Adopted Levels, Gammas

History

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

Q(β^-)=391.5 *15*; S(n)=5118.02 *20*; S(p)=7312 *16*; Q(α)=4213.4 *16* 2021Wa16
S(2n)=11912.3 *22*, S(2p)=13324 *15* (2021Wa16).

2013Fr03 traced the identification of ^{231}Th to G.N. Antonoff, Phil. Mag. 22, 419 (1911), where decay of natural uranium was studied for α and β radiations, and half-life of 1.5 d (or 36 h) was proposed for a new activity labeled as uranium Y. This reference is not listed in 1931Cu01 or in 1940Li01 (Table of Isotopes). The adopted half-life of 25.57 h *8* here is from measurements by 1958Ca19 and 1951Ja17.

Mass measurement by Schottky mass spectrometry: 2005LiZZ.

A total of 28 s-wave neutron resonances are reported between 1.427 *5* keV and 563 keV, with resonance parameters in 2018MuZZ evaluation. See ^{230}Th(n,γ),(n,n):Resonances dataset for energies and widths.

Additional information 1.

Theoretical calculations: consult the NSR database (www.nndc.bnl.gov/nsr) for 49 primary references, 23 dealing with half-lives of α and cluster decays and other aspects of radioactive decays, and 26 with nuclear structure calculations. These references are listed under 'document' records in this dataset, which can be accessed through on-line ENSDF database at www.nndc.bnl.gov/ensdf/.

^{231}Th Levels

Three high-spin bands, two tentatively assigned to signature partners of the ν5/2[633] configuration up to 57/2$^+$ for α=+1/2 and 51/2$^+$ for α=−1/2 are given in ^{232}Th(^{209}Bi,^{210}Biγ) dataset from 2002AbZV thesis. As firm assignment could not be made in this work, these two bands and a third one with a cascade of eight transitions have not been given in the Adopted dataset.

Cross Reference (XREF) Flags

A	^{231}Ac β^- decay (7.5 min)	E	^{230}Th(n,γ) E=2 keV:arc	I	^{232}Th(d,t)
B	^{235}U α decay (7.04×10^8 y)	F	^{230}Th(n,γ),(n,n):resonances	J	^{232}Th(^{3}He,α)
C	^{230}Th(n,γ) E=th	G	^{230}Th(d,p)	K	^{232}Th(^{209}Bi,^{210}Biγ)
D	^{230}Th(n,γ) E=th:primary γ	H	^{232}Th(d,p2nγ)		

E(level)[†]	J$^\pi$[g]	$T_{1/2}$[h]	XREF	Comments
0.0[j]	5/2$^+$[‡]	25.57 h *8*	ABCD HI	%β^-=100 %α≈2×10^{-14} is expected as negligible, as deduced by evaluators from theoretical $T_{1/2}(\beta^-)$>100 s and $T_{1/2}(\alpha)$=4.9×10^{17} s (2019Mo01). $T_{1/2}$: 1958Ca19 measured 25.52 h *1*, where unweighted average was taken in β counting of 18 different sources, prepared and purified in five different irradiations of ^{230}Th by neutrons, with individual values (in h) being: 25.57, 25.44, 25.51, 25.43, 25.51, 25.43, 25.52, 25.56, 25.47, 25.58, 25.51, 25.59, 25.42, 25.58, 25.66, 25.45, 25.56 and 25.51, without uncertainties on individual data points. Evaluators obtain an unweighted average of 25.517 h *16* or 25.52 h *2*. In addition, there is no discussion in 1958Ca19 about the systematic uncertainties in the counting procedure and least-squares fits of decay curves. Based on a spread of values in 1958Ca19, which may serve as an indicator of systematic uncertainty, evaluators estimate a total uncertainty of 0.08 h. 1951Ja17 (also plutonium project report ANL-4176, p23 (1948)) measured $T_{1/2}$=25.64 h *10*, from an average of 25.56 h *6* and 25.73 h *6* for two samples counted using a G.M. counter, where the uncertainties were from dispersion in data, with no discussion of the systematic uncertainties, however an uncertainty of 0.10 h seems to encompass both the statistical and systematic uncertainties. Evaluators adopt $T_{1/2}$=25.57 h *8* from weighted average of 25.52 h *8* (1958Ca19) and 25.64 h *10* (1951Ja17). Other measurements: 25.76 h *21* (1983Ch06); 25.0 h *5* (1973Ch24); 25.7 h *2* (1971Ko48); 25.2 h, 25.8 h

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Adopted Levels, Gammas (continued)

^{231}Th Levels (continued)

E(level)[†]	Jπ[g]	$T_{1/2}$[h]	XREF	Comments
				(1963Na06); 24.3 h *20* (1956Ph61); 25.51 h *23* (1949Kn09, also 25.5 h in AECD-1880 report (1948)); 24.5 h (Y. Nishina et al., Nature 142, 874 (1938)); 24.0 h (1932Gr01). In 1931Cu01 evaluation, $T_{1/2}$=24.6 h, without citation of a reference for a measurement of this value in their Table I. Weighted average of all the measurements listed with uncertainties is 25.58 h *8*, with revised uncertainty of 0.08 h in 1958Ca19. Jπ: L(d,t)=2; log *ft* values to 84.2, 5/2$^+$; 101.4, 7/2$^+$; and 320, 3/2$^-$ levels in ^{231}Pa require 5/2; 247.6 E2 γ from 247.5, 1/2$^+$ level.
41.9521[j] *16*	7/2$^+$[‡]		ABCD HIJ	Jπ: L(d,t)=4; 41.96γ M1+E2 to 5/2$^+$.
96.129[j] *3*	9/2$^+$[‡]		BCD GHIJ	Jπ: L(d,t)=4; band member.
162.11[j] *3*	11/2$^+$[‡]		B GHIJ	Jπ: L(d,t)=6; band member. Jπ: L=6 in (^{3}He,α).
185.7160[k] *13*	5/2$^-$[#]	1.07 ns *8*	ABCD G I	Jπ: 144γ E1 to 7/2$^+$, 185.7γ E1 to 5/2$^+$; rotational band structure. $T_{1/2}$: other: 0.77 ns *12* from ^{235}U α decay.
205.3101[k] *15*	(7/2$^-$)[#]		ABCD G I	Jπ: 163γ (E1) to 7/2$^+$, 205γ (E1) to 5/2$^+$; Rotational band structure.
221.3966[l] *20*	3/2$^+$[@]	<74 ps	ABCDE GHI	XREF: G(225). Jπ: M1 γ ray from 1/2$^+$ in neutron avg. res. capture; band member from 'Fingerprint' method in (d,t) (2008Bu14).
≈225?	(13/2$^+$)		J	
236.899[k] *7*	9/2$^-$[#]		BCD I	Jπ: 51γ to 5/2$^-$, 74.8γ to 11/2$^+$; band member.
240.6?[i]	(13/2$^+$)		H	
240.8794[l] *24*	5/2$^+$[@]		ABCD GHIJ	Jπ: L(d,p)=L(d,t)=2; 199γ M1 to 7/2$^+$. (9/2$^+$) suggested in (^{3}He,α) with L=3-6 could be for a different level.
247.5867[m] *20*	1/2$^+$	<74 ps	A CDE G I	Jπ: L(d,p)=L(d,t)=0.
272.1800[m] *15*	3/2$^+$		A CDE G I	XREF: G(271). Jπ: L(d,p)=L(d,t)=2; M1 γ ray from 1/2$^+$ in neutron avg. res. capture; 272γ M1+E2 to 5/2$^+$.
275.4250[l] *25*	7/2$^+$		BCD Hi	Jπ: 179γ M1(+E2) to 9/2$^+$, 275γ M1 to 5/2$^+$; L(d,t)=(4+5).
277.60[k] *6*	(11/2$^-$)[#]		B G iJ	XREF: J(284). Jπ: 41γ to 9/2$^-$, 73γ to 7/2$^-$, 115γ to 11/2$^+$; L(d,t)=(4+5); band member.
301.7429[s] *19*	5/2$^+$[a]		BCD G I	XREF: B(?). Jπ: 301.7γ M1 to 5/2$^+$, 259.8γ M1+E2 to 7/2$^+$; L(d,t)=(2); band member.
317.0809[m] *22*	5/2$^+$[d]		BCD G I	Jπ: L(d,t)=2; 275γ M1+E2 to 7/2$^+$, 317γ M1 to 5/2$^+$; band member.
324.913[l] *7*	(9/2)$^+$[@]		BCD GHIJ	XREF: J(326). Jπ: L(d,p)=L(d,t)=4; 229γ M1 to 9/2$^+$; band member. (11/2$^+$) suggested in (^{3}He,α).
330.6?[j]	(15/2$^+$)[‡]		H	
333[k] *3*	(13/2$^-$)[#]		B G I	Jπ: band member.
348.3 *5*	(1/2$^+$,3/2$^+$)		CDE	XREF: E(?). Jπ: possible M1 γ from 1/2$^+$ resonance state.
351.511[m] *6*	7/2$^+$[a]		BCD G I	XREF: B(355). Jπ: 255γ M1 to 9/2$^+$, 351γ M1 to 5/2$^+$.
377.573[s] *9*	(7/2)$^+$[d]		BCD G I	Jπ: 281γ M1 to 9/2$^+$; band member.
380.0 *3*	1/2$^+$,3/2$^+$		CD	Jπ: M1 γ from 1/2$^+$ resonance state.

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Adopted Levels, Gammas (continued)

^{231}Th Levels (continued)

E(level)[†]	J^{π}[g]	$T_{1/2}$[h]	XREF	Comments
385.68? 4	(5/2$^+$ to 11/2$^+$)[@]		B	E(level): 2008Bu14, in their (d,t) work, see a very weak peak near 385 keV but assign to a possible contaminant. The authors question the existence of this level from very weak γ rays in α decay. In ^{235}U α decay, work in 2017Le03 reported intensity of the 343.5γ and 2018Ma03 reported the intensity of 289.5γ. No experiment has reported the placement of these γ rays from coincidence data. J^{π}: 290γ to 9/2$^+$, 343γ to 7/2$^+$. 2008Bu14, in (d,t) work, discussed that this level cannot be the 11/2$^+$ member of 3/2[631] band, based on comparison of measured and calculated cross sections. In the (d,t) work of 1972Gr19, 11/2, 3/2[631] assignment appears incorrect, in view of analysis by 2008Bu14.
386.5? 5	(1/2$^+$,3/2$^+$)		E	J^{π}: possible M1 γ from 1/2$^+$ resonance state.
387.828[q] 3	7/2$^-$[c]		BCD	J^{π}: Favored α decay (HF=2.0) from ^{235}U 7/2$^-$[743].
402.0[k] 3	(15/2)$^-$[#]		G IJ	J^{π}: L(d,p)=L(d,t)=7; band member.
432.7?[i]	(17/2$^+$)		H	
447.4[s] 7	(9/2)$^+$[d]		G I	XREF: G(449). J^{π}: L(d,p)=4; band member.
452.192[q] 18	9/2$^-$[c]		B	J^{π}: Favored α decay HF=3.7. 215γ to 9/2$^-$, 266γ to 5/2$^-$, 356γ to 9/2$^+$.
466.5 3	(1/2$^-$,3/2$^-$)		G I	L(d,t)=(1).
478? 6			J	
490[m] 3	(11/2$^+$)[a]		G	J^{π}: band member. E(level): ≈487 keV, (d,t) (1970Bo31).
501.2 5			CD	
510.897?[r] 11	(7/2)$^+$		CD	J^{π}: 469γ M1(+E2) to 7/2$^+$; possible band member.
530[s] 3	(11/2$^+$)[d]		g i	XREF: i(533.9). J^{π}: L(d,t)=(6,7); band member.
530.23[q] 5	(11/2$^-$)[c]		B g i	XREF: i(533.9). J^{π}: L(d,t)=(6,7); band member.
536.7 7			CD	
544.9?[j]	(19/2$^+$)[‡]		H	
554.6503[n] 16	(1/2)$^-$[b]	503 ps 12	A CDE G I	J^{π}: L(d,p)=L(d,t)=1; E1 γ from 1/2$^+$ neutron avg. res. capture; band member.
568 3			B G	XREF: B(?).
579[r] 1	(9/2$^+$)		G IJ	J^{π}: L(d,p)=4; L(d,t)=(4).
590.8396[t] 24	3/2$^-$[e]		CDE g I	J^{π}: L(d,t)=1; E1 γ ray from 1/2$^+$ in neutron avg. res. capture; 405γ E2+M1 to 5/2$^-$; band member. Note that (d,t) strength is not consistent with 3/2[761] configuration assignment.
593.6173[n] 20	(3/2)$^-$[b]	0.10 ns 4	A CDE g i	XREF: E(595.2)i(594.8). $T_{1/2}$: from $\beta\gamma\gamma$(t) in ^{231}Ac decay (1999Aa03). J^{π}: L(d,t)=3+1; E1 γ ray from 1/2$^+$ in neutron avg. res. capture; band member.
595.9738[n] 21	5/2$^-$[b]		CD i	XREF: i(594.8). J^{π}: L(d,t)=3+1; 244γ E1 to 7/2$^+$, 324γ (E1) to 3/2$^+$; band member.
619.638[v] 4	3/2$^-$		CDE g I	J^{π}: L(d,t)=1; E1 γ ray from 1/2$^+$ in neutron avg. res. capture; 434γ (M1) to 5/2$^-$.
623.935?[w] 18	(5/2$^-$)		CD g	J^{π}: 438γ E0(+M1) to 5/2$^-$.
629.3428[t] 22	(5/2)$^-$[e]		CD I	J^{π}: 444γ M1(+E2) to 5/2$^-$, 424γ M1+E2 to (7/2$^-$); L(d,t)=(3); band member.

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Adopted Levels, Gammas (continued)

^{231}Th Levels (continued)

E(level)[†]	J^{π}[g]	XREF	Comments
634.046?[w] *13*	(7/2$^-$)	BCD	J^{π}: 429γ M1+E0(+E2) to (7/2$^-$).
646.6 *4*	(5/2$^-$,7/2$^-$)	I	J^{π}: L(d,t)=3.
655.939?[t] *15*	(7/2$^-$)	CD G IJ	J^{π}: 419γ (M1) to 9/2$^-$, 470γ M1 to 5/2$^-$. Possible 7/2 member of 3/2$^-$[761] rotational band.
684.4908[o] *24*	(5/2)$^-$	CD G I	J^{π}: 479γ (E2) to (7/2$^-$), 499γ M1 to 5/2$^-$; L(d,t)=1(+3); possible bandhead.
687.631[u] *3*	1/2$^+$	CDE	XREF: E(685.6). J^{π}: 440γ E0+M1 to 1/2$^+$. J^{π}: E0 to 1/2$^+$.
693.50 *18*		CD	
704[q] *2*	(15/2$^-$)[c]	G	J^{π}: band member.
709.099[u] *4*	3/2$^+$	CD I	J^{π}: L(d,t)=2; 437γ M1+E0(+E2) to 3/2$^+$.
713.755[y] *3*	3/2$^-$[f]	CDE i	XREF: i(718.0). J^{π}: L(d,t)=1+3; E1 from 1/2$^+$ in neutron avg. res. capture; 528γ M1 to 5/2$^-$.
720.302[y] *6*	(7/2)$^-$[f]	CD G i	J^{π}: L(d,t)=1+3; 534γ M1 to 5/2$^-$, 515γ M1+E2 to (7/2$^-$); band member.
735.263[u] *7*	(5/2)$^+$	CD	J^{π}: 463γ M1+E2 to 3/2$^+$, 488γ (E2) to 1/2$^+$.
750.0 *3*	(5/2$^-$,7/2$^-$)	G IJ	J^{π}: L(d,t)=3. (15/2$^-$) suggested in (^{3}He,α).
769.9 *6*	(11/2$^+$,13/2$^+$)	I	J^{π}: L(d,t)=(6).
793.027[x] *4*	1/2$^+$[&]	CDE I	XREF: E(794.2). J^{π}: 545γ E0(+M1) to 1/2$^+$.
802 *3*		G	
808.508[x] *8*	3/2$^+$[&]	CD I	J^{π}: 536γ E0+M1(+E2) to 3/2$^+$.
812.3 *2*	(5/2)$^-$	G IJ	E(level): possible doublet as indicated in (d,t). J^{π}: L(d,t)=3(+1) with possible configuration=ν5/2[503] (2008Bu14). 15/2 suggested as member of 1/2[770] band in 1987Wh01, deduced from energies of other members of this band is not supported by $\sigma(\theta)$ distribution in (d,t) and σ(^{3}He,α)/σ(d,t) ratio which is consistent with L=3 rather than L=7 required by J=[15/2] (2008Bu14).
820.552[u] *7*	1/2$^+$	CD	J^{π}: 573γ M1+E0 to 1/2$^+$.
833.169[y] *4*	(1/2)$^-$[f]	CDE I	XREF: E(834.5). J^{π}: 239γ M1 to (3/2)$^-$; band member.
839.303[u] *9*	3/2$^+$	CDE G	XREF: E(840.1)G(837). J^{π}: 567γ M1+E0 to 3/2$^+$.
841.42 *5*	1/2$^-$,3/2$^-$	I	J^{π}: L(d,t)=1.
846.4 *4*	(1/2$^+$,3/2$^+$)	CDE	XREF: E(?). J^{π}: possible M1 γ from 1/2$^+$ resonance state.
854.5 *4*	(7/2$^+$,9/2,11/2$^-$)	I	J^{π}: L(d,t)=4,5.
867.00 *4*	5/2$^-$,7/2$^-$	CD G	J^{π}: 681γ (M1+E2) to 5/2$^-$, 630γ E2 to 9/2$^-$, 479γ (E2) to 7/2$^-$.
869.7 *11*	1/2$^+$	E I	XREF: E(869.9). J^{π}: L(d,t)=0.
871 *3*	(7/2)$^+$	J	J^{π}: L(^{3}He,α)=4.
875.549[p] *4*	(3/2)$^-$	CDE I	J^{π}: L(d,t)=1; 321γ M1+E2 to (1/2)$^-$.
889.997[u] *12*	5/2$^+$	CD G I	XREF: G(881). J^{π}: L(d,t)=2; 614γ M1 to 7/2$^+$, 649γ (M1) to 5/2$^+$, 669γ E2+M1 to 3/2$^+$. 1987Wh01 in (n,γ) E=th predicted the 7/2$^+$, 1/2$^+$[640] state at 891.6 keV.
893 *2*		G	J^{π}: 7/2$^+$ suggested in (d,p).
899.2 *6*		CD	
914.90[p] *4*	(5/2)$^-$	CD IJ	J^{π}: L(d,t)=3; 729γ (M1(+E2)) to 5/2$^-$. Possible 5/2$^-$ member of 3/2[501] rotational band.
930.6 *5*	(3/2$^+$,5/2$^+$)	I	J^{π}: L(d,t)=(2).
936.307 *10*	(5/2)$^-$	CD	J^{π}: 548γ M1+E2 to 7/2$^-$, 343γ (M1) to (3/2)$^-$.
942.2 *9*		CD G I	XREF: G(947)I(944.2).
960.809[z] *12*	3/2$^+$	CD I	XREF: I(958.0). J^{π}: 739γ M1+E0 to 3/2$^+$.

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Adopted Levels, Gammas (continued)

^{231}Th Levels (continued)

E(level)[†]	Jπ[g]	XREF	Comments
966.0[x] 6	3/2+,5/2+[&]	G IJ	Jπ: L(d,t)=2. 9/2+ suggested in (d,p). (11/2+) proposed in (^{3}He,α). There could be two other different levels near this energy if the results of (d,p) and (^{3}He,α) prove to be valid.
974.4 7		I	
981 3		G	
990.5 7		I	
1004.232 21	3/2+	CDE G I	XREF: I(1003.0). Jπ: E1,M1 from 1/2+ in neutron avg. res. capture; 763γ M1 to 5/2+; L(d,t)=(1+2).
1011.5 9		g I	XREF: g(1016).
1020.730 6	3/2−	CDE g I	XREF: g(1016)I(1021.7). Jπ: L(d,t)=1; 427γ M1 to (3/2)−, 773γ to 1/2+.
1033.0 3	1/2+	CD I	Jπ: L(d,t)=0.
1056.27 3	(3/2+)	CD G I	XREF: I(1053). Jπ: 835γ (M1) to 3/2+, 1014γ (E2) to 7/2+.
1066.191 23	(5/2,7/2)+	CD G	Jπ: 749γ (M1) to 5/2+, 688γ E2+M1 to (7/2)+.
1074.346 17	(3/2)−	CDE I	XREF: E(1075.1)I(1076.5). Jπ: E1,M1 from 1/2+ in neutron avg. res. capture; 483γ M1+E2 to 3/2−, 757γ to 5/2+.
1081.331 15	1/2−,3/2−	CDE G	Jπ: 490γ M1 to 3/2−, 527γ M1 to (1/2)−.
1081.6 6	3/2+,5/2+	I	E(level),Jπ: L(d,t)=2 suggests a level separate from 1081.3 with negative parity.
1086.811 10	5/2+	CD G I	XREF: I(1091.8). Jπ: 709γ E2+M1 to (7/2)+, 493γ (E1) to (3/2)−. L(d,t)=(2) for 1091.8.
1094.25 24	1/2−,3/2−	CD	Jπ: E1 primary γ from 1/2+.
1102.252 8	3/2−	CDE G I	XREF: E(1103.3)I(1103.0). Jπ: L(d,t)=1; E1 from 1/2+ in neutron avg. res. capture; 418γ M1 to (5/2)−.
1106 6	(7/2+,9/2+)	J	L(^{3}He,α)=(4).
1115.4 6		G I	
1126.0 6	3/2+,5/2+	I	Jπ: L(d,t)=2.
1133.80 8	(1/2+,3/2+)	CDE	Jπ: (M1) from 1/2+ in neutron avg. res. capture;
1155.5 4		CD I	
1159.751 8	(3/2)−	CDE G I	Jπ: E1 from 1/2+ in neutron avg. res. capture; 919γ (E1) to 5/2+.
1172.990 24	3/2−	CDE G I	XREF: I(1171.2). Jπ: L(d,t)=1; E1,M1 from 1/2+ in neutron avg. res. capture; 459γ M1 to 3/2−, 544γ (M1) to (5/2)−.
1181.2 6	1/2−,3/2−	I	Jπ: L(d,t)=1.
1187.0 7		IJ	XREF: J(?).
1193.2 8		CD	
1200.47 17	1/2−,3/2−	CDE G I	Jπ: L(d,t)=1.
1213.86 22		CD G	
1219.05 25	(1/2+,3/2+)	CDE I	XREF: E(1219.1)I(1220.2). Jπ: From (n,γ), E=2 keV:ARC.
1222 3	(1/2+,3/2+)	E G	XREF: E(1222.0). Jπ: From (n,γ), E=2 keV:avg.
1235 2		I	
1251.46 18		CD	
1262 3		I	
1271.1 6	1/2−,3/2−	E	Jπ: From (n,γ), E=2 keV:avg.
1273 1	3/2+,5/2+	I	Jπ: L(d,t)=2.
1274.5 4	1/2−,3/2−	CD	Jπ: E1 primary γ from 1/2+.
1282 3		G	
1292 2		I	
1300 2		I	
1323 2		I	
1327 2		G IJ	XREF: J(1332).
1339 2		G	
1345.7 11		I	

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Adopted Levels, Gammas (continued)

^{231}Th Levels (continued)

E(level)[†]	J^{π}[g]	XREF	Comments
1352.8 *11*	1/2⁻,3/2⁻	G I	J^{π}: L(d,t)=1.
1366 *4*		G	
1372 *2*		G I	
1393 *1*	1/2⁻,3/2⁻	G I	J^{π}: L(d,t)=1.
1405.6 *10*	1/2⁻,3/2⁻	G I	J^{π}: L(d,t)=1.
1414 *5*		G	
1430.6 *11*		I	
1437.2 *10*	3/2⁺,5/2⁺	I	J^{π}: L(d,t)=2.
1452 *1*		I	
1458 *2*		I	
1464 *1*	(1/2⁻,3/2⁻)	Ij	E(level): possible doublet. J^{π}: L(d,t)=1,(2).
1476 *2*		Ij	
1487.4 *11*	1/2⁻,3/2⁻	I	J^{π}: L(d,t)=1.
1494.3 *11*		I	
1523 *2*		I	
1533 *2*		I	
1542 *2*		I	
1572 *1*	(5/2⁻,7/2⁻)	IJ	J^{π}: L(d,t)=(3). L(^{3}He,α) ≥3.
1585 *1*	1/2⁻,3/2⁻	I	J^{π}: L(d,t)=1.
1601 *1*	1/2⁻,3/2⁻	I	J^{π}: L(d,t)=1.
1608 *1*		I	
1619.5 *10*	1/2⁻,3/2⁻	I	J^{π}: L(d,t)=1.
1627 *2*		I	
1648 *1*		I	
1654 *1*		I	
1666 *2*		I	
1678 *2*		IJ	J^{π}: (15/2⁻) suggested in (^{3}He,α).
1696 *1*		I	
1708 *1*	1/2⁻,3/2⁻	I	J^{π}: L(d,t)=1.
1714 *1*		I	
(5118.15 *3*)	1/2⁺	CD	E(level): S(n)=5118.02 keV *20* (2021Wa16).
(5119.84 *11*)	1/2⁺	E	E(level): S(n)+E(n), S(n)=5118.02 keV *20* (2021Wa16), E(n)=2 keV. J^{π}: s-wave n-capture in 0⁺ g.s. of ^{230}Th.

† From least-squares fit to Eγ data, when levels are populated in any of the four γ-ray studies. The gamma-ray energy uncertainty is assumed as 0.5 keV when not stated. Reduced χ^2 of 2.07 is somewhat larger than critical χ^2=1.25 at 95% confidence level, with only three low energy and four high-energy primary γ rays in (n,γ) poorly fitted.

‡ Member of K=5/2 rotational band. Energies calculated using α=6.8 keV and including Coriolis mixing. Band structure: 0⁻ (5/2⁺), 42⁻ (7/2⁺), 96⁻ (9/2⁺), 162 keV (11/2⁺) (1987Wh01).

\# Member of K=5/2 rotational band. Energies calculated using α=6.7 keV and including Coriolis mixing. Band structure: 185.1- (5/2⁻), 205.5- (7/2⁻), 237.2- (9/2⁻), 280.4- (11/2⁻), 331.6- (13/2⁻), 403.9 keV (15/2⁻) (1987Wh01).

@ Member of K=3/2 rotational band. Energies calculated using α=6.8 keV and including Coriolis mixing. Band structure: 220.7- (3/2⁺), 241.7- (5/2⁺), 276.9- (7/2⁺), 323.2- (9/2⁺), and 385.8 keV (11/2⁺) (1987Wh01).

& Member of K=1/2 rotational band. Energies calculated using α=6.8 keV, a=+0.16, and including Coriolis mixing. Band structure: 792.3- (1/2⁺), 808.7- (3/2⁺), 853.0- (5/2⁺), 891.6- (7/2⁺), 970.9- (9/2⁺), 1032.0 keV (11/2⁺) (1987Wh01).

a Member of K=1/2 rotational band. Energies calculated using α=6.8 keV, a=−0.39, and including Coriolis mixing. Band structure: 247.7- (1/2⁺), 271.5- (3/2⁺), 302.0- (5/2⁺), 352.7- (7/2⁺), 409.5- (9/2⁺), 489.3 keV (11/2⁺) (1987Wh01).

b Member of K=1/2 rotational band. Energies calculated using α=6.7 keV, a=+0.93, and including Coriolis mixing. Band structure: 554- (1/2⁻), 594- (3/2⁻), and 596 keV (5/2⁻) (1987Wh01).

c Member of K=7/2 rotational band. Energies calculated using α=6.7 keV, and including Coriolis mixing. Band structure: 388.6-

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{231}Th Levels (continued)

(7/2$^-$), 452.9- (9/2$^-$), 527.2- (11/2$^-$), 598.9- (13/2$^-$), and 705.4 keV (15/2$^-$) (1987Wh01).

[d] Member of K=5/2 rotational band. Energies calculated using α=6.8 keV and including Coriolis mixing. Band structure: 317.8- (5/2$^+$), 376.0- (7/2$^+$), 447.9- (9/2$^+$), 531.5 keV (1987Wh01).

[e] Member of K=3/2 rotational band. Energies calculated using α=6.7 keV and including Coriolis mixing. Band structure: 588.6- (3/2$^-$), 629.3- (5/2$^-$), and 658.5 keV (7/2$^-$) (1987Wh01).

[f] Member of K=1/2 rotational band. Energies calculated using α=6.8 keV, a=−7.3, and including Coriolis mixing. Band structure: 833.5- (1/2$^-$), 711.6- (3/2$^-$), 984.2- (5/2$^-$), 723.0- (7/2$^-$), and 812.2 keV (15/2$^-$) (1987Wh01).

[g] From γ-ray deexcitation in (n,γ) E=thermal. Levels populated by capture γ rays in ^{230}Th(n,γ) E=2 keV:ARC have J=1/2, 3/2, based on the multipolarity of the capture γ ray. Additional arguments are given with individual levels. See detailed arguments for J^π assignments in 1987Wh01. In (d,t), "fingerprint" method (comparison of experimental spectroscopic strengths or cross sections of members of a rotational band with those predicted by perturbed (and unperturbed) Coriolis calculations) has been used by 2008Bu14 to assign J^π for levels which form members of a band based on a Nilsson configuration.

[h] For excited states, values are from $\beta\gamma\gamma$(t) in ^{231}Ac decay (1999Aa03).

[i] Band(A): ν5/2[633],α=+1/2. The 13/2$^+$ and 17/2$^+$ members are tentatively included from 1993AcZZ in ^{232}Th(d,p2nγ).

[j] Band(a): ν5/2[633],α=−1/2. The 15/2$^+$ and 19/2$^+$ members are tentatively included from 1993AcZZ in ^{232}Th(d,p2nγ).

[k] Band(B): ν5/2[752].

[l] Band(C): ν3/2[631].

[m] Band(D): ν1/2[631].

[n] Band(E): ν1/2[501].

[o] Band(F): ν5/2[503].

[p] Band(G): ν3/2[501].

[q] Band(H): ν7/2[743].

[r] Band(I): ν7/2[624].

[s] Band(J): ν5/2[622].

[t] Band(K): ν3/2[761].

[u] Band(L): ν1/2[631]$\otimes$0$^+$ + ν5/2[633]$\otimes$2$^+$.

[v] Band(M): ν3/2[631]$\otimes$0$^-$.

[w] Band(N): ν5/2[752]$\otimes$0$^+$ + ν3/2[631]$\otimes$0$^-$.

[x] Band(O): ν1/2[640] + ν1/2[631]$\otimes$0$^+$.

[y] Band(P): ν1/2[770].

[z] Band(Q): ν3/2[631]$\otimes$0$^+$.

$\gamma(^{231}Th)$

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[b]	δ[b]	α[d]	Comments
41.9521	7/2+	41.98 5	100	0.0	5/2+	M1+E2	0.95 10	3.7×10² 4	
96.129	9/2+	54.25 5	13 4	41.9521	7/2+	M1+E2	0.85 25	100 29	
		96.09 2	100 6	0.0	5/2+	[E2]		13.6 2	
162.11	11/2+	120.35 5	100	41.9521	7/2+	[E2]		5.04 7	E_γ: somewhat poor fit. Level-energy difference=120.15 3. E_γ: from α decay, based on least squares fit Eγ=119.989 2.
185.7160	5/2−	143.765 2	19.11 14	41.9521	7/2+	E1		0.207 3	B(E1)(W.u.)=8.0×10⁻⁶ +7−6
		185.713 2	100.0 12	0.0	5/2+	E1		0.1124 16	B(E1)(W.u.)=1.95×10⁻⁵ +16−14
205.3101	(7/2−)	19.55 5		185.7160	5/2−	[M1]		114.7 19	
		109.176 31	32.2 13	96.129	9/2+	[E1]		0.0932 13	
		163.357 2	100.0 8	41.9521	7/2+	(E1)		0.1525 22	
		205.311 2	99.2 10	0.0	5/2+	(E1)		0.0887 13	
221.3966	3/2+	221.392 20	100.0	0.0	5/2+	M1		1.96 3	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 B(M1)(W.u.)>0.0092
236.899	9/2−	31.60 5	7.2 27	205.3101	(7/2−)	[M1]		110.7 16	
		51.21 5	5.3 12	185.7160	5/2−	[E2]		274 4	
		74.94 4	11.5 21	162.11	11/2+	[E1]		0.252 4	E_γ: somewhat poor fit. Level-energy difference=74.79 3.
		140.759 20	33.2 23	96.129	9/2+	[E1]		0.218 3	
		194.942 7	100.0 21	41.9521	7/2+	[E1]		0.100 2	
240.6?	(13/2+)	144.5 3	100	96.129	9/2+				
240.8794	5/2+	198.927 3	62 4	41.9521	7/2+	M1		2.64 4	
		240.876 4	100 6	0.0	5/2+	M1(+E2)	0.3 3	1.45 22	
247.5867	1/2+	(26.2[@])	≤53[@]	221.3966	3/2+	[M1]		192 4	
		247.586[&] 3	100[&] 18	0.0	5/2+	E2		0.312 5	B(E2)(W.u.)>58
272.1800	3/2+	(24.6[@])	2.2[@] 13	247.5867	1/2+	[M1]		231 5	
		(31.3[@])	≤7.5[@]	240.8794	5/2+	(M1)		114 2	
		(50.8[@])	≤10.4[@]	221.3966	3/2+	[M1]		27.3 5	
		230.243[&] 11	5.5[&] 12	41.9521	7/2+	[E2]		0.399 6	
		272.181[&] 2	100[&] 15	0.0	5/2+	M1+E2	0.64 10	0.85 6	
275.4250	7/2+	34.7[f] 1	≈97	240.8794	5/2+	[M1]		83.9 14	
		54.1 1	<2.6	221.3966	3/2+	[E2]		210 4	
		179.297 2	40 6	96.129	9/2+	M1(+E2)	0.25 25	3.4 4	I_γ: from (n,γ), not seen in α decay.
		233.470 3	100 7	41.9521	7/2+	M1		1.688 24	
		275.428 4	25 5	0.0	5/2+	M1(+E2)	0.25 25	1.02 12	I_γ: from weighted average of values from α decay and (n,γ) E=th.
277.60	(11/2−)	41.1		236.899	9/2−	[M1]		51.0 7	
		72.7 2	100 7	205.3101	(7/2−)	[E2]		50.8 10	

$^{231}_{90}Th_{141}$-8

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

E_i(level)	J^π_i	E_γ[†]	I_γ[†]	E_f	J^π_f	Mult.[b]	δ[b]	α[d]	Comments
277.60	(11/2⁻)	115.45 5	8.19 9	162.11	11/2⁺	[E1]		0.348 5	
		182.1[f]		96.129	9/2⁺				E_γ: tentative γ from α decay, probably very weak, from coincidence data (1975Va11).
301.7429	5/2⁺	80.347[&] 2	51[&] 8	221.3966	3/2⁺				
		259.790[&] 4	36[&] 6	41.9521	7/2⁺	M1+E2	0.65 10	0.96 7	
		301.741[&] 3	100[&] 16	0.0	5/2⁺	M1		0.880 13	
317.0809	5/2⁺	76.198[&] 4	20[&] 3	240.8794	5/2⁺	[M1+E2]		24 17	
		95.7[f]		221.3966	3/2⁺				
		275.129[&] 2	100[&] 15	41.9521	7/2⁺	M1+E2	0.6 1	0.84 6	I_γ: from (n,γ) E=th.
		317.063 12	4.6 9	0.0	5/2⁺	M1		0.723 10	I_γ: from (n,γ) E=th.
324.913	(9/2)⁺	228.785 6	100 15	96.129	9/2⁺	M1		1.79 3	
		282.92 5	65 23	41.9521	7/2⁺	[M1+E2]		0.60 40	
330.6?	(15/2⁺)	168.1 3	100	162.11	11/2⁺				
351.511	7/2⁺	255.365[&] 10	79[&] 16	96.129	9/2⁺	M1		1.315 19	
		309.557[&] 12	100[&] 21	41.9521	7/2⁺	(E2)		0.1534 22	
		351.512[&] 23	64[&] 13	0.0	5/2⁺	M1		0.545 8	
377.573	(7/2)⁺	136.55 5	100 6	240.8794	5/2⁺	[M1+E2]		5.3 24	
		173.0 10	45 20	205.3101	(7/2⁻)	[E1]		0.132 2	
		281.440 9	≈25	96.129	9/2⁺	M1		1.005 14	
385.68?	(5/2⁺ to 11/2⁺)	289.56 4	74 14	96.129	9/2⁺				
		343.5 2	100 9	41.9521	7/2⁺				
387.828	7/2⁻	147.0[f]		240.8794	5/2⁺				E_γ: tentative γ from α decay, from coincidence data (1975Va11).
		150.937 20	6.8 9	236.899	9/2⁻	[M1+E2]		3.9 19	
		182.504 10	38.5 14	205.3101	(7/2⁻)	[M1+E2]		2.1 13	
		202.110 3	100 3	185.7160	5/2⁻	[M1+E2]		1.6 9	
		291.65 3	3.4 4	96.129	9/2⁺				
		345.92 3	3.2 4	41.9521	7/2⁺				
		387.84 3	2.59 22	0.0	5/2⁺				
432.7?	(17/2⁺)	192.1 2	100	240.6?	(13/2⁺)				
452.192	9/2⁻	(64.45 5)		387.828	7/2⁻	[M1+E2]		52 39	E_γ: γ ray is expected, but it has not been observed.
		215.30 5	58 4	236.899	9/2⁻	[M1+E2]		1.3 8	
		246.83 3	100 6	205.3101	(7/2⁻)	[M1]		1.445 20	
		266.47 5	12.9 20	185.7160	5/2⁻	[E2]		0.245 4	
		291.2		162.11	11/2⁺				
		356.03 5	4.7 16	96.129	9/2⁺				
		410.29 4	4.5 13	41.9521	7/2⁺				
510.897?	(7/2)⁺	468.944[&][f] 10	100[&]	41.9521	7/2⁺	M1+E2	0.7 2	0.18 3	
530.23	(11/2⁻)	142.40 5	100	387.828	7/2⁻	[E2]		2.48 4	

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

E_i(level)	J^π_i	E_γ[†]	I_γ[†]	E_f	J^π_f	Mult.[b]	δ[b]	α[d]	Comments
544.9?	(19/2+)	214.3 3	100	330.6?	(15/2+)				
554.6503	(1/2)−	282.471[‡] 2	100[@] 3	272.1800	3/2+	E1		0.0425 6	B(E1)(W.u.)=6.94×10−6 20
		307.063[‡] 2	78.5[@] 9	247.5867	1/2+	E1		0.0353 5	B(E1)(W.u.)=4.24×10−6 12
		368.934[‡] 2	39.2[@] 6	185.7160	5/2−	E2		0.0927 13	B(E2)(W.u.)=0.336 10
590.8396	3/2−	289.092[&] 10	3.0[&] 6	301.7429	5/2+				
		385.532[&] 3	25[&] 4	205.3101	(7/2−)	(E2)		0.0822 12	
		405.121[&] 3	100[&] 15	185.7160	5/2−	E2+M1	1.4 2	0.173 22	
593.6173	(3/2)−	346.1[@] 2	17[@] 4	247.5867	1/2+	(E1)		0.0272 4	B(E1)(W.u.)=4.1×10−6 +28−14
		372.221[‡] 2	43 6	221.3966	3/2+	E1		0.0232 3	B(E1)(W.u.)=8×10−6 +6−3 I_γ: weighted average from (n,γ) E=th and β^- decay.
		388.3[@] 2	9.5[@] 30	205.3101	(7/2−)	[E2]		0.0806 11	B(E2)(W.u.)=0.40 +29−16
		407.899[‡] 2	100[@] 11	185.7160	5/2−	E2		0.0708 10	B(E2)(W.u.)=3.3 +22−10
595.9738	5/2−	244.451[&] 10	18[&] 4	351.511	7/2+	E1		0.0591 8	
		323.794[&] 2	100[&] 15	272.1800	3/2+	(E1)		0.0314 5	
		374.590[&] 9	23[&] 5	221.3966	3/2+	(E1)		0.0229 3	
		390.662[&] 4	63[&] 12	205.3101	(7/2−)	M1+E2	1.2 3	0.21 5	
		410.252[&] 10	29[&] 6	185.7160	5/2−	M1		0.358 5	
619.638	3/2−	302.540[&] 7	28[&] 6	317.0809	5/2+	(E1)		0.0365 5	
		317.886[&] 22	7.9[&] 16	301.7429	5/2+				
		398.242[&] 10	38[&] 8	221.3966	3/2+	(E1)		0.0201 3	
		433.927[&] 4	100[&] 16	185.7160	5/2−	(M1)		0.308 4	
623.935?	(5/2−)	418.62[e&] 4	[e&]	205.3101	(7/2−)				
		438.22[&] 2	[&]	185.7160	5/2−	E0(+E2+M1)			
629.3428	(5/2)−	424.032[&] 4	38[&] 7	205.3101	(7/2−)	M1+E2	0.9 1	0.209 16	
		443.626[&] 2	100[&] 15	185.7160	5/2−	M1(+E2)	0.4 4	0.26 6	
		629.368[&] 15	9.6[&] 15	0.0	5/2+				
634.046?	(7/2−)	428.71[&] 4	100[&] 22	205.3101	(7/2−)	M1+E0(+E2)			
		448.339[&] 18	87[&] 44	185.7160	5/2−				
655.939?	(7/2−)	419.031[&f] 16	100[&] 21	236.899	9/2−	(M1)		0.338 5	
		470.25[&f] 3	71[&] 17	185.7160	5/2−	M1		0.248 4	
684.4908	(5/2)−	479.19[e&] 5	9.6[e&] 16	205.3101	(7/2−)	E2+M1	3.0 8	0.066 14	
		498.775[&] 2	100[&] 15	185.7160	5/2−	M1		0.211 3	
687.631	1/2+	415.460[&] 8	12.1[&] 20	272.1800	3/2+	(M1)		0.346 5	
		440.044[&] 7	18[&] 3	247.5867	1/2+	E0+M1			
		466.227[&] 3	81[&] 12	221.3966	3/2+	M1		0.253 4	

Adopted Levels, Gammas (continued)

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

E_i(level)	J^π_i	E_γ[†]	I_γ[†]	E_f	J^π_f	Mult.[b]	δ[b]	α[d]	Comments
687.631	1/2+	687.658[&] 7	100[&] 15	0.0	5/2+	(E2)		0.0210 3	E_γ: somewhat poor fit. Level-energy difference=687.630 3.
709.099	3/2+	392.038[&] 13	17[&] 4	317.0809	5/2+				
		436.917[&] 4	100[&] 14	272.1800	3/2+	M1+E0(+E2)			
		468.209[e&] 19	26[e&] 6	240.8794	5/2+	M1(+E2)		0.15 10	
		487.689[e&] 23	20[e&] 4	221.3966	3/2+	(E2)		0.0453 6	
713.755	3/2−	325.925[&] 3	24[&] 4	387.828	7/2−				
		441.64[&] 4	5.0[&] 10	272.1800	3/2+				
		528.038[&] 3	100[&] 16	185.7160	5/2−	M1		0.181 3	
720.302	(7/2)−	418.62[e&] 4	2.6[e&] 4	301.7429	5/2+				
		444.892[&] 14	16[&] 4	275.4250	7/2+	(E1)		0.01599 23	
		514.991[&] 7	100[&] 15	205.3101	(7/2−)	M1+E2	1.0 2	0.117 17	
		534.562[&] 15	15[&] 3	185.7160	5/2−	M1		0.1755 25	
735.263	(5/2)+	433.517[&] 8	100[&] 16	301.7429	5/2+	(E2)		0.0605 9	
		463.085[&] 12	75[&] 16	272.1800	3/2+	M1+E2	1.2 2	0.136 19	
		487.689[e&] 23	42[e&] 9	247.5867	1/2+	(E2)		0.0453 6	
793.027	1/2+	491.284[&] 4	100[&] 15	301.7429	5/2+	(E2)		0.0445 6	
		520.847[&] 14	30[&] 5	272.1800	3/2+	E2+M1	1.5 3	0.085 16	
		545.420[&] 16	<7.4[&]	247.5867	1/2+	E0(+M1)			
		793.04[&] 3	34[&] 7	0.0	5/2+				
808.508	3/2+	456.990[&f] 11	110[&] 19	351.511	7/2+	(E2)		0.0531 8	Mult.: E2(+M1) from ce data in $^{231}Th(n,\gamma)$. Level scheme requires pure E2.
		506.74[&] 7	45[&] 10	301.7429	5/2+				
		536.336[&] 17	76[&] 17	272.1800	3/2+	E0+M1(+E2)			
		560.875[&] 21	58[&] 12	247.5867	1/2+				
		587.155[&] 17	81[&] 14	221.3966	3/2+	M1		0.1366 19	
		766.6[&] 3	43[&] 11	41.9521	7/2+				
		808.38[&] 9	100[&] 30	0.0	5/2+				
820.552	1/2+	503.44[&] 6	19[&] 5	317.0809	5/2+				
		572.964[&] 7	100[&] 17	247.5867	1/2+	M1+E0			
		599.20[&] 4	21[&] 5	221.3966	3/2+				
		820.43[&] 7	37[&] 6	0.0	5/2+				
833.169	(1/2)−	239.548[&] 4	100[&] 15	593.6173	(3/2)−	M1		1.571 22	
		278.524[&] 14	7.0[&] 15	554.6503	(1/2)−				
		585.607[&] 13	28[&] 5	247.5867	1/2+				

Adopted Levels, Gammas (continued)

γ(^{231}Th) (continued)

E_i(level)	J^π_i	E_γ[†]	I_γ[†]	E_f	J^π_f	Mult.[b]	δ[b]	α[d]
833.169	(1/2)$^-$	611.80[&] *2*	23[&] *4*	221.3966	3/2$^+$			
839.303	3/2$^+$	284.659[&] *13*	20[&] *4*	554.6503	(1/2)$^-$			
		522.218[&] *16*	64[&] *10*	317.0809	5/2$^+$	(M1)		0.187 *3*
		567.108[&] *19*	69[&] *12*	272.1800	3/2$^+$	M1+E0		
		617.87[&] *4*	34[&] *7*	221.3966	3/2$^+$	M1+E0		
		797.56[&] *13*	45[&] *10*	41.9521	7/2$^+$			
		839.36[&] *5*	100[&] *16*	0.0	5/2$^+$	(E2)		0.01403 *20*
867.00	5/2$^-$,7/2$^-$	479.19[e&] *5*	100[e&] *17*	387.828	7/2$^-$	(E2)		0.0472 *7*
		630.00[&] *6*	51[&] *11*	236.899	9/2$^-$	E2		0.0253 *4*
		681.37[&] *7*	80[&] *13*	185.7160	5/2$^-$	(M1+E2)		0.06 *4*
875.549	(3/2)$^-$	255.903[&] *11*	25[&] *5*	619.638	3/2$^-$			
		320.899[&] *4*	83[&] *13*	554.6503	(1/2)$^-$	M1+E2	0.9 *2*	0.45 *7*
		875.54[&] *7*	100[&] *17*	0.0	5/2$^+$			
889.997	5/2$^+$	614.563[&] *14*	100[&] *16*	275.4250	7/2$^+$	M1		0.1209 *17*
		649.142[&] *23*	77[&] *12*	240.8794	5/2$^+$	(M1)		0.1046 *15*
		668.56[&] *10*	41[&] *9*	221.3966	3/2$^+$	E2+M1	1.2 *3*	0.053 *11*
914.90	(5/2)$^-$	673.96[&] *13*	34[&] *14*	240.8794	5/2$^+$			
		678.1[&] *3*	22[&] *7*	236.899	9/2$^-$			
		729.19[&] *5*	55[&] *9*	185.7160	5/2$^-$	(M1(+E2))		0.05 *3*
		914.91 *7*	100 *16*	0.0	5/2$^+$			
936.307	(5/2)$^-$	342.702[&] *17*	10.9[&] *22*	593.6173	(3/2)$^-$	(M1)		0.584 *8*
		548.454[&] *15*	36[&] *6*	387.828	7/2$^-$	E2+M1	1.5 *3*	0.074 *14*
		619.27[&] *13*	29.6[&] *9*	317.0809	5/2$^+$			
		750.621[&] *16*	100[&] *18*	185.7160	5/2$^-$	M1		0.0711 *10*
		936.17[&] *6*	100[&] *18*	0.0	5/2$^+$			
960.809	3/2$^+$	643.85[&] *7*	19[&] *5*	317.0809	5/2$^+$			
		658.97[&] *6*	20[&] *5*	301.7429	5/2$^+$	M1+E2	1.0 *3*	0.062 *14*
		688.611[e&] *24*	85[e&] *15*	272.1800	3/2$^+$	E2+M1	1.1 *2*	0.052 *7*
		713.234[&] *16*	100[&] *15*	247.5867	1/2$^+$	M1+E2	0.6 *1*	0.065 *5*
		719.74[&] *12*	19[&] *5*	240.8794	5/2$^+$			
		739.409[&] *25*	70[&] *12*	221.3966	3/2$^+$	M1+E0(+E2)		
		775.04[&] *13*	26[&] *8*	185.7160	5/2$^-$			
		918.92[e&] *11*	49[e&] *8*	41.9521	7/2$^+$	(E2)		0.01175 *17*
1004.232	3/2$^+$	626.64[&] *4*	34[&] *8*	377.573	(7/2)$^+$			
		763.363[&] *24*	100[&] *19*	240.8794	5/2$^+$	M1		0.0680 *10*

Adopted Levels, Gammas (continued)

γ(^{231}Th) (continued)

E_i(level)	J^π_i	E_γ[†]	I_γ[†]	E_f	J^π_f	Mult.[b]	δ[b]	α[d]
1020.730	3/2⁻	336.240[&] 10	40[&] 8	684.4908	(5/2)⁻	M1+E2	0.63 25	0.47 8
		427.110[&] 7	100[&] 15	593.6173	(3/2)⁻	M1		0.321 5
		773.18[&] 13	45[&] 11	247.5867	1/2⁺			
		799.38[&] 5	89[&] 15	221.3966	3/2⁺			
		834.92[e] 5	131[e] 21	185.7160	5/2⁻	(M1)		0.0537 8
1056.27	(3/2⁺)	784.05[&] 9	26[&] 5	272.1800	3/2⁺			
		808.74[&] 9	23[&] 4	247.5867	1/2⁺			
		834.92[e&] 5	34[e&] 6	221.3966	3/2⁺	(M1)		0.0537 8
		1014.33[&] 4	100[&] 20	41.9521	7/2⁺	(E2)		
1066.191	(5/2,7/2)⁺	688.611[e&] 24	100[e&] 18	377.573	(7/2)⁺	E2+M1	1.1 2	0.052 7
		749.14[&] 5	56[&] 9	317.0809	5/2⁺	(M1)		0.0715 10
		844.55[&] 18	25[&] 6	221.3966	3/2⁺			
		1024.91[&] 25	41[&] 14	41.9521	7/2⁺			
		1066.07[&] 15	45[&] 15	0.0	5/2⁺			
1074.346	(3/2)⁻	483.507[&] 17	88[&] 19	590.8396	3/2⁻	E2+M1	1.4 3	0.108 21
		757.28[&] 18	71[&] 17	317.0809	5/2⁺			
		888.49[&] 19	100[&] 22	185.7160	5/2⁻			
1081.331	1/2⁻,3/2⁻	487.689[e&] 23	100[e&] 21	593.6173	(3/2)⁻	(E2)		0.0453 6
		490.51[&] 2	100[&] 21	590.8396	3/2⁻	M1		0.221 3
		526.68[&] 5	58[&] 14	554.6503	(1/2)⁻	(M1)		0.183 3
1086.811	5/2⁺	493.177[&] 25	8.9[&] 18	593.6173	(3/2)⁻	(E1)		0.01297 18
		709.220[&] 14	100[&] 16	377.573	(7/2)⁺	E2+M1	0.8 2	0.058 8
		785.08[e&] 8	19[e&] 3	301.7429	5/2⁺			
		811.408[&] 15	68[&] 11	275.4250	7/2⁺	E2		0.01501 21
		814.64[&] 4	26[&] 4	272.1800	3/2⁺	(E2)		0.01489 21
1102.252	3/2⁻	388.482[&] 9	100[&] 11	713.755	3/2⁻			
		417.793[&] 14	65[&] 15	684.4908	(5/2)⁻	M1		0.341 5
		468.209[e&] 19	89[e&] 19	634.046?	(7/2⁻)	[E2]		0.0500 7
		482.62[&] 5	31[&] 8	619.638	3/2⁻			
		785.08[e&] 8	125[e&] 21	317.0809	5/2⁺			
		861.86[e&] 24	50[e&] 12	240.8794	5/2⁺			
1133.80	(1/2⁺,3/2⁺)	816.70[&f] 9	119[&] 26	317.0809	5/2⁺			
		861.86[e&] 24	71[e&] 17	272.1800	3/2⁺			
		886.15[&] 25	100[&] 24	247.5867	1/2⁺			
1159.751	(3/2)⁻	445.996[&] 7	100[&] 15	713.755	3/2⁻	E2+M1	1.17 20	0.150 21

$^{231}_{90}Th_{141}$-13

γ(^{231}Th) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[b]	δ[b]	α[d]	Comments
1159.751	(3/2)$^-$	918.92[e&] *11*	72[e&] *12*	240.8794	5/2$^+$	(E1)		0.00400 *6*	
		974.15[&] *16*	43[&] *13*	185.7160	5/2$^-$				
1172.990	3/2$^-$	459.22[&] *8*	100[&] *28*	713.755	3/2$^-$	M1(+E2)	<0.8	0.264 *4*	
		488.55[&] *5*	50[&] *11*	684.4908	(5/2)$^-$				
		543.66[&] *3*	72[&] *15*	629.3428	(5/2)$^-$	(M1)		0.1677 *24*	
		785.08[e&] *8*	226[e&] *37*	387.828	7/2$^-$				
(5118.15)	1/2$^+$	3843.6[‡a] *4*	3.9 *6*	1274.5	1/2$^-$,3/2$^-$	E1[c]			
		3866.66[‡a] *17*	9.4 *7*	1251.46					
		3899.07[‡a] *24*	8.1 *8*	1219.05	(1/2$^+$,3/2$^+$)	(M1)[c]			Mult.: required by level scheme.
		3904.26[‡a] *21*	9.8 *8*	1213.86					
		3917.71[‡a] *17*	11.2 *8*	1200.47	1/2$^-$,3/2$^-$	D[c]			
		3924.9[‡a] *8*	1.5 *5*	1193.2					
		3946.19[‡] *24*	5.6 *5*	1172.990	3/2$^-$	D[c]			
		3958.49[‡] *12*	75 *4*	1159.751	(3/2)$^-$	E1[c]			
		3962.6[‡a] *4*	7.1 *12*	1155.5					
		3984.31 *9*	9.4 *7*	1133.80	(1/2$^+$,3/2$^+$)	(M1)[c]			E_γ: reported $E\gamma$=3981.82 *17* in (n,γ) E=th (1987Wh01), but level-energy difference gives 3984.35 *9*, which after removal of recoil is 3984.31, which is adopted here in place of authors′ value of 3981.82.
		4023.87[‡a] *23*	5.3 *5*	1094.25	1/2$^-$,3/2$^-$	E1[c]			
		4062.44[‡] *13*	18.7 *11*	1056.27	(3/2$^+$)				E_γ: poor fit. Level-energy difference=4062.44 *13*.
		4085.1[‡a] *3*	3.6 *5*	1033.0	1/2$^+$				
		4096.72[‡] *13*	26.5 *15*	1020.730	3/2$^-$	E1[c]			E_γ: poor fit. Level-energy difference=4097.38 *3*.
		4113.98[‡] *13*	25.7 *15*	1004.232	3/2$^+$	(M1)[c]			
		4157.42[‡] *17*	8.6 *6*	960.809	3/2$^+$				
		4175.9[‡a] *9*	1.3 *4*	942.2					
		4182.51[‡a] *19*	7.0 *5*	936.307	(5/2)$^-$				E_γ: somewhat poor fit. Level-energy difference=4181.81 *3*.
		4218.9[‡a] *6*	1.4 *3*	899.2					
		4242.45[‡] *15*	17.5 *12*	875.549	(3/2)$^-$	D[c]			
		4271.7[‡a] *4*	3.8 *5*	846.4	(1/2$^+$,3/2$^+$)				
		4278.73[‡] *17*	20.7 *14*	839.303	3/2$^+$	(M1)[c]			
		4284.91[‡] *12*	100 *5*	833.169	(1/2)$^-$	(E1)[c]			Mult.: E1 or M1 from average reduced intensities in (n,γ) E=2 keV:ARC, ΔJ^π consistent with E1.
		4297.14[‡] *21*	8.4 *8*	820.552	1/2$^+$				
		4404.39[‡] *11*	38.9 *23*	713.755	3/2$^-$	E1[c]			
		4424.61[‡a] *17*	13.3 *9*	693.50					

Adopted Levels, Gammas (continued)

γ(^{231}Th) (continued)

E_i(level)	J^π_i	E_γ[†]	I_γ[†]	E_f	J^π_f	Mult.[b]	Comments
(5118.15)	1/2+	4462.2[‡] 3	2.4 3	655.939?	(7/2−)		
		4498.5[‡] 3	2.3 4	619.638	3/2−	E1[c]	
		4523.95[‡] 25	15.3 23	593.6173	(3/2)−	E1[c]	
		4527.09[‡] 11	63 4	590.8396	3/2−	E1[c]	
		4563.45[‡] 9	49.6 23	554.6503	(1/2)−	E1[c]	
		4581.4[‡a] 7	1.5 3	536.7			
		4616.9[‡a] 5	2.7 4	501.2			
		4738.1[‡a] 3	13.7 23	380.0	1/2+,3/2+	M1[c]	
		4769.8[‡a] 5	3.8 6	348.3	(1/2+,3/2+)	M1[c]	
		4845.92[‡] 6	16.5 8	272.1800	3/2+	M1[c]	
		4870.1[‡] 3	2.6 3	247.5867	1/2+	M1[c]	
		4896.82[‡] 21	7.3 6	221.3966	3/2+	M1[c]	
		5117.69[‡] 17	4.5 3	0.0	5/2+		
(5119.84)	1/2+	3848.7[#] 6	33 7	1271.1	1/2−,3/2−	E1[c]	
		3898.0[#] 29	19 7	1222	(1/2+,3/2+)	(M1)[c]	
		3900.9[#] 32	17 7	1219.05	(1/2+,3/2+)	(M1)[c]	
		3918.0[#] 8	26 7	1200.47	1/2−,3/2−	D[c]	
		3947.3[#] 6	40 10	1172.990	3/2−	D[c]	E_γ: somewhat poor fit. Level-energy difference=3946.19 24.
		3960.9[#] 4	55 7	1159.751	(3/2)−	E1[c]	
		3985.7[#] 26	21 7	1133.80	(1/2+,3/2+)	(M1)[c]	
		4016.7[#] 4	69 7	1102.252	3/2−	E1[c]	
		4038.8[#] 9	29 10	1081.331	1/2−,3/2−	D[c]	
		4044.9[#] 8	36 10	1074.346	(3/2)−	D[c]	
		4099.0[#] 3	81 10	1020.730	3/2−	E1[c]	
		4116.3[#] 5	43 7	1004.232	3/2+	D[c]	
		4245.1[#] 10	36 12	875.549	(3/2)−	D[c]	
		4250.1[#] 11	31 12	869.7	1/2+	D[c]	
		4276.3[#f] 16	21 10	846.4	(1/2+,3/2+)	(M1)[c]	
		4279.9[#] 14	31 14	839.303	3/2+	D[c]	
		4285.5[#] 8	38 10	833.169	(1/2)−	D[c]	
		4325.9[#] 12	17 7	793.027	1/2+	M1[c]	
		4406.7[#] 3	81 7	713.755	3/2−	E1[c]	
		4434.3[#] 5	48 7	687.631	1/2+	D[c]	
		4500.0[#] 3	88 7	619.638	3/2−	E1[c]	
		4524.7[#] 9	67 29	593.6173	(3/2)−	E1[c]	

$^{231}_{90}Th_{141}$-15

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

E_i(level)	J^π_i	E_γ[†]	I_γ[†]	E_f	J^π_f	Mult.[b]
(5119.84)	$1/2^+$	4528.5[#] *7*	100 *29*	590.8396	$3/2^-$	E1[c]
		4564.9[#] *3*	74 *7*	554.6503	$(1/2)^-$	E1[c]
		4733.4[#f] *5*	41 *7*	386.5?	$(1/2^+,3/2^+)$	(M1)[c]
		4770.2[#f] *10*	19 *7*	348.3	$(1/2^+,3/2^+)$	(M1)[c]
		4847.9[#] *7*	29 *7*	272.1800	$3/2^+$	M1[c]
		4872.7[#] *7*	31 *7*	247.5867	$1/2^+$	M1[c]
		4898.5[#] *7*	36 *7*	221.3966	$3/2^+$	M1[c]

† From ^{235}U alpha decay, unless otherwise specified. Precise gamma-ray energies available from (n,γ) E=th were used in deducing weighted averaged energies listed in ^{235}U α decay dataset. For γ rays from levels above 634 keV and of J<15/2, all energies and branching ratios are available only from (n,γ) E=thermal.

‡ Primary γ ray in (n,γ) E=thermal.

Primary γ ray in (n,γ) E=2 keV res.

@ From ^{231}Ac β^- decay.

& From ^{230}Th(n,γ), E=th.

a Primary γ in (n,γ) E=th populates a level from which no secondary γ rays are known.

b Based on ce data in (n,γ) E=th (1987Wh01), with multipolarities of primary γ rays from average resonance capture, deduced from average reduced intensities. In cases where upper limit on α(K)exp for secondary γ rays excludes all mult other than E1 or E2, they were shown as (M1), (E1) or (E2) when the γ-ray placement implies a certain multipolarity. Multipolarities shown as E0+M1(+E2) indicate that the α(exp) require some M1(+E2) E2 admixture to E0. Exceptions are noted.

c Multipolarity of primary γ rays in (n,γ) E=th and (n,γ) E=2 keV from average resonance capture (ARC) data, where these were deduced from average reduced intensities (see 1987Wh01 for details).

d 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.

e Multiply placed with undivided intensity.

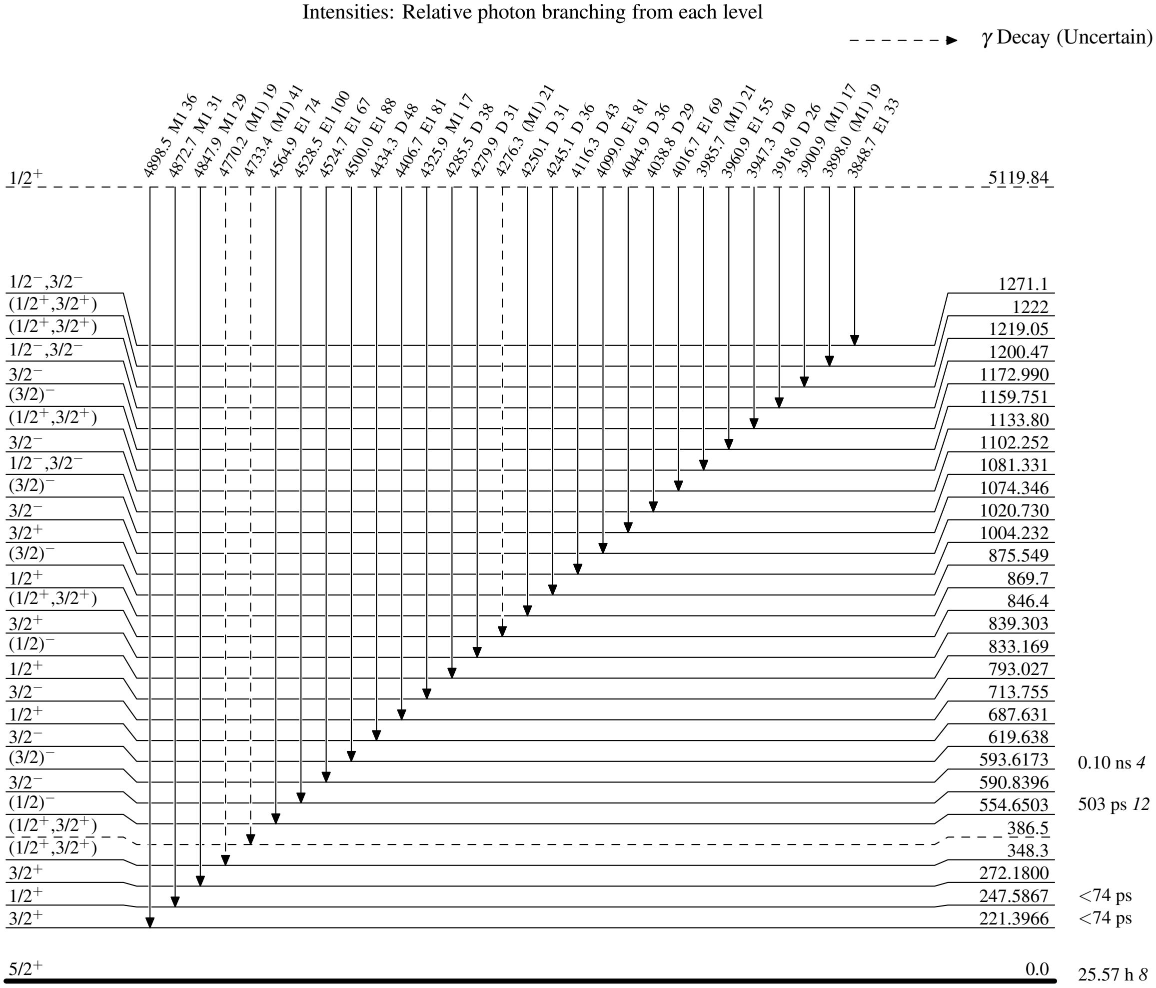
f Placement of transition in the level scheme is uncertain.

$^{231}_{90}Th_{141}$-16

Adopted Levels, Gammas

Level Scheme

Intensities: Relative photon branching from each level

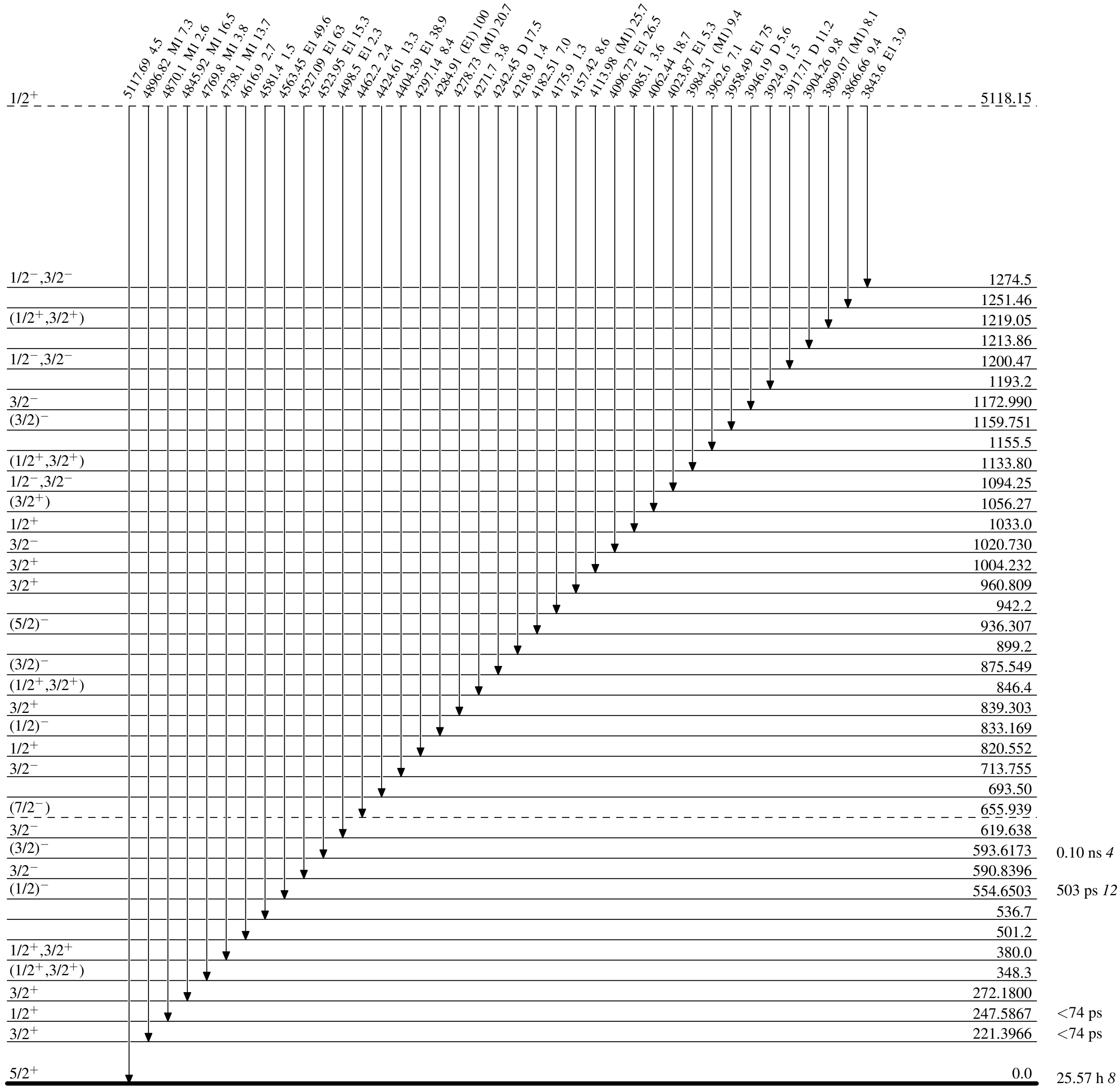


$^{231}_{90}Th_{141}$

Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level

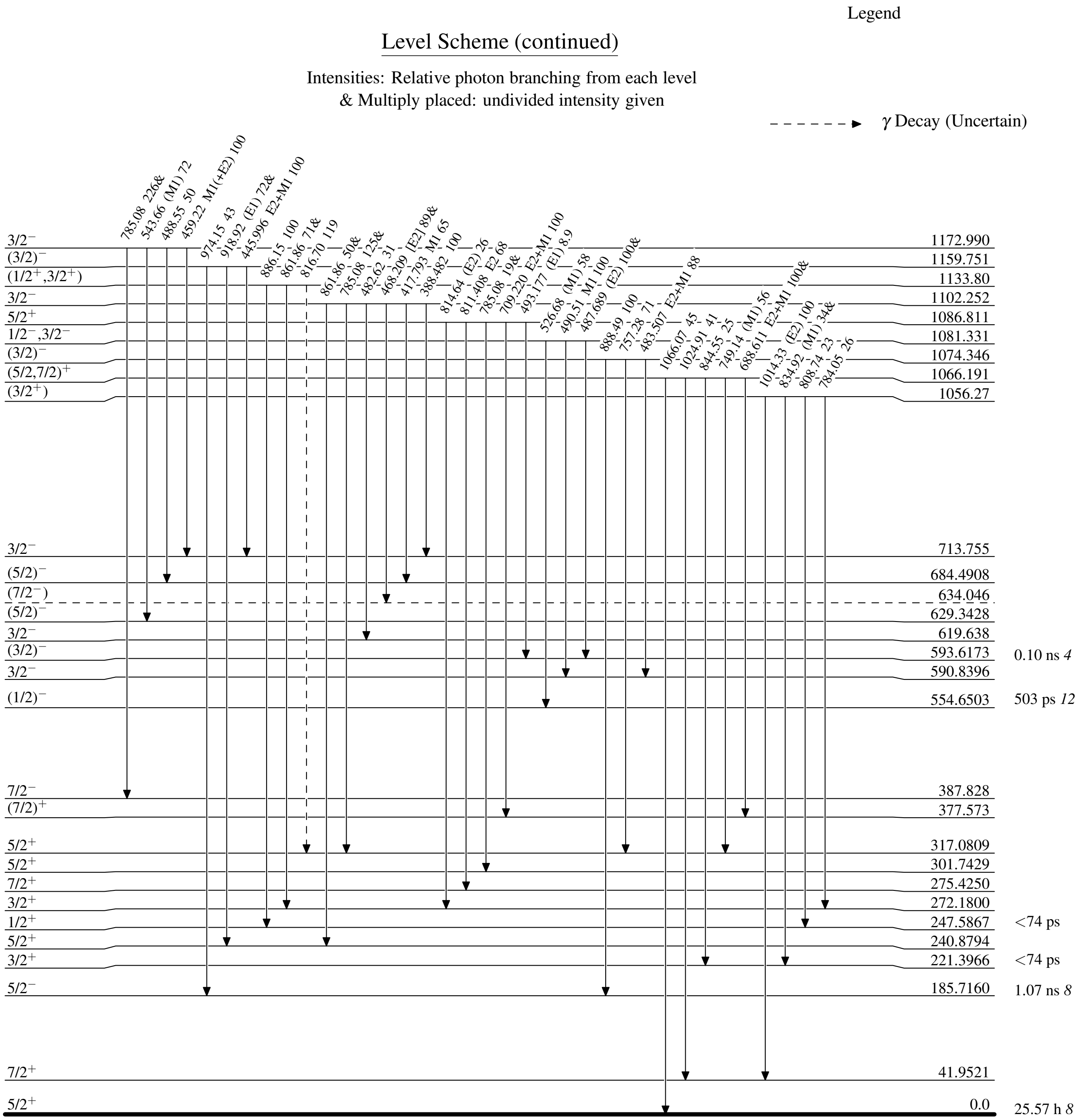


$^{231}_{90}Th_{141}$

Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level
& Multiply placed: undivided intensity given

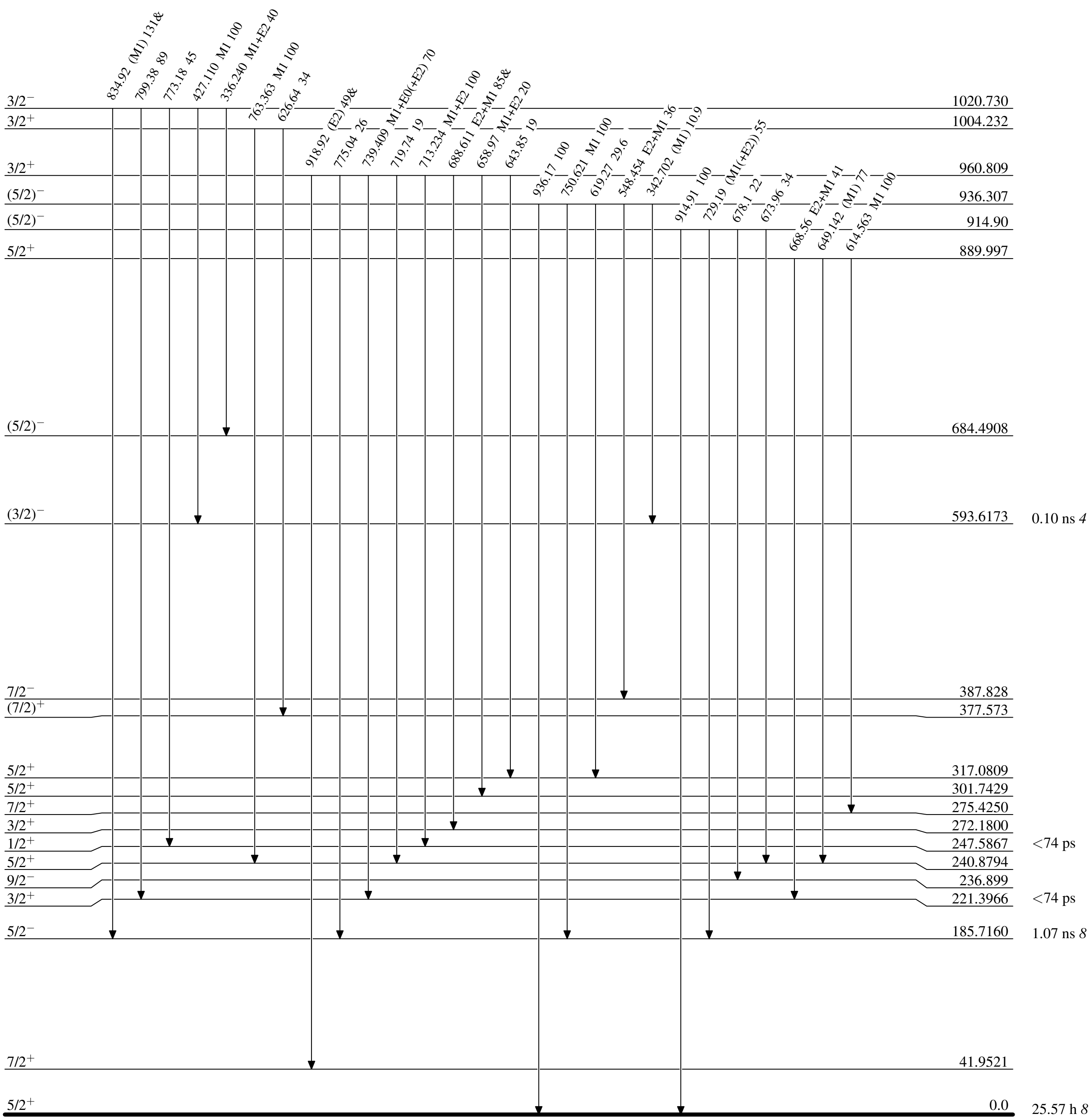


$^{231}_{90}Th_{141}$

Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level
& Multiply placed: undivided intensity given



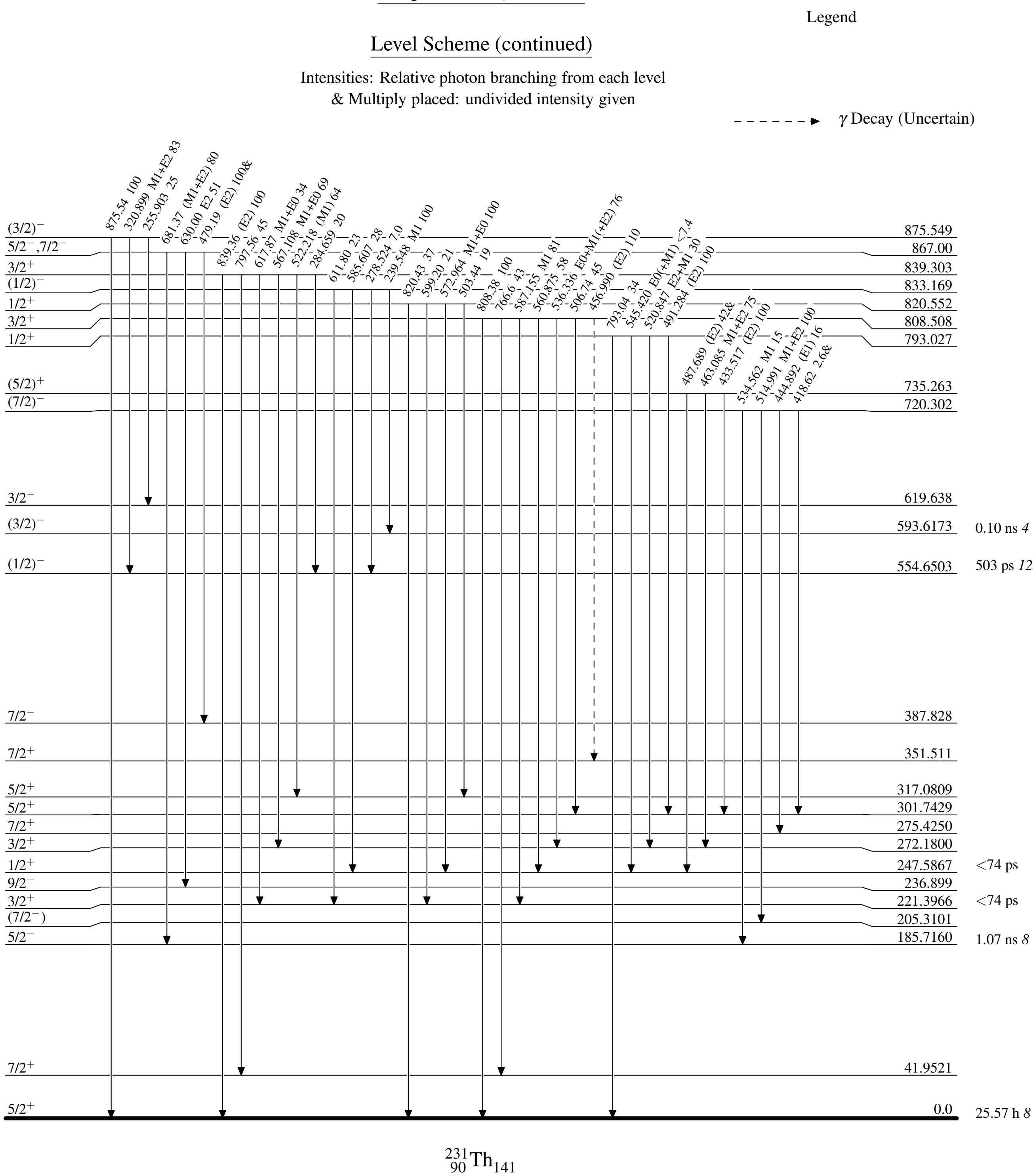
$^{231}_{90}Th_{141}$

Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level

& Multiply placed: undivided intensity given



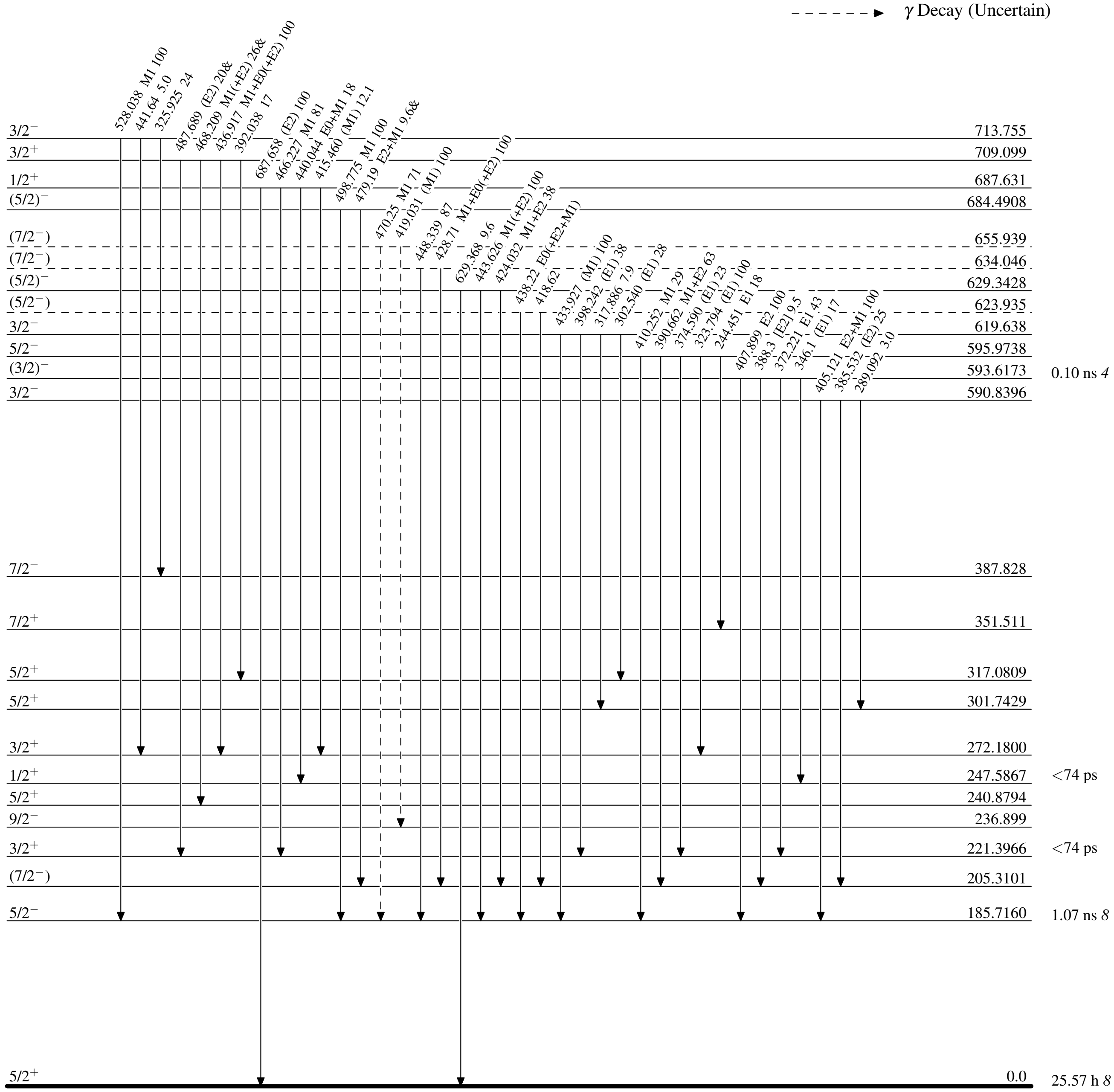
Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level
& Multiply placed: undivided intensity given

Legend

γ Decay (Uncertain)



$^{231}_{90}Th_{141}$

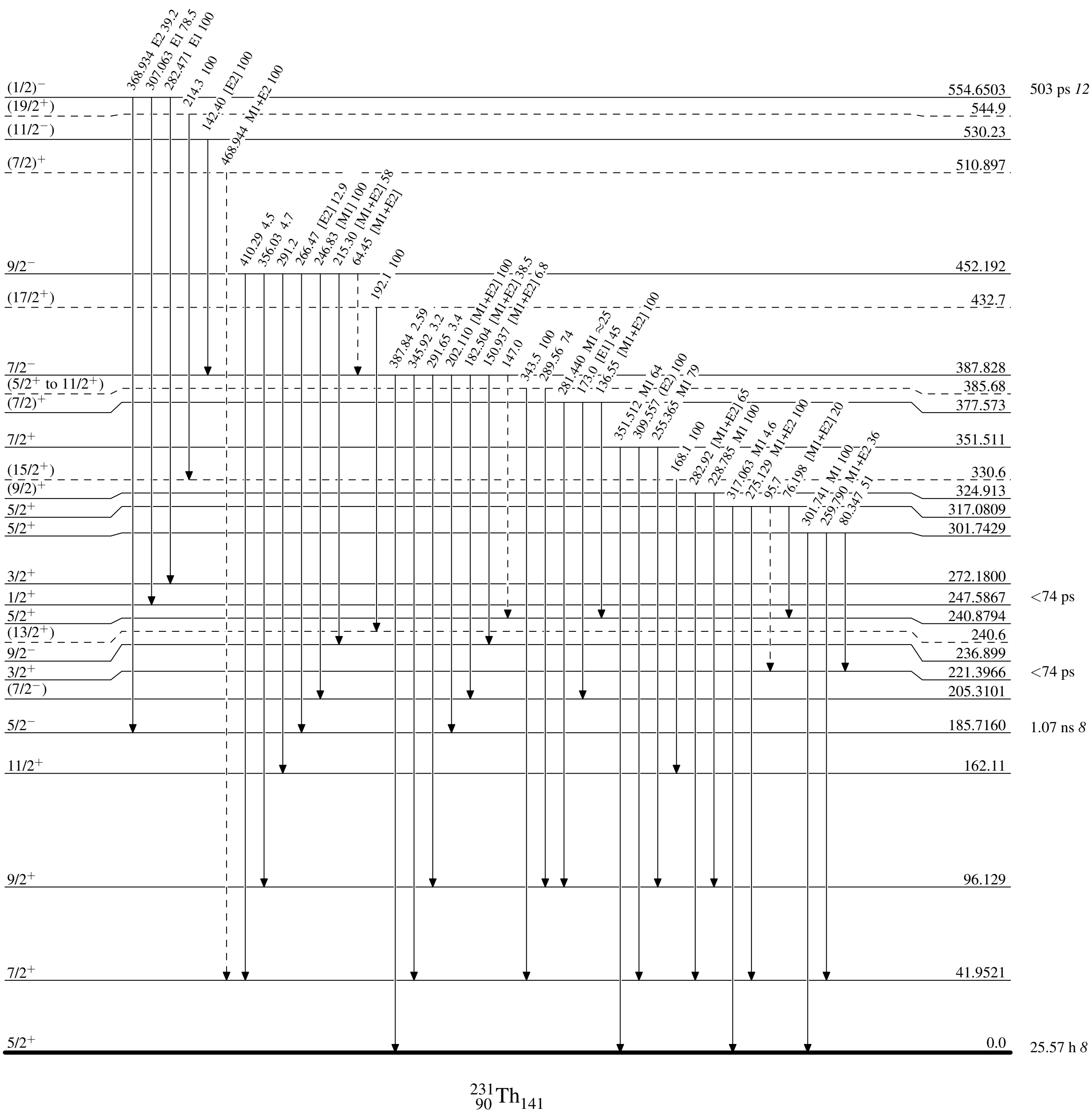
Adopted Levels, Gammas

Legend

Level Scheme (continued)

Intensities: Relative photon branching from each level
& Multiply placed: undivided intensity given

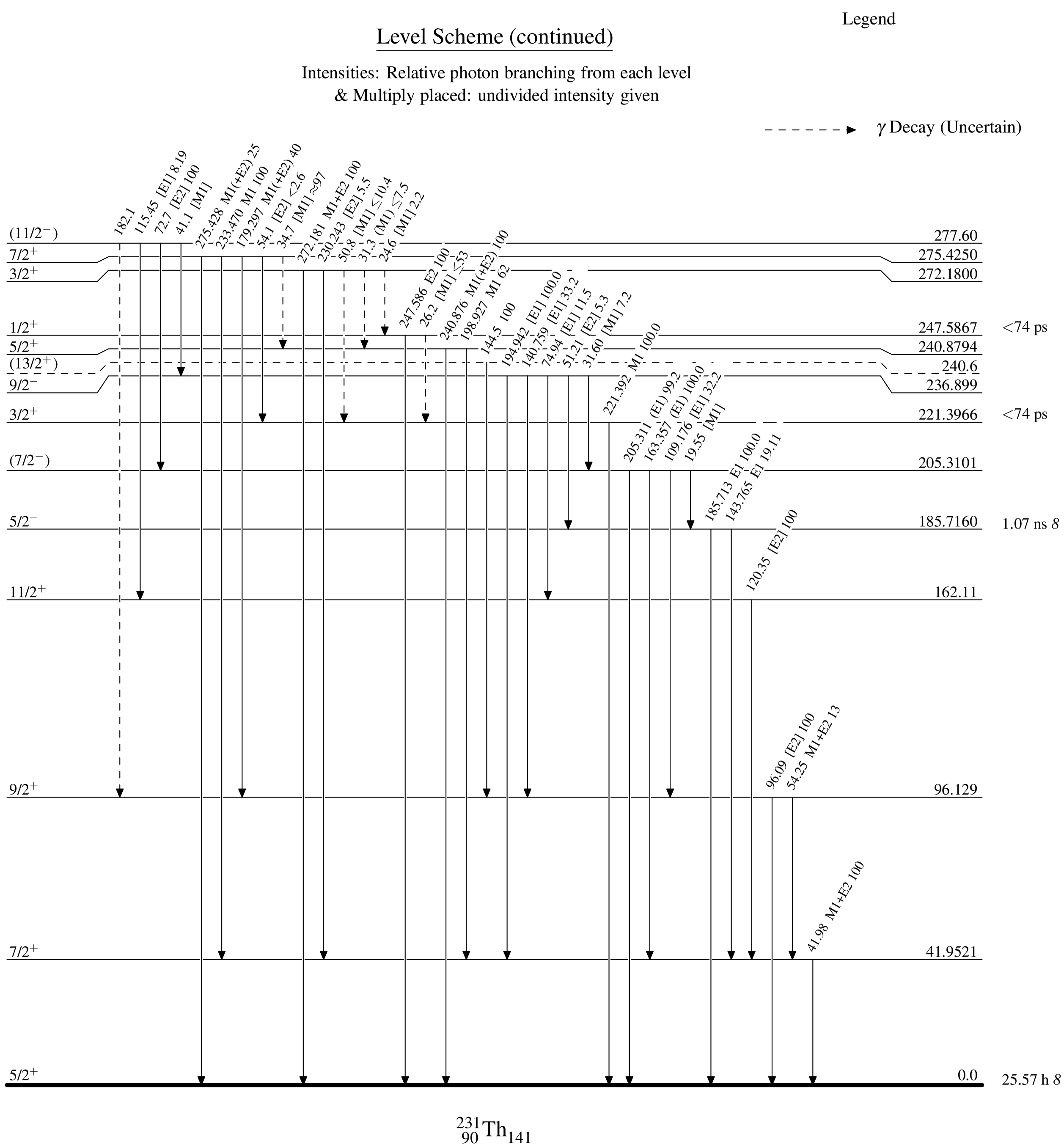
- - - - - ► γ Decay (Uncertain)



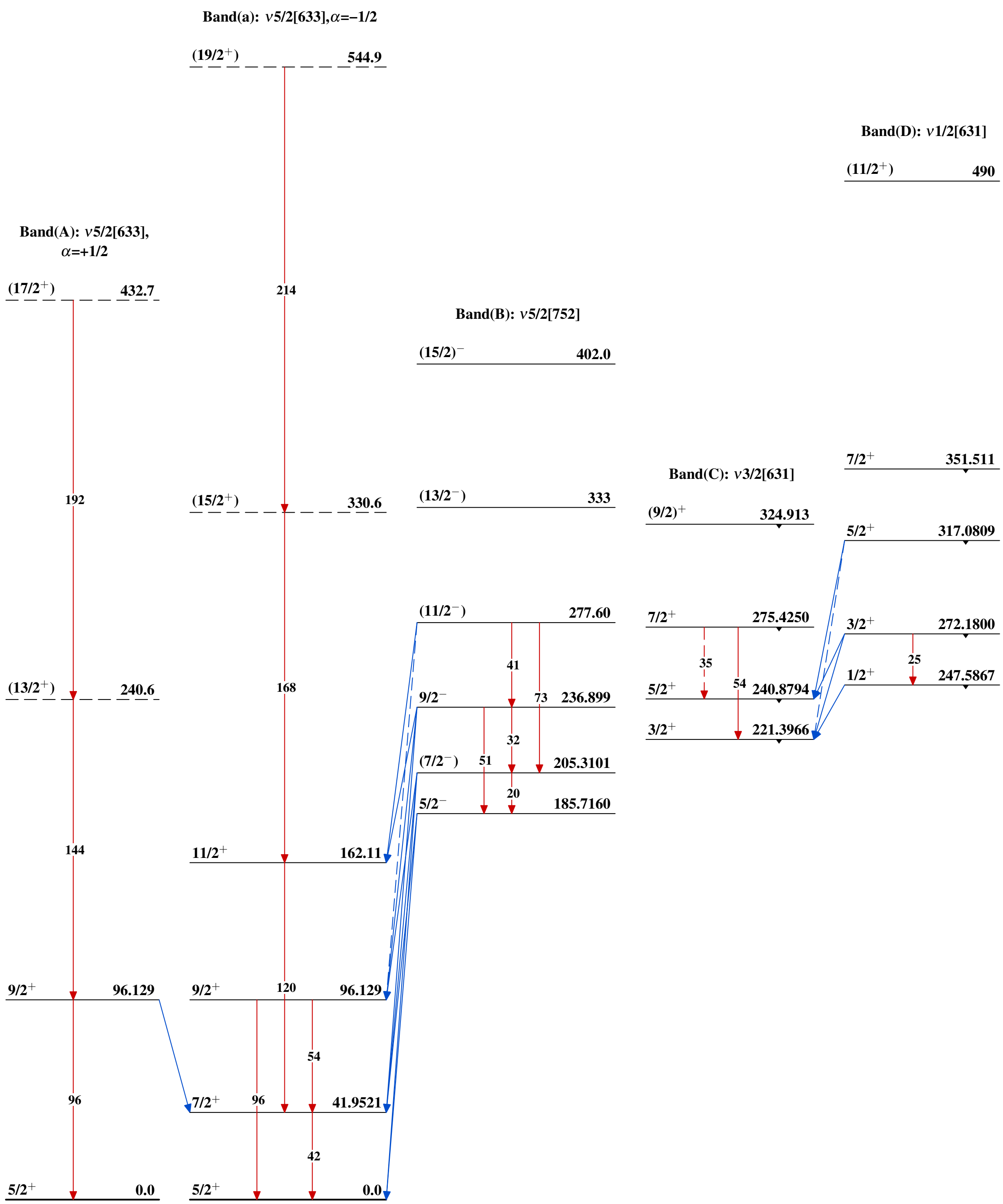
Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level
& Multiply placed: undivided intensity given

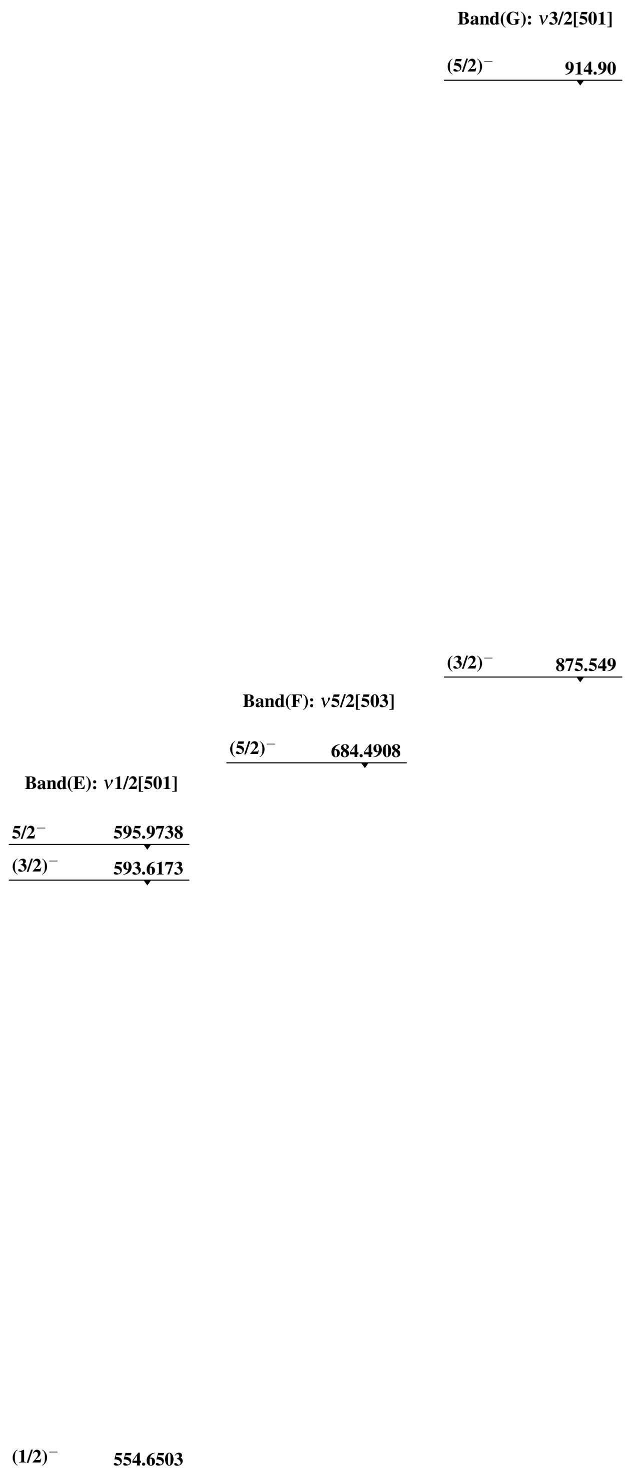


Adopted Levels, Gammas



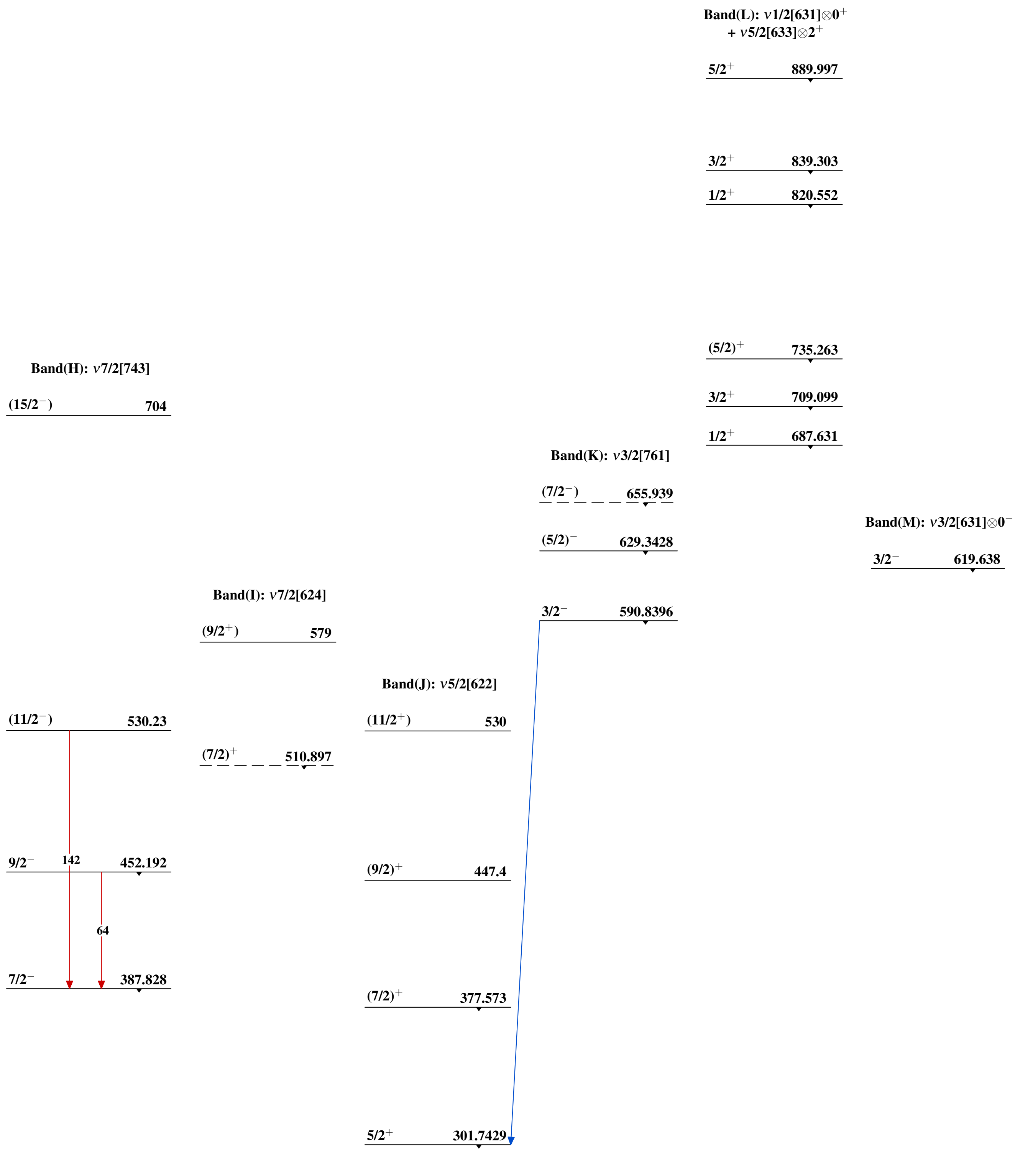
$^{231}_{90}Th_{141}$

Adopted Levels, Gammas (continued)



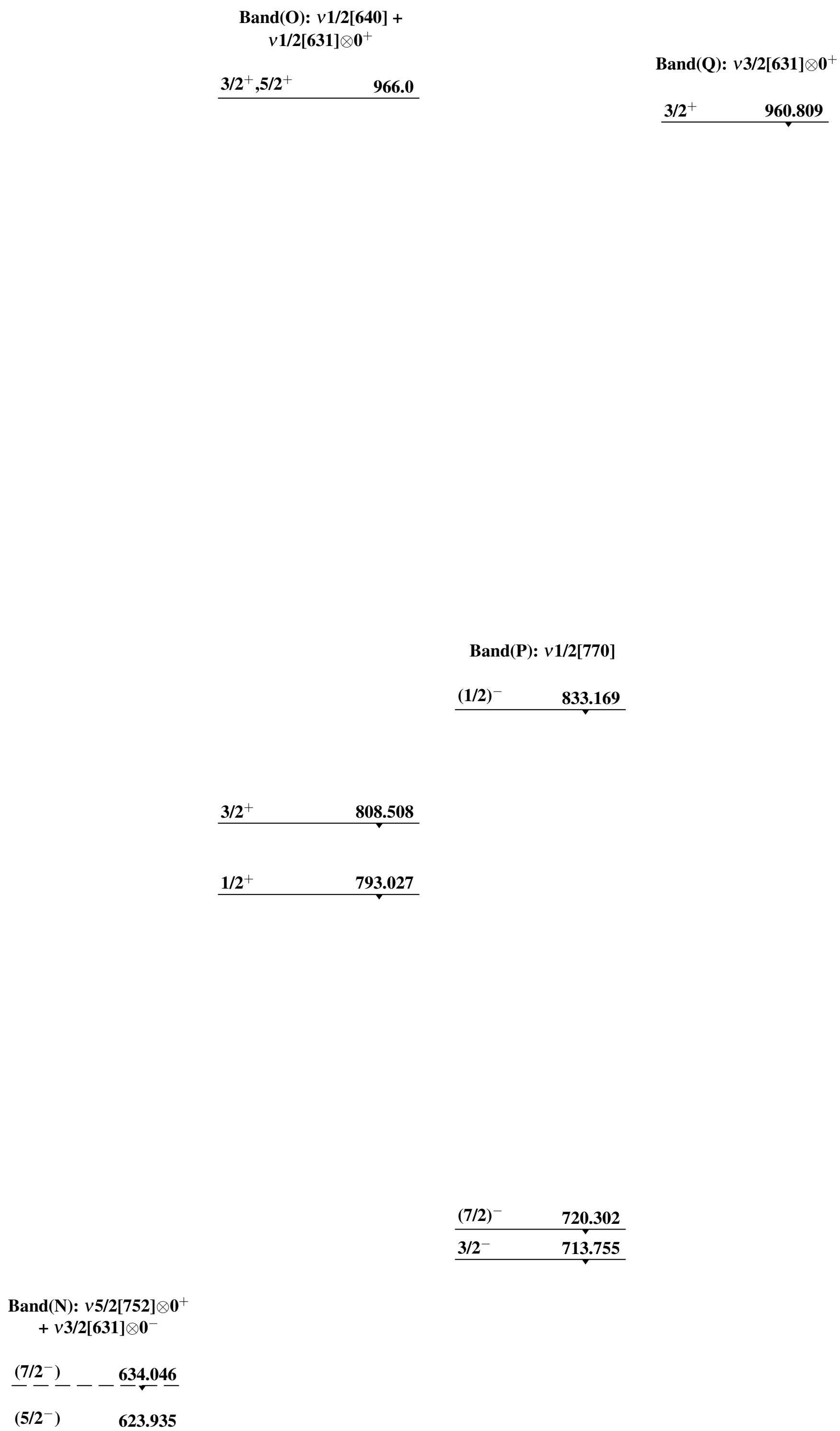
$^{231}_{90}Th_{141}$

Adopted Levels, Gammas (continued)



$^{231}_{90}Th_{141}$

Adopted Levels, Gammas (continued)



$^{231}_{90}Th_{141}$