^{231}Ac β^- decay (7.5 min) 1999Aa03,1986Gi08,1973Ch24

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}Ac: E=0.0; J$^\pi$=1/2$^+$; $T_{1/2}$=7.5 min *1*; Q(β^-)=1947 *13*; %β^- decay=100.0

^{231}Ac-J$^\pi$,$T_{1/2}$: From ^{231}Ac Adopted Levels. Nilsson configuration=π1/2[400].

^{231}Ac-Q(β^-): From 2021Wa16.

1999Aa03: ^{231}Ac produced in spallation of 1-GeV protons on a ^{231}Th target, and subsequently mass separated in the ISOLDE-CERN mass separator. Measured Eγ, Iγ, level half-lives by $\beta\gamma\gamma$(t) fast timing method using HPGe detector for γ radiation and plastic scintillator for β^-. The Eγ values in this work seem to be nominal values with no stated uncertainties. Deduced γ-transition probabilities from measured level half-lives, known multipolarities and γ-ray branching ratios, and compared with detailed quasiparticle-plus-phonon model (QPM) calculations with Coriolis coupling.

1986Gi08: ^{231}Ac produced by bombarding targets of natural tungsten with 2.7-GeV ^{238}U ions from UNILAC at GSI, followed by mass separation. Measured Eγ, Iγ, x rays, $\beta\gamma$-coin using HPGe detector for γ radiation and plastic scintillator for β^-. Deduced γ-ray multipolarities from x-ray and γ-ray data.

1985Hi02: ^{231}Ac as daughter product in spallation of ^{238}U by 600 MeV protons. Measured K x-ray, γ, K x-ray(t) using Ge(Li) detectors. Energies and intensities of six γ rays given as well as intensity of Th K-x rays.

1973Ch24: ^{231}Ac produced In ^{232}Th(γ,p),E=150 MeV bremsstrahlung; and ^{232}Th(n,pn),E=14 MeV, followed by chemical separation at Mainz. Measured $T_{1/2}$=7.5 min *1*, energies and intensities of 22 γ rays, β^-, Th x-rays, x-ray(t), γ(t) using Ge(Li) detectors for γ and x rays and scintillation detector for β radiation.

1960Ta19: measured an activity with $T_{1/2}$=15 min *1*, Eβ=2100 keV *100*, γ rays of 85- and 185-keV, and very weak and uncertain γ rays of 280-, 390-, and 710 keV. The disagreement in the half-life value and in the intensity of the 280-keV γ ray (the strongest from ^{231}Ac) suggest that this activity is not ^{231}Ac. It may be due to Tellurium (1999Aa03,1973Ch24).

Th K x-ray intensity of 45.6% *27*, relative to Iγ(282γ)=39.0% *16*, deduced by evaluators using the computer program RADLST and the γ-ray data presented here, compared with an experimental value of 37.0% *16* (1985Hi02). Measured I(K x-ray)=95 *4* with Iγ(282γ)=100 *8*. A total average radiation energy of 2065 keV *74*, deduced by evaluators using the computer program RADLST, compared with Q(β^-)=1947 keV *13* from 2021Wa16. These results reflect the consistency of the decay scheme.

Evaluators′ note about the decay scheme: spectral information for seven low-energy transitions (19-51 keV) is limited and makes the decay scheme incomplete in that respect.

^{231}Th Levels

1973Ch24 placed the 396.9-, 503.5-, and 528.1-keV, deexciting levels at 713 and 820 keV. 1999Aa03, however, have interpreted these transitions as due to sum peaks in the γ-ray spectrum. Therefore, the existence of these levels could not be confirmed.

E(level)†	J$^\pi$‡	$T_{1/2}$#	Comments
0.0	5/2$^+$	25.57 h *8*	$T_{1/2}$: from the Adopted Levels.
41.951 *2*	7/2$^+$		
185.716 *2*	5/2$^-$	1.073 ns *79*	$T_{1/2}$: 1999Aa03 compared their value with 0.77 ns *12* from 1959St49 measured in ^{235}U α decay, and explained the discrepancy as due to the latter value measured using NaI(Tl) detectors, thus affected by γ rays other than those due to direct feeding and deexcitation of the 185.7-keV level.
205.310 *2*	(7/2$^-$)		
221.3985 *10*	3/2$^+$	≤74 ps	
240.877 *2*	5/2$^+$		
247.587 *2*	1/2$^+$	≤74 ps	
272.181 *2*	3/2$^+$		
554.651 *2*	(1/2)$^-$	503 ps *12*	1973Ch24 placed 512.4- and 554.4- γ rays deexciting this level. These γ rays, however, have been interpreted as sum peaks in the spectrum (1999Aa03). Configuration=ν1/2[501].
593.618 *2*	(3/2)$^-$	98 ps *36*	

Continued on next page (footnotes at end of table)

^{231}Ac β^- decay (7.5 min) 1999Aa03,1986Gi08,1973Ch24 (continued)

^{231}Th Levels (continued)

† Deduced from least-squares fit to γ-ray energies.
‡ From the Adopted Levels.
# From $\beta\gamma\gamma$(t) (1999Aa03), unless otherwise specified.

β^- radiations

E(decay)	E(level)	Iβ^-†	Log *ft*	Comments
(1353 *13*)	593.618	6.5 *7*	6.60 *5*	av Eβ=457.5 *51*
(1392 *13*)	554.651	88 *5*	5.51 *3*	av Eβ=472.7 *51*
(1675‡ *13*)	272.181			av Eβ=584.4 *52* Iβ^-: 3 *9*, consistent with zero feeding.
(1699‡ *13*)	247.587			av Eβ=594.3 *53* Iβ^-: −7 *11*, consistent with zero feeding.
(1726‡ *13*)	221.3985	<9	>6.8	av Eβ=604.8 *53* Iβ=9 *8* from transition intensity balance, 3.6 *52* from 100−(Iβ(593)+Iβ(554)+Iβ(186)), consistent with almost zero feeding.
(1761‡ *13*)	185.716	1.9 *11*	8.5^{1u} *3*	av Eβ=592.4 *50*

† Absolute intensity per 100 decays.
‡ Existence of this branch is questionable.

$\gamma(^{231}$Th)

Iγ normalization: From ΣI(γ+ce)=100 to g.s. and 42 level, not including the transition intensity of the 42-keV transition. No β^- feeding is expected to the g.s. and the 42-keV level due to ΔJ^π involved.

Measured intensity of Th K-x rays=95 *4* relative to 100 for 282.5γ (1985Hi02), uncertainty on intensity is statistical only.

Following eight γ rays reported by 1973Ch24 were not seen by 1999Aa03 and 1986Gi08: 68.8 (Iγ=5 *3*), 350.7 (Iγ=2.4 *4*), 375.7 (Iγ=4.1 *6*), 396.9 (Iγ=1.9 *3*), 400.2 (Iγ=2.6 *4*), 503.5 (Iγ=1.1 *2*), 512.4 (Iγ=1.2 *2*), 528.1 (Iγ=2.3 *4*), 554.4 (Iγ=3.9 *6*); intensities relative to 100 for 282.5γ.

E$_\gamma$[†]	I$_\gamma$[b]	E$_i$(level)	J$^\pi_i$	E$_f$	J$^\pi_f$	Mult.[&]	δ[a]	α[c]	I$_{(\gamma+ce)}$[@b]	Comments
(19.55 *5*)	≤0.006	205.310	(7/2$^-$)	185.716	5/2$^-$	[M1]		114.7 *19*	0.6 *2*	%Iγ≤0.0020 I$_\gamma$: from 1999Aa03, based on estimated I(γ+ce) and α for M1.
(24.6[#])	0.15[#] *9*	272.181	3/2$^+$	247.587	1/2$^+$	[M1]		231 *5*	35 *20*	%Iγ=0.058 *35* α(theory) for assumed 0.1 keV uncertainty in transition energy. I$_\gamma$: from 1999Aa03, based on estimated I(γ+ce) (1999Aa03) and α for M1.
(26.2[#])	≤0.6[#]	247.587	1/2$^+$	221.3985	3/2$^+$	[M1]		192 *4*	97 *17*	%Iγ≤0.20 α(theory) for assumed 0.1 keV uncertainty in transition energy. I$_\gamma$: from 1999Aa03, based on estimated I(γ+ce) (1999Aa03) and α for M1. Other I(γ+ce)=74.7 (1986Gi08).
(31.3[#])	≤0.5[#]	272.181	3/2$^+$	240.877	5/2$^+$	(M1)		114 *2*	54 *3*	%Iγ≤0.18 α(theory) for assumed 0.1 keV uncertainty in transition energy. I$_\gamma$: from 1999Aa03, based on estimated I(γ+ce) (1999Aa03) and α for M1. Other I(γ+ce)=50.9 (1986Gi08). Mult.: from 1986Gi08, based on measured α(L)exp from the observed intensity of L x-rays in coincidence with the 241γ.
(39.0[‡])	≤0.040[‡]	593.618	(3/2)$^-$	554.651	(1/2)$^-$	[M1]		59.5 *10*	≤2.4	%Iγ≤0.016 I$_\gamma$: from I(γ+ce)≤2.4 from model calculations (1999Aa03) and α for M1.
(41.98 *5*)	0.09 *2*	41.951	7/2$^+$	0.0	5/2$^+$	M1+E2	0.95 *10*	3.7×10^2 *4*	38 *3*	%Iγ=0.040 *5* α(L)=330 *70*; α(M)=89 *20*; α(N)=24 *6* α(O)=5.3 *12*; α(P)=0.88 *19*; α(Q)=0.0063 *10* I$_\gamma$: from I(γ+ce)=38 *3* (1999Aa03) and α=440 *100*. 1999Aa03 give Iγ=0.08 *2* using α=450 *80*. Other I(γ+ce)=37.0 (1986Gi08). Mult.,δ: from the Adopted dataset.

γ(^{231}Th) (continued)

E_γ [†]	I_γ [b]	E_i(level)	J^π_i	E_f	J^π_f	Mult. [&]	α [c]	$I_{(\gamma+ce)}$ [@b]	Comments
(50.8[#])	≤0.7[#]	272.181	3/2$^+$	221.3985	3/2$^+$	[M1]	27.3 *5*	≤20	%Iγ≤0.28 α(theory) for assumed 0.1 keV uncertainty in transition energy. I_γ: from estimated I(γ+ce)=37 *4*-I(γ+ce)(24.6γ) (1999Aa03) and α for M1. Note that in Table 2, 1999Aa03 give Iγ≤1.3. Other: I(γ+ce)=39.0 (1986Gi08).
143.765 *2*	8.6 *5*	185.716	5/2$^-$	41.951	7/2$^+$	E1	0.207 *3*		%Iγ=3.35 *25* α(K)=0.1618 *24*; α(L)=0.0345 *5*; α(M)=0.00834 *12* α(N)=0.00220 *4*; α(O)=0.000504 *8*; α(P)=9.10×10^{-5} *14*; α(Q)=5.86×10^{-6} *9* E_γ: 143.7 *2* (1986Gi08), 143.6 *2* (1973Ch24) in β^- decay. I_γ: weighted average: 8.6 *5* (1999Aa03), 8.5 *9* (1986Gi08), 8.3 *11* and 10 *3* (1973Ch24).
(163.357 *2*)		205.310	(7/2$^-$)	41.951	7/2$^+$				
185.713 *2*	41.9 *20*	185.716	5/2$^-$	0.0	5/2$^+$	E1	0.1125 *16*		%Iγ=16.3 *11* α(K)=0.0887 *13*; α(L)=0.0180 *3*; α(M)=0.00433 *7* α(N)=0.001143 *17*; α(O)=0.000263 *4*; α(P)=4.82×10^{-5} *7*; α(Q)=3.32×10^{-6} *5* E_γ: 185.7 *2* (1986Gi08), 185.6 *2* (1973Ch24), 185.68 *2* (1985Hi02, statistical uncertainty only) in β^- decay. I_γ: Mandel-Paule average: 43.0 *20* (1999Aa03), 38.0 *20* (1986Gi08), 42.8 *8* (1985Hi02, statistical uncertainty only), 43 *5* and 49 *9* (1973Ch24).
198.927 *3*	7.2 *8*	240.877	5/2$^+$	41.951	7/2$^+$	M1	2.64 *4*		%Iγ=2.80 *34* α(K)=2.11 *3*; α(L)=0.401 *6*; α(M)=0.0963 *14* α(N)=0.0257 *4*; α(O)=0.00608 *9*; α(P)=0.001180 *17*; α(Q)=0.0001120 *16* E_γ: 198.9 *2* (1986Gi08), 198.9 *2* (1973Ch24) in β^- decay. I_γ: weighted average: 6.6 *12* (1999Aa03), 7.5 *8* (1986Gi08), 7.2 *10* and 6 *3* (1973Ch24).
(205.311 *2*)		205.310	(7/2$^-$)	0.0	5/2$^+$				
221.392 *20*	45.3 *34*	221.3985	3/2$^+$	0.0	5/2$^+$	M1	1.96 *3*		%Iγ=17.6 *16* α(K)=1.566 *22*; α(L)=0.296 *5*; α(M)=0.0712 *10* α(N)=0.0190 *3*; α(O)=0.00450 *7*; α(P)=0.000873 *13*; α(Q)=8.28×10^{-5} *12* E_γ: 221.2 *2* (1986Gi08), 221.2 *2* (1973Ch24), 221.38 *1* (1985Hi02, statistical uncertainty only) in β^- decay. I_γ: Mandel-Paule average: 48.2 *24* (1999Aa03), 39.7 *20* (1986Gi08), 45.4 *4* (1985Hi02, statistical uncertainty only), 49 *6* and 56 *9* (1973Ch24).
(230.243 *11*)	0.37 *11*	272.181	3/2$^+$	41.951	7/2$^+$	[E2]	0.399 *6*		%Iγ=0.14 *4* α(K)=0.1223 *18*; α(L)=0.203 *3*; α(M)=0.0551 *8* α(N)=0.01476 *21*; α(O)=0.00332 *5*; α(P)=0.000564 *8*; α(Q)=8.57×10^{-6} *12* I_γ: from γ-branching ratio in the Adopted dataset.

$^{231}_{90}$Th$_{141}$-4

γ(^{231}Th) (continued)

E_γ[†]	I_γ[b]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[&]	δ[a]	α[c]	Comments
240.876 *4*	10.4 *6*	240.877	5/2$^+$	0.0	5/2$^+$	M1(+E2)	0.3 *3*	1.45 *22*	%Iγ=4.05 *30* α(K)=1.14 *21*; α(L)=0.228 *13*; α(M)=0.0553 *21* α(N)=0.0148 *6*; α(O)=0.00348 *16*; α(P)=0.00067 *5*; α(Q)=6.1×10^{-5} *11* E_γ: 240.9 *2* (1986Gi08), 240.6 *2* (1973Ch24), 240.89 *5* (1985Hi02, statistical uncertainty only) in β^- decay. I_γ: Mandel-Paule average: 11.3 *8* (1999Aa03), 9.4 *9* (1986Gi08), 10.5 *9* (1985Hi02, statistical uncertainty only), 11.0 *14* and 6 *3* (1973Ch24).
247.586 *3*	1.13 *20*	247.587	1/2$^+$	0.0	5/2$^+$	E2		0.312 *5*	%Iγ=0.44 *8* α(K)=0.1065 *15*; α(L)=0.1512 *22*; α(M)=0.0409 *6* α(N)=0.01096 *16*; α(O)=0.00247 *4*; α(P)=0.000421 *6*; α(Q)=7.18×10^{-6} *11* E_γ: 247.4 *2* (1986Gi08), 247.4 *2* (1973Ch24) in β^- decay. I_γ: weighted average: 1.5 *4* (1999Aa03), 0.7 *5* (1986Gi08), 1.1 *2* (1973Ch24).
272.181 *2*	6.7 *8*	272.181	3/2$^+$	0.0	5/2$^+$	M1+E2	0.64 *10*	0.85 *6*	%Iγ=2.61 *33* α(K)=0.65 *6*; α(L)=0.148 *5*; α(M)=0.0365 *10* α(N)=0.00975 *25*; α(O)=0.00228 *7*; α(P)=0.000432 *15*; α(Q)=3.5×10^{-5} *3* E_γ: 271.9 *2* (1986Gi08), 271.9 *2* (1973Ch24) in β^- decay. I_γ: weighted average: 6.8 *8* (1999Aa03), 6.3 *8* (1986Gi08), 6.7 *10* and 9 *3* (1973Ch24).
282.471 *2*	100 *3*	554.651	(1/2)$^-$	272.181	3/2$^+$	E1		0.0425 *6*	%Iγ=38.9 *21* α(K)=0.0340 *5*; α(L)=0.00644 *9*; α(M)=0.001546 *22* α(N)=0.000409 *6*; α(O)=9.50×10^{-5} *14*; α(P)=1.768×10^{-5} *25*; α(Q)=1.341×10^{-6} *19* E_γ: 282.3 *2* (1986Gi08), 282.3 *2* (1973Ch24), 282.46 *1* (1985Hi02, statistical uncertainty only) in β^- decay. I_γ: 100 *3* (1999Aa03), 100.0 *30* (1986Gi08), 100 *8* (1985Hi02), 100 *10* (1973Ch24).
307.063 *2*	78.5 *9*	554.651	(1/2)$^-$	247.587	1/2$^+$	E1		0.0353 *5*	%Iγ=30.5 *15* α(K)=0.0283 *4*; α(L)=0.00530 *8*; α(M)=0.001270 *18* α(N)=0.000336 *5*; α(O)=7.82×10^{-5} *11*; α(P)=1.459×10^{-5} *21*; α(Q)=1.126×10^{-6} *16* E_γ: 306.9 *2* (1986Gi08), 306.9 *2* (1973Ch24), 307.05 *1* (1985Hi02, statistical uncertainty only) in β^- decay. I_γ: Mandel-Paule average: 76.9 *26* (1999Aa03), 75.2 *25* (1986Gi08), 79.1 *9* (1985Hi02, statistical uncertainty only), 77 *9* and 84 *13* (1973Ch24).
321.7[‡d]	≤0.7[‡]	593.618	(3/2)$^-$	272.181	3/2$^+$				%Iγ≤0.27
333.3[‡d]	≤0.5[‡]	554.651	(1/2)$^-$	221.3985	3/2$^+$				%Iγ≤0.19
346.1 *2*	1.4 *3*	593.618	(3/2)$^-$	247.587	1/2$^+$	[E1]		0.0272 *4*	%Iγ=0.54 *12*

From ENSDF

$^{231}_{90}$Th$_{141}$-5

γ(^{231}Th) (continued)

E_γ[†]	I_γ[b]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[&]	α[c]	Comments
								α(K)=0.0218 *3*; α(L)=0.00402 *6*; α(M)=0.000963 *14* α(N)=0.000255 *4*; α(O)=5.94×10^{-5} *9*; α(P)=1.113×10^{-5} *16*; α(Q)=8.80×10^{-7} *13* E_γ: from 1986Gi08. I_γ: weighted average: 1.5 *3* (1999Aa03), 1.2 *5* (1986Gi08).
352.7[‡,d]	≤0.3[‡]	593.618	(3/2)$^-$	240.877	5/2$^+$			%Iγ≤0.12
368.934 *2*	38.8 *7*	554.651	(1/2)$^-$	185.716	5/2$^-$	E2	0.0927 *13*	%Iγ=15.1 *7* α(K)=0.0485 *7*; α(L)=0.0326 *5*; α(M)=0.00865 *13* α(N)=0.00232 *4*; α(O)=0.000526 *8*; α(P)=9.18×10^{-5} *13*; α(Q)=2.85×10^{-6} *4* E_γ: 368.8 *2* (1986Gi08), 368.8 *2* (1973Ch24), 368.93 *1* (1985Hi02, statistical uncertainty only) in β^- decay. I_γ: Mandel-Paule average: 38.3 *24* (1999Aa03), 36.0 *15* (1986Gi08), 39.6 *5* (1985Hi02, statistical uncertainty only), 38 *5* and 37 *7* (1973Ch24).
372.221 *2*	4.0 *7*	593.618	(3/2)$^-$	221.3985	3/2$^+$	E1	0.0233 *3*	%Iγ=1.56 *28* α(K)=0.0187 *3*; α(L)=0.00342 *5*; α(M)=0.000817 *12* α(N)=0.000216 *3*; α(O)=5.05×10^{-5} *7*; α(P)=9.49×10^{-6} *14*; α(Q)=7.60×10^{-7} *11* E_γ: 372.0 *2* (1986Gi08), 372.0 *2* (1973Ch24) in β^- decay. I_γ: weighted average: 4.1 *11* (1999Aa03), 3.4 *8* (1986Gi08), 4.4 *7* (1973Ch24).
388.3 *2*	0.81 *26*	593.618	(3/2)$^-$	205.310	(7/2$^-$)	[E2]	0.0806 *11*	%Iγ=0.32 *10* α(K)=0.0438 *7*; α(L)=0.0272 *4*; α(M)=0.00719 *11* α(N)=0.00192 *3*; α(O)=0.000437 *7*; α(P)=7.66×10^{-5} *11*; α(Q)=2.55×10^{-6} *4* E_γ: from 1973Ch24. I_γ: weighted average: 0.58 *18* (1999Aa03), 1.1 *2* (1973Ch24). E_γ: Not seen in ^{230}Th(n,γ) (Iγ<0.4).
407.899 *2*	8.5 *9*	593.618	(3/2)$^-$	185.716	5/2$^-$	E2	0.0708 *10*	%Iγ=3.3 *4* α(K)=0.0398 *6*; α(L)=0.0229 *4*; α(M)=0.00604 *9* α(N)=0.001616 *23*; α(O)=0.000368 *6*; α(P)=6.47×10^{-5} *10*; α(Q)=2.29×10^{-6} *4* E_γ: 407.8 *2* (1986Gi08), 407.8 *2* (1973Ch24) in β^- decay. I_γ: weighted average: 8.3 *16* (1999Aa03), 8.5 *9* (1986Gi08), 8.5 *12* and 9 *4* (1973Ch24). Mult.: from the Adopted dataset. 1986Gi08 reported M1.
512.7[‡,d]	≤0.9[‡]	554.651	(1/2)$^-$	41.951	7/2$^+$			%Iγ≤0.35 Existence of this transition (from (1/2)$^-$ to 7/2$^+$) is unlikely as it involves mult=E3.
554.7[‡,d]	≤0.6[‡]	554.651	(1/2)$^-$	0.0	5/2$^+$			%Iγ≤0.23
593.6[‡,d]	≤0.8[‡]	593.618	(3/2)$^-$	0.0	5/2$^+$			%Iγ≤0.31

[†] From the Adopted Levels, Gammas dataset, where values from (n,γ) and ^{235}U α decay are more precise than those available from ^{231}Ac β^-. Measured values from ^{231}Ac decay are listed under comments. Exceptions are noted.

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

‡ This γ was not seen by 1999Aa03 with only an upper limit of Iγ deduced from the spectrum. This γ is not listed in the Adopted dataset.

From 1999Aa03, derived either from the $\gamma\gamma$-coin data or from intensity balance arguments, with the assumption of no direct β feeding to levels below 500 keV.

@ From γ-ray transition intensity balance.

& From conversion coefficients deduced from the intensities of x-rays and γ rays measured in coincidence mode (1986Gi08). However, conversion coefficients are not given by 1986Gi08. Exceptions are noted.

[a] From the Adopted Levels, Gammas dataset.

[b] For absolute intensity per 100 decays, multiply by 0.389 *18*.

[c] 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.

[d] Placement of transition in the level scheme is uncertain.

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Decay Scheme

Intensities: I_γ per 100 parent decays