ho14). Others: 1966TrZZ, Ice(L)=50% (1960As02), agrees with data in 1975Ho14.
63.86[†] *3*	0.34 *6*	247.320	7/2$^+$	183.4955	5/2$^+$	M1+E2	0.6 *3*	39 *16*	%Iγ=0.023 *4* α(L1)exp=8.2 *15* α(L)=28 *12*; α(M)=7.5 *33* α(N)=2.03 *88*; α(O)=0.47 *20*; α(P)=0.079 *31*; α(Q)=0.0023 *5* E_γ: others: 63.65 *5* (1977Ba72), 63.7 *2* (1973Br12, from $\gamma\gamma$-coin). I_γ: weighted average: 0.68 *14* (1973Br12), 0.35 *5* (1975Ho14), 0.29 *5* (1999Ch12). Other: 0.343 *16* (1977Ba72). Ice(L1)/100 decays=0.21 (1975Ho14).
68.5[†] *1*	0.088 *4*	77.694	5/2$^-$	9.21	1/2$^-$	E2		73.3 *10*	%Iγ=0.00598 *29* α(L1)exp+α(L2)exp=27 *7*; α(L3)exp=14 *6* α(L)=53.5 *9*; α(M)=14.76 *24* α(N)=3.98 *7*; α(O)=0.898 *14*; α(P)=0.1448 *23*; α(Q)=0.000423 *7* E_γ: γ from 1975Ho14 only. I_γ: weighted average: 0.088 *4* (1999Ch12), 0.088 *22* (1975Ho14). I(ce)/100 decays: Ice(L1+L2)=0.18, Ice(L3)=0.14 (1975Ho14).
72.7510[‡] *29*	3.82 *10*	174.160	(5/2$^-$)	101.408	7/2$^+$	[E1]		0.280 *4*	%Iγ=0.260 *7* α(L)=0.211 *3*; α(M)=0.0517 *8* α(N)=0.01363 *19*; α(O)=0.00310 *5*; α(P)=0.000519 *8*; α(Q)=2.33×10^{-5} *4* E_γ: statistical uncertainty=0.0025 keV (1979Bo30). Others: 72.70 *5* (1977Ba72), 72.78 *2* (1975Ho14), 72.66 *6* (1973Br12), 72.74 *5* (1973Te06). I_γ: weighted average: 4.0 *4* (1973Br12), 3.8 *2* (1973Te06), 3.86 *23* (1975Ho14), 3.8 *1* (1999Ch12). Other: 4.05 *6* (1977Ba72).
73.0 *1*	0.10 *4*	247.320	7/2$^+$	174.160	(5/2$^-$)	[E1]		0.277 *4*	E_γ: γ reported only by 1973Br12 from their $\gamma\gamma$-coin spectra.
77.69	0.063 *10*	77.694	5/2$^-$	0.0	3/2$^-$	[M1+E2]		24 *16*	%Iγ=0.0043 *7* α(L)=18 *12*; α(M)=5 *4* α(N)=1.3 *9*; α(O)=0.30 *20*; α(P)=0.05 *3*; α(Q)=0.0009 *7* E_γ: γ reported by 1999Ch12 only. α: assuming 0.1 keV uncertainty for Eγ.

γ(^{231}Pa) (continued)

E_γ	I_γ[#a]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[@]	δ	α[b]	Comments
81.2280[‡] *21*	13.3 *5*	183.4955	5/2$^+$	102.2685	3/2$^+$	M1(+E2)	0.00 *8*	7.66 *20*	%Iγ=0.904 *34* α(L1)exp=4.2 *7*; α(M)exp=1.2 *3* α(L)=5.78 *14*; α(M)=1.40 *4* α(N)=0.374 *11*; α(O)=0.0898 *24*; α(P)=0.0172 *4*; α(Q)=0.001422 *22* E_γ: statistical uncertainty=0.0014 keV (1979Bo30). Others: 81.16 *5* (1977Ba72), 81.24 *2* (1975Ho14), 81.18 *5* (1973Br12), 81.20 *6* (1973Te06). I_γ: weighted average: 14.2 *14* (1973Br12), 13.5 *9* (1973Te06), 13.7 *8* (1975Ho14), 13.5 *5* (1999Ch12), 12.15 *66* (2017Le03). Other: 11.69 *10* (1977Ba72). Measured %Iγ=0.849 *45* (2017Le03). I(ce)/100 decays: Ice(L1)=4.2, Ice(M)=1.1 (1975Ho14).
82.0870[‡] *22*	6.2 *3*	183.4955	5/2$^+$	101.408	7/2$^+$	M1(+E2)	0.04 *6*	7.47 *23*	%Iγ=0.422 *21* α(L1)exp=4.8 *10*; α(L3)exp=0.043 *20*; α(M)exp=1.4 *4* α(L)=5.63 *17*; α(M)=1.36 *5* α(N)=0.365 *12*; α(O)=0.088 *3*; α(P)=0.0167 *5*; α(Q)=0.001377 *22* E_γ: statistical uncertainty=0.0014 keV (1979Bo30). Others: 82.02 *5* (1977Ba72), 82.11 *2* (1975Ho14), 82.02 *6* (1973Br12), 82.06 *7* (1973Te06). I_γ: NRM weighted average: 7.2 *7* (1973Br12), 6.8 *4* (1973Te06), 6.2 *5* (1975Ho14), 6.0 *3* (1999Ch12), 5.07 *29* (2017Le03). Other: 4.68 *7* (1977Ba72). Measured %Iγ=0.353 *20* (2017Le03). I(ce)/100 decays: Ice(L1)=2.2, Ice(L3)=0.02, Ice(M)=0.64 (1975Ho14).
84.2140[‡] *22*	100	84.2153	5/2$^+$	0.0	3/2$^-$	E1		2.17 *21*	%Iγ=6.80 *10* α(L1)exp=0.92 *16*; α(L2)exp=0.57 *10*; α(L3)exp=0.036 *6*; α(M)exp=0.49 *9*; α(N)exp=0.11 *2*; α(O)exp=0.03 *1* α(exp)=2.8 *4*; α(L1)exp=1.3 *2*; α(L2)exp=0.65 *15*; α(L3)exp=0.046 *14* (1960As02) L1/L2=1.9; L1/L2=1.6; L3/L1=0.035 *9* (1961Ho29) L1/L2=2.5 (1957Ju30) E_γ: statistical uncertainty=0.0013 keV (1979Bo30). Others: 84.221 *4* (1984He12), 84.16 *5* (1977Ba72), 84.21 *2* (1975Ho14). I_γ: 100 (1973Br12), 100 (1973Te06), 100 (1975Ho14), 100 (1977Ba72), 100 (1999Ch12), 100 *5* (2017Le03). Measured %Iγ=6.98 *36* (2017Le03), 6.60 *25* (1999Ch12), 6.84 *10* (1984He12), 6.6 *3* (1982Va04). Other: 7.2 *10* (1960As02). α: from sum of measured conversion coefficients from 1975Ho14. as the E1 transition of 84.2 keV has been found to be anomalous with much larger L1 and L2 conversion coefficients as compared to theoretical values form BrIcc code.

$^{231}_{91}$Pa$_{140}$-8

γ(^{231}Pa) (continued)

E_γ	I_γ[#a]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[@]	δ	α[b]	Comments
									I(ce)/100 decays: Ice(L1)=6.93, Ice(L2)=4.25, Ice(L3)=0.27, Ice(M)=3.68, Ice(N)=0.83, Ice(O)=0.22 (1975Ho14). From BrIcc code, α(L)0.1434 *20*, α(M)=0.0350 *5*, α(N)=0.00925 *13*, L-subshell ratios are quoted by 1960As02 from 1961Ho29 (first L1/L2 from ^{231}Th, second from ^{231}U) and from 1957Ju30 (from ^{231}Th decay). Mult.: this transition is anomalously converted with a factor of 12.8 *21* for α(L1)exp and α(L2)exp, while α(L3)exp agrees with theory (1960As02). See also 1970Gr36 and 2008Go10 for an analysis of the anomalous E1 character of this transition.
89.95 *2*	15.0 *5*	174.160	(5/2$^-$)	84.2153	5/2$^+$	(E1)[&]		0.1598 *23*	%Iγ=1.020 *34* α(L)=0.1205 *17*; α(M)=0.0294 *5* α(N)=0.00777 *11*; α(O)=0.001782 *25*; α(P)=0.000304 *5*; α(Q)=1.467$\times10^{-5}$ *21* E_γ: weighted average of 89.94 *5* (1977Ba72), 89.95 *2* (1975Ho14), 89.94 *5* (1973Br12), 89.95 *4* (1973Te06). I_γ: weighted average: 15.3 *15* (1973Br12), 15.3 *8* (1973Te06), 14.5 *9* (1975Ho14), 15.0 *5* (1999Ch12). Other: 13.25 *12* (1977Ba72).
93.02[†] *4*	0.70 *8*	102.2685	3/2$^+$	9.21	1/2$^-$	(E1)		0.1463 *21*	%Iγ=0.048 *5* α(L)exp<2 (1973Br12) α(L)=0.1103 *16*; α(M)=0.0269 *4* α(N)=0.00711 *10*; α(O)=0.001633 *23*; α(P)=0.000279 *4*; α(Q)=1.363$\times10^{-5}$ *20* E_γ: others: 93.0 *1* (1973Br12), 92.91 *10* (1973Te06). I_γ: unweighted average: 0.50 *5* (1973Br12), 0.9 *2* (1973Te06), 0.69 *8* (1975Ho14), 0.71 *8* (1999Ch12). Mult.: 1973Br12 deduced α(L)exp and probable E1 multipolarity for for the 93.0 transition, based on α(L)exp for the 102.3 transition and its (E1) multipolarity (1965Ho13), and relative intensities of the 93.3- and 102.1-keV γ rays from their coincidence and singles measurements,
99.2780[‡] *36*	1.98 *10*	183.4955	5/2$^+$	84.2153	5/2$^+$	M1+E2	0.35 *7*	5.2 *4*	%Iγ=0.135 *7* α(M1)exp+α(M2)exp=0.74 *11*; α(M3)exp=0.16 *3*; α(N)exp=0.28 *8* α(L)=3.9 *3*; α(M)=0.97 *8* α(N)=0.261 *20*; α(O)=0.062 *5*; α(P)=0.0113 *7*; α(Q)=0.00072 *3* E_γ: statistical uncertainty=0.0030 keV (1979Bo30). Others: 99.33 *5* (1977Ba72), 99.28 *2* (1975Ho14), 99.30 *5* (1973Br12), 99.33 *5* (1973Te06). I_γ: weighted average: 2.1 *2* (1973Br12), 2.2 *2* (1973Te06), 1.85 *11* (1975Ho14), 2.0 *1* (1999Ch12), 1.97 *11* (2017Le03). Other: 1.56 *4* (1977Ba72). Measured %Iγ=0.137 *7* (2017Le03). I(ce)/100 decays: Ice(M1+M2)=0.112, Ice(M3)=0.024, Ice(N)=0.042 (1975Ho14).

From ENSDF

$\gamma(^{231}$Pa) (continued)

E_γ	I_γ [#a]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [@]	α [b]	Comments
102.2700[‡] *24*	6.6 *2*	102.2685	3/2$^+$	0.0	3/2$^-$	(E1)[&]	0.1141 *16*	%Iγ=0.449 *14* α(L)exp=0.17 (1965Ho13,1967Le24,1973Br12) α(L)=0.0860 *12*; α(M)=0.0210 *3* α(N)=0.00554 *8*; α(O)=0.001276 *18*; α(P)=0.000220 *3*; α(Q)=1.107×10^{-5} *16* E_γ: statistical uncertainty=0.0013 keV (1979Bo30). Others: 102.23 *5* (1977Ba72), 102.27 *2* (1975Ho14), 102.30 *5* (1973Br12), 102.32 *4* (1973Te06). I_γ: weighted average: 6.7 *7* (1973Br12), 6.8 *4* (1973Te06), 6.3 *5* (1975Ho14), 6.6 *2* (1999Ch12). Others: 4.62 *25* (2017Le03, seems discrepant), 5.42 *8* (1977Ba72). Measured %Iγ=0.322 *17* (2017Le03) seems discrepant.
105.79 *3*	0.118 *10*	183.4955	5/2$^+$	77.694	5/2$^-$	[E1]	0.1043 *15*	%Iγ=0.0080 *7* α(L)=0.0787 *11*; α(M)=0.0192 *3* α(N)=0.00507 *8*; α(O)=0.001168 *17*; α(P)=0.000202 *3*; α(Q)=1.027×10^{-5} *15* E_γ: weighted average of 105.65 *10* (1977Ba72), 105.81 *3* (1975Ho14), 105.73 *10* (1973Br12), 105.74 *10* (1973Te06). I_γ: weighted average: 0.14 *2* (1973Br12), 0.13 *8* (1973Te06), 0.11 *1* (1975Ho14), 0.12 *1* (1999Ch12) Other: 0.482 *25* for doublet (1977Ba72).
106.61 *3*	0.267 *11*	218.244	(7/2$^-$)	111.648	(9/2$^+$)	[E1]	0.1023 *14*	%Iγ=0.0182 *8* α(L)=0.0772 *11*; α(M)=0.0188 *3* α(N)=0.00497 *7*; α(O)=0.001145 *16*; α(P)=0.000198 *3*; α(Q)=1.010×10^{-5} *15* E_γ: weighted average of 106.61 *3* (1975Ho14), 106.58 *10* (1973Br12), 106.66 *8* (1973Te06). Other: 106.85 *10* (1977Ba72). I_γ: weighted average: 0.34 *4* (1973Br12), 0.33 *10* (1973Te06), 0.262 *15* (1975Ho14), 0.264 *11* (1999Ch12). Other: 0.482 *25* for doublet (1977Ba72).
115.63[†] *3*	0.015 *4*	174.160	(5/2$^-$)	58.570	7/2$^-$	[M1+E2]	9.9 *35*	%Iγ=0.00102 *27* α(K)=5.4 *52*; α(L)=3.3 *13*; α(M)=0.88 *38* α(N)=0.24 *11*; α(O)=0.055 *23*; α(P)=0.0093 *32*; α(Q)=2.8×10^{-4} *23* E_γ: other: 115.5 *2* (1973Br12). I_γ: weighted average: 0.015 *3* (1975Ho14), 0.015 *4* (1999Ch12). Other: 0.04 *1* (1973Br12). In 1977Ba72, Iγ mixed with sum line.
116.83 *2*	0.336 *20*	218.244	(7/2$^-$)	101.408	7/2$^+$	(E1)[&]	0.342 *5*	%Iγ=0.0228 *14* α(K)=0.262 *4*; α(L)=0.0608 *9*; α(M)=0.01478 *21* α(N)=0.00391 *6*; α(O)=0.000904 *13*; α(P)=0.0001574 *22*; α(Q)=8.26×10^{-6} *12* E_γ: weighted average of 116.80 *10* (1977Ba72), 116.82 *2* (1975Ho14), 116.91 *5* (1973Br12).

$^{231}_{91}$Pa$_{140}$-10

$\gamma(^{231}Pa)$ (continued)

E_γ	I_γ[#a]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[@]	δ	α[b]	Comments
									I_γ: weighted average: 0.39 *4* (1973Br12), 0.318 *20* (1975Ho14), 0.34 *2* (1999Ch12). Other: 0.367 *21* (1977Ba72).
124.927 *18*	0.88 *2*	183.4955	5/2$^+$	58.570	7/2$^-$	(E1)[&]		0.294 *4*	%Iγ=0.0598 *16* α(K)=0.226 *4*; α(L)=0.0511 *8*; α(M)=0.01241 *18* α(N)=0.00329 *5*; α(O)=0.000761 *11*; α(P)=0.0001331 *19*; α(Q)=7.12$\times10^{-6}$ *10* E_γ: NRM weighted average of 124.914 *17* (1979Bo30, statistical uncertainty 0.017 keV, systematic uncertainty is negligible), 125.00 *10* (1977Ba72), 124.93 *2* (1975Ho14), 125.10 *5* (1973Br12). I_γ: weighted average: 0.95 *9* (1973Br12), 0.86 *5* (1975Ho14), 0.88 *2* (1999Ch12). Other: 1.01 *4* (1977Ba72).
134.03 *2*	0.379 *10*	218.244	(7/2$^-$)	84.2153	5/2$^+$	(E1)[&]		0.249 *4*	%Iγ=0.0258 *7* α(K)=0.192 *3*; α(L)=0.0426 *6*; α(M)=0.01033 *15* α(N)=0.00274 *4*; α(O)=0.000635 *9*; α(P)=0.0001116 *16*; α(Q)=6.10$\times10^{-6}$ *9* E_γ: weighted average of 134.00 *5* (1977Ba72), 134.03 *2* (1975Ho14), 134.14 *8* (1973Br12). I_γ: weighted average: 0.42 *5* (1973Br12), 0.37 *2* (1975Ho14), 0.38 *1* (1999Ch12). Other: 0.562 *21* (1977Ba72).
135.670 *11*	1.19 *4*	247.320	7/2$^+$	111.648	(9/2$^+$)	M1(+E2)	0.1 *+4−1*	8.5 *10*	%Iγ=0.0809 *27* α(K)exp=5.6 *10*; α(L)exp=0.95 *30*; α(M)exp=0.27 *6* α(K)=6.7 *13*; α(L)=1.32 *17*; α(M)=0.32 *6* α(N)=0.086 *15*; α(O)=0.021 *4*; α(P)=0.0039 *5*; α(Q)=0.00032 *6* E_γ: weighted average of 135.664 *11* (1979Bo30, statistical uncertainty of 0.011 keV, systematic uncertainty is negligible); 135.66 *5* (1977Ba72); 135.68 *2* (1975Ho14); 135.77 *6* (1973Br12). I_γ: weighted average: 1.3 *1* (1973Br12), 1.20 *8* (1975Ho14), 1.17 *4* (1999Ch12). Other: 1.704 *28* (1977Ba72). I(ce)/100 decays: Ice(K)=0.51, Ice(L)=0.083, Ice(M)=0.024 (1975Ho14).
136.75[†] *7*	0.066 *3*	320.211	3/2$^-$	183.4955	5/2$^+$	[E1]		0.237 *3*	%Iγ=0.00449 *21* α(K)=0.184 *3*; α(L)=0.0404 *6*; α(M)=0.00981 *14* α(N)=0.00260 *4*; α(O)=0.000603 *9*; α(P)=0.0001061 *15*; α(Q)=5.83$\times10^{-6}$ *9* E_γ: other: 136.78 *20* (1973Br12). I_γ: weighted average: 0.09 *3* (1973Br12), 0.065 *3* (1975Ho14), 0.067 *3* (1999Ch12).
140.54[†] *4*	0.011 *1*	218.244	(7/2$^-$)	77.694	5/2$^-$	[M1+E2]		5.3 *25*	%Iγ=0.00075 *7*

From ENSDF

γ(^{231}Pa) (continued)

E_γ	I_γ[#a]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[@]	δ	α[b]	Comments
									α(K)=3.2 *30*; α(L)=1.5 *4*; α(M)=0.40 *12* α(N)=0.108 *32*; α(O)=0.0250 *66*; α(P)=0.0043 *9*; α(Q)=1.6×10^{-4} *13* I_γ: weighted average: 0.011 *1* (1975Ho14), 0.011 *1* (1999Ch12).
145.06[†] *4*	0.087 *6*	247.320	7/2$^+$	102.2685	3/2$^+$	(E2)		2.46 *4*	%Iγ=0.00592 *41* α(K)=0.237 *4*; α(L)=1.627 *23*; α(M)=0.448 *7* α(N)=0.1209 *17*; α(O)=0.0274 *4*; α(P)=0.00448 *7*; α(Q)=2.86×10^{-5} *4* E_γ: other: 145.15 *30* (1973Br12). I_γ: weighted average: 0.12 *3* (1973Br12), 0.089 *6* (1975Ho14), 0.084 *6* (1999Ch12). Mult.: 1975Ho14 state that from ce intensity limit, multipolarity cannot be M2, E3 or higher, thus restricted to dipole or E2.
145.94 *2*	0.48 *2*	247.320	7/2$^+$	101.408	7/2$^+$	M1+E2	0.78 *24*	5.2 *7*	%Iγ=0.0326 *14* α(K)exp=3.2 *7*; α(L)exp=0.7 *3* α(K)=3.5 *8*; α(L)=1.26 *8*; α(M)=0.32 *3* α(N)=0.087 *8*; α(O)=0.0204 *16*; α(P)=0.00362 *19*; α(Q)=0.00017 *4* E_γ: weighted average of 145.90 *5* (1977Ba72), 145.94 *2* (1975Ho14), 146.00 *7* (1973Br12). I_γ: weighted average: 0.58 *6* (1973Br12), 0.49 *3* (1975Ho14), 0.47 *2* (1999Ch12). Other: 0.571 *25* (1977Ba72). I(ce)/100 decays: Ice(K)=0.115, Ice(L)=0.024 (1975Ho14).
163.1010[‡] *54*	2.33 *8*	247.320	7/2$^+$	84.2153	5/2$^+$	M1(+E2)	0.0 *3*	5.1 *3*	%Iγ=0.158 *6* α(K)exp=3.6 *5*; α(L)exp=0.53 *9*; α(M)exp=0.12 *5* α(K)=4.0 *4*; α(L)=0.776 *19*; α(M)=0.187 *7* α(N)=0.0502 *19*; α(O)=0.0120 *4*; α(P)=0.00230 *5*; α(Q)=0.000190 *15* E_γ: statistical uncertainty=0.0043 keV (1979Bo30). Others: 163.15 *5* (1977Ba72), 163.12 *2* (1975Ho14), 163.16 *6* (1973Br12). I_γ: weighted average: 2.6 *3* (1973Br12), 2.38 *14* (1975Ho14), 2.30 *8* (1999Ch12). Others: 6.46 *35* (2017Le03, seems discrepant), 2.75 *6* (1977Ba72). Measured %Iγ=0.452 *24* (2017Le03) seems discrepant. I(ce)/100 decays: Ice(K)=0.64, Ice(L)=0.093, Ice(M)=0.022 (1975Ho14).
165.00[†] *5*	0.052 *2*	174.160	(5/2$^-$)	9.21	1/2$^-$	[E2]		1.464 *21*	%Iγ=0.00354 *15* α(K)=0.209 *3*; α(L)=0.917 *13*; α(M)=0.252 *4* α(N)=0.0681 *10*; α(O)=0.01545 *22*; α(P)=0.00254 *4*; α(Q)=1.96×10^{-5} *3* E_γ: others: 164.70 *10* (1977Ba72), 164.94 *10* (1973Br12). I_γ: weighted average: 0.06 *3* (1973Br12), 0.060 *6* (1975Ho14), 0.051 *2* (1999Ch12). Other: 0.200 *11* (1977Ba72).

$^{231}_{91}$Pa$_{140}$-12

$\gamma(^{231}$Pa) (continued)

E_γ	I_γ[#a]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[@]	α[b]	Comments
169.65 *3*	0.020 *1*	247.320	7/2+	77.694	5/2−	[E1]	0.1421 *20*	%Iγ=0.00136 *7* α(K)=0.1113 *16*; α(L)=0.0233 *4*; α(M)=0.00564 *8* α(N)=0.001497 *21*; α(O)=0.000349 *5*; α(P)=6.22×10^{-5} *9*; α(Q)=3.63×10^{-6} *5* E_γ: weighted average of 169.66 *3* (1975Ho14) and 169.58 *10* (1973Br12). I_γ: weighted average: 0.03 *1* (1973Br12), 0.0185 *15* (1975Ho14), 0.021 *1* (1999Ch12).
174.15[†] *2*	0.268 *10*	174.160	(5/2−)	0.0	3/2−	[M1+E2]	2.7 *15*	%Iγ=0.0182 *7* α(K)=1.8 *16*; α(L)=0.68 *4*; α(M)=0.177 *22* α(N)=0.048 *6*; α(O)=0.0111 *11*; α(P)=0.00196 *6*; α(Q)=8.7×10^{-5} *71* E_γ: others: 174.1 *10* (1977Ba72), 174.19 *8* (1973Br12). I_γ: weighted average: 0.31 *3* (1973Br12), 0.278 *17* (1975Ho14), 0.26 *1* (1999Ch12). Other: 0.704 *21* for doublet (1977Ba72).
[x]177.66	0.00095 *20*					[D,E2]	2.0 *18*	%Iγ=6.5×10^{-5} *14* E_γ: γ reported by 1999Ch12 only.
183.489 *20*	0.502 *20*	183.4955	5/2+	0.0	3/2−	(E1)[&]	0.1181 *17*	%Iγ=0.0340 *14* α(K)=0.0928 *13*; α(L)=0.0191 *3*; α(M)=0.00463 *7* α(N)=0.001228 *18*; α(O)=0.000287 *4*; α(P)=5.13×10^{-5} *8*; α(Q)=3.05×10^{-6} *5* E_γ: weighted average of 183.480 *25* (1979Bo30, statistical uncertainty of 0.025 keV, systematic uncertainty is negligible), 183.4 *1* (1977Ba72), 183.50 *2* (1975Ho14), 183.47 *7* (1973Br12). I_γ: weighted average: 0.57 *6* (1973Br12), 0.506 *20* (1975Ho14), 0.49 *2* (1999Ch12). Other: 1.005 *26* (1977Ba72).
188.76[†] *2*	0.049 *2*	247.320	7/2+	58.570	7/2−	[E1]	0.1105 *16*	%Iγ=0.00333 *14* α(K)=0.0869 *13*; α(L)=0.01782 *25*; α(M)=0.00431 *6* α(N)=0.001144 *16*; α(O)=0.000267 *4*; α(P)=4.79×10^{-5} *7*; α(Q)=2.87×10^{-6} *4* E_γ: others: 188.7 *1* (1977Ba72), 188.77 *20* (1973Br12). I_γ: weighted average: 0.08 *1* (1973Br12), 0.049 *3* (1975Ho14), 0.049 *1* (1999Ch12). Other: 0.084 *8* (1977Ba72).
217.94[†] *3*	0.60 *1*	320.211	3/2−	102.2685	3/2+	E1	0.0789 *11*	%Iγ=0.0408 *9* α(K)exp≤0.11; α(L)exp≤0.08 α(K)=0.0624 *9*; α(L)=0.01248 *18*; α(M)=0.00301 *5* α(N)=0.000801 *12*; α(O)=0.000187 *3*; α(P)=3.38×10^{-5} *5*; α(Q)=2.10×10^{-6} *3* E_γ: others: 217.977 *106* (1979Bo30), 218.00 *5* (1977Ba72, not fully resolved), 218.00 *7* (1973Br12). I_γ: weighted average: 0.67 *7* (1973Br12), 0.62 *5* (1975Ho14), 0.60 *1* (1999Ch12). Other: 0.96 *3* for triplet (1977Ba72). I(ce)/100 decays: Ice(K)≤0.005, Ice(L)≤0.0037 (1975Ho14).
236.04 *6*	0.140 *6*	320.211	3/2−	84.2153	5/2+	[E1]	0.0657 *9*	%Iγ=0.0095 *4*

From ENSDF

$^{231}_{91}$Pa$_{140}$-13

γ(^{231}Pa) (continued)

E_γ	I_γ[#a]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[@]	α[b]	Comments
								α(K)=0.0521 *8*; α(L)=0.01028 *15*; α(M)=0.00248 *4* α(N)=0.000659 *10*; α(O)=0.0001545 *22*; α(P)=2.80×10^{-5} *4*; α(Q)=1.770×10^{-6} *25* E_γ: weighted average of 236.01 *3* (1975Ho14) and 236.17 *7* (1973Br12). Others: 236.1 *1* (1977Ba72, not fully resolved). I_γ: weighted average: 0.18 *2* (1973Br12), 0.14 *1* (1975Ho14), 0.138 *5* (1999Ch12). Other: 1.47 *3* for doublet (1977Ba72).
240.27[†] *5*	0.0045 *5*	317.95	(3/2$^+$)	77.694	5/2$^-$	[E1]	0.0630 *9*	%Iγ=3.06×10^{-4} *34* α(K)=0.0500 *7*; α(L)=0.00984 *14*; α(M)=0.00237 *4* α(N)=0.000631 *9*; α(O)=0.0001480 *21*; α(P)=2.68×10^{-5} *4*; α(Q)=1.704×10^{-6} *24* E_γ: other: 240.4 *2* (1973Br12). I_γ: weighted average: 0.0050 *5* (1973Br12), 0.0043 *15* (1975Ho14), 0.0040 *5* (1999Ch12).
242.51 *4*	0.0126 *6*	320.211	3/2$^-$	77.694	5/2$^-$	[M1+E2]	1.01 *66*	%Iγ=0.00086 *4* α(K)=0.72 *61*; α(L)=0.22 *4*; α(M)=0.055 *7* α(N)=0.0147 *17*; α(O)=0.0035 *5*; α(P)=0.00062 *13*; α(Q)=3.5×10^{-5} *28* E_γ: weighted average of 242.50 *4* (1975Ho14) and 242.6 *1* (1973Br12). I_γ: weighted average: 0.0130 *6* (1973Br12), 0.013 *1* (1975Ho14), 0.011 *1* (1999Ch12).
249.60[†] *7*	0.012 *1*	351.86	(5/2$^-$)	102.2685	3/2$^+$	[E1]	0.0578 *8*	%Iγ=0.00082 *7* α(K)=0.0459 *7*; α(L)=0.00898 *13*; α(M)=0.00216 *3* α(N)=0.000575 *8*; α(O)=0.0001351 *19*; α(P)=2.45×10^{-5} *4*; α(Q)=1.571×10^{-6} *22* E_γ: others: 249.8 (1977Ba72), 249.8 *3* (1973Br12). I_γ: weighted average: 0.010 *2* (1973Br12), 0.012 *1* (1975Ho14), 0.012 *1* (1999Ch12).
250.45[†] *7*	0.010 *1*	351.86	(5/2$^-$)	101.408	7/2$^+$	[E1]	0.0573 *8*	%Iγ=0.00068 *7* α(K)=0.0455 *7*; α(L)=0.00891 *13*; α(M)=0.00215 *3* α(N)=0.000571 *8*; α(O)=0.0001340 *19*; α(P)=2.43×10^{-5} *4*; α(Q)=1.559×10^{-6} *22* E_γ: other: 250.5 *3* (1973Br12). I_γ: weighted average: 0.011 *2* (1973Br12), 0.010 *1* (1975Ho14), 0.010 *1* (1999Ch12).
267.72 *9*	0.0217 *14*	351.86	(5/2$^-$)	84.2153	5/2$^+$	[E1]	0.0493 *7*	%Iγ=0.00148 *10* α(K)=0.0393 *6*; α(L)=0.00760 *11*; α(M)=0.00183 *3* α(N)=0.000487 *7*; α(O)=0.0001144 *16*; α(P)=2.08×10^{-5} *3*; α(Q)=1.355×10^{-6} *19* E_γ: weighted average of 267.62 *8* (1975Ho14), 267.80 *7* (1973Br12). I_γ: weighted average: 0.0230 *6* (1973Br12), 0.018 *2* (1975Ho14), 0.019 *1* (1999Ch12).
274.10[†] *10*	0.00051 *15*	351.86	(5/2$^-$)	77.694	5/2$^-$	[M1+E2]	0.71 *48*	%Iγ=3.5×10^{-5} *10*

$^{231}_{91}Pa_{140}$-14

$\gamma(^{231}$Pa) (continued)

E_γ	I_γ[#a]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[@]	δ	α[b]	Comments
									α(K)=0.52 *43*; α(L)=0.14 *4*; α(M)=0.036 *7* α(N)=0.0098 *19*; α(O)=0.0023 *5*; α(P)=4.2×10^{-4} *12*; α(Q)=2.5×10^{-5} *20* I_γ: weighted average: 0.00046 *15* (1975Ho14), 0.0006 *2* (1999Ch12).
308.78[†] *7*	0.0064 *8*	317.95	(3/2$^+$)	9.21	1/2$^-$	[E1]		0.0358 *5*	%Iγ=0.00044 *6* α(K)=0.0287 *4*; α(L)=0.00544 *8*; α(M)=0.001306 *19* α(N)=0.000348 *5*; α(O)=8.19×10^{-5} *12*; α(P)=1.500×10^{-5} *21*; α(Q)=1.005×10^{-6} *14* E_γ: other: 308.9 *3* (1973Br12). I_γ: unweighted average: 0.008 *1* (1973Br12), 0.0060 *6* (1975Ho14), 0.0053 *2* (1999Ch12).
311.00[†] *5*	0.047 *2*	320.211	3/2$^-$	9.21	1/2$^-$	M1(+E2)	0.7 *9*	0.61 *27*	%Iγ=0.00320 *14* α(L)exp=0.09 *3*; α(M)exp=0.03 *1*; α(N)exp=0.009 *3* α(K)=0.47 *24*; α(L)=0.107 *24*; α(M)=0.026 *5* α(N)=0.0071 *14*; α(O)=0.0017 *4*; α(P)=0.00031 *8*; α(Q)=2.2×10^{-5} *11* E_γ: other: 311.0 *1* (1973Br12). I_γ: weighted average: 0.054 *5* (1973Br12), 0.045 *3* (1975Ho14), 0.046 *2* (1999Ch12). I(ce)/100 decays: Ice(L)=0.00032, Ice(M)=0.00011, Ice(N)=0.00003 (1975Ho14).
317.87[†] *8*	0.00151 *25*	317.95	(3/2$^+$)	0.0	3/2$^-$	[E1]		0.0336 *5*	%Iγ=10.2×10^{-5} *17* α(K)=0.0269 *4*; α(L)=0.00508 *8*; α(M)=0.001221 *18* α(N)=0.000325 *5*; α(O)=7.66×10^{-5} *11*; α(P)=1.404×10^{-5} *20*; α(Q)=9.47×10^{-7} *14* E_γ: other: 318.0 *4* (1973Br12). I_γ: unweighted average: 0.0020 *2* (1973Br12), 0.00123 *15* (1975Ho14), 0.0013 *2* (1999Ch12).
320.15[†] *8*	0.0024 *6*	320.211	3/2$^-$	0.0	3/2$^-$	[M1+E2]		0.46 *32*	%Iγ=0.00016 *4* α(K)=0.34 *28*; α(L)=0.088 *29*; α(M)=0.0221 *61* α(N)=0.0059 *17*; α(O)=0.00140 *41*; α(P)=2.57×10^{-4} *89*; α(Q)=1.6×10^{-5} *13* E_γ: other: 320.2 *3* (1973Br12). I_γ: unweighted average: 0.0035 *3* (1973Br12), 0.0017 *2* (1975Ho14), 0.0020 *2* (1999Ch12).
351.80[†] *10*	0.0010 *2*	351.86	(5/2$^-$)	0.0	3/2$^-$	[M1+E2]		0.35 *25*	%Iγ=6.8×10^{-5} *14* α(K)=0.26 *21*; α(L)=0.066 *25*; α(M)=0.0165 *53* α(N)=0.0044 *14*; α(O)=0.00105 *35*; α(P)=1.93×10^{-4} *74*; α(Q)=1.25×10^{-5} *96* I_γ: weighted average: 0.011 *2* (1975Ho14), 0.010 *2* (1999Ch12).

From ENSDF

$^{231}_{91}$Pa$_{140}$-15

$\gamma(^{231}Pa)$ (continued)

† From 1975Ho14.
‡ From 1979Bo30 (curved crystal spectrometer), systematic uncertainty of $2\times10^{-5}\times E\gamma$, relative to an absolute standard, as specified by the authors, is included in quadrature by evaluators.
# Weighted average of values from 2017Le03, 1999Ch12, 1975Ho14, 1973Te06, and 1973Br12, unless otherwise specified. Values from 1977Ba72 are not used in averaging as there are large differences between their values and several other consistent data in the references which have been used in the averaging procedure.
@ From ce data in 1975Ho14, where α(exp) were determined using α(L3)(theory)=50.9 for 58.6γ (mult=E2), and %Iγ(58.6γ)=0.48 *2*. Evaluators have adjusted the conversion coefficients listed in 1975Ho14 using α(L3)(theory)=47.0 (from BrIcc code) and adopted %Iγ(58.6γ)=0.471 *14*.
& E1 assigned by 1975Ho14 from ce intensity or intensity limits at 2σ level. As no numerical data are provided in this work for transition, evaluators consider the assignment as tentative.
[a] For absolute intensity per 100 decays, multiply by 0.0680 *10*.
[b] Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.
[x] γ ray not placed in level scheme.

^{231}Th β^- decay (25.57 h) 1999Ch12,1975Ho14,1973Br12