Adopted Levels, Gammas

History

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

Q(β^-)=570.3 *20*; S(n)=6528 *8*; S(p)=5246.3 *11*; Q(α)=4375 *12* 2017Wa10
S(2n)=12077.6 *17*, S(2p)=12851 *13* (2017Wa10).
See ^{232}Pa(n,γ),(n,n):resonances dataset for 28 neutron resonances in the energy range of 0.33 eV to 20.63 eV.
Other reaction:
1998Er01, 1995Er02, 1993Er01: ^{232}Th(d,nF),E=7.5-15.6 MeV; measured fission fragment $\sigma(\theta)$ using single-crystal targets, and blocking technique. Deduced deduced mean fission lifetimes vs excitation energy, and level densities in second potential well.
Theoretical studies: consult the NSR database at www.nndc.bnl.gov for 16 references dealing with theoretical structure calculations, and seven related to decay modes and half-lives.

^{233}Pa Levels

Uncertain levels at 219 and 283 keV deduced from questionable α transitions are not included here.
Level energies for various configurations were calculated by 1974Mo18 and 1975Iv06.

Cross Reference (XREF) Flags

A	^{233}Th β^- decay (21.83 min)	D	^{232}Pa(n,γ),(n,n):resonances
B	^{237}Np α decay (2.144×10^6 y)	E	^{234}U(t,α),(pol t,α)
C	^{232}Th(^{3}He,d),(α,t)	F	^{232}Th(^{209}Bi,^{208}Pbγ)

E(level)†	Jπ‡	$T_{1/2}$	XREF	Comments
0.0@	3/2$^-$	26.975 d *13*	ABC EF	%β^-=100 μ=4.0 *7* (1989Ra17,2019StZV) Q=−3.0 *4* (1961Ma42,2016St14) μ,Q: from low-temperature nuclear orientation (quoted in 1989Ra17 compilation from Annual report of the Institute Srahlen und Kernphysik, Universitat Bonn, p152, 1983-84); also adopted in 2019StZV evaluation. Other: +3.4 *8* (1961Ma42, atomic beam). Jπ: spin measured by atomic beam (1961Ma42). Spin and parity from analyzing power $A_y(\theta)$ in (pol t,α). $T_{1/2}$: from 2000Us01 evaluation. Measured values: 27.02 d *3* (2000Us01, from γ-decay curves for eight γ rays, followed for five half-lives); 26.9 d *1* (1999Po33, γ-decay curve), 26.967 d *2* (1986Jo08, ionization chamber), 26.95 d *6* (1957Wr37, ionization chamber and proportional counter), 27.0 d *1* (1956Mc60, ionization chamber and proportional counter). Others: 27.46 d *18* (2002Ab03, γ-decay curve), 27 d (1947Le01), 27.4 d *4* (1941Gr03), 25 d (1941Se09), 27 d (E. Haggstrom: Phys. Rev. 59, 322 (1941), from conversion lines), ≈25 d (1938Me04).
6.677# *12*	1/2$^-$		AB F	Jπ: 194.9, E1 γ from 3/2$^+$; fit to a band.
57.111@ *10*	7/2$^-$		ABC EF	Jπ: 57.1, E2 γ to 3/2$^-$; γ from 5/2$^+$; analyzing power $A_y(\theta)$ in (pol t,α).
70.546# *19*	5/2$^-$		AB F	Jπ: 131.1, E1 γ from 3/2$^+$; γ from 7/2$^+$ and to 1/2$^-$.
86.481& *8*	5/2$^+$	36.5 ns *4*	AB	Jπ: 86.48, E1 γ to 3/2$^-$; 29.37, E1 γ to 7/2$^-$. $T_{1/2}$: from $\alpha\gamma$(t) in α decay. Weighted average of 35.7 ns *4* (1972Mc12), 36.4 ns *5* (1972Mc29), 35.7 ns *5* (1972Wi11), 35.4 ns *8* (α(29.6γ)(t),1972Wi11), 37.4 ns *4* (α(65-105 α)(t),1971Ga16), 36.8 ns *16* (α(70-90 γ)(t),1968Ob02), 36.9 ns *5* (1961Ma10), 36.9 ns *4* (α(ce, <100 keV)(t),1954En11).
94.660& *11*	3/2$^+$		AB	Jπ: 94.68, E1 γ to 3/2$^-$; 143.2, M1+E2 γ from 5/2$^+$; γ to 1/2$^-$.
103.656& *18*	7/2$^+$		ABc e	XREF: e(107).

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Adopted Levels, Gammas (continued)

^{233}Pa Levels (continued)

E(level)†	Jπ‡	XREF	Comments
			Jπ: L+1/2 from analyzing power $A_y(\theta)$ in (pol t,α) for 107 *2* doublet gives 7/2+ for one and 9/2+ for the other; 108.7γ, M1+E2 from 5/2+; γ to 7/2−; γ branching from 9/2+, band assignment.
109.05& *3*	9/2+	Bc e	XREF: e(107). Jπ: analyzing power and cross section in (pol t,α) for 107 *2* doublet gives 7/2+ for one and 9/2+ for the other; band assignment.
133.2& *2*	(11/2+)	B	Jπ: γ to 9/2+ member of the band; energy fit to band.
163.26@ *5*	(11/2−)	B F	Jπ: γ to 7/2−; γ from 9/2+; energy fit to band.
169.169a *9*	1/2+	AB e	XREF: e(171). Jπ: gammas to 1/2−, 3/2−, and 3/2+; analyzing power $A_y(\theta)$ in (pol t,α) for 171 doublet giving 1/2+ for one and 13/2+ for the other.
173& *1*	13/2+	C e	XREF: e(171). Jπ: analyzing power $A_y(\theta)$ in (pol t,α) for 171 doublet giving 1/2+ for one level and 13/2+ for the other.
179.1# *4*	(9/2−)	B F	Jπ: energy fit to band; α hindrance factor; probable γ to the 5/2− member of the band.
201.645a *16*	3/2+	AB E	XREF: E(205). Jπ: 201.62γ, E1 to 3/2−; γ to 5/2+; L-1/2 from analyzing power $A_y(\theta)$ in (pol t,α).
212.348a *13*	5/2+	AB	Jπ: 155.24γ, E1 to 7/2−; 212.29γ, E1 to 3/2−.
237.904b *11*	5/2+	AB	Jπ: favored α decay (HF=2.86) from 5/2+ g.s. decay of ^{237}Np; 151.4γ, M1+E2 to 5/2+; 143.2γ, M1+E2 to 3/2+; γ rays to 7/2+ and 7/2−.
257.173c *14*	5/2−	AB	Jπ: 257.37γ, M1+E2 to 3/2−; 186.8γ, M1+E2 to 5/2−; γ to 7/2+.
279.727a *21*	(7/2+)	B	Jπ: gammas to 5/2+, 5/2− and 9/2+; pattern of γ decays to 1/2[501] and 3/2[651] bands.
296	(5/2+,11/2−)	E	E(level): 298 *3* in (^{3}He,d),(α,t) agrees in energy with that from (pol t,α), but a doublet with L=(4+3) and 7/2+ and 7/2− is proposed in (^{3}He,d),(α,t). Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
300.489b *25*	7/2+	Bc	XREF: c(298). E(level): 298 *3* in (^{3}He,d),(α,t) with L-(4+3) and 7/2+ and 7/2− is proposed. Jπ: 62.6γ to 5/2+ member of the band; pattern of γ transitions to 3/2[651] band; (^{3}He,d),(α,t) data.
303.62a *6*	(9/2+)	B	Jπ: γ to 7/2+,3/2[651] state; band assignment. Unfavored α decay (HF=127) from 5/2+ ground state of ^{237}Np supports the assignment.
306.04c *10*	(7/2−)	Bc	XREF: c(298). E(level): 298 *3* in (^{3}He,d),(α,t) with L=(4+3) and 7/2+ and 7/2− is proposed. Jπ: γ to 5/2− member of the band, gammas to 5/2+ and 7/2− levels; (^{3}He,d) and (α,t) data; energy fit to band.
323.6@ *3*	(15/2−)	F	
330.9# *5*	(13/2−)	F	
355	3/2+	E	E(level): the levels in (pol t,α) and (^{3}He,d),(α,t) are at the same energy, but different J^π values are proposed. Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
355c *2*	(9/2−)	C	E(level): see comment for 355, 3/2+ level. Jπ: L=(5) from σ(^{3}He,d))/σ(α,t); band assignment.
365.94b *7*	9/2+	B	Jπ: γ branchings to 5/2+, 9/2+ and (11/2−) levels; band assignment. Unfavored α decay (HF=59) from 5/2+ ground state of ^{237}Np supports the assignment.
421?c *4*	(11/2−)	C E	XREF: E(411). Jπ: L=(5) from σ(^{3}He,d))/σ(α,t); band assignment.
447.731 *14*	3/2−	A c	Jπ: 190.55γ, M1+E2 to 5/2−; 440.9γ, M1(+E2) to 1/2−. Configuration=π3/2[532] suggested by 1970Se06.
454.42e *4*	3/2+	A c E	Jπ: 359.7γ, M1(+E2) to 3/2+; 285.5γ, M1(+E2) to 1/2+; γ rays to 5/2+ and 5/2−; analyzing power $A_y(\theta)$ in (pol t,α).
488e	(5/2+)	E	Jπ: from cross section data and band assignment in (t,α).
517.7# *6*	(17/2−)	F	
528.8@ *5*	(19/2−)	F	

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Adopted Levels, Gammas (continued)

^{233}Pa Levels (continued)

E(level)[†]	Jπ[‡]	XREF	Comments
529 *2*	(13/2$^+$)	C E	XREF: E(523). Jπ: L=(6) in (^{3}He,d),(α,t) and proposed 13/2$^+$ member of configuration=π1/2[660].
553.883 *13*	1/2$^+$,3/2$^+$	A	Jπ: 459.2, M1(+E2) γ to 3/2$^+$; β feeding from 1/2$^+$ parent, log *ft*=6.8.
555	11/2$^+$	E	Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
585.48 *3*	3/2$^+$	A	Jπ: 499.0, M1(+E2) γ to 5/2$^+$; 490.8, M1 γ to 3/2$^+$; β feeding from 1/2$^+$ parent, log *ft*=7.6.
586	7/2$^+$	E	E(level): 586 in (t,α) and 589 *4* in (^{3}He,d),(α,t) agree in energy, but different J^π values are proposed. Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
589[b] *4*	(13/2$^+$)	C	E(level): see comment for 586 level. Jπ: L=(6) in (^{3}He,d),(α,t), and proposed 13/2$^+$ member of 5/2[642].
669.88[d] *3*	3/2$^-$	A C	Jπ: 412.5, M1+E2 γ to 5/2$^-$; L=(1) in (^{3}He,d),(α,t) and proposed bandhead of 3/2[521] configuration.
703	(3/2$^-$)	E	E(level): 703 in (t,α) and 704 *3* in (^{3}He,d),(α,t) agree in energy, but different J^π values are proposed. Jπ: analyzing power A_y in (pol t,α).
704[d] *3*	(5/2$^-$)	C	Jπ: L=(3) in (^{3}He,d),(α,t), and proposed 5/2$^-$ member of 3/2[521] configuration.
739.3[#] *7*	(21/2$^-$)	F	
749[d] *1*	(7/2$^-$)	C E	XREF: E(742). Jπ: analyzing power $A_y(\theta)$ in (pol t,α); also L=(3) in (^{3}He,d), (α,t) and proposed 7/2$^-$ member of 3/2[521] configuration.
764.54 *3*	1/2$^+$,3/2$^+$	A	Jπ: 595.2γ, M1(+E2) γ to 1/2$^+$.
776.7[@] *6*	(23/2$^-$)	F	
803[d] *4*	(9/2$^-$)	C E	XREF: C(?)E(800). Jπ: L=(5) in (^{3}He,d),(α,t) and proposed 9/2$^-$ member of 3/2[521] configuration.
811.61 *6*	3/2$^+$	A	Jπ: 226.3, M1+E2 γ to 3/2$^+$; 725.0γ, M1(+E2) to 5/2$^+$; β feeding from 1/2$^+$ parent, log *ft*=6.6.
852 *4*		C E	XREF: E(833).
871[d] *2*	(11/2$^-$)	C	E(level): 871 *2* in (^{3}He,d),(α,t) and 872 in (pol t,α) agree in energy, but different J^π values are proposed in the two studies. Jπ: L=(5) in (^{3}He,d),(α,t) and proposed 11/2$^-$ member of 3/2[521] configuration.
872	(3/2$^-$)	E	E(level): see comment for 871 level. Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
941.97 *22*	(3/2)	A E	XREF: E(942). Jπ: β feeding from 1/2$^+$ parent with log *ft*=6.95; γ rays to 5/2$^-$ and 5/2$^+$.
968.6 *3*	(1/2,3/2)	A	Jπ: β feeding from 1/2$^+$ parent with log *ft*=7.2.
984.78 *11*	(3/2)$^+$	A c	Jπ: 431.4, M1(+E2) γ to 1/2$^+$,3/2$^+$; gammas to 1/2$^-$ and 7/2$^+$.
992.9[#] *7*	(25/2$^-$)	F	
998	(9/2$^+$)	c E	Jπ: analyzing power $A_y(\theta)$ in (pol t,α); 9/2$^+$, 1/2[660] configuration proposed by 1979Fl02; but 1977Th04 also proposed tentative 11/2$^-$, 9/2[514], both in (t,α).
1018.63 *19*	(3/2)	A	Jπ: γ rays to 5/2$^+$, 5/2$^-$, 1/2$^+$ and 1/2$^-$ levels; log *ft*=6.6 from 1/2$^+$ parent.
1044 *12*		E	
1062.9[@] *6*	(27/2$^-$)	F	
1064.5 *6*	(3/2)	A	Jπ: β feeding from 1/2$^+$ parent, log *ft*=7.2. J^π=3/2$^+$ from 960.8γ to 7/2$^+$, but 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.
1073	5/2$^+$	E	Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
1138.94 *22*	(1/2,3/2)	A	Jπ: β feeding from 1/2$^+$ parent with log *ft*=7.3.
1143 *3*		C	
1179 *3*	1/2$^+$	C E	XREF: E(1176). Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
1240 *3*	(1/2$^+$,3/2$^-$)	C E	XREF: E(1233). Jπ: analyzing power $A_y(\theta)$ in (pol t,α).

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Adopted Levels, Gammas (continued)

^{233}Pa Levels (continued)

E(level)[†]	Jπ[‡]	XREF	Comments
1274 *5*	1/2+	C E	XREF: E(1267). Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
1276.5[#] *8*	(29/2−)	F	
1318 *4*	1/2+	C E	XREF: E(1308). Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
1358 *4*		C	
1384.7[@] *7*	(31/2−)	F	
1386	5/2+	E	Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
1403 *3*	5/2+	C E	XREF: E(1417). Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
1486	(5/2+,11/2−)	E	Jπ: analyzing power $A_y(\theta)$ in (pol t,α).
1557		E	
1588.6[#] *9*	(33/2−)	F	
1625		E	
1680		E	
1738.4[@] *8*	(35/2−)	F	
1928.8[#] *9*	(37/2−)	F	
2121.5[@] *8*	(39/2−)	F	
2297.4[#] *10*	(41/2−)	F	
2533.0[@] *10*	(43/2−)	F	
2692.7[#] *10*	(45/2−)	F	
2973.0[@] *10*	(47/2−)	F	
3115.3[#] *11*	(49/2−)	F	
3569.6[#] *11*	(53/2−)	F	
4050.9[#] *11*	(57/2)	F	

[†] From least-squares fit to Eγ values, assuming 0.3 keV uncertainty for Eγ when not stated. For levels populated only in the particle-transfer reactions, averages were taken of available data.

[‡] For low-spin states, see ^{232}Th(^{3}He,d),(α,t) and ^{234}U(t,α),(pol t,α) datasets for methods of determining J^π and Nilsson assignments based on vector analyzing power measurements in (pol t,α), and comparison of experimental and theoretical cross sections for Nilsson orbital assignments. Assignments for high-spin (J>11/2) states are based on probable rotational bands and yrast population pattern in heavy-ion reactions. Additional J^π arguments are given for individual levels.

[#] Band(A): π1/2[530],α=+1/2.

[@] Band(a): π1/2[530],α=−1/2.

[&] Band(B): π3/2[651]. Perturbed by strong Coriolis interaction with π5/2[642] and π1/2[660] bands. See 1969BrZV, 1969Ho04, 1975El03 for discussions.

[a] Band(C): $K^\pi=1/2^+$. Possibly mixed π1/2[400] + π1/2[660] Strongly Coriolis coupled with π3/2[651] and π5/2[642] bands.

[b] Band(D): π5/2[642]. Strongly Coriolis coupled with π3/2[651] band.

[c] Band(E): π5/2[523]. A=6.0.

[d] Band(F): π3/2[521]. A=6.4 4.

[e] Band(G): π3/2[402].

Adopted Levels, Gammas (continued)

γ(^{233}Pa)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[†]	δ[†]	α[‡]	Comments
6.677	1/2⁻	6.68 *5*	100	0.0	3/2⁻	(M1)		3.04×10^3 *8*	
57.111	7/2⁻	57.116 *20*	100	0.0	3/2⁻	E2		175.5 *25*	
70.546	5/2⁻	63.94 *6*	100 *4*	6.677	1/2⁻	(E2)		102.0	
		70.49 *10*	100 *4*	0.0	3/2⁻	[M1+E2]		38 *27*	
86.481	5/2⁺	29.373 *10*	100 *3*	57.111	7/2⁻	E1		3.07	B(E1)(W.u.)=3.15×10^{-5} *14*
		86.485 *10*	84.8 *9*	0.0	3/2⁻	E1		1.43 *8*	B(E1)(W.u.)=1.05×10^{-6} *6* α: experimental conversion coefficient measured by 1972SeZI. Transition is anomalous, the total conversion coefficient is much enhanced as compared to the theoretical value of 0.177.
94.660	3/2⁺	8.22 *5*	≈1.0	86.481	5/2⁺	(M1)		1.64×10^3 *4*	
		87.99 *3*	22.0 *4*	6.677	1/2⁻	[E1]		0.1694	
		94.67 *5*	100.0 *10*	0.0	3/2⁻	E1		0.1398	
103.656	7/2⁺	(9.0)		94.660	3/2⁺	[E2]		4.2×10^5	
		17.40 *5*		86.481	5/2⁺	[M1+E2]		8.0×10^3 *78*	E_γ: poor fit, level-energy difference=17.18 *2*.
		46.53 *4*		57.111	7/2⁻	[E1]		0.91	
109.05	9/2⁺	(5.18)		103.656	7/2⁺				
		22.6		86.481	5/2⁺				
133.2	(11/2⁺)	24.14[&] *10*		109.05	9/2⁺				
163.26	(11/2⁻)	54.40 *10*		109.05	9/2⁺				
		106.12 *5*		57.111	7/2⁻	[E2]		9.3	
169.169	1/2⁺	74.57 *10*	16.1 *7*	94.660	3/2⁺	[M1+E2]		29 *20*	
		162.505 *12*	49.9 *26*	6.677	1/2⁻	(E1)		0.1574	I_γ: unweighted average from β^- and α decays.
		169.161 *10*	100.0 *10*	0.0	3/2⁻	[E1]		0.1431	
179.1	(9/2⁻)	109.10[&] *10*		70.546	5/2⁻				
201.645	3/2⁺	(32.46)		169.169	1/2⁺				
		115.44 *20*	1.1 *5*	86.481	5/2⁺	[M1+E2]		10.0 *35*	
		131.093 *20*	47.2 *9*	70.546	5/2⁻	E1		0.262	
		194.95 *2*	100.0 *13*	6.677	1/2⁻	E1		0.1024	
		201.673 *25*	21.3 *5*	0.0	3/2⁻	E1		0.0946	
212.348	5/2⁺	108.7	41.8 *18*	103.656	7/2⁺	M1(+E2)	<0.9	4.4 *12*	I_γ: from α decay, γ not observed in β^- decay.
		117.703 *20*	100.0 *24*	94.660	3/2⁺	M1+E2	0.46 *+22−13*	11.5 *10*	
		141.74[&] *10*		70.546	5/2⁻				
		155.242 *20*	52.2 *11*	57.111	7/2⁻	E1		0.1755	I_γ: from α decay. Other: 79 *10* from β^- decay.
		212.32 *2*	89.4 *18*	0.0	3/2⁻	E1		0.0839	I_γ: from α decay. Other: 224 *21* from β^- decay is in severe disagreement. The intensities of the 117.7 and 212.3 γ rays given in 2008De31 measurement seem problematic. Evaluators recommend γ-branching ratios for the 212-keV level from α decay, as the level is more strongly populated in this decay as compared to that in β^- decay.
237.904	5/2⁺	36.24 *10*	1.20 *24*	201.645	3/2⁺	M1+E2	0.31 *9*	2.1×10^2 *8*	E_γ,I_γ: from α decay. Transition not observed in β^- decay.

$^{233}_{91}Pa_{142}$-5

Adopted Levels, Gammas (continued)

γ(^{233}Pa) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[†]	δ[†]	α[‡]	Comments
237.904	5/2$^+$	134.276 *20*	17.3 *7*	103.656	7/2$^+$	[M1+E2]	≈0.4	≈8.0	
		143.248 *10*	100.0 *26*	94.660	3/2$^+$	M1+E2	0.69 *19*	5.8 *6*	
		151.408 *15*	58.7 *7*	86.481	5/2$^+$	M1+E2	0.28 *12*	5.9 *3*	
		180.79 *5*	3.75 *24*	57.111	7/2$^-$	[E1]		0.1223	E_γ,I_γ: from α decay. Other: 9.7 *26* in β^- decay.
		237.884 *24*	13.76 *22*	0.0	3/2$^-$	[E1]		0.0645	
257.173	5/2$^-$	153.5 *1*	77.7 *12*	103.656	7/2$^+$	[E1]		0.180	All γ data from 257 level are from β^- decay. This level may be weakly populated in α decay.
		162.504 *12*	70 *10*	94.660	3/2$^+$	[E1]		0.1574	
		170.9 *3*	96.8 *12*	86.481	5/2$^+$	[E1]		0.1397	
		186.8 *1*	39.9 *14*	70.546	5/2$^-$	M1+E2	0.8 *3*	2.5 *5*	
		250.5 *3*	9.0 *6*	6.677	1/2$^-$	[E2]		0.317	
		257.37 *15*	100.0 *21*	0.0	3/2$^-$	M1+E2	1.1 *2*	0.80 *12*	
279.727	(7/2$^+$)	170.62 *5*	46 *9*	109.05	9/2$^+$	[M1+E2]	≈0.4	≈4.0	
		176.09 *5*	37 *9*	103.656	7/2$^+$	[M1+E2]	≈0.4	≈3.67	
		193.24 *3*	100 *4*	86.481	5/2$^+$	[M1+E2]	≈0.4	≈2.8	
		209.20 *3*	32.5 *21*	70.546	5/2$^-$	[E1]		0.087	
		222.6 *2*	4.6 *23*	57.111	7/2$^-$	[E1]		0.075	
300.489	7/2$^+$	62.59 *10*	17 *6*	237.904	5/2$^+$	[M1+E2]		65 *49*	
		191.43 *3*	52 *4*	109.05	9/2$^+$	[M1+E2]		2.0 *12*	
		196.85 *5*	59 *3*	103.656	7/2$^+$	[M1+E2]	≈0.4	≈2.67	
		214.01 *4*	100 *3*	86.481	5/2$^+$	[M1+E2]	≈0.4	≈2.1	
		229.94 *5*	31 *8*	70.546	5/2$^-$	[E1]		0.0697	
303.62	(9/2$^+$)	139.9[&] *1*	13.9 *12*	163.26	(11/2$^-$)	[E1]		0.225	
		194.67 *20*	100 *24*	109.05	9/2$^+$	[M1+E2]		1.9 *12*	
		199.95 *6*	16.1 *24*	103.656	7/2$^+$	[M1+E2]		1.8 *11*	
306.04	(7/2$^-$)	48.96[&] *10*		257.173	5/2$^-$	[M1+E2]		2.0×10^2 *17*	
		219.8[&]		86.481	5/2$^+$	[E1]		0.0774	
		248.93 *10*		57.111	7/2$^-$	[M1+E2]		0.9 *6*	
323.6	(15/2$^-$)	160.3		163.26	(11/2$^-$)				
330.9	(13/2$^-$)	151.8		179.1	(9/2$^-$)				
365.94	9/2$^+$	153.37 *10*	56 *10*	212.348	5/2$^+$	[E2]		1.96	
		186.86 *35*	28 *28*	179.1	(9/2$^-$)	[E1]		0.113	
		202.9 *2*	44 *18*	163.26	(11/2$^-$)	[E1]		0.093	
		257.09[#] *20*	59 *13*	109.05	9/2$^+$	[M1+E2]		0.9 *6*	
		262.44 *15*	43.1 *18*	103.656	7/2$^+$	[M1+E2]		0.8 *6*	
		279.65 *20*	100 *4*	86.481	5/2$^+$	[E2]		0.222	
447.731	3/2$^-$	190.552 *14*	45.0 *7*	257.173	5/2$^-$	M1(+E2)	<0.5	2.8 *5*	
		210.6 *2*	9.3 *6*	237.904	5/2$^+$	[E1]		0.0855	
		246.0 *3*	2.1 *3*	201.645	3/2$^+$	[E1]		0.0597	
		278.7 *4*	2.5 *3*	169.169	1/2$^+$	[E1]		0.045	
		361.4 *2*	11.4 *3*	86.481	5/2$^+$	[E1]		0.0255	
		377.2 *2*	14.4 *5*	70.546	5/2$^-$	[M1+E2]		0.29 *20*	

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

Adopted Levels, Gammas (continued)

γ(^{233}Pa) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[†]	δ[†]	α[‡]	Comments
447.731	3/2⁻	440.94 *4*	100.0 *12*	6.677	1/2⁻	M1(+E2)	<0.7	0.28 *5*	
		447.762 *20*	54.6 *8*	0.0	3/2⁻	M1(+E2)	<0.6	0.28 *4*	
454.42	3/2⁺	216.7 *2*	15.0 *8*	237.904	5/2⁺	[M1+E2]		1.4 *9*	
		242.3	3.3 *7*	212.348	5/2⁺	[M1+E2]		1.0 *7*	
		252.9 *3*	7.6 *4*	201.645	3/2⁺	[M1+E2]		0.9 *6*	
		285.5 *3*	17.7 *10*	169.169	1/2⁺	M1(+E2)	<0.7	0.92 *14*	
		359.74 *4*	100.0 *13*	94.660	3/2⁺	M1(+E2)	<0.23	0.54 *3*	
		368.0 *3*	4.3 *88*	86.481	5/2⁺	[M1+E2]		0.31 *22*	
		383.5	2.2 *7*	70.546	5/2⁻	[E1]		0.0225	
517.7	(17/2⁻)	186.8		330.9	(13/2⁻)				
528.8	(19/2⁻)	205.2		323.6	(15/2⁻)				
553.883	1/2⁺,3/2⁺	316.1	0.37 *4*	237.904	5/2⁺	[M1,E2]		0.47 *33*	
		459.222 *7*	100.0 *10*	94.660	3/2⁺	M1(+E2)	<0.6	0.26 *4*	
		467.6 *3*	1.46 *4*	86.481	5/2⁺	[M1,E2]		0.16 *11*	
		497.1[&] *4*	1.29 *4*	57.111	7/2⁻				Placement considered uncertain as it involves transition from 1/2⁺,3/2⁺ level to 7/2⁻, 57 level.
		553.7	0.30 *3*	0.0	3/2⁻				
585.48	3/2⁺	347.4 *3*	9.2 *5*	237.904	5/2⁺	[M1+E2]		0.37 *25*	
		490.80 *6*	68.4 *10*	94.660	3/2⁺	M1(+E2)	<0.6	0.21 *3*	
		499.02 *4*	100.0 *11*	86.481	5/2⁺	M1(+E2)	<0.8	0.19 *4*	
		578.7	1.08 *32*	6.677	1/2⁻				
669.88	3/2⁻	412.5 *5*	100 *9*	257.173	5/2⁻	M1+E2	1.0 *3*	0.23 *6*	
		583.2	19 *6*	86.481	5/2⁺				
		663.3 *5*	45 *6*	6.677	1/2⁻	[M1+E2]		0.07 *4*	
		669.885[@] *28*	≈17[@]	0.0	3/2⁻	[M1+E2]		0.06 *4*	
739.3	(21/2⁻)	221.6		517.7	(17/2⁻)				
764.54	1/2⁺,3/2⁺	179.1 *1*	5.53 *10*	585.48	3/2⁺	M1(+E2)	<0.7	3.4 *5*	
		211.3 *2*	4.02 *18*	553.883	1/2⁺,3/2⁺	M1+E2	1.0 *3*	1.5 *4*	
		309.9	0.64 *6*	454.42	3/2⁺	[M1+E2]		0.50 *34*	
		526.5 *2*	9.22 *20*	237.904	5/2⁺	[M1,E2]		0.12 *8*	
		552.2 *2*	3.28 *10*	212.348	5/2⁺	[M1,E2]		0.11 *7*	
		562.6 *2*	10.85 *22*	201.645	3/2⁺	[M1+E2]		0.10 *7*	
		595.2 *2*	23.45 *28*	169.169	1/2⁺	M1(+E2)	<0.9	0.12 *3*	
		669.885[@] *28*	100.0[@] *10*	94.660	3/2⁺	M1(+E2)	<0.5	0.097 *9*	
		678.04 *10*	12.88 *18*	86.481	5/2⁺	[M1,E2]		0.06 *4*	
		757.6 *2*	6.45 *14*	6.677	1/2⁻				
		764.3 *2*	17.73 *22*	0.0	3/2⁻				
776.7	(23/2⁻)	247.9		528.8	(19/2⁻)				
811.61	3/2⁺	226.3 *1*	27.0 *11*	585.48	3/2⁺	M1+E2	0.7 *3*	1.5 *3*	
		257.30[#] *15*		553.883	1/2⁺,3/2⁺	[M1+E2]		0.8 *6*	
		573.6 *3*	52.5 *14*	237.904	5/2⁺	[M1+E2]		0.10 *6*	
		599.3 *2*	46.5 *8*	212.348	5/2⁺	[M1+E2]		0.09 *6*	

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

Adopted Levels, Gammas (continued)

γ(^{233}Pa) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[†]	δ[†]	α[‡]
811.61	3/2$^+$	610.0 *3*	89.6 *18*	201.645	3/2$^+$	[M1+E2]		0.08 *5*
		642.5 *2*	31.9 *8*	169.169	1/2$^+$	[M1+E2]		0.07 *5*
		707.9 *5*	14.4 *8*	103.656	7/2$^+$	[E2]		0.0209
		716.9 *4*	66.5 *13*	94.660	3/2$^+$	[M1+E2]		0.054 *34*
		725.0 *4*	100.0 *14*	86.481	5/2$^+$	M1(+E2)	<0.5	0.078 *7*
		740.9 *2*	37.3 *8*	70.546	5/2$^-$			
		805.2 *2*	33.8 *10*	6.677	1/2$^-$			
		811.4 *7*	9.5 *3*	0.0	3/2$^-$			
941.97	(3/2)	703.6 *5*	24.7 *14*	237.904	5/2$^+$			
		870.7 *7*	8.4 *6*	70.546	5/2$^-$			
		935.5 *3*	100.0 *19*	6.677	1/2$^-$			
		942.2 *5*	13.0 *8*	0.0	3/2$^-$			
968.6	(1/2,3/2)	873.9 *3*	100.0 *25*	94.660	3/2$^+$			
		962.8 *9*	12.5 *17*	6.677	1/2$^-$			
		968.6 *10*	69.2 *25*	0.0	3/2$^-$			
984.78	(3/2)$^+$	398.8 *2*	10.6 *7*	585.48	3/2$^+$	[M1+E2]		0.25 *18*
		431.4 *5*	16.9 *4*	553.883	1/2$^+$,3/2$^+$	M1(+E2)	<0.5	0.31 *3*
		727.8	2.76 *19*	257.173	5/2$^-$			
		783.3 *4*	5.3 *3*	201.645	3/2$^+$	[M1+E2]		0.043 *26*
		816.1 *2*	18.5 *6*	169.169	1/2$^+$	[M1+E2]		0.039 *24*
		880.7 *3*	9.2 *4*	103.656	7/2$^+$	[E2]		0.01345
		890.0 *3*	100.0 *13*	94.660	3/2$^+$	[M1+E2]		0.031 *18*
		898.4 *8*	2.1 *4*	86.481	5/2$^+$	[M1+E2]		0.030 *18*
		978.6 *8*	5.5 *3*	6.677	1/2$^-$			
		985.0 *8*	9.7 *3*	0.0	3/2$^-$			
992.9	(25/2$^-$)	253.6		739.3	(21/2$^-$)			
1018.63	(3/2)	433.2 *4*	95 *3*	585.48	3/2$^+$			
		464.8	21.1 *25*	553.883	1/2$^+$,3/2$^+$			
		806.4 *5*	100 *4*	212.348	5/2$^+$			
		817.0 *6*	77 *4*	201.645	3/2$^+$			
		849.3 *7*	31.7 *25*	169.169	1/2$^+$			
		948.0 *8*	48.8 *25*	70.546	5/2$^-$			
		1011 *1*	15.5 *16*	6.677	1/2$^-$			
1062.9	(27/2$^-$)	286.2		776.7	(23/2$^-$)			
1064.5	(3/2)	960.8 *8*	100 *5*	103.656	7/2$^+$			
		994.3 *10*	14.6 *25*	70.546	5/2$^-$			
		1007 *1*	34 *5*	57.111	7/2$^-$			
1138.94	(1/2,3/2)	1132.1	100 *33*	6.677	1/2$^-$			
		1139.1	67 *17*	0.0	3/2$^-$			
1276.5	(29/2$^-$)	283.6		992.9	(25/2$^-$)			
1384.7	(31/2$^-$)	321.8		1062.9	(27/2$^-$)			
1588.6	(33/2$^-$)	312.1		1276.5	(29/2$^-$)			
1738.4	(35/2$^-$)	353.7		1384.7	(31/2$^-$)			

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

Adopted Levels, Gammas (continued)

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

E_i(level)	J_i^π	E_γ †	E_f	J_f^π	E_i(level)	J_i^π	E_γ †	E_f	J_f^π	E_i(level)	J_i^π	E_γ †	E_f	J_f^π
1928.8	$(37/2^-)$	340.2	1588.6	$(33/2^-)$	2533.0	$(43/2^-)$	411.5	2121.5	$(39/2^-)$	3115.3	$(49/2^-)$	422.6	2692.7	$(45/2^-)$
2121.5	$(39/2^-)$	383.1	1738.4	$(35/2^-)$	2692.7	$(45/2^-)$	395.3	2297.4	$(41/2^-)$	3569.6	$(53/2^-)$	454.3	3115.3	$(49/2^-)$
2297.4	$(41/2^-)$	368.6	1928.8	$(37/2^-)$	2973.0	$(47/2^-)$	440.0	2533.0	$(43/2^-)$	4050.9	(57/2)	481.3&	3569.6	$(53/2^-)$

† From ^{237}Np α decay and ^{233}Th β^- decay. Recommended values represent weighted averages of Eγ and Iγ when γ-ray data for a level are available from both the studies. Exceptions are noted. The gamma-ray data from levels of high spins (J>11/2) are available only from (^{209}Bi,^{208}Pbγ).

‡ 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.

Multiply placed.

@ Multiply placed with intensity suitably divided.

& Placement of transition in the level scheme is uncertain.

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

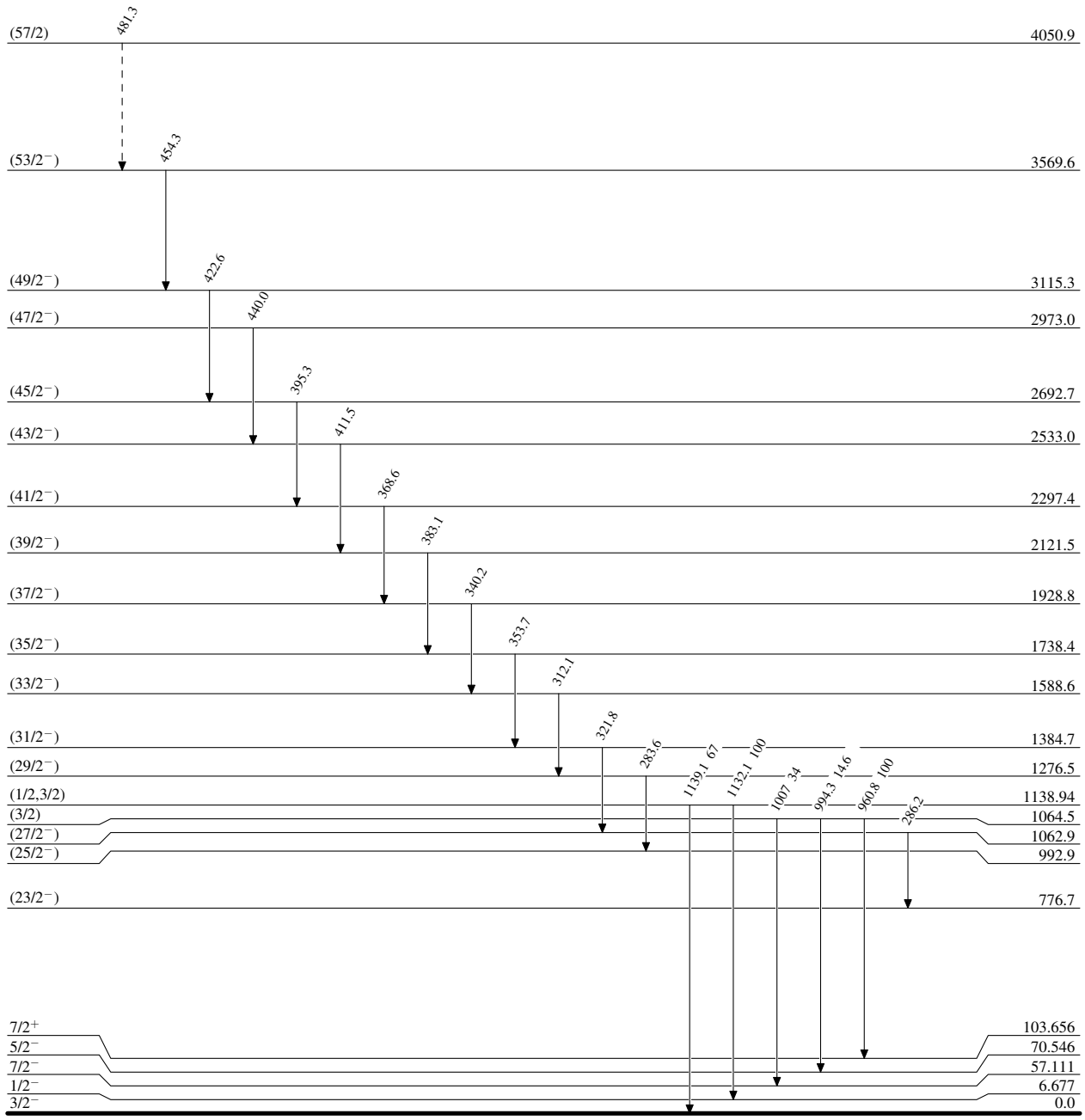
Adopted Levels, Gammas

Legend

Level Scheme

Intensities: Relative photon branching from each level

γ Decay (Uncertain)

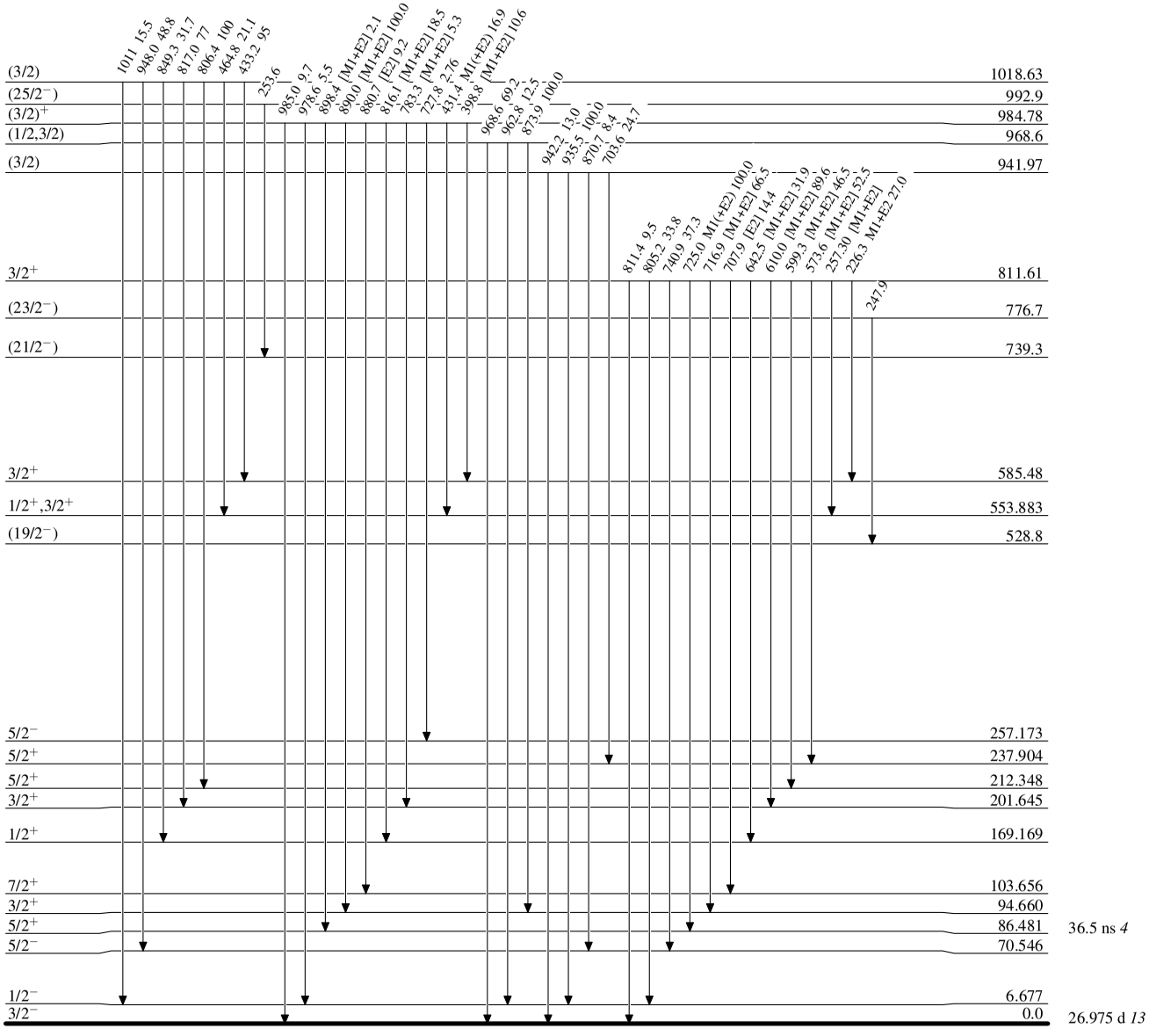


$^{233}_{91}Pa_{142}$

Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level

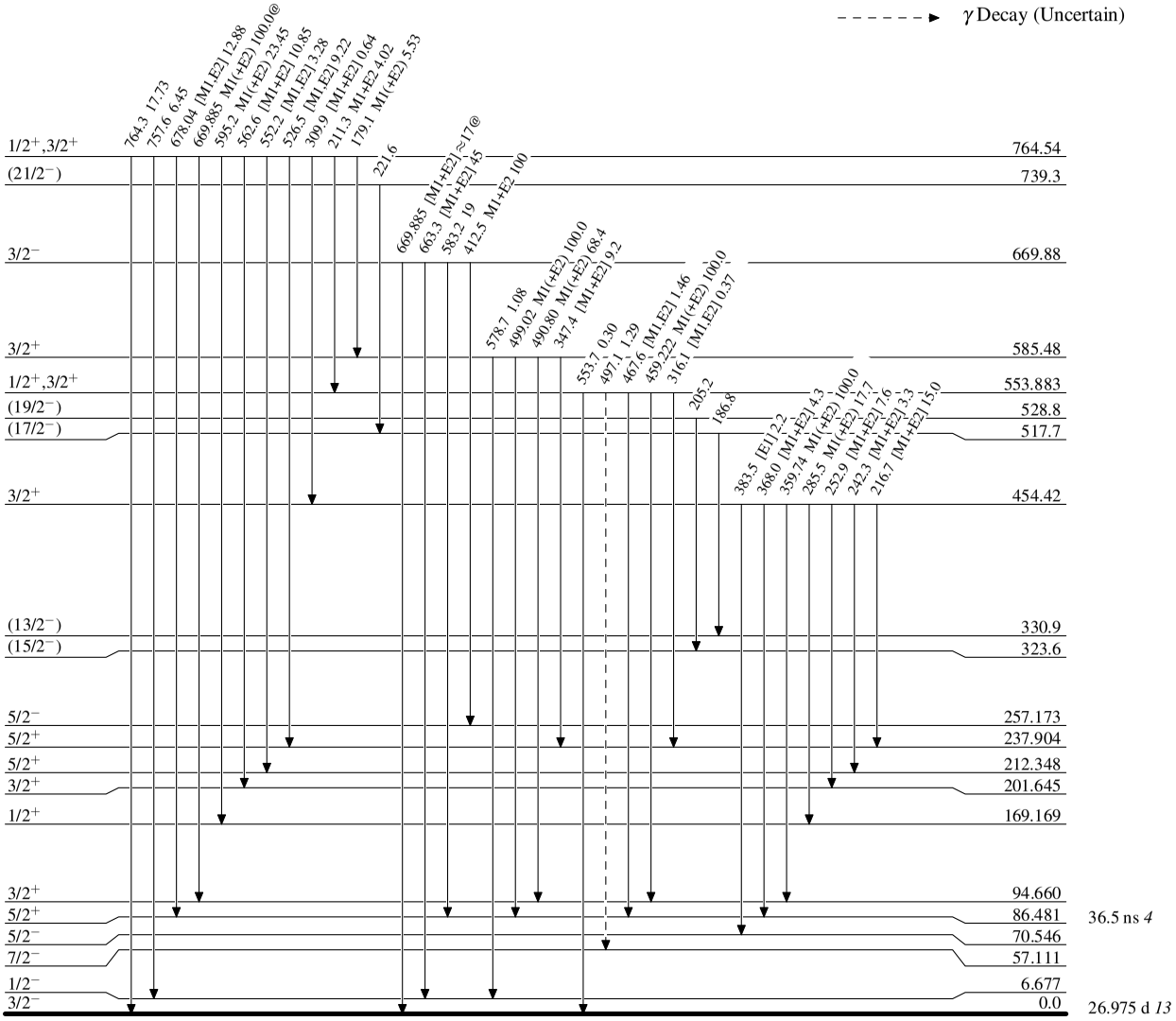


$^{233}_{91}Pa_{142}$

Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level
@ Multiply placed: intensity suitably divided



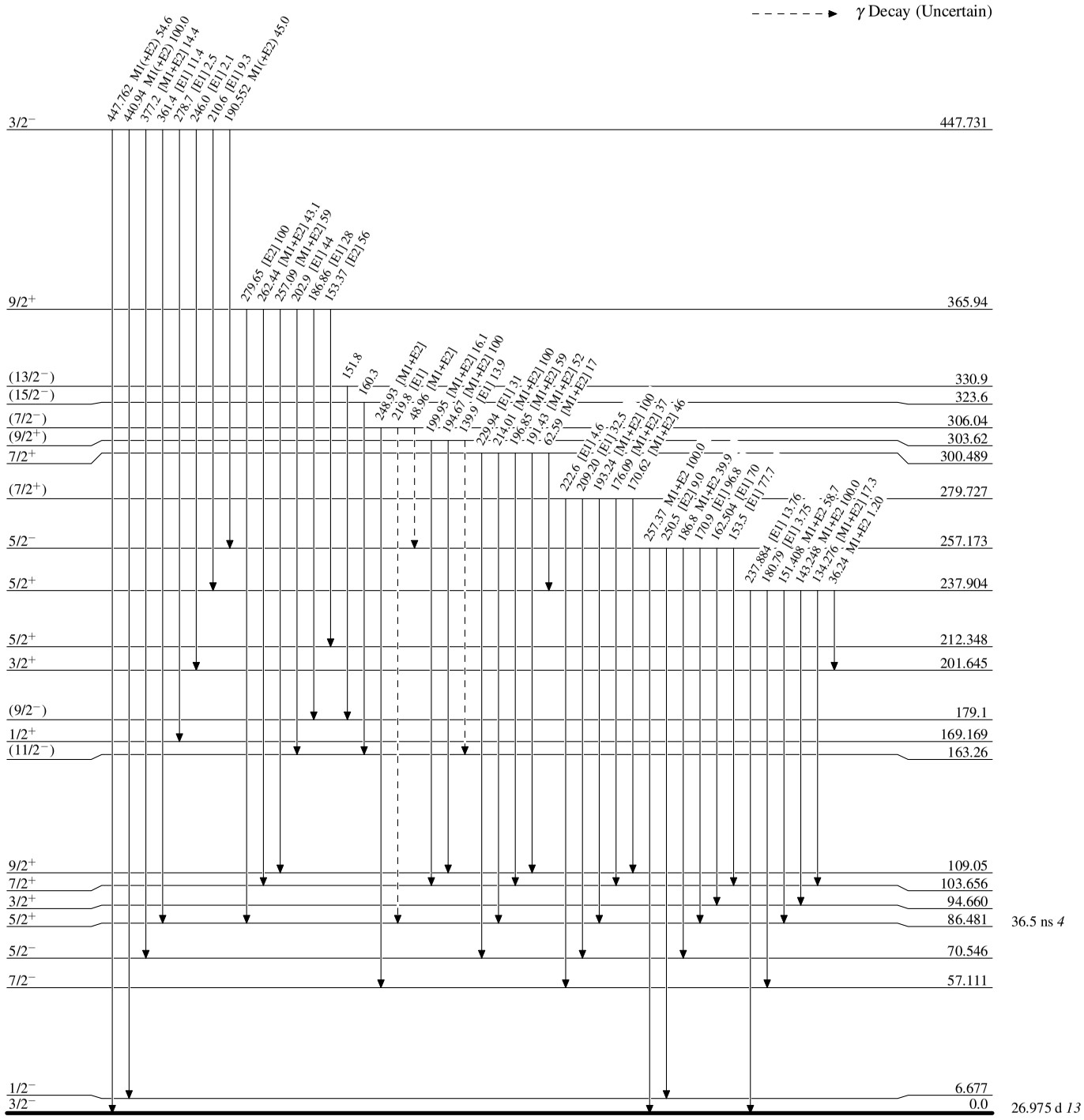
$^{233}_{91}Pa_{142}$

Adopted Levels, Gammas

Legend

Level Scheme (continued)

Intensities: Relative photon branching from each level
@ Multiply placed: intensity suitably divided



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

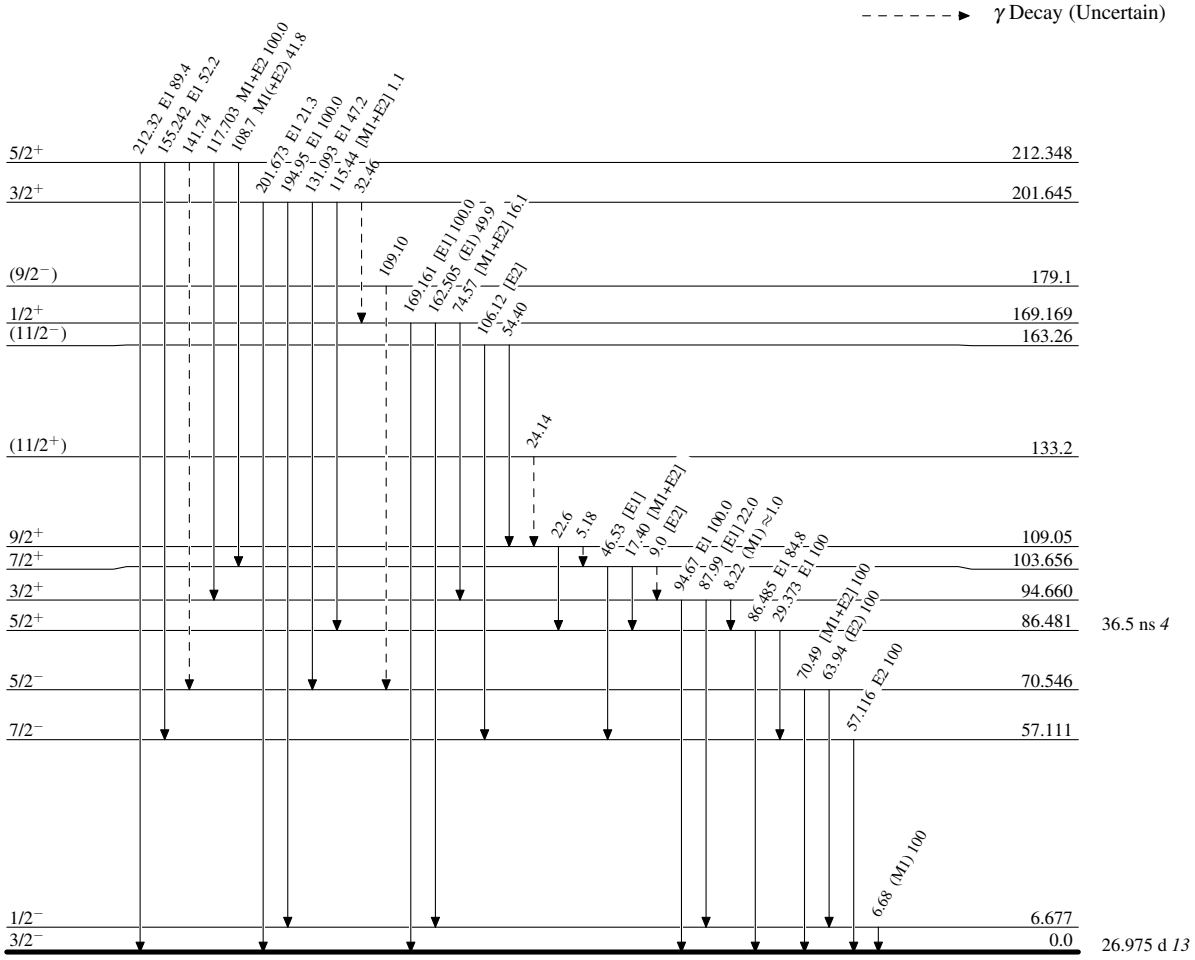
Adopted Levels, Gammas

Legend

Level Scheme (continued)

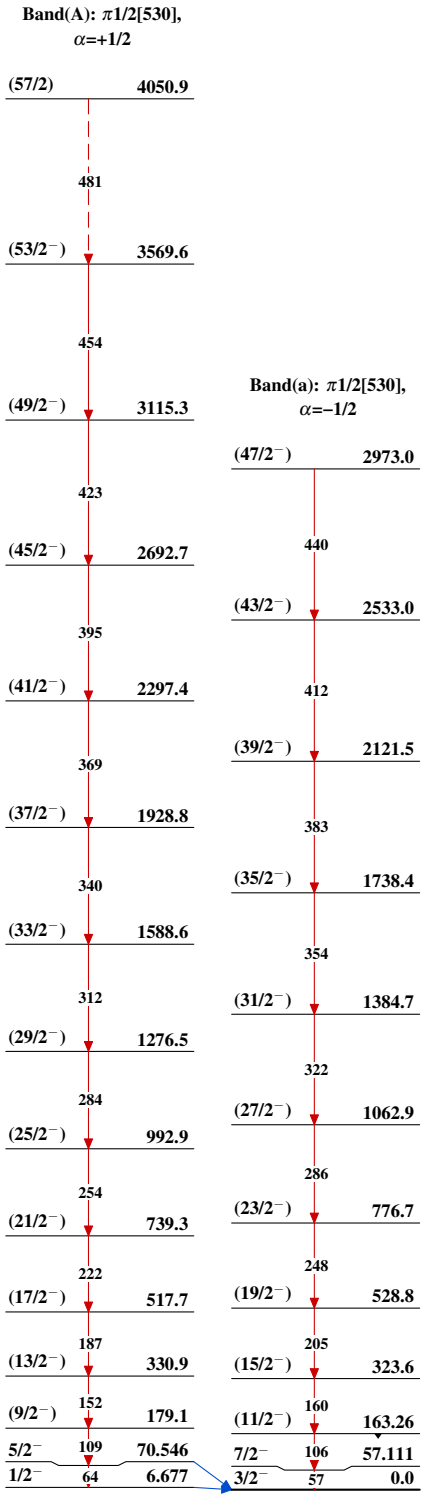
Intensities: Relative photon branching from each level
@ Multiply placed: intensity suitably divided

γ Decay (Uncertain)



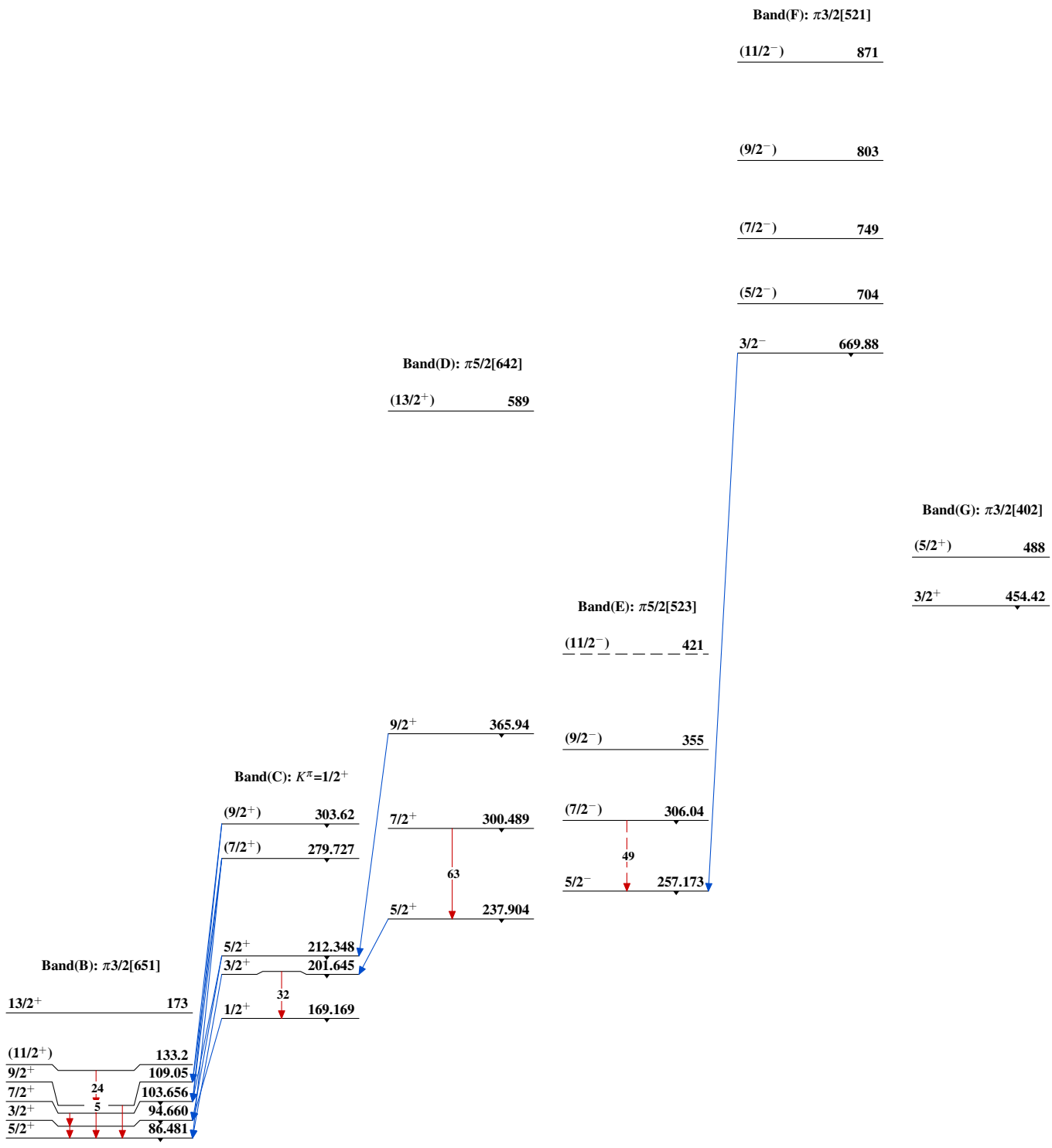
$^{233}_{91}Pa_{142}$

Adopted Levels, Gammas



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

Adopted Levels, Gammas (continued)



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