^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	B. Singh, J. K. Tuli, E. Browne	NDS 170, 499 (2020)	8-Oct-2020

Parent: ^{233}Th: E=0; $J^\pi=1/2^+$; $T_{1/2}$=21.83 min *4*; Q(β^-)=1242.2 *11*; %β^- decay=100.0

^{233}Th-J^π,$T_{1/2}$: From the Adopted Levels of ^{233}Th.

^{233}Th-Q(β^-): From 2017Wa10.

2008De31: multiply purified source from (n,γ) used to measure absolute Iγ, x-ray intensities, and half-life of the decay of ^{233}Th using liquid scintillation counters and HPGe detectors. Authors did not provide their measured gamma-ray energies.

1972SeZI (also 1970Se06,1968Se07,1968Se06): measured Eγ, Iγ, $\gamma\gamma$-coin, ce, using Ge(Li) detector for γ rays, and solenoidal spectrometer for conversion electrons.

1969HoZY: measured Eγ, Iγ, $\gamma\gamma$-coin, I(x rays), $T_{1/2}$ using Ge(Li) detectors. Gamma rays reported from 39.6 to 1201 keV.

1970-Malmskog: S.G. Malmskog: unpublished data for Eγ, Iγ from 16 to 986 keV listed by 1972SeZI.

1969-Fettweis: P. Fettweis and J. Verviers: priv. comm. to 1972SeZI: Eγ, Iγ data from 86 to 935 keV listed by 1972SeZI.

Others with Eγ, Iγ data for selected gamma rays:

1979Bo30: measured precise Eγ of 11 γ rays using a crystal spectrometer.

1972De67: measured Eγ, Iγ for four γ rays (29.39, 57.10, 88.00 and 94.68 keV). No uncertainties were given.

1972Vo08: measured Eγ for six gamma rays from the decay of ^{233}Th.

1969Va06: measured energies of 53 γ rays from 76.1 to 976.8 keV, using Ge(Li) detector, but with no uncertainties listed. No intensities were reported either. The $\gamma\gamma$-coin measurements used scintillation detectors. An extensive level scheme was proposed, with Nilsson model assignments.

1968Br25: measured Eγ, Iγ.

1968Da24: measured energies of 11 γ rays from 59 to 416 keV.

1957Fr55, 1957Dr46, 1952Ru10, 1950Bu68: measured Eβ, Iβ, Eγ, Iγ.

Isotopic identification and $T_{1/2}$: 1998Us01, 1989Ab05, 1969HoZY, 1957Dr46, 1955Je26, 1952Ru10, 1947Se05, 1941Gr03.

Decay scheme as given by 2008De31 mostly based on earlier studies by 1972SeZI and 1969HoZY, and by 1972Vo08 from (n,γ).

^{233}Pa Levels

E(level)[†]	J^π	$T_{1/2}$	Comments
0.0	$3/2^-$	26.975 d *13*	$T_{1/2}$: from the Adopted Levels.
6.676 *14*	$1/2^-$		
57.098 *19*	$7/2^-$		
70.55 *4*	$5/2^-$		
86.423 *24*	$5/2^+$	36.5 ns *4*	$T_{1/2}$: from the Adopted Levels.
94.666 *19*	$3/2^+$		
103.661 *22*	$7/2^+$		
169.169 *10*	$1/2^+$		
201.605 *23*	$3/2^+$		
212.328 *17*	$5/2^+$		
237.917 *18*	$5/2^+$		
257.176 *18*	$5/2^-$		
447.733 *16*	$3/2^-$		
454.42 *4*	$3/2^+$		
553.888 *20*	$1/2^+$,$3/2^+$		
585.44 *4*	$3/2^+$		
669.88 *3*	$3/2^-$		
764.53 *3*	$1/2^+$,$3/2^+$		
811.60 *7*	$3/2^+$		
941.97[‡] *22*	(3/2)		
968.7[‡] *3*	(1/2,3/2)		
984.80 *10*	$(3/2)^+$		
1018.64 *16*	(3/2)		
1064.5[‡] *6*	(3/2)		J^π: 1/2,3/2 from log *ft* value of 7.2 from $1/2^+$ parent; $3/2^+$ from 960.8γ to $7/2^+$, but

Continued on next page (footnotes at end of table)

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

^{233}Pa Levels (continued)

E(level)[†]	J$^\pi$	Comments
		$3/2^-$ from 1007γ to $7/2^-$, suggesting that one of these placements is questionable. The weak 994.3γ to $5/2^-$ is consistent with both the assignments.
1138.94[‡] *15*	(1/2,3/2)	

[†] From least-squares fit to Eγ values, assuming 0.2 keV uncertainty. when not given.
[‡] Level population proposed by 2008De31.

β^- radiations

Measured values are given in comments.

E(decay)	E(level)	Iβ^-[†@]	Log ft[‡]	Comments
(103.3 *11*)	1138.94	0.0010 *2*	7.3 *1*	av Eβ=26.83 *30*
(177.7 *13*)	1064.5	0.0064 *5*	7.17 *4*	av Eβ=52.27 *39*
(223.6 *11*)	1018.64	0.0515 *23*	6.58 *2*	av Eβ=60.63 *33*
(257.4 *11*)	984.80	0.203 *4*	6.18 *1*	av Eβ=70.57 *33*
(273.5 *12*)	968.7	0.0224 *6*	7.22 *1*	av Eβ=75.36 *34*
(300.2 *11*)	941.97	0.0554 *13*	6.95 *1*	av Eβ=83.40 *34*
(430.6 *11*)	811.60	0.367 *8*	6.64 *1*	av Eβ=124.03 *36*
(477.7 *11*)	764.53	1.182 *20*	6.27 *1*	av Eβ=139.22 *36* E(decay): 580 (1957Fr55), possibly for 764+585 levels.
(572.3 *11*)	669.88	0.0173 *13*	8.37 *4*	av Eβ=170.55 *37*
(656.8 *11*)	585.44	0.147 *18*	7.64 *6*	av Eβ=199.29 *38*
(688.3 *11*)	553.888	1.19 *5*	6.80 *2*	av Eβ=210.18 *39* E(decay): 790 (1957Fr55).
(787.8 *11*)	454.42	0.214 *14*	7.74 *3*	av Eβ=245.14 *40*
(794.5 *11*)	447.733	0.77 *5*	7.20 *3*	av Eβ=247.52 *40* E(decay): 880 (1957Fr55), possibly for 447.8+454.4 levels.
(985.0[&] *11*)	257.176	<0.06	>9.1[1u]	av Eβ=308.99 *38*
(1040.6[&] *11*)	201.605	0.026 *17*	9.1 *3*	av Eβ=337.24 *41*
(1073.0 *11*)	169.169	1.4 *8*	7.4 *3*	av Eβ=349.36 *42* E(decay): 1073 (1957Fr55).
(1147.5 *11*)	94.666	≈11	≈6.6	av Eβ=377.43 *42* E(decay): 1158 (1957Fr55).
(1235.5 *11*)	6.676	≈30[#]	≈6.3	av Eβ=410.88 *42*
(1242.2 *11*)	0.0	≈55[#]	≈6.0	av Eβ=413.44 *43* E(decay): 1230 *10* (1957Dr46), 1245 *3* (1957Fr55) for β transition to g.s.+6.65 level. Others: 1952Ru10, 1950Bu68. Iβ^-: ≈100% (1957Dr46), <87% (1957Fr55) for 0+6.65 levels.

[†] From 2008De31.
[‡] Deduced by the evaluators.
[#] Estimated from decay scheme. Iβ(0+6.7 level)≈83.6% (2008De31).
[@] Absolute intensity per 100 decays.
[&] Existence of this branch is questionable.

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$

Iγ normalization: 2008De31 measured absolute intensities per 100 decays. They determined the effective number of disintegrations by dividing the peak areas in summed ten individual spectra, collected over 5 min each, by the product of photon intensity and energy-dependent detection efficiency. 2008De31 state that earlier photon intensity normalization of 2.7% (from 1957Fr55) for 86γ leads to intensities ≈30% too high compared to their adopted values for prominent radiations as: L x-ray (8.23% *8*), K x-ray (1.32% *10*), 29γ (2.17% *1*), 86γ (1.843% *2*) and 459γ (0.989% *2*).
All the ce data given here are from 1972SeZI, unless otherwise stated.
x-rays per 100 decays from 1969HoZY: 0.54 *7* for $K_{\alpha 2}$, 1.01 *7* for $K_{\alpha 1}$, 0.28 for $K_{\beta 1}$ and 0.09 for $K_{\beta 2}$.

x-rays intensities per 100 decays from 2008De31 measurement:

Energy	Intensity
11.32	0.14 *1*
13.291	2.84 *2*
15.35	0.16 *1*
16.008	1.013 *12*
16.708	3.124 *20*
19.571	0.78 *1*
20.217	0.171 *5*
92.282	0.39 *1*
95.863	0.615 *7*
107.595	0.075 *2*
108.422	0.160 *3*
111.87	0.061 *2*
112.38	0.018 *2*

E_γ †	I_γ ‡ [g]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [b]	α [h]	$I_{(\gamma+ce)}$ [g]	Comments
6.68 *5*	≈0.010	6.676	1/2⁻	0.0	3/2⁻	(M1)	3.04×10^3 *8*		α(M)=2.25×10^3 *6* α(N)=610 *17*; α(O)=146 *4*; α(P)=28.0 *8*; α(Q)=2.33 *7* E_γ: from conversion electron spectra only (1972SeZI). I_γ: from measured Ice(N1)=9 *1*, Ice(N2)=1.2 *2* (1972SeZI) and theoretical α(N1)=537 *15*, α(N2)=67.0 *18* for M1.
8.22 *5*	≈0.008	94.666	3/2⁺	86.423	5/2⁺	(M1)	1.64×10^3 *4*	≈13	α(M)=1.22×10^3 *3*; α(N)=329 *8*; α(O)=78.9 *19*; α(P)=15.1 *4*; α(Q)=1.25 *3* E_γ: from conversion electron spectra only (1972SeZI). $I_{(\gamma+ce)}$: from intensity balance at 86.4 level, where no β feeding is expected. Ice(N2)=1.8 *3*, Ice(N3)=1.7 *3* (1972SeZI). δ(E2/M1)<0.11 from N2/N3 ratio in 1972SeZI.
17.40 *5*		103.661	7/2⁺	86.423	5/2⁺	[M1+E2]	8.0×10^3 *78*	*f*	E_γ: from conversion electron spectra only (1972SeZI).
29.36 *4*	2.17 *7*	86.423	5/2⁺	57.098	7/2⁻	E1	3.07		α(L1)exp=0.44; α(L2)exp=0.8; α(L3)exp=1.0; α(M1)exp=0.12;

$^{233}_{91}Pa_{142}$-3

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ[†]	I_γ[‡][g]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	δ[b]	α[h]	Comments
									α(M2)exp=0.16; α(M3)exp=0.21 α(M4)exp=0.08; α(N1)exp=0.08; α(N2)exp=0.06; α(N3)exp=0.05; α(O)exp=0.04 (1972SeZI) α(L)=2.30 *4*; α(M)=0.586 *9* α(N)=0.1529 *23*; α(O)=0.0332 *5*; α(P)=0.00488 *7*; α(Q)=0.0001511 *22* I_γ: 2.1727 *647* (2008De31). Eγ=29.36 *4* (1972SeZI), 29.60 *5* (1969HoZY), 29.41 *5* (1970-Malmskog). Iγ=2.5 (1972SeZI), 0.95 (1969HoZY). Ice(L1)=1.1 *2*, Ice(L2)=2.0 *3*, Ice(L3)=2.7 *3*, Ice(M1)=0.30 *6*, Ice(M2)=0.40 *7*, Ice(M3)=0.52 *7*, Ice(M4)=0.19 *5*, Ice(N1)=0.19 *5*, Ice(N2)=0.15 *4*, Ice(N3)=0.12 *4*, Ice(O)=0.10 *3* (1972SeZI).
(36.32[d] *2*)	0.00014 *3*	237.917	5/2$^+$	201.605	3/2$^+$	M1+E2[c]	0.31[c] *9*	2.13×10^2 *76*	α(L)=1.57×10^2 *56*; α(M)=41 *16* α(N)=11.1 *41*; α(O)=2.56 *93*; α(P)=0.44 *15*; α(Q)=0.0144 *5*
[x]45.08[a] *10*									Eγ=45.08 *10* (1972SeZI, $\gamma\gamma$-coin only).
(46.53[d] *4*)		103.661	7/2$^+$	57.098	7/2$^-$	[E1]		0.914	α(L)=0.687 *10*; α(M)=0.1707 *25* α(N)=0.0448 *7*; α(O)=0.01000 *15*; α(P)=0.001587 *23*; α(Q)=5.98×10^{-5} *9*
57.13 *4*	0.0498 *15*	57.098	7/2$^-$	0.0	3/2$^-$	E2		175	α(L1)exp=2.6; α(L2)exp=67; α(L3)exp=65; α(M2)exp=22 α(M3)exp=0.18 α(M4)exp=5.6; α(N2)exp=7.4; α(N3)exp=5.5; α(O)exp=2.8 (1972SeZI) α(L)=128.1 *19*; α(M)=35.3 *5* α(N)=9.50 *14*; α(O)=2.14 *3*; α(P)=0.345 *5*; α(Q)=0.000910 *13* I_γ: 0.0498 *14* (2008De31). Eγ: weighted average of 57.11 *5* (1979Bo30), 57.15 *4* (1972SeZI), 57.1 *1* (1969HoZY). Other: 57.14 *5* (1970-Malmskog). Iγ=0.054 (1972SeZI), 0.061 (1969HoZY), 0.21 (1970-Malmskog). Ice(L1)=0.14 *5*, Ice(L2)=3.60 *5*, Ice(L3)=3.50 *5*, Ice(M2)=1.20 *15*, Ice(M3)=1.00 *15*, Ice(M4)=0.20 *5*, Ice(N2)=0.4 *1*, Ice(N3)=0.30 *5*, Ice(O)=0.15 *4* mixed with Ice(K) of 169.5γ (1972SeZI).
63.93[a] *6*	≈0.0010	70.55	5/2$^-$	6.676	1/2$^-$	(E2)		102.1	α(L)=74.5 *11*; α(M)=20.5 *3* α(N)=5.54 *9*; α(O)=1.249 *19*; α(P)=0.201 *3*; α(Q)=0.000564 *9* Eγ: from conversion electron spectra only (1972SeZI). I_γ: 0.0005 *2* from α(L2)=40.5, α(L3)=32.6 for E2, and Ice(L2)=0.03 *1*, Ice(L3)=0.03 *1* (1972SeZI), but intensity balance at this level requires about double the intensity.

$^{233}_{91}Pa_{142}$-4

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡g]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	α[h]	Comments
(70.49[d] *10*)	≈0.0010	70.55	5/2$^-$	0.0	3/2$^-$	[M1+E2]	38 *27*	α(L)=28 *19*; α(M)=7.5 *54* α(N)=2.0 *15*; α(O)=0.46 *33*; α(P)=0.076 *51*; α(Q)=0.00126 *89* I_γ: from Iγ(70.5γ)/Iγ(63.9γ)=1.0 *3*, as in the Adopted Gammas, where the data are from ^{237}Np α decay.
74.7 *2*	0.0402 *17*	169.169	1/2$^+$	94.666	3/2$^+$	[M1+E2]	29 *20*	α(L)=21 *14*; α(M)=5.8 *40* α(N)=1.6 *11*; α(O)=0.35 *24*; α(P)=0.059 *37*; α(Q)=0.00106 *76* Eγ=74.7 *2* (1972SeZI), 74.70 *10* (1970-Malmskog), 76.1 (1969Va06). Iγ=0.052 (1972SeZI), 0.064 (1970-Malmskog).
[x]80.0								Only ce lines were observed by 1972SeZI: Ice(L1)=0.025 *7*, Ice(L2)=0.020 *7*; mult=E2 suggested by 1972SeZI.
86.50 *5*	1.843 *19*	86.423	5/2$^+$	0.0	3/2$^-$	E1	1.43 *8*	α(L1)exp=0.27; α(L2)exp=0.30; α(L3)exp=0.035; α(M1)exp=0.13; α(M2)exp=0.10; α(M3)exp=0.017 α(N1)exp=0.05; α(O)exp=0.017 (1972SeZI) I_γ: 1.8428 *18* (2008De31). Eγ=86.50 *5* (1972SeZI), 86.6 *1* (1969HoZY), 86.3 *1* (1969-Fettweis), 86.55 *5* (1970-Malmskog). Iγ=2.7 (1972SeZI), 2.7 (1969HoZY), 2.7 (1969-Fettweis), 2.7 (1970-Malmskog). Value of absolute intensity=2.7 taken from 1957Fr55. Ice(L1)=0.7 *1*, Ice(L2)=0.8 *1*, Ice(L3)=0.10 *2*, Ice(M1)=0.35 *5*, Ice(M2)=0.28 *4*, Ice(M3)=0.047 *10* mixed Ice(K) of 195γ, Ice(N1)=0.14 *4*, Ice(O)=0.05 *1* (1972SeZI). Mult.,α: from experimental ce data in ^{237}Np α decay. Transition is anomalous, the total conversion coefficient is much enhanced as compared to the theoretical value of 0.177.
87.8 *2*	0.1698 *19*	94.666	3/2$^+$	6.676	1/2$^-$	[E1]	0.170 *3*	α(L)=0.1284 *20*; α(M)=0.0314 *5* α(N)=0.00828 *13*; α(O)=0.00190 *3*; α(P)=0.000323 *5*; α(Q)=1.547×10^{-5} *23* I_γ: 0.1698 *8* (2008De31). Eγ=87.8 *2* (1972SeZI, from $\gamma\gamma$-coin), 89.51 *15* (1969-Fettweis), 88.6 *7* (1970-Malmskog); 88.2 (1969Va06). Iγ=0.3 (1972SeZI), 1.1 (1969-Fettweis), 0.27 (1970-Malmskog). E_γ: from ce data in 1972SeZI, Ice(K)=0.05 *2*.
[x]90.1[a]								
94.68 *5*	0.775 *8*	94.666	3/2$^+$	0.0	3/2$^-$	E1	0.1397	α(L)=0.1053 *15*; α(M)=0.0257 *4* α(N)=0.00679 *10*; α(O)=0.001559 *22*; α(P)=0.000267 *4*; α(Q)=1.311×10^{-5} *19* I_γ: 0.7749 *13* (2008De31). E_γ: from the Adopted Gammas. Measured values from ^{233}Th decay are: Eγ=94.7 *2* (1972SeZI), 94.5 *5* (1969HoZY), 93.97 *10* (1969-Fettweis), 94.60 (1970-Malmskog); 94.5 (1969Va06). Iγ=0.8 (1972SeZI), 0.88 (1969HoZY), 5.5 (1969-Fettweis), 0.92 (1970-Malmskog). Ice(L1)=0.05 *2*, Ice(M1)=0.010 *5* mixed with Ice(K) of 201γ (1972SeZI).
[x]105.2[a] *1*	0.029							E_γ,I_γ: from 1969HoZY only, Iγ adjusted from 0.043 to 0.029. Others: Eγ=105.58 *10*, Iγ=0.10 (1969-Fettweis); Eγ=106.8 (1969Va06).

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡g]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	δ[b]	α[h]	Comments
(108.7[d])	0.0018 *3*	212.328	5/2$^+$	103.661	7/2$^+$	M1(+E2)[c]	<0.9[c]	4.4 *12*	α(L)=2.57 *9*; α(M)=0.62 *3* α(N)=0.168 *8*; α(O)=0.0401 *16*; α(P)=0.00759 *24*; α(Q)=0.000598 *15* I_γ: from Iγ(108.7γ)/Iγ(155.2γ)=0.80 *4*, as in the Adopted Gammas, where the data are from ^{237}Np α decay.
115.44[&] *20*	0.0003 *7*	201.605	3/2$^+$	86.423	5/2$^+$	[M1+E2]		10.0 *35*	α(K)=5.4 *52*; α(L)=3.3 *13*; α(M)=0.89 *39* α(N)=0.24 *11*; α(O)=0.055 *23*; α(P)=0.0094 *32*; α(Q)=2.9×10^{-4} *23*
117.5 *2*	0.0029[e] *3*	212.328	5/2$^+$	94.666	3/2$^+$	M1+E2[c]	0.46[c] *+22−13*	11.5 *10*	α(K)=9.3 *5*; α(L)=2.17 *12*; α(M)=0.54 *4* α(N)=0.144 *10*; α(O)=0.0342 *21*; α(P)=0.0064 *3*; α(Q)=0.000452 *23* Eγ=117.5 *2*, Iγ=0.0015 (1972SeZI).
131.1 *1*	0.0508 *10*	201.605	3/2$^+$	70.55	5/2$^-$	E1[c]		0.262	α(K)=0.202 *3*; α(L)=0.0451 *7*; α(M)=0.01094 *16* α(N)=0.00290 *4*; α(O)=0.000672 *10*; α(P)=0.0001179 *17*; α(Q)=6.40×10^{-6} *9* I_γ: 0.0508 *8* (2008De31) Eγ=131.1 *1* (1972SeZI), 131.2 *1* (1969HoZY), 131.22 *10* (1969-Fettweis), 131.20 *20* (1970-Malmskog). Iγ=0.056 (1972SeZI), 0.074 (1969HoZY), 0.058 (1969-Fettweis), 0.079 (1970-Malmskog).
134.276[&] *20*	0.0018 *5*	237.917	5/2$^+$	103.661	7/2$^+$	[M1+E2][c]	≈0.4[c]	≈8.04	α(K)≈6.05; α(L)≈1.484; α(M)≈0.369 α(N)≈0.0991; α(O)≈0.0235; α(P)≈0.00433; α(Q)≈0.000291
143.32 *6*	0.0114 *7*	237.917	5/2$^+$	94.666	3/2$^+$	M1+E2[c]	0.69[c] *19*	5.8 *6*	α(L1)exp=1.0 (1972SeZI) α(K)=4.0 *7*; α(L)=1.31 *8*; α(M)=0.34 *3* α(N)=0.090 *7*; α(O)=0.0211 *15*; α(P)=0.00378 *18*; α(Q)=0.00020 *3* Eγ=143.2 *1* (1972SeZI), 143.35 *5* (1969HoZY), 143.36 *20* (1969-Fettweis), 143.38 *20* (1970-Malmskog). Iγ=0.014 (1972SeZI), 0.020 (1969HoZY), 0.012 (1969-Fettweis), 0.024 (1970-Malmskog). Ice(L1)=0.014 (1972SeZI).
[x]147.5[&]	0.0018 *6*								
151.5 *2*	0.0067 *3*	237.917	5/2$^+$	86.423	5/2$^+$	M1+E2[c]	0.28[c] *12*	5.9 *3*	α(K)=4.6 *4*; α(L)=0.99 *3*; α(M)=0.242 *10* α(N)=0.065 *3*; α(O)=0.0155 *6*; α(P)=0.00291 *7*; α(Q)=0.000220 *14* Eγ=151.5 *2*, Iγ=0.009 (1972SeZI).
153.5 *1*	0.0407 *6*	257.176	5/2$^-$	103.661	7/2$^+$	[E1]		0.180	α(K)=0.1404 *20*; α(L)=0.0301 *5*; α(M)=0.00728 *11* α(N)=0.00193 *3*; α(O)=0.000449 *7*; α(P)=7.96×10^{-5} *12*; α(Q)=4.52×10^{-6} *7* I_γ: 0.0407 *4* (2008De31).

$^{233}_{91}Pa_{142}$-6

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ[†]	I_γ[‡g]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	δ[b]	α[h]	Comments
									Eγ=153.6 *2* (1972SeZI), 153.5 *1* (1969HoZY), 153.74 *10* (1969-Fettweis), 153.54 *20* (1970-Malmskog). Iγ=0.066 (1972SeZI), 0.062 (1969HoZY), 0.071 (1969-Fettweis), 0.077 (1970-Malmskog).
155.242[&] *20*	0.0023 *3*	212.328	5/2$^+$	57.098	7/2$^-$	E1[c]		0.1755	α(K)=0.1368 *20*; α(L)=0.0292 *4*; α(M)=0.00708 *10* α(N)=0.00188 *3*; α(O)=0.000437 *7*; α(P)=7.74×10^{-5} *11*; α(Q)=4.41×10^{-6} *7*
162.504[j#] *12*	0.1305[j] *52*	169.169	1/2$^+$	6.676	1/2$^-$	(E1)		0.1574	α(K)=0.1230 *18*; α(L)=0.0260 *4*; α(M)=0.00630 *9* α(N)=0.001670 *24*; α(O)=0.000389 *6*; α(P)=6.91×10^{-5} *10*; α(Q)=3.99×10^{-6} *6* α(K)exp=0.12 (1972SeZI) Eγ: Other measured values in ^{233}Th decay are: Eγ=162.5 *1* (1972SeZI), 162.7 *1* (1969HoZY), 162.70 *10* (1969-Fettweis), 162.55 *10* (1970-Malmskog), 161.9 (1969Va06). Iγ=0.32 (1972SeZI), 0.28 (1969HoZY), 0.31 (1969-Fettweis), 0.30 (1970-Malmskog). I_γ: 0.1674 *10* for the doublet (2008De31). Intensity divided based on Iγ(162)/I(169)=0.52 *2* in Adopted Gammas, where it is taken from ^{237}Np α decay. Rest of the intensity i.e. 0.0369 *52* of the 162γ is assigned from the 257 level. Ice(K)=0.010 *5* (1972SeZI).
162.504[j] *12*	0.0369[j] *52*	257.176	5/2$^-$	94.666	3/2$^+$	[E1]		0.1574	α(K)=0.1230 *18*; α(L)=0.0260 *4*; α(M)=0.00630 *9* α(N)=0.001670 *24*; α(O)=0.000389 *6*; α(P)=6.91×10^{-5} *10*; α(Q)=3.99×10^{-6} *6*
169.162[#] *10*	0.2509 *26*	169.169	1/2$^+$	0.0	3/2$^-$	[E1]		0.1431	α(K)=0.1120 *16*; α(L)=0.0235 *4*; α(M)=0.00568 *8* α(N)=0.001508 *22*; α(O)=0.000351 *5*; α(P)=6.26×10^{-5} *9*; α(Q)=3.65×10^{-6} *6* I_γ: 0.2509 *8* (2008De31). Eγ: other measurements: Eγ=169.1 *2* (1972SeZI), 169.4 *1* (1969HoZY), 169.36 *10* (1969-Fettweis), 170.3 (1969Va06). Iγ=0.34 (1972SeZI), 0.47 (1969HoZY), 0.50 (1969-Fettweis).
170.9 *3*	0.0507 *6*	257.176	5/2$^-$	86.423	5/2$^+$	[E1]		0.1397	α(K)=0.1094 *16*; α(L)=0.0229 *4*; α(M)=0.00554 *9* α(N)=0.001470 *22*; α(O)=0.000343 *5*; α(P)=6.11×10^{-5} *9*; α(Q)=3.57×10^{-6} *6* I_γ: 0.0507 *4* (2008De31). Eγ=170.7 *3* (1972SeZI), 171.2 *3* (1969HoZY), 171.32 *30* (1969-Fettweis). Iγ=0.13 (1972SeZI), 0.014 (1969HoZY), 0.071 (1969-Fettweis).
179.1 *1*	0.0278 *5*	764.53	1/2$^+$,3/2$^+$	585.44	3/2$^+$	M1(+E2)	<0.7	3.4 *5*	α(L1)exp=0.5 (1972SeZI) α(K)=2.6 *5*; α(L)=0.603 *12*; α(M)=0.149 *6* α(N)=0.0399 *16*; α(O)=0.0095 *3*; α(P)=0.001766 *25*; α(Q)=0.000124 *22*

$^{233}_{91}Pa_{142}$-7

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡ g]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [b]	δ [b]	α [h]	Comments
									I_γ: 0.0278 *4* (2008De31). Ice(L1)=0.018 *6* (1972SeZI). Eγ=179.0 *2* (1972SeZI), 179.1 *1* (1969HoZY), 179.32 *10* (1969-Fettweis), 179.18 *30* (1970-Malmskog). Iγ=0.038 (1972SeZI), 0.054 (1969HoZY), 0.033 (1969-Fettweis), 0.041 (1970-Malmskog).
180.79[&] *5*	0.0011 *3*	237.917	5/2$^+$	57.098	7/2$^-$	[E1]		0.1223	α(N)=0.001275 *18*; α(O)=0.000298 *5*; α(P)=5.32×10^{-5} *8*; α(Q)=3.15×10^{-6} *5* α(K)=0.0960 *14*; α(L)=0.0199 *3*; α(M)=0.00480 *7*
186.8 *1*	0.0209 *7*	257.176	5/2$^-$	70.55	5/2$^-$	M1+E2	0.8 *3*	2.5 *5*	α(K)exp=2.2; α(L1)exp=0.27 (1972SeZI) α(K)=1.74 *49*; α(L)=0.530 *8*; α(M)=0.135 *5* α(N)=0.0362 *12*; α(O)=0.00850 *20*; α(P)=0.00153 *3*; α(Q)=8.4×10^{-5} *22* Eγ=186.8 *2* (1972SeZI), 186.8 *1* (1969HoZY), 186.13 *15* (1969-Fettweis), 186.88 *30* (1970-Malmskog). Iγ=0.034 (1972SeZI), 0.023 (1969HoZY), 0.058 (1969-Fettweis), 0.039 (1970-Malmskog). Ice(K)=0.075, Ice(L1)=0.009 (1972SeZI).
190.552[#] *14*	0.0861 *13*	447.733	3/2$^-$	257.176	5/2$^-$	M1(+E2)	<0.5	2.8 *5*	α(K)exp=3.0; α(L1)exp=0.22; α(M1)exp=0.14; α(N)exp=0.04 (1972SeZI) α(K)=2.1 *5*; α(L)=0.497 *8*; α(M)=0.123 *4* α(N)=0.0331 *10*; α(O)=0.00784 *15*; α(P)=0.00146 *4*; α(Q)=0.000100 *22* I_γ: 0.0861 *9* (2008De31). E_γ: others: 190.54 *8* (1972SeZI), 190.7 *1* (1969HoZY), 190.72 *10* (1969-Fettweis), 190.59 *20* (1970-Malmskog), 191.2 (1969Va06). Iγ=0.13 (1972SeZI), 0.16 (1969HoZY), 0.17 (1969-Fettweis), 0.15 (1970-Malmskog). Ice(K)=0.39, Ice(L1)=0.028, Ice(M1)=0.018, Ice(N)=0.007, mixed with Ice(L1) of 210γ (1972SeZI). δ: from α(K)exp. Others: <0.7 from α(M1)exp is consistent, but 1.4 *+4−3* from α(L1)exp is inconsistent; α(N)exp allows all δ.
194.90 *5*	0.1073 *14*	201.605	3/2$^+$	6.676	1/2$^-$	E1[c]		0.1025	α(L1)exp=0.03 (1972SeZI) α(K)=0.0807 *12*; α(L)=0.01645 *23*; α(M)=0.00398 *6* α(N)=0.001056 *15*; α(O)=0.000247 *4*; α(P)=4.43×10^{-5} *7*; α(Q)=2.68×10^{-6} *4* I_γ: 0.1073 *9* (2008De31). Eγ=194.90 *5* (1972Vo08), 195.0 *2* (1972SeZI), 195.00 *5* (1969HoZY), 195.08 *10* (1969-Fettweis), 195.00 *20* (1970-Malmskog). Iγ=0.16 (1972SeZI), 0.18 (1969HoZY), 0.23 (1969-Fettweis), 0.19 (1970-Malmskog). Ice(L1)=0.005 (1972SeZI).

$^{233}_{91}Pa_{142}$-8

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡ g]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [b]	δ [b]	α [h]	Comments
201.72 *10*	0.0221 *8*	201.605	$3/2^+$	0.0	$3/2^-$	E1 [c]		0.0945	α(K)exp<0.3 (1972SeZI) α(K)=0.0745 *11*; α(L)=0.01511 *22*; α(M)=0.00365 *6* α(N)=0.000969 *14*; α(O)=0.000227 *4*; α(P)=4.08×10^{-5} *6*; α(Q)=2.48×10^{-6} *4* Eγ=201.6 *2* (1972SeZI), 201.75 *10* (1969HoZY), 201.77 *15* (1969-Fettweis), 200.99 *30* (1970-Malmskog), 161.9 (1969Va06). Iγ=0.031 (1972SeZI), 0.031 (1969HoZY), 0.042 (1969-Fettweis), 0.028 (1970-Malmskog). Ice(K)<0.01, mixed with Ice(M1) of 94γ (1972SeZI).
210.6 [@] *2*	0.0178 *11*	447.733	$3/2^-$	237.917	$5/2^+$	[E1]		0.0855	α(K)exp=1.2 (1972SeZI) α(K)=0.0675 *10*; α(L)=0.01358 *20*; α(M)=0.00328 *5* α(N)=0.000871 *13*; α(O)=0.000204 *3*; α(P)=3.67×10^{-5} *6*; α(Q)=2.26×10^{-6} *4* Eγ=210.6 *2* (1972SeZI), 210.1 *3* (1970-Malmskog). Iγ=0.035 (1972SeZI), 0.032 (1970-Malmskog). Ice(K)=0.04 *1* (1972SeZI); M1+E2 suggested by 1972SeZI from α(K)exp is inconsistent with ΔJ^π.
211.3 *2*	0.0202 *9*	764.53	$1/2^+$,$3/2^+$	553.888	$1/2^+$,$3/2^+$	M1+E2	1.0 *3*	1.5 *4*	α(K)exp=1.0 (1972SeZI) α(K)=1.04 *31*; α(L)=0.344 *11*; α(M)=0.0881 *14* α(N)=0.0237 *4*; α(O)=0.00554 *12*; α(P)=0.00099 *5*; α(Q)=5.1×10^{-5} *14* Eγ=211.3 *2* (1972SeZI), 211.3 *3* (1970-Malmskog). Iγ=0.019 (1972SeZI), 0.032 (1970-Malmskog). Ice(K)=0.02 *1* (1972SeZI).
212.32 [&] *2*	0.0065 [e] *6*	212.328	$5/2^+$	0.0	$3/2^-$	E1 [c]		0.0839	α(K)=0.0663 *10*; α(L)=0.01331 *19*; α(M)=0.00321 *5* α(N)=0.000854 *12*; α(O)=0.000200 *3*; α(P)=3.60×10^{-5} *5*; α(Q)=2.22×10^{-6} *4*
216.7 *2*	0.0130 *7*	454.42	$3/2^+$	237.917	$5/2^+$	[M1+E2]		1.40 *88*	α(K)exp=1.1 (1972SeZI) α(K)=0.97 *84*; α(L)=0.32 *4*; α(M)=0.081 *4* α(N)=0.0217 *9*; α(O)=0.0051 *4*; α(P)=0.00091 *12*; α(Q)=4.7×10^{-5} *38* Eγ=216.6 *2* (1972SeZI), 216.9 *2* (1969HoZY), 216.92 *20* (1969-Fettweis), 216.7 *3* (1970-Malmskog). Iγ=0.015 (1972SeZI), 0.055 (1969HoZY), 0.012 (1969-Fettweis), 0.018 (1970-Malmskog). Ice(K)=0.016 *7* (1972SeZI).
226.3 *1*	0.0171 *7*	811.60	$3/2^+$	585.44	$3/2^+$	M1+E2	0.7 *3*	1.5 *3*	α(K)exp=1.1; α(L1)exp=0.3 (1972SeZI) α(K)=1.12 *29*; α(L)=0.284 *14*; α(M)=0.0710 *21* α(N)=0.0191 *6*; α(O)=0.00450 *17*; α(P)=0.00083 *5*; α(Q)=5.3×10^{-5} *13* Ice(K)=0.02 *1*, Ice(L1)=0.007 *3* (1972SeZI).

$^{233}_{91}Pa_{142}$-9

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡g]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	δ[b]	α[h]	Comments
									Eγ=226.1 *2* (1972SeZI), 226.3 *1* (1969HoZY), 226.23 *10* (1969-Fettweis), 226.2 *2* (1970-Malmskog), 801.0 (1969Va06). Iγ=0.023 (1972SeZI), 0.026 (1969HoZY), 0.042 (1969-Fettweis), 0.026 (1970-Malmskog).
237.884[&] *24*	0.0019 *4*	237.917	5/2$^+$	0.0	3/2$^-$	[E1]		0.0645	α(K)=0.0511 *8*; α(L)=0.01008 *15*; α(M)=0.00243 *4* α(N)=0.000646 *9*; α(O)=0.0001516 *22*; α(P)=2.75×10^{-5} *4*; α(Q)=1.740×10^{-6} *25*
242.3[&]	0.0029 *6*	454.42	3/2$^+$	212.328	5/2$^+$	[M1+E2]		1.01 *66*	α(K)=0.72 *61*; α(L)=0.22 *4*; α(M)=0.055 *7* α(N)=0.0148 *17*; α(O)=0.0035 *5*; α(P)=0.00063 *13*; α(Q)=3.5×10^{-5} *28*
246.0 *3*	0.0041 *6*	447.733	3/2$^-$	201.605	3/2$^+$	[E1]		0.0597	α(K)=0.0474 *7*; α(L)=0.00930 *14*; α(M)=0.00224 *4* α(N)=0.000596 *9*; α(O)=0.0001398 *20*; α(P)=2.54×10^{-5} *4*; α(Q)=1.620×10^{-6} *23* Eγ=246.0 *3* (1972SeZI, from γγ-coin).
250.5 *3*	0.0047 *3*	257.176	5/2$^-$	6.676	1/2$^-$	[E2]		0.317	α(K)=0.1044 *15*; α(L)=0.1561 *24*; α(M)=0.0424 *7* α(N)=0.01144 *17*; α(O)=0.00261 *4*; α(P)=0.000437 *7*; α(Q)=6.55×10^{-6} *10* Eγ=250.5 *3*, Iγ=0.0047 (1972SeZI).
252.9 *3*	0.0066 *3*	454.42	3/2$^+$	201.605	3/2$^+$	[M1+E2]		0.9 *6*	α(K)=0.64 *54*; α(L)=0.19 *4*; α(M)=0.048 *7* α(N)=0.0128 *18*; α(O)=0.0030 *5*; α(P)=0.00054 *13*; α(Q)=3.1×10^{-5} *25* Eγ=252.9 *3* (1972SeZI), 252.5 *5* (1970-Malmskog). Iγ=0.012 (1972SeZI), 0.011 (1970-Malmskog).
257.30[i] *15*		811.60	3/2$^+$	553.888	1/2$^+$,3/2$^+$	[M1+E2]		0.85 *56*	α(K)=0.61 *52*; α(L)=0.18 *4*; α(M)=0.045 *7* α(N)=0.0121 *19*; α(O)=0.0028 *5*; α(P)=0.00051 *13*; α(Q)=2.9×10^{-5} *24*
257.37[i] *15*	0.0524 *11*	257.176	5/2$^-$	0.0	3/2$^-$	M1+E2	1.1 *2*	0.80 *12*	α(K)exp=0.5; α(L1)exp=0.13 (1972SeZI) α(K)=0.56 *11*; α(L)=0.174 *8*; α(M)=0.0442 *15* α(N)=0.0119 *4*; α(O)=0.00278 *11*; α(P)=0.00050 *3*; α(Q)=2.7×10^{-5} *5* Iγ: 0.0524 *10* (2008De31). All the intensity of the 257.3 doublet is assigned from the 257 level, based on intensity balance arguments. Eγ=257.30 *15* (1972SeZI, doublet), 257.4 *1* (1969HoZY), 257.45 *10* (1969-Fettweis), 257.3 *4* (1970-Malmskog). Iγ=0.068 (1972SeZI), 0.085 (1969HoZY), 0.15 (1969-Fettweis), 0.081 (1970-Malmskog). Ice(K)=0.035 *7*, Ice(L1)=0.009 *4* (1972SeZI).
278.7[@] *4*	0.0047 *6*	447.733	3/2$^-$	169.169	1/2$^+$	[E1]		0.0450	α(K)=0.0359 *6*; α(L)=0.00691 *10*; α(M)=0.001662 *24* α(N)=0.000442 *7*; α(O)=0.0001040 *15*; α(P)=1.90×10^{-5} *3*; α(Q)=1.244×10^{-6} *18* Eγ=278.7 *4* (1972SeZI), 279.0 *4* (1970-Malmskog), 278.0 (1969Va06). Iγ=0.0078 (1972SeZI).

$^{233}_{91}Pa_{142}$-10

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡g]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	δ[b]	α[h]	Comments
285.5 *3*	0.0154 *9*	454.42	3/2$^+$	169.169	1/2$^+$	M1(+E2)	<0.7	0.92 *14*	α(K)exp=0.8 (1972SeZI) α(K)=0.72 *13*; α(L)=0.149 *12*; α(M)=0.0365 *23* α(N)=0.0098 *7*; α(O)=0.00233 *16*; α(P)=0.00044 *4*; α(Q)=3.4×10^{-5} *6* Eγ=285.5 *3* (1972SeZI), 284.90 *20* (1969-Fettweis). Iγ=0.021 (1972SeZI), 0.048 (1969-Fettweis). Ice(K)=0.016 *4* (1972SeZI).
309.9[&]	0.0032 *3*	764.53	1/2$^+$,3/2$^+$	454.42	3/2$^+$	[M1+E2]		0.50 *34*	α(K)=0.37 *31*; α(L)=0.098 *31*; α(M)=0.0245 *64* α(N)=0.0066 *17*; α(O)=0.00155 *43*; α(P)=2.84×10^{-4} *95*; α(Q)=1.8×10^{-5} *14*
316.1[&]	0.0037 *4*	553.888	1/2$^+$,3/2$^+$	237.917	5/2$^+$	[M1,E2]		0.47 *33*	α(K)=0.35 *29*; α(L)=0.092 *30*; α(M)=0.0230 *62* α(N)=0.0062 *17*; α(O)=0.00146 *42*; α(P)=2.67×10^{-4} *91*; α(Q)=1.7×10^{-5} *13*
347.4 *3*	0.0145 *8*	585.44	3/2$^+$	237.917	5/2$^+$	[M1+E2]		0.37 *25*	α(K)=0.27 *22*; α(L)=0.069 *25*; α(M)=0.0171 *54* α(N)=0.0046 *15*; α(O)=0.00109 *36*; α(P)=2.00×10^{-4} *76*; α(Q)=1.29×10^{-5} *99* Eγ=347.3 *3* (1972SeZI), 347.6 *3* (1969HoZY), 347.5 *3* (1969-Fettweis), 347.5 *5* (1970-Malmskog), 460.5 (1969Va06). Iγ=0.012 (1972SeZI), 0.0081 (1969HoZY), 0.066 (1969-Fettweis), 0.015 (1970-Malmskog).
359.74[#] *4*	0.0869 *11*	454.42	3/2$^+$	94.666	3/2$^+$	M1(+E2)	<0.23	0.54 *3*	α(K)exp=0.58; α(L1)exp=0.077 (1972SeZI) α(K)=0.427 *21*; α(L)=0.082 *3*; α(M)=0.0199 *6* α(N)=0.00534 *16*; α(O)=0.00128 *4*; α(P)=0.000244 *8*; α(Q)=1.98×10^{-5} *10* I$_\gamma$: 0.0869 *7* (2008De31). E$_\gamma$: others: 359.9 *1* (1972SeZI), 359.9 *1* (1969HoZY), 360.09 *10* (1969-Fettweis), 360.1 *1* (1970-Malmskog). Iγ=0.12 (1972SeZI), 0.13 (1969HoZY), 0.39 (1969-Fettweis), 0.15 (1970-Malmskog). Ice(K)=0.07 *1*, Ice(L1)=0.009 *4* (1972SeZI).
361.4 *2*	0.0218 *5*	447.733	3/2$^-$	86.423	5/2$^+$	[E1]		0.0255	α(K)=0.0205 *3*; α(L)=0.00380 *6*; α(M)=0.000911 *13* α(N)=0.000242 *4*; α(O)=5.73×10^{-5} *8*; α(P)=1.055×10^{-5} *15*; α(Q)=7.29×10^{-7} *11* Eγ=361.4 *2* (1972SeZI), 362.0 *6* (1970-Malmskog), 362.9 (1969Va06). Iγ=0.038 (1972SeZI), 0.043 (1970-Malmskog).
368.0 *3*	0.0037 *7*	454.42	3/2$^+$	86.423	5/2$^+$	[M1+E2]		0.31 *22*	α(K)=0.23 *19*; α(L)=0.058 *22*; α(M)=0.0143 *49* α(N)=0.0039 *13*; α(O)=9.1×10^{-4} *33*; α(P)=1.68×10^{-4} *68*; α(Q)=1.11×10^{-5} *84* Eγ=368.0 *3*, Iγ=0.0047 (1972SeZI).
377.2 *2*	0.0275 *9*	447.733	3/2$^-$	70.55	5/2$^-$	[M1+E2]		0.29 *20*	α(N)=0.0036 *13*; α(O)=8.5×10^{-4} *31*; α(P)=1.56×10^{-4} *64*;

$^{233}_{91}Pa_{142}$-11

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ[†]	I_γ[‡g]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	δ[b]	α[h]	Comments
									α(Q)=1.04×10^{-5} *79* α(K)=0.22 *18*; α(L)=0.054 *21*; α(M)=0.0133 *47* Eγ=377.0 *3* (1972SeZI), 377.3 *2* (1969HoZY), 376.94 *10* (1969-Fettweis), 377.2 *4* (1970-Malmskog), 377.2 (1969Va06). Iγ=0.038 (1972SeZI), 0.032 (1969HoZY), 0.10 (1969-Fettweis), 0.041 (1970-Malmskog).
383.5[&]	0.0019 *6*	454.42	3/2$^+$	70.55	5/2$^-$	[E1]		0.0225	α(K)=0.0181 *3*; α(L)=0.00333 *5*; α(M)=0.000797 *12* α(N)=0.000212 *3*; α(O)=5.02×10^{-5} *7*; α(P)=9.26×10^{-6} *13*; α(Q)=6.48×10^{-7} *9*
398.8 *2*	0.0111 *7*	984.80	(3/2)$^+$	585.44	3/2$^+$	[M1+E2]		0.25 *18*	α(K)=0.19 *15*; α(L)=0.045 *19*; α(M)=0.0112 *42* α(N)=0.0030 *11*; α(O)=7.2×10^{-4} *28*; α(P)=1.33×10^{-4} *57*; α(Q)=8.9×10^{-6} *67* Eγ=398.8 *5* (1972SeZI), 398.8 *2* (1969HoZY), 398.77 *20* (1969-Fettweis). Iγ=0.014 (1972SeZI), 0.023 (1969HoZY), 0.046 (1969-Fettweis).
[x]408.8 *5*	0.0005 *4*								Eγ=408.8 *5*, Iγ=0.0038 (1972SeZI); Eγ=413.8 (1969Va06).
412.5 *5*	0.0083 *7*	669.88	3/2$^-$	257.176	5/2$^-$	M1+E2	1.0 *3*	0.23 *6*	α(K)exp=0.17 (1972SeZI) α(K)=0.174 *46*; α(L)=0.041 *6*; α(M)=0.0102 *14* α(N)=0.0027 *4*; α(O)=0.00065 *9*; α(P)=0.000120 *18*; α(Q)=8.2×10^{-6} *21* Ice(K)=0.005 *2* (1972SeZI). Eγ=412.5 *5* (1972SeZI), 413.8 (1969Va06). Iγ=0.013 (1972SeZI).
[x]418.4 *5*	0.0091 *7*								Eγ=408.4 *5*, Iγ=0.012 (1972SeZI).
431.4 *5*	0.0178 *4*	984.80	(3/2)$^+$	553.888	1/2$^+$,3/2$^+$	M1(+E2)	<0.5	0.31 *3*	α(K)exp=0.30 (1972SeZI) α(K)=0.249 *24*; α(L)=0.048 *4*; α(M)=0.0117 *8* α(N)=0.00314 *20*; α(O)=0.00075 *5*; α(P)=0.000143 *10*; α(Q)=1.15×10^{-5} *11* Ice(K)=0.007 *3* (1972SeZI). Eγ=430.9 *4* (1972SeZI), 431.9 *2* (1969HoZY), 431.62 *10* (1969-Fettweis), 430.8 *6* (1970-Malmskog). Iγ=0.023 (1972SeZI), 0.049 (1969HoZY), 0.17 (1969-Fettweis), 0.026 (1970-Malmskog).
433.2 *4*	0.0117 *4*	1018.64	(3/2)	585.44	3/2$^+$	[D,E2]		0.18 *16*	Eγ=433.2 *4* (1972SeZI), 433.1 *6* (1970-Malmskog). Iγ=0.015 (1972SeZI), 0.0043 (1970-Malmskog).
[x]435.0[a] *5*									Eγ=435.0 *5* (1972SeZI, $\gamma\gamma$-coin only).
440.94[#] *4*	0.1912 *23*	447.733	3/2$^-$	6.676	1/2$^-$	M1(+E2)	<0.7	0.28 *5*	α(K)exp=0.25 (1972SeZI) α(K)=0.22 *4*; α(L)=0.044 *5*; α(M)=0.0106 *11* α(N)=0.0028 *3*; α(O)=0.00068 *8*; α(P)=0.000129 *15*; α(Q)=1.02×10^{-5} *17* I$_\gamma$: 0.1912 *13* (2008De31). E$_\gamma$: others: 440.96 *7* (1972Vo08), 441.0 *3* (1972SeZI), 440.9 *2*

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡ g]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [b]	δ [b]	α [h]	Comments
									(1969HoZY), 440.86 *10* (1969-Fettweis), 440.97 *20* (1970-Malmskog), 441.5 (1969Va06). Iγ=0.23 (1972SeZI), 0.27 (1969HoZY), 0.79 (1969-Fettweis), 0.39 (1970-Malmskog). Ice(K)=0.058 *7* (1972SeZI).
447.762[#] *20*	0.1043 *15*	447.733	3/2$^-$	0.0	3/2$^-$	M1(+E2)	<0.6	0.28 *4*	α(K)exp=0.26 (1972SeZI) α(K)=0.22 *3*; α(L)=0.043 *4*; α(M)=0.0104 *9* α(N)=0.00278 *24*; α(O)=0.00066 *6*; α(P)=0.000126 *12*; α(Q)=1.01×10^{-5} *13* I_γ: 0.1043 *10* (2008De31). E_γ: others: 447.77 *30* (1972Vo08), 447.7 *3* (1972SeZI), 447.6 *2* (1969HoZY), 447.57 *10* (1969-Fettweis), 447.6 *20* (1970-Malmskog), 445.3 (1969Va06). Iγ=0.15 (1972SeZI), 0.14 (1969HoZY), 0.42 (1969-Fettweis), 0.18 (1970-Malmskog). Ice(K)=0.037 *7* (1972SeZI).
[x]454.2[a] *5*	0.03								γ from 1969HoZY only, intensity of 0.04 adjusted to 0.03.
459.222[#] *7*	0.989 *10*	553.888	1/2$^+$,3/2$^+$	94.666	3/2$^+$	M1(+E2)	<0.6	0.26 *4*	α(K)exp=0.28; α(L1)exp=0.03 (1972SeZI) α(K)=0.20 *3*; α(L)=0.040 *4*; α(M)=0.0097 *9* α(N)=0.00259 *22*; α(O)=0.00062 *6*; α(P)=0.000118 *11*; α(Q)=9.4×10^{-6} *12* I_γ: 0.9886 *20* (2008De31). E_γ: others: 459.26 *6* (1972Vo08), 459.2 *2* (1972SeZI), 459.2 *1* (1969HoZY), 459.10 *10* (1969-Fettweis), 459.18 *20* (1970-Malmskog), 460.5 (1969Va06). Iγ=1.4 (1972SeZI), 1.4 (1969HoZY), 4.2 (1969-Fettweis), 1.7 (1970-Malmskog). Ice(K)=0.40 *5*, Ice(L1)=0.046 *7* (1972SeZI).
464.8[&]	0.0026 *3*	1018.64	(3/2)	553.888	1/2$^+$,3/2$^+$	[D,E2]		0.15 *13*	
467.6 *3*	0.0144 *4*	553.888	1/2$^+$,3/2$^+$	86.423	5/2$^+$	[M1,E2]		0.16 *11*	α(K)=0.125 *94*; α(L)=0.029 *13*; α(M)=0.0070 *30* α(N)=0.00189 *79*; α(O)=4.5×10^{-4} *20*; α(P)=8.4×10^{-5} *39*; α(Q)=5.8×10^{-6} *43* Eγ=467.5 *3* (1972SeZI), 467.8 *3* (1969HoZY). Iγ=0.018 (1972SeZI), 0.023 (1969HoZY).
[x]473.9 *5*	0.0033 *7*								Eγ=473.9 *5*, Iγ=0.0035 (1972SeZI); Eγ=473.8 *5*, Iγ=0.0027 (1969HoZY).
490.80[#] *6*	0.1078 *15*	585.44	3/2$^+$	94.666	3/2$^+$	M1(+E2)	<0.6	0.21 *3*	α(K)exp=0.21 (1972SeZI) α(K)=0.171 *22*; α(L)=0.033 *3*; α(M)=0.0080 *7* α(N)=0.00216 *19*; α(O)=0.00052 *5*; α(P)=9.8×10^{-5} *10*; α(Q)=7.9×10^{-6} *10* I_γ: 0.1078 *11* (2008De31).

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡ g]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [b]	δ [b]	α [h]	Comments
									E_γ: others: 490.9 *3* (1972SeZI), 490.7 *2* (1969HoZY), 490.70 *10* (1969-Fettweis), 490.82 *20* (1970-Malmskog), 492.0 (1969Va06). Iγ=0.17 (1972SeZI), 0.14 (1969HoZY), 0.46 (1969-Fettweis), 0.15 (1970-Malmskog). Ice(K)=0.037 *7* (1972SeZI).
497.1 [@ k] *4*	0.0128 *4*	553.888	1/2$^+$,3/2$^+$	57.098	7/2$^-$				E_γ: others: 497.1 *4* (1972SeZI), 496.5 (1969Va06). Iγ=0.021 (1972SeZI). Placement considered uncertain as it involves transition from 1/2$^+$,3/2$^+$ level to 7/2$^-$, 57 level.
499.02 [#] *4*	0.1576 *18*	585.44	3/2$^+$	86.423	5/2$^+$	M1(+E2)	<0.8	0.19 *4*	α(K)exp=0.18 (1972SeZI) α(K)=0.15 *3*; α(L)=0.030 *5*; α(M)=0.0074 *10* α(N)=0.0020 *3*; α(O)=0.00047 *7*; α(P)=9.0×10^{-5} *13*; α(Q)=7.1×10^{-6} *14* I_γ: 0.1576 *9* (2008De31). E_γ: others: 499.20 *30* (1972Vo08), 499.0 *3* (1972SeZI), 498.2 *2* (1969HoZY), 498.74 *10* (1969-Fettweis), 498.94 *20* (1970-Malmskog), 500.0 (1969Va06). Iγ=0.21 (1972SeZI), 0.19 (1969HoZY), 0.71 (1969-Fettweis), 0.27 (1970-Malmskog). Ice(K)=0.037 *7* (1972SeZI).
[x]505.5 *6*	0.0055 *3*								Eγ=505.5 *6*, Iγ=0.0049 (1972SeZI).
[x]513.4 *4*	0.0133 *4*								Eγ=513.4 *4*, Iγ=0.020 (1972SeZI); Eγ=513.6 *3*, Iγ=0.034 (1969HoZY); Eγ=513.17 *20*, Iγ=0.18 (1969-Fettweis); Eγ=513.7 *4*, Iγ=0.0021 (1970-Malmskog); Eγ=512.3 (1969Va06).
[x]517.0 *4*	0.0046 *3*								Eγ=517.0 *4*, Iγ=0.0068 (1972SeZI); Eγ=517.5 *3*, Iγ=0.016 (1969HoZY).
526.5 *2*	0.0463 *10*	764.53	1/2$^+$,3/2$^+$	237.917	5/2$^+$	[M1,E2]		0.120 *80*	α(K)=0.092 *68*; α(L)=0.0204 *97*; α(M)=0.0050 *23* α(N)=0.00134 *60*; α(O)=3.2×10^{-4} *15*; α(P)=6.0×10^{-5} *29*; α(Q)=4.3×10^{-6} *31* I_γ: 0.0463 *9* (2008De31). Eγ=526.5 *2* (1972SeZI), 526.6 *2* (1969HoZY), 526.30 *10* (1969-Fettweis), 526.58 *30* (1970-Malmskog), 528.0 (1969Va06). Iγ=0.063 (1972SeZI), 0.064 (1969HoZY), 0.19 (1969-Fettweis), 0.071 (1970-Malmskog).
[x]531.8 *4*	0.0070 *7*								Eγ=531.8 *4*, Iγ=0.0042 (1972SeZI); Eγ=531.9 *3*, Iγ=0.0095 (1969HoZY); Eγ=531.2 *4*, Iγ=0.011 (1970-Malmskog).
552.2 *2*	0.0165 *5*	764.53	1/2$^+$,3/2$^+$	212.328	5/2$^+$	[M1,E2]		0.106 *70*	α(K)=0.082 *59*; α(L)=0.0178 *86*; α(M)=0.0044 *20* α(N)=0.00117 *53*; α(O)=2.8×10^{-4} *13*; α(P)=5.2×10^{-5} *26*; α(Q)=3.8×10^{-6} *27* Eγ=552.1 *3* (1972SeZI), 552.3 *2* (1969HoZY), 551.17 *20* (1969-Fettweis), 551.89 *60* (1970-Malmskog), 553.5 (1969Va06). Iγ=0.024 (1972SeZI), 0.047 (1969HoZY), 0.054 (1969-Fettweis), 0.026 (1970-Malmskog).

$^{233}_{91}Pa_{142}$-14

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡g]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	δ[b]	α[h]	Comments
553.7[&]	0.0030 *3*	553.888	$1/2^+,3/2^+$	0.0	$3/2^-$	[E1]		0.01068	α(K)=0.00866 *13*; α(L)=0.001526 *22*; α(M)=0.000364 *5* α(N)=9.69×10^{-5} *14*; α(O)=2.30×10^{-5} *4*; α(P)=4.30×10^{-6} *6*; α(Q)=3.19×10^{-7} *5*
[x]554.9 *5*	0.0031 *3*								Eγ=554.9 *5*, Iγ=0.0035 (1972SeZI); Eγ=553.76 *25*, Iγ=0.0033 (1969-Fettweis); Eγ=554.4 *7*, Iγ=0.0086 (1970-Malmskog).
562.6 *2*	0.0545 *11*	764.53	$1/2^+,3/2^+$	201.605	$3/2^+$	[M1+E2]		0.101 *67*	α(K)=0.078 *56*; α(L)=0.0169 *82*; α(M)=0.0042 *19* α(N)=0.00111 *51*; α(O)=2.6×10^{-4} *13*; α(P)=5.0×10^{-5} *25*; α(Q)=3.6×10^{-6} *26* I_γ: 0.0545 *10* (2008De31). Eγ=562.8 *4* (1972SeZI), 562.6 *2* (1969HoZY), 562.56 *10* (1969-Fettweis), 562.79 *40* (1970-Malmskog), 564.0 (1969Va06). Iγ=0.070 (1972SeZI), 0.088 (1969HoZY), 0.22 (1969-Fettweis), 0.084 (1970-Malmskog).
573.6 *3*	0.0332 *9*	811.60	$3/2^+$	237.917	$5/2^+$	[M1+E2]		0.096 *63*	α(K)=0.074 *53*; α(L)=0.0161 *78*; α(M)=0.0039 *18* α(N)=0.00105 *49*; α(O)=2.5×10^{-4} *12*; α(P)=4.7×10^{-5} *24*; α(Q)=3.4×10^{-6} *24* I_γ: 0.0332 *8* (2008De31). Eγ=573.7 *4* (1972SeZI), 573.5 *3* (1969HoZY), 573.40 *15* (1969-Fettweis), 573.76 *40* (1970-Malmskog), 576.9 (1969Va06). Iγ=0.042 (1972SeZI), 0.043 (1969HoZY), 0.136 (1969-Fettweis), 0.043 (1970-Malmskog).
578.7[&]	0.0017 *5*	585.44	$3/2^+$	6.676	$1/2^-$	[E1]		0.00980	α(K)=0.00796 *12*; α(L)=0.001395 *20*; α(M)=0.000332 *5* α(N)=8.85×10^{-5} *13*; α(O)=2.10×10^{-5} *3*; α(P)=3.93×10^{-6} *6*; α(Q)=2.94×10^{-7} *5*
583.2[&]	0.0016 *5*	669.88	$3/2^-$	86.423	$5/2^+$	[E1]		0.00966	α(K)=0.00784 *11*; α(L)=0.001373 *20*; α(M)=0.000327 *5* α(N)=8.72×10^{-5} *13*; α(O)=2.07×10^{-5} *3*; α(P)=3.87×10^{-6} *6*; α(Q)=2.90×10^{-7} *4*
595.2 *2*	0.1178 *14*	764.53	$1/2^+,3/2^+$	169.169	$1/2^+$	M1(+E2)	<0.9	0.12 *3*	α(K)exp=0.10 (1972SeZI) α(K)=0.094 *22*; α(L)=0.018 *4*; α(M)=0.0045 *8* α(N)=0.00119 *20*; α(O)=0.00029 *5*; α(P)=5.4×10^{-5} *10*; α(Q)=4.3×10^{-6} *10* I_γ: 0.1178 *8* (2008De31). Ice(K)=0.016 *7* (1972SeZI). Eγ=595.2 *2* (1972SeZI), 595.3 *2* (1969HoZY), 595.15 *10* (1969-Fettweis), 595.3 *4* (1970-Malmskog), 596.0 (1969Va06). Iγ=0.16 (1972SeZI), 0.12 (1969HoZY), 0.50 (1969-Fettweis).
599.3 *2*	0.0294 *5*	811.60	$3/2^+$	212.328	$5/2^+$	[M1+E2]		0.085 *56*	α(K)=0.066 *47*; α(L)=0.0142 *70*; α(M)=0.0035 *17* α(N)=9.3×10^{-4} *44*; α(O)=2.2×10^{-4} *11*; α(P)=4.2×10^{-5} *21*; α(Q)=3.1×10^{-6} *21* I_γ: 0.0294 *4* (2008De31). Eγ=599.1 *4* (1972SeZI), 599.3 *2* (1969HoZY), 599.36 *10* (1969-Fettweis), 599.13 *40* (1970-Malmskog).

$^{233}_{91}Pa_{142}$-15

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡ g]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [b]	δ [b]	α [h]	Comments
610.0 *3*	0.0567 *11*	811.60	3/2$^+$	201.605	3/2$^+$	[M1+E2]		0.081 *53*	Iγ=0.047 (1972SeZI), 0.041 (1969HoZY), 0.12 (1969-Fettweis), 0.047 (1970-Malmskog). α(K)=0.063 *45*; α(L)=0.0135 *67*; α(M)=0.0033 *16* α(N)=8.9×10^{-4} *42*; α(O)=2.1×10^{-4} *10*; α(P)=4.0×10^{-5} *20*; α(Q)=2.9×10^{-6} *20* I_γ: 0.0567 *9* (2008De31). Eγ=610.0 *3* (1972SeZI), 609.9 *2* (1969HoZY), 609.89 *10* (1969-Fettweis), 610.2 *5* (1970-Malmskog), 609.8 (1969Va06).
642.5 *2*	0.0202 *5*	811.60	3/2$^+$	169.169	1/2$^+$	[M1+E2]		0.071 *46*	Iγ=0.085 (1972SeZI), 0.080 (1969HoZY), 0.24 (1969-Fettweis), 0.097 (1970-Malmskog). α(K)=0.056 *39*; α(L)=0.0118 *59*; α(M)=0.0029 *14* α(N)=7.7×10^{-4} *37*; α(O)=1.83×10^{-4} *88*; α(P)=3.4×10^{-5} *18*; α(Q)=2.6×10^{-6} *18* I_γ: 0.0202 *4* (2008De31). Eγ=642.3 *4* (1972SeZI), 642.6 *2* (1969HoZY), 642.53 *10* (1969-Fettweis), 642.39 *40* (1970-Malmskog), 641.9 (1969Va06).
663.3 *5*	0.0037 *5*	669.88	3/2$^-$	6.676	1/2$^-$	[M1+E2]		0.066 *42*	Iγ=0.028 (1972SeZI), 0.028 (1969HoZY), 0.091 (1969-Fettweis), 0.030 (1970-Malmskog). α(K)=0.051 *35*; α(L)=0.0108 *54*; α(M)=0.0026 *13* α(N)=7.1×10^{-4} *34*; α(O)=1.68×10^{-4} *81*; α(P)=3.2×10^{-5} *16*; α(Q)=2.4×10^{-6} *16* Eγ=663.3 *5*, Iγ=0.0024 (1972SeZI).
x665.0 [a] *5*	0.05								γ from 1969HoZY only, Iγ=0.07 is adjusted to 0.05.
669.885 [j @] *28*	≈0.0014 [j]	669.88	3/2$^-$	0.0	3/2$^-$	[M1+E2]		0.064 *41*	α(K)=0.050 *34*; α(L)=0.0105 *53*; α(M)=0.0026 *13* α(N)=6.9×10^{-4} *33*; α(O)=1.64×10^{-4} *79*; α(P)=3.1×10^{-5} *16*; α(Q)=2.3×10^{-6} *16* I_γ: 0.5038 *15* (2008De31).
669.885 [j] *28*	0.5024 [j] *52*	764.53	1/2$^+$,3/2$^+$	94.666	3/2$^+$	M1(+E2)	<0.5	0.097 *9*	α(K)exp=0.10 (1972SeZI) α(K)=0.077 *7*; α(L)=0.0147 *11*; α(M)=0.00353 *25* α(N)=0.00095 *7*; α(O)=0.000227 *17*; α(P)=4.3×10^{-5} *4*; α(Q)=3.5×10^{-6} *4* I_γ: 0.5038 *15* (2008De31), most of the intensity of 669.9 doublet is assigned from the 764 level. Based on Alaga rule, only a small component may belong from the 669 level. E_γ: weighted average of 669.901 *16* (1979Bo30), 669.64 *20* (1972Vo08), 669.8 *2* (1972SeZI), 669.75 *5* (1969HoZY). Others: 669.98 *10* (1969-Fettweis), 669.8 *3* (1970-Malmskog), 670.5 (1969Va06). Iγ=0.68 (1972SeZI), 0.63 (1969HoZY), 2.3 (1969-Fettweis), 0.75 (1970-Malmskog).

$^{233}_{91}Pa_{142}$-16

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡g]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	δ[b]	α[h]	Comments
									Ice(K)=0.068 *10* (1972SeZI). Total Iγ=0.5038 *15* (2008De31); divided by 2008De31.
678.04[#] *10*	0.0647 *9*	764.53	1/2$^+$,3/2$^+$	86.423	5/2$^+$	[M1,E2]		0.062 *40*	α(K)=0.049 *33*; α(L)=0.0102 *51*; α(M)=0.0025 *12* α(N)=6.6×10^{-4} *32*; α(O)=1.58×10^{-4} *77*; α(P)=3.0×10^{-5} *15*; α(Q)=2.2×10^{-6} *15* I_γ: 0.0647 *6* (2008De31). E_γ: others: 677.8 *4* (1972SeZI), 677.8 *3* (1969HoZY), 677.88 *15* (1969-Fettweis), 678.0 *4* (1970-Malmskog), 801.0 (1969Va06). Iγ=0.087 (1972SeZI), 0.082 (1969HoZY), 0.27 (1969-Fettweis), 0.094 (1970-Malmskog).
[x]681.2 *6*	0.0143 *4*								Eγ=681.2 *6*, Iγ=0.018 (1972SeZI); Eγ=682.6 *5*, Iγ=0.011 (1969HoZY); Eγ=681.5 *5*, Iγ=0.012 (1969-Fettweis); Eγ=680.1 (1969Va06).
[x]690.0[&]	0.0021 *5*								
[x]698.5 *6*	0.0106 *5*								Eγ=698.5 *6*, Iγ=0.012 (1972SeZI); Eγ=697.5 *5*, Iγ=0.0095 (1969HoZY); Eγ=697.85 *15*, Iγ=0.050 (1969-Fettweis); Eγ=698.7 *6*, Iγ=0.013 (1970-Malmskog).
703.6[@] *5*	0.0091 *5*	941.97	(3/2)	237.917	5/2$^+$	[D,E2]		0.05 *4*	Eγ=703.7 *6* (1972SeZI), 703.6 *5* (1969HoZY), 703.6 *6* (1970-Malmskog). Iγ=0.011 (1972SeZI), 0.0068 (1969HoZY), 0.011 (1970-Malmskog).
707.9 *5*	0.0091 *5*	811.60	3/2$^+$	103.661	7/2$^+$	[E2]		0.0209	α(N)=0.000310 *5*; α(O)=7.26×10^{-5} *11*; α(P)=1.310×10^{-5} *19*; α(Q)=6.87×10^{-7} *10* α(K)=0.01476 *21*; α(L)=0.00454 *7*; α(M)=0.001153 *17* Eγ=708.0 *6* (1972SeZI), 707.8 *5* (1969HoZY), 708.0 *6* (1970-Malmskog), 707.9 (1969Va06). Iγ=0.012 (1972SeZI), 0.0068 (1969HoZY), 0.141 (1969-Fettweis), 0.011 (1970-Malmskog).
716.9 *4*	0.0421 *8*	811.60	3/2$^+$	94.666	3/2$^+$	[M1+E2]		0.054 *34*	α(K)=0.042 *28*; α(L)=0.0087 *44*; α(M)=0.0021 *11* α(N)=5.7×10^{-4} *28*; α(O)=1.36×10^{-4} *67*; α(P)=2.6×10^{-5} *13*; α(Q)=1.9×10^{-6} *13* I_γ: 0.0421 *8* (2008De31). Eγ=716.9 *4* (1972SeZI), 716.7 *2* (1969HoZY), 716.78 *30* (1969-Fettweis), 716.96 *60* (1970-Malmskog), 718.1 (1969Va06). Iγ=0.056 (1972SeZI), 0.054 (1969HoZY), 0.20 (1969-Fettweis), 0.060 (1970-Malmskog).
725.0 *4*	0.0633 *9*	811.60	3/2$^+$	86.423	5/2$^+$	M1(+E2)	<0.5	0.078 *7*	α(K)exp=0.10 (1972SeZI) α(K)=0.063 *6*; α(L)=0.0119 *9*; α(M)=0.00286 *21* α(N)=0.00077 *6*; α(O)=0.000183 *13*; α(P)=3.5×10^{-5} *3*; α(Q)=2.86×10^{-6} *25* I_γ: 0.0633 *6* (2008De31). Ice(K)=0.010 *5* (1972SeZI).

$^{233}_{91}Pa_{142}$-17

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡g]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	α[h]	Comments
								Eγ=725.0 *4* (1972SeZI), 724.8 *2* (1969HoZY), 724.80 *10* (1969-Fettweis), 725.1 *6* (1970-Malmskog), 724.0 (1969Va06). Iγ=0.087 (1972SeZI), 0.081 (1969HoZY), 0.33 (1969-Fettweis), 0.090 (1970-Malmskog).
727.8[&]	0.0029 *2*	984.80	$(3/2)^+$	257.176	$5/2^-$	[E1]	0.00636	α(K)=0.00519 *8*; α(L)=0.000889 *13*; α(M)=0.000211 *3* α(N)=5.63×10^{-5} *8*; α(O)=1.339×10^{-5} *19*; α(P)=2.52×10^{-6} *4*; α(Q)=1.95×10^{-7} *3*
740.9 *2*	0.0236 *5*	811.60	$3/2^+$	70.55	$5/2^-$	[E1]	0.00616	α(K)=0.00502 *7*; α(L)=0.000859 *12*; α(M)=0.000204 *3* α(N)=5.44×10^{-5} *8*; α(O)=1.294×10^{-5} *19*; α(P)=2.43×10^{-6} *4*; α(Q)=1.88×10^{-7} *3* Iγ: 0.0236 *4* (2008De31). Eγ=740.9 *4* (1972SeZI), 740.9 *2* (1969HoZY), 740.87 *15* (1969-Fettweis), 741.1 *8* (1970-Malmskog), 740.5 (1969Va06). Iγ=0.031 (1972SeZI), 0.039 (1969HoZY), 0.11 (1969-Fettweis), 0.011 (1970-Malmskog).
[x]744.9 *5*	0.0053 *2*							Eγ=744.9 *5*, Iγ=0.0068 (1972SeZI).
[x]751.6 *6*	0.0023 *4*							Eγ=751.6 *6*, Iγ=0.004 (1972SeZI); Eγ=751.0 (1969Va06).
757.6 *2*	0.0324 *7*	764.53	$1/2^+,3/2^+$	6.676	$1/2^-$	[E1]	0.00591	α(N)=5.21×10^{-5} *8*; α(O)=1.240×10^{-5} *18*; α(P)=2.33×10^{-6} *4*; α(Q)=1.81×10^{-7} *3* α(K)=0.00482 *7*; α(L)=0.000823 *12*; α(M)=0.000195 *3* Iγ: 0.0324 *6* (2008De31). Eγ=757.8 *4* (1972SeZI), 757.6 *2* (1969HoZY), 757.66 *10* (1969-Fettweis), 757.8 *7* (1970-Malmskog), 757.0 (1969Va06). Iγ=0.042 (1972SeZI), 0.042 (1969HoZY), 0.16 (1969-Fettweis), 0.047 (1970-Malmskog).
764.3 *2*	0.0891 *11*	764.53	$1/2^+,3/2^+$	0.0	$3/2^-$	[E1]	0.00581	α(N)=5.12×10^{-5} *8*; α(O)=1.220×10^{-5} *17*; α(P)=2.30×10^{-6} *4*; α(Q)=1.784×10^{-7} *25* α(K)=0.00475 *7*; α(L)=0.000809 *12*; α(M)=0.000192 *3* Iγ: 0.0891 *7* (2008De31). Eγ=764.4 *4* (1972SeZI), 764.3 *2* (1969HoZY), 764.57 *10* (1969-Fettweis), 764.5 (1970-Malmskog), 763.1 (1969Va06). Iγ=0.12 (1972SeZI), 0.11 (1969HoZY), 0.42 (1969-Fettweis), 0.12 (1970-Malmskog).
[x]767.5[&]	0.0032 *2*							
[x]774.0 *4*	0.0108 *5*							Eγ=774.0 *4*, Iγ=0.014 (1972SeZI); Eγ=774.2 *3*, Iγ=0.011 (1969HoZY); Eγ=774.38 *20* (1969-Fettweis); Eγ=774.4 *7*, Iγ=0.015 (1970-Malmskog); Eγ=775.7 (1969Va06).
783.3 *4*	0.0056 *3*	984.80	$(3/2)^+$	201.605	$3/2^+$	[M1+E2]	0.043 *26*	α(K)=0.034 *22*; α(L)=0.0069 *35*; α(M)=0.00168 *81* α(N)=4.5×10^{-4} *22*; α(O)=1.07×10^{-4} *53*; α(P)=2.0×10^{-5} *11*; α(Q)=1.55×10^{-6} *99* Eγ=782.7 *5* (1972SeZI), 783.5 *3* (1969HoZY), 785.4 *5* (1969-Fettweis), 783.7 *7* (1970-Malmskog), 785.0 (1969Va06). Iγ=0.0061 (1972SeZI), 0.0081 (1969HoZY), 0.10 (1969-Fettweis), 0.013 (1970-Malmskog).

$^{233}_{91}Pa_{142}$-18

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ[†]	I_γ[‡g]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	α[h]	Comments
[x]784.2 *5*	0.0022 *2*							Eγ=784.2 *5*, Iγ=0.0049 (1972SeZI).
805.2 *2*	0.0214 *6*	811.60	3/2$^+$	6.676	1/2$^-$	[E1]	0.00529	α(K)=0.00432 *6*; α(L)=0.000733 *11*; α(M)=0.0001740 *25* α(N)=4.64×10^{-5} *7*; α(O)=1.105×10^{-5} *16*; α(P)=2.08×10^{-6} *3*; α(Q)=1.628×10^{-7} *23* Eγ=804.8 *4* (1972SeZI), 805.3 *2* (1969HoZY), 805.13 *10* (1969-Fettweis), 805.6 *6* (1970-Malmskog), 801.0 (1969Va06). Iγ=0.031 (1972SeZI), 0.034 (1969HoZY), 0.141 (1969-Fettweis), 0.0056 (1970-Malmskog).
806.4 *5*	0.0123 *5*	1018.64	(3/2)	212.328	5/2$^+$	[D,E2]	0.04 *3*	Eγ=806.4 *5*, Iγ=0.013 (1972SeZI).
811.4 *7*	0.0060 *2*	811.60	3/2$^+$	0.0	3/2$^-$	[E1]	0.00522	α(K)=0.00426 *6*; α(L)=0.000723 *11*; α(M)=0.0001715 *25* α(N)=4.57×10^{-5} *7*; α(O)=1.089×10^{-5} *16*; α(P)=2.05×10^{-6} *3*; α(Q)=1.606×10^{-7} *23* Eγ=811.6 *7* (1972SeZI), 811 *1* (1969HoZY), 811.5 *6* (1969-Fettweis), 811.8 *7* (1970-Malmskog), 811.9 (1969Va06). Iγ=0.0078 (1972SeZI), 0.0068 (1969HoZY), 0.029 (1969-Fettweis), 0.011 (1970-Malmskog).
816.1 *2*	0.0195 *6*	984.80	(3/2)$^+$	169.169	1/2$^+$	[M1+E2]	0.039 *24*	α(K)=0.031 *20*; α(L)=0.0062 *31*; α(M)=0.00150 *72* α(N)=4.0×10^{-4} *20*; α(O)=9.6×10^{-5} *47*; α(P)=1.82×10^{-5} *92*; α(Q)=1.39×10^{-6} *88* Eγ=815.9 *4* (1972SeZI), 816.2 *2* (1969HoZY), 816.25 *10* (1969-Fettweis), 816.2 *7* (1970-Malmskog). Iγ=0.028 (1972SeZI), 0.034 (1969HoZY), 0.15 (1969-Fettweis), 0.041 (1970-Malmskog).
817.0 *6*	0.0095 *5*	1018.64	(3/2)	201.605	3/2$^+$	[D,E2]	0.034 *28*	Eγ=817.0 *6*, Iγ=0.016 (1972SeZI).
[x]832.0[a] *3*	0.0055							Eγ=832.0 *3*, Iγ=0.0081 (1969HoZY), intensity adjusted to 0.0055; Eγ=831.99 *25*, Iγ=0.025 (1969-Fettweis).
[x]846.8[a] *7*	0.0010							Eγ=846.8 *7*, Iγ=0.0014 (1972SeZI), intensity adjusted to 0.0010; Eγ=846.8 *3*, Iγ=0.011 (1969HoZY); Eγ=846.90 *20*, Iγ=0.050 (1969-Fettweis); Eγ=846.8 *8*, Iγ=0.0015 (1970-Malmskog).
849.3 *7*	0.0039 *3*	1018.64	(3/2)	169.169	1/2$^+$	[D,E2]	0.030 *25*	Eγ=849.3 *7* (1972SeZI), 851.8 *8* (1969-Fettweis). Iγ=0.0047 (1972SeZI), 0.050 (1969-Fettweis).
870.7[@] *7*	0.0031 *2*	941.97	(3/2)	70.55	5/2$^-$	[D,E2]	0.028 *24*	Eγ=870.7 *7*, Iγ=0.0021 (1972SeZI).
873.9[@] *3*	0.0120 *3*	968.7	(1/2,3/2)	94.666	3/2$^+$	[D,E2]	0.028 *24*	Eγ=874.0 *5* (1972SeZI), 873.8 *3* (1969HoZY), 873.81 *15* (1969-Fettweis), 874.24 *8* (1970-Malmskog), 873.0 (1969Va06). Iγ=0.0082 (1972SeZI), 0.020 (1969HoZY), 0.066 (1969-Fettweis), 0.021 (1970-Malmskog).
880.7 *3*	0.0097 *4*	984.80	(3/2)$^+$	103.661	7/2$^+$	[E2]	0.01345	α(N)=0.0001731 *25*; α(O)=4.08×10^{-5} *6*; α(P)=7.48×10^{-6} *11*; α(Q)=4.51×10^{-7} *7* α(K)=0.01000 *14*; α(L)=0.00258 *4*; α(M)=0.000645 *9* Eγ=880.9 *5* (1972SeZI), 880.6 *3* (1969HoZY), 880.04 *20* (1969-Fettweis), 881.3 *8* (1970-Malmskog), 879.5 (1969Va06). Iγ=0.0078 (1972SeZI), 0.014 (1969HoZY), 0.037 (1969-Fettweis), 0.015 (1970-Malmskog).

$^{233}_{91}Pa_{142}$-19

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡ g]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [b]	α [h]	Comments
890.0 *3*	0.1052 *13*	984.80	$(3/2)^+$	94.666	$3/2^+$	[M1+E2]	0.031 *18*	α(K)=0.025 *15*; α(L)=0.0049 *25*; α(M)=0.00120 *57* α(N)=3.2×10^{-4} *16*; α(O)=7.7×10^{-5} *37*; α(P)=1.45×10^{-5} *72*; α(Q)=1.12×10^{-6} *68* I_γ: 0.1052 *8* (2008De31). Eγ=890.1 *5* (1972SeZI), 889.9 *3* (1969HoZY), 889.89 *15* (1969-Fettweis), 890.5 *6* (1970-Malmskog), 887.2 (1969Va06). Iγ=0.014 (1972SeZI), 0.011 (1969HoZY), 0.054 (1969-Fettweis), 0.015 (1970-Malmskog).
898.4 *8*	0.0022 *4*	984.80	$(3/2)^+$	86.423	$5/2^+$	[M1+E2]	0.031 *18*	α(K)=0.024 *15*; α(L)=0.0048 *24*; α(M)=0.00117 *56* α(N)=3.1×10^{-4} *15*; α(O)=7.5×10^{-5} *36*; α(P)=1.41×10^{-5} *71*; α(Q)=1.09×10^{-6} *66* Eγ=898.4 *8* (1972SeZI), Iγ=0.0033 (1972SeZI).
x918.9 [a] *5*	0.005							γ from 1969HoZY only, intensity of 0.007 adjusted to 0.005.
935.5 [@] *3*	0.0369 *7*	941.97	(3/2)	6.676	$1/2^-$	[D,E2]	0.024 *20*	I_γ: 0.0369 *6* (2008De31). Eγ=935.2 *7* (1972SeZI), 935.6 *3* (1969HoZY), 934.79 *10* (1969-Fettweis), 935.4 *7* (1970-Malmskog), 931.0 (1969Va06). Iγ=0.049 (1972SeZI), 0.043 (1969HoZY), 0.17 (1969-Fettweis), 0.054 (1970-Malmskog).
942.2 [@] *5*	0.0048 *3*	941.97	(3/2)	0.0	$3/2^-$	[D,E2]	0.023 *19*	Eγ=941.9 *8* (1972SeZI), 942.3 *5* (1969HoZY), 942.6 *8* (1970-Malmskog), 939.5 (1969Va06). Iγ=0.0078 (1972SeZI), 0.0068 (1969HoZY), 0.0086 (1970-Malmskog).
x942.8 [&]	0.0019 *3*							
948.0 *8*	0.0060 *3*	1018.64	(3/2)	70.55	$5/2^-$	[D,E2]	0.023 *19*	Eγ=948.0 *8* (1972SeZI), 948.7 *8* (1970-Malmskog). Iγ=0.0075 (1972SeZI), 0.0085 (1970-Malmskog).
x955.0 *10*	0.0002 *3*							Eγ=955.0 *10*, Iγ=0.0054 (1969HoZY).
960.8 [@] *8*	0.0041 *2*	1064.5	(3/2)	103.661	$7/2^+$	[Q]	0.05 *4*	Eγ=960.8 *8*, Iγ=0.0068 (1972SeZI).
962.8 [@] *9*	0.0015 *2*	968.7	(1/2,3/2)	6.676	$1/2^-$	[D,E2]	0.022 *18*	Eγ=962.8 *9* (1972SeZI), 962.5 *10* (1969HoZY), 961.6 *8* (1970-Malmskog). Iγ=0.0014 (1972SeZI), 0.0068 (1969HoZY), 0.0064 (1970-Malmskog).
968.6 [@] *10*	0.0083 *3*	968.7	(1/2,3/2)	0.0	$3/2^-$	[D,E2]	0.022 *18*	Eγ=968.2 *9* (1972SeZI), 970.8 *20* (1969HoZY), 969.8 *9* (1970-Malmskog), 966.5 (1969Va06). Iγ=0.011 (1972SeZI), 0.0041 (1969HoZY), 0.011 (1970-Malmskog).
978.6 *8*	0.0058 *3*	984.80	$(3/2)^+$	6.676	$1/2^-$	[E1]	0.00374	α(K)=0.00306 *5*; α(L)=0.000512 *8*; α(M)=0.0001211 *17* α(N)=3.23×10^{-5} *5*; α(O)=7.71×10^{-6} *11*; α(P)=1.458×10^{-6} *21*; α(Q)=1.164×10^{-7} *17* Eγ=978.3 *8* (1972SeZI), 979.1 *10* (1969HoZY), 978.6 *4* (1970-Malmskog), 976.8 (1969Va06). Iγ=0.0075 (1972SeZI), 0.0061 (1969HoZY), 0.0064 (1970-Malmskog).
985.0 *8*	0.0102 *3*	984.80	$(3/2)^+$	0.0	$3/2^-$	[E1]	0.00369	α(K)=0.00303 *5*; α(L)=0.000506 *8*; α(M)=0.0001197 *17* α(N)=3.19×10^{-5} *5*; α(O)=7.62×10^{-6} *11*; α(P)=1.441×10^{-6} *21*; α(Q)=1.151×10^{-7} *17* Eγ=985.0 *8* (1972SeZI), 985.5 *10* (1970-Malmskog). Iγ=0.0014 (1972SeZI), 0.015 (1969HoZY).

$^{233}_{91}Pa_{142}$-20

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

E_γ [†]	I_γ [‡ g]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [b]	α [h]	Comments
994.3[@] *10*	0.0006 *1*	1064.5	(3/2)	70.55	5/2$^-$	[D,E2]	0.020 *16*	Eγ=995 *1* (1972SeZI), 993.5 *10* (1969HoZY). Iγ=0.0028 (1972SeZI), 0.0014 (1969HoZY).
[x]1001 *1*	0.0008 *2*							Eγ=1001 *1*, Iγ=0.0040 (1972SeZI).
1007[@] *1*	0.0014 *2*	1064.5	(3/2)	57.098	7/2$^-$	[Q]	0.05 *4*	Eγ=1007 *1*, Iγ=0.0028 (1972SeZI).
1011[@] *1*	0.0019 *2*	1018.64	(3/2)	6.676	1/2$^-$	[D,E2]	0.019 *16*	Eγ=1011 *1*, Iγ=0.0040 (1972SeZI).
[x]1026.5[a] *10*	0.0055							γ from 1969HoZY only, intensity of 0.0081 adjusted to 0.0055.
[x]1092.5[a] *10*	0.0052							γ from 1969HoZY only, intensity of 0.0077 adjusted to 0.0052.
1132.1[&]	0.0006 *2*	1138.94	(1/2,3/2)	6.676	1/2$^-$	[D,E2]	0.015 *12*	
1139.1[&]	0.0004 *1*	1138.94	(1/2,3/2)	0.0	3/2$^-$	[D,E2]	0.015 *12*	
[x]1146[a] *1*	0.0020							Eγ=1146 *1*, Iγ=0.0029 (1972SeZI), intensity adjusted to 0.0020; Eγ=1143.5 *10*, Iγ=0.007 (1969HoZY).
[x]1201[a] *1*	0.005							γ from 1969HoZY only, intensity of 0.007 adjusted to 0.005.

[†] Values are weighted averages of 1972SeZI and 1969HoZY, when possible. More precise values from 1979Bo30 and 1972Vo08, and some from the Adopted Gammas (based on ^{237}Np α decay) are given when available. Other exceptions are noted. It should be noted that 1972SeZI has more complete data, but the energies in this work are somewhat less precise than in 1969HoZY. Values listed in Table 4 of 2008De31 were taken by the authors from 2005Si15 evaluation.

[‡] Values are from 2008De31, per 100 decays of ^{233}Th. Authors mention that uncertainty due to detection efficiencies were not included in their quoted intensities in Table 4. 2008De31 state detection efficiency uncertainties of ≈1% at 100 keV and ≈0.5% at 1 MeV. Evaluators have used 1% overall uncertainty, and added that in quadrature to the uncertainties given by the authors in Table 4. Values measured in previous studies are given under comments. These values are higher by a factor of 1.5 as the values were normalized to absolute Iγ=2.7% (measured by 1957Fr55) for the 86-keV transition. The photon intensity of the 86-keV transition is determined as 1.8428% *18* (uncertainty in detector efficiency not included) in 2008De31.

[#] Measurement of 1979Bo30 using crystal spectrometer.

[@] Placement is from 2008De31, as shown in the decay scheme matrix Fig. 4.

[&] γ reported by 2008De31 only in the decay of ^{233}Th. Energy is taken from the Adopted Gammas, when given with uncertainty, otherwise from 2008De31. Placement is shown by 2008De31 in the decay scheme matrix Fig. 4, see also the Adopted dataset.

[a] γ not reported in 2008De31. Intensity reported in previous 2005Si15 evaluation is adjusted to the Iγ normalization of 2008De31, requiring multiplying the intensity by a factor of 0.68.

[b] From ce measurements of 1972SeZI unless otherwise stated. For ce data from 1972SeZI, mixing ratios were deduced by the evaluators using BrIccMixing code with the assumption of 25% uncertainty in the ce data, as no uncertainties were given by 1972SeZI. All the assignments match those in the Adopted Gammas.

[c] From the Adopted Gammas, based on data from ^{237}Np α decay.

[d] γ not observed in ^{233}Th β^- decay; energy taken from the Adopted Gammas.

[e] Iγ(212.3)/Iγ(117.5)=2.24 *32* is in severe disagreement with 0.894 *28* from the Adopted Gammas, where the ratio is adopted from ^{237}Np α decay, as the 212-keV level is more strongly populated in that decay as compared to that in β^- decay. One or both the intensities are problematic in this decay.

[f] Total transition intensity feeding the 103.66 level is 0.164% *9*, but its division among the 46.5- and the 17.4-keV transitions is unknown, as no branching ratio is available. There cannot be any direct β feeding to the 103.66, 7/2$^+$ level from 1/2$^+$ parent state.

[g] Absolute intensity per 100 decays.

$^{233}_{91}Pa_{142}$-21

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY (continued)

$\gamma(^{233}Pa)$ (continued)

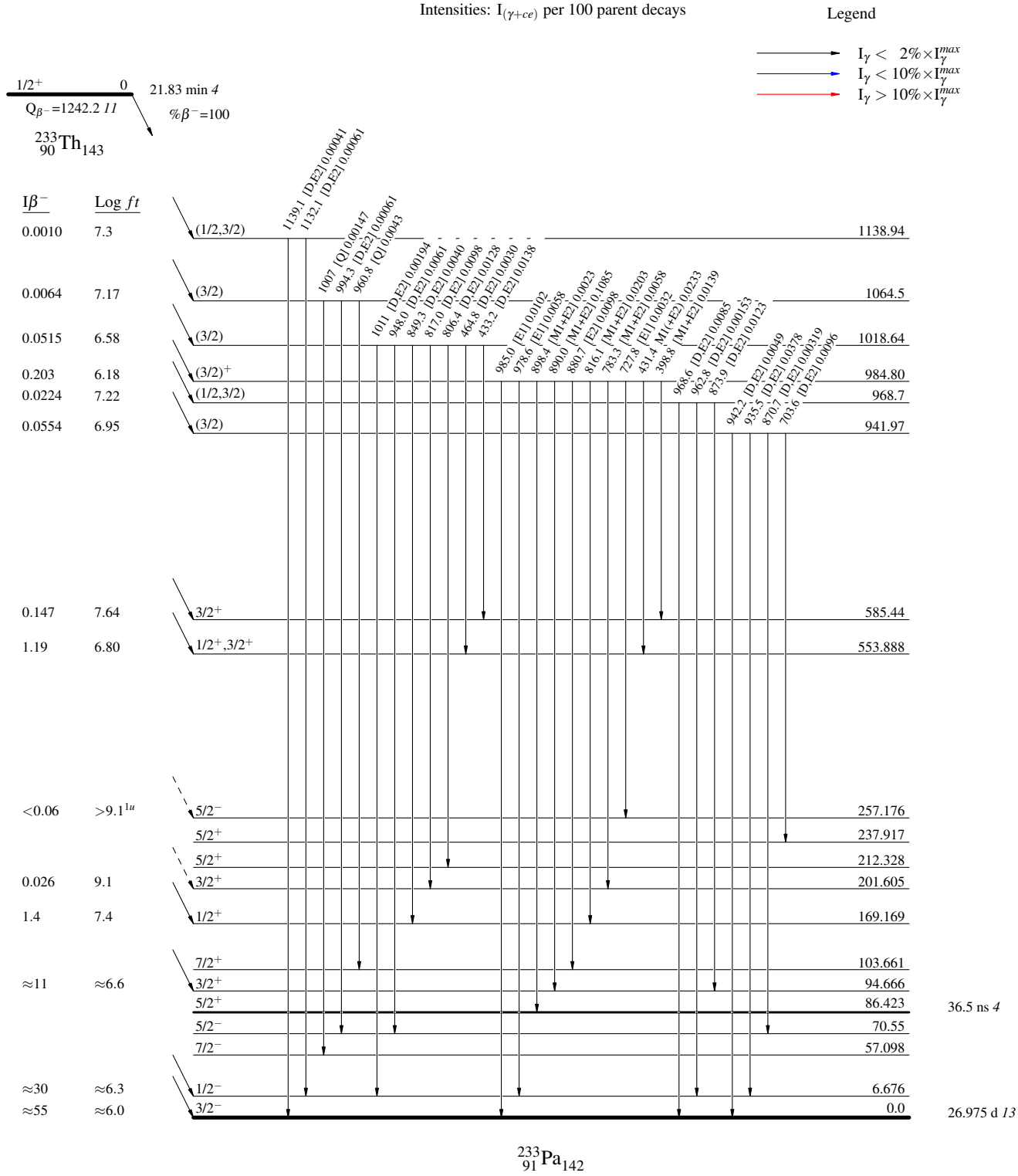
[h] Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.
[i] Multiply placed.
[j] Multiply placed with intensity suitably divided.
[k] Placement of transition in the level scheme is uncertain.
[x] γ ray not placed in level scheme.

$^{233}_{91}Pa_{142}$-22

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY

Decay Scheme

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

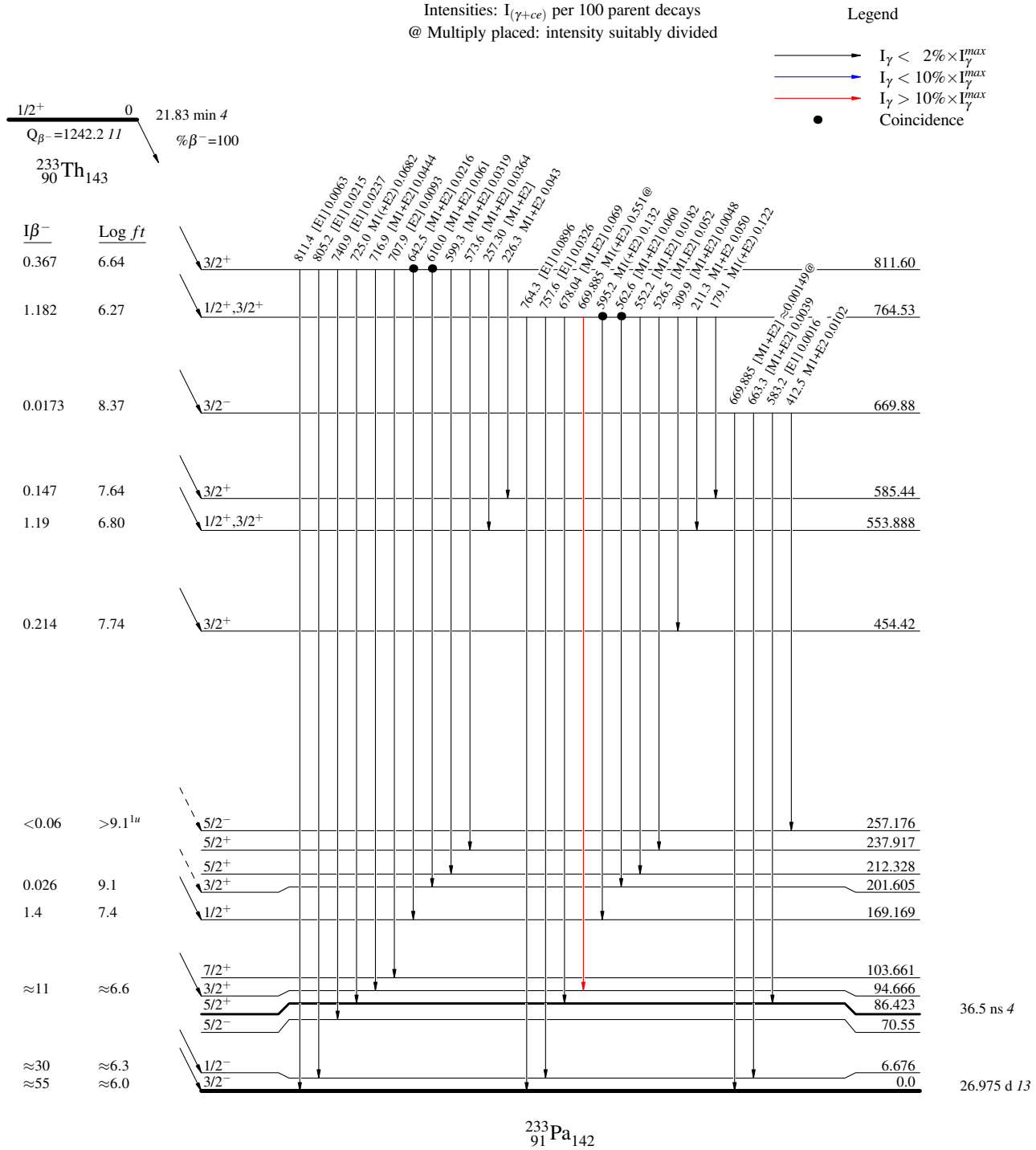


$^{233}_{91}Pa_{142}$

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY

Decay Scheme (continued)

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

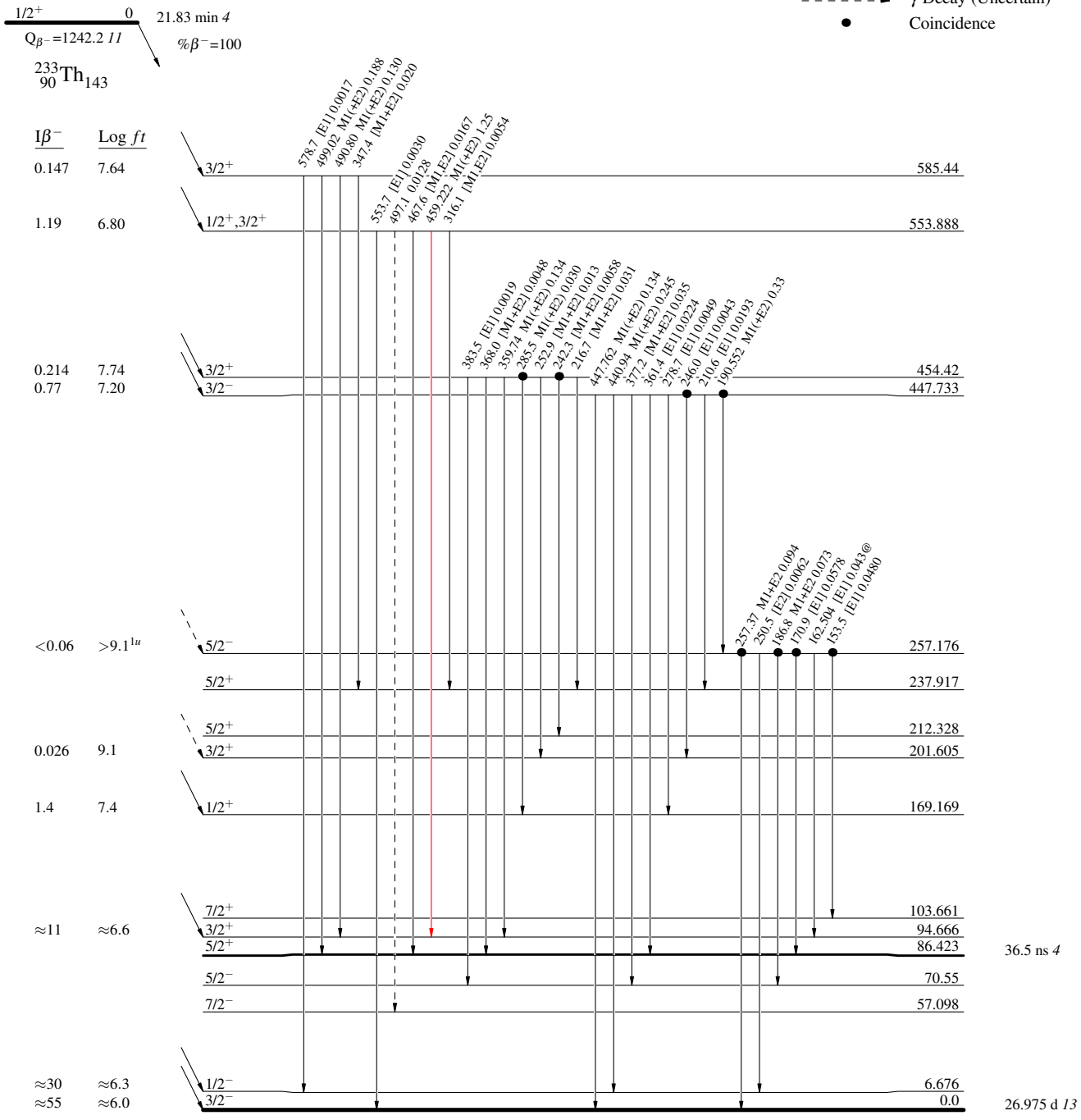


^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY

Decay Scheme (continued)

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

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)
Coincidence



$^{233}_{91}Pa_{142}$

^{233}Th β^- decay (21.83 min) 2008De31,1972SeZI,1969HoZY

Decay Scheme (continued)

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