Coulomb excitation 2003Wu03

History

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

2003Wu03 (also 1999Wu05, 1996Le01, 1992De51): (^{58}Ni,^{58}Ni′γ), E=255, 260, 261 MeV; and (^{32}S,^{32}S′γ),E=148 MeV. Measured Eγ, Iγ, γγ-coin, (particle)γ-coin using 20 Compton-suppressed Ge detectors of the NORDBALL array, a PSD-silicon detector and a 110 PIN-diode particle-detector system in conjunction with a segmented mosaic detector. GOSIA least-squares fitting code was used for the analysis of γ-ray intensities and gamma-ray branching ratios to obtain reduced matrix elements. The authors also reanalyzed their (p,2nγ) data as presented in 1996Le01, and some revisions were proposed in Table 2 of 2003Wu03.

1996Le01 (same group as 2003Wu03): ^{231}Pa(^{32}S,^{32}S′γ),E=148 MeV. Measured Eγ, Iγ, γγ-coin, (particle)γ-coin. Following γ rays were not reported in their later paper 2003Wu03: 209.8 *3*, Iγ=1.1 *3* placed from a 927 level; 255.7 *2* (Iγ=2.0 *3*); 343.2 *4*, Iγ=0.6 *2*; 346.3 *3*, Iγ=1.0 *3*.

1992De51 (same group as 2003Wu03, 1996Le01): (α,α′),E=16,17 MeV; (^{32}S,^{32}S′γ),E=140 MeV. Measured scattered α particles using Q3D magnetic spectrograph for (α,α′), and Eγ, Iγ, γγ-coin, (particle)γ-coin for (^{32}S,^{32}S′γ). A total of 22 γ rays reported from ^{32}S Coulomb excitation, out of which 11 were placed in 1/2[530] band up to 23/2$^-$. From (α,α′), B(E2) values were deduced for the 58.5 and 77.5 levels.

R.M.E.=reduced matrix element from model-independent search from GOSIA least-squares fitting code for π1/2[530], π3/2[651] and mixed π1/2[400]+π1/2[660] bands.

The level scheme is from 2003Wu03, which is considered by the evaluators, as superseding earlier studies from the same group reported in 1996Le01 and 1992De51. Most results in 2003Wu03 are from (^{58}Ni,^{58}Ni′γ) experiment.

B(Eλ) and B(Mλ) values are up values when listed for the levels, and down values when listed for the gammas.

^{231}Pa Levels

Reduced transition probabilities: B(E1), B(M1), B(E2), B(E3), B(E4) are deduced by evaluators from (R.M.E.)^2/(2J+1), where J=initial spin. R.M.E.=Reduced Matrix Element given in Tables 4 and 5 of 2003Wu03. Units: E1 R.M.E. in eb$^{1/2}$, E2 R.M.E. in eb, E3 R.M.E. in eb$^{3/2}$, E4 R.M.E. in eb^2, M1 R.M.E. in μ_N. Correspondingly, units of deduced transition probabilities are: e^{2}b for B(E1), e^{2}b^2 for B(E2), e^{2}b^3 for B(E3), e^{2}b^4 for B(E4), and μ_N^2 for B(M1).

E(level)[†]	Jπ[‡]	$T_{1/2}$	Comments
0.0[#]	3/2$^-$		
8.8[#] *4*	1/2$^-$		E2 R.M.E. (from 3/2$^-$,g.s.)=−2.37 *13*. B(E2)(from 3/2$^-$,g.s.)=1.40 *+16−15*. Sufficient information is lacking for deducing level $T_{1/2}$.
58.53[#] *16*	7/2$^-$	281 ps *17*	E2 R.M.E. (from 3/2$^-$,g.s.)=+3.868 *+107−96*. B(E2)(from 3/2$^-$,g.s.)=3.74 *+21−18*. Other: 4.5 *7* and 5.9 *9* (1992De51). $T_{1/2}$: deduced by evaluators from B(E2) for 58.6γ. This value is in agreement with 274 ps *10* from γ(ce)(t) in ^{231}Th β$^-$ decay (1975Ho14).
77.52[#] *17*	5/2$^-$		E2 R.M.E. (from 1/2$^-$,8.8)=+3.12 *+56−37*. B(E2)(from 1/2$^-$,8.8)=3.2 *+13−7*. E2 R.M.E. (from 3/2$^-$,g.s.)=1.899 *+83−88*. B(E2)(from 3/2$^-$,g.s.)=0.90 *8*. Other: 1.0 *3* (1992De51). Sufficient information is lacking for deducing level $T_{1/2}$, as 77.6γ is a double placement with undivided intensity, and Iγ(68.5γ) is unknown. In Fig. 9 of 1992De51, branching ratio of 87% (apparently I(γ+ce)) for an M1 transition of 19.0 keV to the 7/2$^-$ member of the band at 58.5 keV was calculated using rotational model, Q_0 and (g_K-g_R) parameters.
83.90[@] *22*	5/2$^+$		E1 R.M.E. (from 3/2$^-$,g.s.)=+3.62×10^{-4} *+70−170*. B(E1)(from 3/2$^-$,g.s.)=3.3×10^{-8} *+14−24*. E1 R.M.E. (from 7/2$^-$,58.5)=+2.140×10^{-3} *+160−90*. B(E1)(from 7/2$^-$,58.5)=0.57×10^{-6} *+9−4*. Sufficient information is lacking for deducing level $T_{1/2}$, as the intensity of the 83.8γ is a lower

Continued on next page (footnotes at end of table)

Coulomb excitation 2003Wu03 (continued)

^{231}Pa Levels (continued)

E(level)[†]	Jπ[‡]	$T_{1/2}$	Comments
			limit and that of the 25.4γ is unknown.
101.26[@] *21*	7/2+		
101.8[@] *3*	3/2+		
111.58[@] *19*	9/2+		E3 R.M.E. (from 3/2−,g.s.)=+0.646 *+54−277*. B(E3)(from 3/2−,g.s.)=0.104 *+19−70*. Sufficient information is lacking for deducing level $T_{1/2}$.
168.72[#] *16*	11/2−	154 ps *12*	E2 R.M.E. (from 7/2−,58.5)=+5.51 *+23−21*. B(E2)(from 7/2−,58.5)=3.8 *3*. $T_{1/2}$: deduced by evaluators from B(E2) and γ branching ratio for 110γ.
171.70[@] *19*	11/2+		E3 R.M.E. (from 5/2−,77.5)=+0.73 *+29−30*. B(E3)(from 5/2−,77.5)=0.09 *+8−6*. $T_{1/2}$: sufficient information is lacking for deducing level $T_{1/2}$.
174.0[a] *3*	5/2−		
183.4[b] *4*	5/2+		
189.10[@] *17*	13/2+		
193.02[#] *19*	9/2−	13.6 ps *19*	E2 R.M.E. (from 5/2−,77.5)=+3.885 *+87−96*. B(E2)(from 5/2−,77.5)=2.52 *+11−13*. E2 R.M.E. (from 7/2−,58.5)=+1.43 *+12−15*. B(E2)(from 7/2−,58.5)=0.26 *5*. M1 R.M.E. (from 11/2−,168.7)=−2.53 *+21−30*. B(M1)(from 11/2−,168.7)=0.53 *+14−8*. $T_{1/2}$: deduced by evaluators from B(E2) and branching ratio for 115.5γ.
218.3[a] *3*	7/2−		
247.24[b] *25*	7/2+		
273.7[&] *3*	1/2+		
274.8[a] *3*	9/2−		
300.95[@] *19*	15/2+	82 ps *20*	E2 R.M.E. (from 11/2+,171.7)=+6.10 *+103−42*. B(E2)(from 11/2+,171.7)=3.1 *+11−4*. E3 R.M.E. (from 9/2−,193.0)=+0.86 *+34−29*. B(E3)(from 9/2−,193.0)=0.07 *+7−4*. M1 R.M.E. (from 13/2+,189.1)=+0.419 *+55−80*. B(M1)(from 13/2+,189.1)=0.013 *+3−5*. $T_{1/2}$: deduced by evaluators from B(E2) and γ branching ratio for 129.2γ, assuming pure M1 for 111.8γ.
304.6[b] *4*	(9/2+)		
311.65[&] *25*	5/2+	0.12 ns *+17−6*	E1 R.M.E. (from 3/2−,g.s.)=+1.32×10^{-3} *+54−34*. B(E1)(from 3/2−,g.s.)=0.44×10^{-6} *+42−20*. E1 R.M.E. (from 7/2−,58.5)=−3.01×10^{-3} *+95−85*. B(E1)(from 7/2−,58.5)=1.1×10^{-6} *+8−6*. E3 R.M.E. (from 11/2−,168.7)=−0.87 *+27−17*. B(E3)(from 11/2−,168.7)=0.06 *3*. $T_{1/2}$: deduced by evaluators from B(E1) and γ branching ratio for 253.2γ.
316.80[@] *18*	17/2+	77 ps *+27−18*	E2 R.M.E. (from 13/2+,189.1)=+6.60 *+44−61*. B(E2)(from 13/2+,189.1)=3.1 *+4−5*. M1 R.M.E. (from 15/2+,300.9)=+2.038 *+168−95*. B(M1)(from 15/2+,300.9)=0.26 *+4−2*. $T_{1/2}$: deduced by evaluators from B(E2) and γ branching ratio for 127.7γ.
317.78[&] *25*	3/2+	0.07 ns *+11−3*	E1 R.M.E. (from 1/2−,8.8)=+1.30×10^{-3} *+56−45*. B(E1)(from 1/2−,8.8)=0.9×10^{-6} *+8−5*. E1 R.M.E. (from 3/2−,g.s.)=+1.43×10^{-3} *+40−51*. B(E1)(from 3/2−,g.s.)=0.5×10^{-6} *3*. E3 R.M.E. (from 3/2−,g.s.)=−0.58 *+12−14*.

Continued on next page (footnotes at end of table)

Coulomb excitation 2003Wu03 (continued)

^{231}Pa Levels (continued)

E(level)[†]	Jπ[‡]	$T_{1/2}$	Comments
			B(E3)(from 3/2⁻,g.s.)=0.08 +5−3. $T_{1/2}$: deduced by evaluators from B(E1) and branching ratio for 308.9γ.
319.9[c] 3	3/2⁻		
328.85[#] 17	15/2⁻	74 ps 7	E2 R.M.E. (from 11/2⁻,168.7)=+6.35 +21−24. B(E2)(from 11/2⁻,168.7)=3.36 +23−25. E4 R.M.E. (from 7/2⁻,58.5)=+2.85 +99−84. B(E4)(from 7/2⁻,58.5)=1.0 +8−5. $T_{1/2}$: deduced by evaluators from B(E2) and branching ratio for 160.1γ.
344.5[a] 3	11/2⁻		
351.6[c] 3	5/2⁻		
351.71[#] 19	13/2⁻	10 ps +11−7	E2 R.M.E. (from 9/2⁻,193.0)=+5.885 +224−46. B(E2)(from 9/2⁻,193.0)=3.2 +13−7. E2 R.M.E. (from 11/2⁻,168.7)=+0.85 +18−36. B(E2)(from 11/2⁻,168.7)=0.060 +28−40. M1 R.M.E. (from 15/2⁻,328.9)=−2.96 +21−79. B(M1)(from 15/2⁻,328.9)=0.55 +33−8. $T_{1/2}$: deduced by evaluators from B(E2) and branching ratio for 158.5γ.
391.93[&] 23	9/2⁺	94 ps +58−39	E1 R.M.E. (from 7/2⁻,58.5)=+2.18×10^{-3} +17−24. B(E1)(from 7/2⁻,58.5)=0.59×10^{-6} +10−12. E1 R.M.E. (from 11/2⁻,168.7)=−3.40×10^{-3} +47−36. B(E1)(from 11/2⁻,168.7)=0.96×10^{-6} +22−24. E2 R.M.E. (from 5/2⁺,311.7)=+4.73 +116−31. B(E2)(from 5/2⁺,311.7)=3.7 +21−4. E3 R.M.E. (from 3/2⁻,g.s.)=+0.47 +13−11. B(E3)(from 3/2⁻,g.s.)=0.06 3. E3 R.M.E. (from 15/2⁻,328.9)=−1.06 +21−40. B(E3)(from 15/2⁻,328.9)=0.07 +6−2. $T_{1/2}$: deduced by evaluators from B(E1) and branching ratio for 333.5γ.
395.75[c] 22	7/2⁻		
406.1[b] 3	(11/2⁺)		
408.49[&] 23	7/2⁺	0.05 ns +10−3	E1 R.M.E. (from 5/2⁻,77.5)=+2.58×10^{-3} +42−93. B(E1)(from 5/2⁻,77.5)=1.1×10^{-6} +4−6. E2 R.M.E. (from 3/2⁺,317.8)=+4.02 +93−199. B(E2)(from 3/2⁺,317.8)=4.0 +21−30. E3 R.M.E. (from 3/2⁻,g.s.)=+0.39 +11−16. B(E3)(from 3/2⁻,g.s.)=0.038 25. $T_{1/2}$: deduced by evaluators from B(E1) and branching ratio for 330.9γ.
424.90[a] 22	13/2⁻		
450.54[c] 22	9/2⁻		
487.59[@] 20	19/2⁺	21 ps 4	E2 R.M.E. (from 15/2⁺,300.9)=+7.06 +41−48. B(E2)(from 15/2⁺,300.9)=3.1 4. E3 R.M.E. (from 13/2⁻,351.7)=+0.96 +36−19. B(E3)(from 13/2⁻,351.6)=0.07 +5−3. M1 R.M.E. (from 17/2⁺,316.8)=+0.754 +78−149. B(M1)(from 17/2⁺,316.9)=0.032 +6−12. $T_{1/2}$: deduced by evaluators from B(E2) and branching ratio for 186.6γ.
494.77[@] 18	21/2⁺	31 ps 11	E2 R.M.E. (from 17/2⁺,316.8)=+7.49 +69−47. B(E2)(from 17/2⁺,316.9)=3.1 +6−4. M1 R.M.E. (from 19/2⁺,487.6)=+4.01 +15−16. B(M1)(from 19/2⁺,487.6)=0.80 +7−6. $T_{1/2}$: deduced by evaluators from B(E2) and branching ratio for 177.96γ.
520.5[a] 3	(15/2⁻)		
525.14[&] 23	13/2⁺	54 ps +33−25	E1 R.M.E. (from 11/2⁻,168.7)=+2.57×10^{-3} +35−28.

Continued on next page (footnotes at end of table)

Coulomb excitation 2003Wu03 (continued)

^{231}Pa Levels (continued)

E(level)[†]	J^{π}[‡]	$T_{1/2}$	Comments
			B(E1)(from 11/2⁻,168.7)=0.55×10^{-6} *+16−11*. E2 R.M.E. (from 9/2⁺,391.9)=+5.88 *+133−67*. B(E2)(from 9/2⁺,391.9)=3.5 *+17−7*. $T_{1/2}$: deduced by evaluators from B(E1) and branching ratio for 356.2γ.
535.73[#] *17*	19/2⁻	30.4 ps *21*	E2 R.M.E. (from 15/2⁻,328.9)=+7.20 *+21−19*. B(E2)(from 15/2⁻,328.9)=3.24 *+19−17*. E4 R.M.E. (from 11/2⁻,168.7)=+3.3 *+13−11*. B(E4)(from 11/2⁻,168.7)=0.9 *+9−5*. $T_{1/2}$: deduced by evaluators from B(E2) and branching ratio for 206.88γ.
542.7[&] *4*	11/2⁺	43 ps *+78−24*	E1 R.M.E. (from 9/2⁻,193.0)=+3.44×10^{-3} *+61−107*. B(E1)(from 9/2⁻,193.0)=1.2×10^{-6} *+4−6*. E2 R.M.E. (from 7/2⁺,408.5)=+5.3 *+12−14*. B(E2)(from 7/2⁺,408.5)=3.5 *+18−16*. E3 R.M.E. (from 5/2⁻,77.5)=+0.87 *+18−19*. B(E3)(from 5/2⁻,77.5)=0.13 *5*. $T_{1/2}$: deduced by evaluators from B(E1) and branching ratio for 349.7γ.
551.51[#] *19*	17/2⁻	23.4 ps *15*	E2 R.M.E. (from 13/2⁻,351.7)=+7.05 *+15−14*. B(E2)(from 13/2⁻,351.6)=3.55 *+15−14*. E2 R.M.E. (from 15/2⁻,328.9)=+0.84 *+18−26*. B(E2)(from 15/2⁻,328.9)=0.044 *+21−23*. M1 R.M.E. (from 19/2⁻,535.7)=−3.333 *+127−74*. B(M1)(from 19/2⁻,535.8)=0.56 *+2−5*. $T_{1/2}$: deduced by evaluators from B(E2) and branching ratio for 199.8γ.
604.0[d] *3*	(3/2⁻)		
631.9[d] *3*	(5/2⁻)		
677.8[d] *4*	(7/2⁻)		
705.2[&] *3*	17/2⁺	34 ps *14*	E1 R.M.E. (from 15/2⁻,328.9)=+3.90×10^{-3} *+86−32*. B(E1)(from 15/2⁻,328.9)=0.95×10^{-6} *+31−15*. E2 R.M.E. (from 13/2⁺,525.1)=+6.8 *+17−16*. B(E2)(from 13/2⁺,525.1)=3.3 *+19−14*. $T_{1/2}$: deduced by evaluators from B(E1) and branching ratio for 376.4γ.
717.1[&] *3*	15/2⁺	37 ps *13*	E1 R.M.E. (from 13/2⁻,351.7)=+3.21×10^{-3} *+36−39*. B(E1)(from 13/2⁻,351.7)=0.74×10^{-6} *17*. E2 R.M.E. (from 11/2⁺,542.7)=+6.37 *+190−60*. B(E2)(from 11/2⁺,542.7)=3.4 *+23−6*. E3 R.M.E. (from 9/2⁻,193.0)=+1.06 *+47−23*. B(E3)(from 9/2⁻,193.0)=0.11 *+12−4*. $T_{1/2}$: deduced by evaluators from B(E1) and branching ratio for 365.4γ.
721.38[@] *20*	25/2⁺	30 ps *+30−6*	E2 R.M.E. (from 21/2⁺,494.8)=+8.26 *+86−287*. B(E2)(from 21/2⁺,494.8)=2.6 *+6−13*. $T_{1/2}$: deduced by evaluators from B(E2) for 226.6γ.
728.4[@] *3*	23/2⁺	6.9 ps *15*	$T_{1/2}$: deduced by evaluators from B(E2) and branching ratio for 240.9γ. E2 R.M.E. (from 19/2⁺,487.6)=+7.89 *+69−98*. B(E2)(from 19/2⁺,487.6)=3.1 *+6−7*. E3 R.M.E. (from 17/2⁻,551.5)=+1.06 *+26−23*. B(E3)(from 17/2⁻,551.5)=0.06 *+4−2*.
734.0[d] *4*	(9/2⁻)		
785.56[#] *19*	23/2⁻	13.5 ps *8*	$T_{1/2}$: deduced by evaluators from B(E2) and branching ratio for 249.8γ. E2 R.M.E. (from 19/2⁻,535.7)=+8.12 *+23−25*. B(E2)(from 19/2⁻,535.7)=3.30 *+19−20*. E4 R.M.E. (from 15/2⁻,328.9)=+3.8 *+12−15*. B(E4)(from 15/2⁻,328.9)=0.9 *+7−6*.
788.06[#] *20*	21/2⁻	19.3 ps *16*	$T_{1/2}$: deduced by evaluators from B(E2) and branching ratio for 236.58γ.

Continued on next page (footnotes at end of table)

Coulomb excitation 2003Wu03 (continued)

^{231}Pa Levels (continued)

E(level)†	Jπ‡	$T_{1/2}$	Comments
			E2 R.M.E. (from 17/2$^-$,551.5)=+7.58 *+28−29*. B(E2)(from 17/2$^-$,551.5)=3.19 *24*. In Fig. 9 of 1992De51, branching ratio of 12% (apparently I(γ+ce)) for an M1 transition of 2.5 keV to the 19/2$^-$ member of the band at 785.56 keV was calculated using rotational model, Q_0 and (g_K-g_R) parameters.
930.2& *5*	21/2$^+$		
946.0& *5*	19/2$^+$		E1 R.M.E. (from 17/2$^-$,551.5)=+4.61×10^{-3} *+47−66*. B(E1)(from 17/2$^-$,551.5)=1.18×10^{-6} *+25−31*. E2 R.M.E. (from 15/2$^+$,717.1)=+7.24 *+173−72*. B(E2)(from 15/2$^+$,717.1)=3.3 *+17−6*. Sufficient information is lacking for deducing level $T_{1/2}$ as the 394.5γ is a double placement with undivided intensity and Iγ(228.9γ) is unknown.
993.8@ *3*	29/2$^+$		
1019.2@ *4*	27/2$^+$	6 ps *+11−4*	$T_{1/2}$: deduced by evaluators from B(M1) and γ-branching for 298.0γ.
1057.11# *21*	25/2$^-$	10.2 ps *18*	E2 R.M.E. (from 21/2$^-$,788.1)=+8.38 *+60−35*. B(E2)(from 21/2$^-$,788.1)=3.2 *+5−3*. $T_{1/2}$: deduced by evaluators from B(E2) and γ-branching for 269.1γ.
1074.29# *23*	27/2$^-$	6.2 ps *+13−9*	E2 R.M.E. (from 23/2$^-$,785.6)=+8.73 *+35−50*. B(E2)(from 23/2$^-$,785.6)=3.18 *+26−36*. M1 R.M.E. (from 25/2$^-$,1057.1)=+3.75 *+184−31*. B(M1)(from 25/2$^-$,1057.1)=0.54 *+66−8*. $T_{1/2}$: deduced by evaluators from B(E2) and γ-branching for 288.7γ.
1196.2& *4*	23/2$^+$		
1307.8@ *4*	33/2$^+$		
1355.5# *4*	29/2$^-$	6.8 ps *+7−17*	E2 R.M.E. (from 25/2$^-$,1057.1)=+9.06 *+51−169*. B(E2)(from 25/2$^-$,1057.1)=3.2 *+3−11*. M1 R.M.E. (from 27/2$^-$,1074.3)=+0.54 *+22−11*. B(M1)(from 27/2$^-$,1074.3)=0.010 *+11−3*. $T_{1/2}$: deduced by evaluators from B(E2) and γ-branching for 298.6γ.
1357.5@ *5*	31/2$^+$		
1398.1# *3*	31/2$^-$	3.1 ps *+11−6*	E2 R.M.E. (from 27/2$^-$,1074.3)=+9.38 *+38−80*. B(E2)(from 27/2$^-$,1074.3)=3.1 *+3−5*. M1 R.M.E. (from 29/2$^-$,1355.5)=+4.02 *+40−125*. B(M1)(from 29/2$^-$,1355.5)=0.54 *+11−28*. $T_{1/2}$: deduced by evaluators from B(E2) and γ-branching for 323.8γ.
1660.4@ *6*	37/2$^+$		
1683.2# *5*	33/2$^-$		
1754.1# *4*	35/2$^-$	1.2 ps *+19−7*	$T_{1/2}$: deduced by evaluators from B(E1)↓=9×10^{-6} *4* and γ-branching for 446.9γ. E2 R.M.E. (from 31/2$^-$,1398.1)=+0.10 *+39−41*. B(E2)(from 31/2$^-$,1398.1)=0.0003 *+72−3* or 0.0003 *+27−3*, first for +0.39 uncertainty, second for −0.41 uncertainty in R.M.E.
2040.4# *10*	37/2$^-$		
2139.3# *5*	39/2$^-$	1.2 ps *+32−8*	$T_{1/2}$: deduced by evaluators from B(E1)↓=1.6×10^{-5} *+13−10* and γ-branching for 479.0γ.

† From least-squares fit to Eγ data.
‡ As given in Figs. 4 and 7 of 2003Wu03, based on band structures and Nilsson assignments.
# Band(A): π1/2[530].
@ Band(B): π3/2[651].
& Band(C): π1/2[400]+π1/2[660].

Continued on next page (footnotes at end of table)

Coulomb excitation 2003Wu03 (continued)

^{231}Pa Levels (continued)

[a] Band(D): π5/2[512].
[b] Band(E): π5/2[642].
[c] Band(F): π3/2[532].
[d] Band(G): π3/2[521].

$\gamma(^{231}Pa)$

Transition probabilities in Weisskopf units are deduced by evaluators from: B(E1)(W.u.)=41.2(B(E1)↓); B(E2)(W.u.)=118.8(B(E2)↓); B(E3)(W.u.)=315.4(B(E3)↓); B(E4)(W.u.)=792.0(B(E4)↓); B(M1)(W.u.)=0.558(B(M1)↓) for A=231; where B(Eλ)↓=B(Eλ)↑($2J_i$+1)/($2J_f$+1).

E_γ[†]	I_γ	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α[b]	Comments
(7.2[@])	0.014 *4*	494.77	21/2+	487.59	19/2+	[M1]	2.4×10^3 *6*	B(M1)(W.u.)=0.406 *+36−31*. Iγ=0.014 *+4−3* deduced from B(M1)(W.u.)(7.2γ)/B(E2)(W.u.)(177.96γ) and Iγ(177.96γ).
(8.8)		8.8	1/2−	0.0	3/2−	[M1+E2]		B(E2)(W.u.)=333 *+38−36*. Mult.: from experimental B(E2), the transition is expected to be M1+E2, probably dominant M1. α(theory)=1.34×10^3 for M1, 4.67×10^5 for E2 for Eγ=8.8 *4*.
(15.8[@])	0.28 *2*	551.51	17/2−	535.73	19/2−	[M1]	235 *24*	B(M1)(W.u.)=0.347 *+12−31*. I_γ: 0.28 *2* deduced by evaluators from B(M1)(W.u.)(15.8γ)/B(E2)(W.u.)(199.8γ) and Iγ. In Fig. 9 of 1992De51, branching ratio of 51% (apparently I(γ+ce)) for an M1 transition of 15.8 keV to the 19/2− member of the band at 535.7 keV was calculated using rotational model, Q_0 and (g_K-g_R) parameters.
(15.9[@])	0.17 *3*	316.80	17/2+	300.95	15/2+	[M1]	230 *50*	B(M1)(W.u.)=0.129 *+20−10*. Iγ=0.17 *3* deduced from B(M1)(W.u.)(15.9γ)/B(E2)(W.u.)(127.7γ).
(17.2[@])	0.031 *16*	1074.29	27/2−	1057.11	25/2−	[M1]	183 *17*	B(M1)(W.u.)=0.28 *+34−4*. I_γ: 0.019 *+28−4* deduced by evaluators from B(E2)(W.u.)(288.7γ)/B(M1)(W.u.)(17.2γ).
(22.8[@])	0.7 *5*	351.71	13/2−	328.85	15/2−	[M1]	320 *22*	B(M1)(W.u.)=0.35 *+21−5*. In Fig. 9 of 1992De51, branching ratio of 90% (probably I(γ+ce)) for an M1 transition of 22.8 keV to the 15/2− member of the band at 328.9 keV was theoretically calculated using rotational model, Q_0 and (g_K-g_R) parameters. Iγ=0.49 *+68−23* deduced from B(E4)(W.u.)(270.4γ)/B(E2)(W.u.)(160.13γ) and Iγ(160.13).
(24.3[@])	0.70 *14*	193.02	9/2−	168.72	11/2−	[M1]	270 *40*	B(M1)(W.u.)=0.35 *+9−5*. Deduced Iγ=0.67 *+17−10* from B(M1)(W.u.) for 24.3γ and B(E2)(W.u.) and Iγ for 115.5γ. In Fig. 9 of 1992De51, branching ratio of 94% (apparently I(γ+ce)) for an M1 transition of 24.3 keV to the 11/2− member of the band at 168.7 keV was calculated using rotational model, Q_0 and (g_K-g_R) parameters.
(25.4[@])		83.90	5/2+	58.53	7/2−	[E1]	4.5 *5*	B(E1)(W.u.)=31×10^{-6} *+5−2*.
(42.6[@])	0.038 *21*	1398.1	31/2−	1355.5	29/2−	[M1]	50.7 *20*	B(M1)(W.u.)=0.28 *+6−15*. I_γ: 0.040 *+15−23* deduced by evaluators from B(E2)(W.u.)(323.8γ)/B(M1)(W.u.)(42.6γ).
42.7 *8*	0.7 *4*	101.26	7/2+	58.53	7/2−	[E1]	1.15 *6*	

$^{231}_{91}Pa_{140}$-7

Coulomb excitation 2003Wu03 (continued)

γ(^{231}Pa) (continued)

E_γ[†]	I_γ	E_i(level)	J^π_i	E_f	J^π_f	Mult.	α[b]	Comments
(48.2[@])	3.2 16	535.73	19/2⁻	487.59	19/2⁺	[E1]	0.83 5	E1 R.M.E.=−0.0128 +32−50. B(E1)=8×10^{-6} +8−3. B(E1)(W.u.)=3.3×10^{-4} +33−12. Iγ=2.4 +24−9 deduced from B(E1)(W.u.)(48.2γ)/B(E2)(W.u.)(206.9γ) and Iγ(206.9γ).
53.2 8	0.7 3	111.58	9/2⁺	58.53	7/2⁻	[E1]	0.64 3	
57.2 2	7.8 7	168.72	11/2⁻	111.58	9/2⁺	[E1]	0.529 9	E1 R.M.E. (from branching ratios)=5.3×10^{-3} 3. B(E1)=2.34×10^{-6} +27−16. B(E1)(W.u.)=9.6×10^{-5} +11−7. E1 R.M.E.=+4.01×10^{-3} +48−32. B(E1)=1.34×10^{-6} +34−21. B(E1)(W.u.)=5.5×10^{-5} +14−9.
(57.2[@])	0.091 23	785.56	23/2⁻	728.4	23/2⁺	[E1]	0.53 3	I_γ: 0.091 23 deduced by evaluators from B(E2)(W.u.)(249.8γ)/B(E1)(W.u.)(57.2γ). α: assuming 1.0 keV uncertainty in Eγ. E1 R.M.E.=−0.0155 +22−14. B(E1)=1.0×10^{-5} +2−3. B(E1)(W.u.)=4.1×10^{-5} +8−12.
58.6 2	7.7 6	58.53	7/2⁻	0.0	3/2⁻	[E2]	155 4	B(E2)(W.u.)=222 +13−11. Eγ=58.6 2, Iγ=4.9 9 (1996Le01).
60.3 3	2.8 6	171.70	11/2⁺	111.58	9/2⁺	[M1]	18.3 4	M1 R.M.E. (from branching ratios)=0.32 6. B(M1)=0.0085 +35−29. B(M1)(W.u.)=0.0047 +19−16.
[x]60.5 3	1.3 6							
(63.0[@a])		391.93	9/2⁺	328.85	15/2⁻	[E3]	4.4×10^3 2	B(E3)(W.u.)=35 +30−10. Iγ=0.4×10^{-9} +6−2 deduced from B(E3)(W.u.)(63.0γ)/B(E1)(W.u.)(333.5γ) and Iγ(333.5).
68.5		77.52	5/2⁻	8.8	1/2⁻	[E2]	73.3 10	B(E2)(W.u.)=127 +52−28. E_γ: from Fig. 4; not listed in Tables 1 and 2. Eγ=68.5 6, Iγ<0.5 (1996Le01).
70.4 3	0.7 2	171.70	11/2⁺	101.26	7/2⁺	[E2]	64.3 16	
72.8 2	1.2 3	174.0	5/2⁻	101.26	7/2⁺	[E1]	0.279 5	Eγ=72.8 2, Iγ=1.3 2 (1996Le01).
77.6[d] 2	2.1[d] 2	77.52	5/2⁻	0.0	3/2⁻	[M1+E2]	25 16	B(E2)(W.u.)=71 6. Eγ=78.3 2, Iγ=1.3 2 (1996Le01).
77.6[d] 2	2.1[d] 2	189.10	13/2⁺	111.58	9/2⁺	[E2]	40.5 8	
(80.2[@])	0.2 1	391.93	9/2⁺	311.65	5/2⁺	[E2]	34.6 12	B(E2)(W.u.)=264 +150−29. Iγ=0.15 +15−4 deduced from B(E2)(W.u.)(80.2γ)/B(E1)(W.u.)(333.5γ) and Iγ(333.5).
81.2[#]	1.7[#] 3	183.4	5/2⁺	101.8	3/2⁺	[M1]	7.67 11	Eγ=81.2 2, Iγ=2.9 4 (1996Le01).
81.6 4	1.4 5	193.02	9/2⁻	111.58	9/2⁺	[E1]	0.207 4	E1 R.M.E. (from branching ratios)=2.3×10^{-3} 4. B(E1)=0.53×10^{-6} +20−17. B(E1)(W.u.)=2.2×10^{-5} +8−7.
82.1[#]	1.7[#] 3	183.4	5/2⁺	101.26	7/2⁺	[M1]	7.43 11	
83.8 4	>2.0	83.90	5/2⁺	0.0	3/2⁻	[E1]	2.17 21	B(E1)(W.u.)=9.1×10^{-7} +39−66. E_γ: contaminated with Eγ=83.780 from background line. I_γ: >1.5 5 in Table 1 of 2003Wu03. α: experimental value of anomalous conversion coefficient (1975Ho14). Eγ=83.9 2, Iγ=5.1 6 (1996Le01).

From ENSDF

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

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

E_γ[†]	I_γ	E_i(level)	J^π_i	E_f	J^π_f	Mult.	δ	α[b]	Comments
89.9 *3*	5.1 *6*	174.0	5/2−	83.90	5/2+	[E1]		0.160 *3*	Eγ=90.0 *1*, Iγ=4.9 *6* (1996Le01).
(90.7[@])	0.15 *14*	408.49	7/2+	317.78	3/2+	[E2]		19.4 *6*	B(E2)(W.u.)=238 *+125−179*. Iγ=0.07 *+22−6* deduced from B(E2)(W.u.)(90.7γ)/B(E1)(W.u.)(330.9γ) and Iγ(330.9γ).
91.4[f] *6*	4 *3*	193.02	9/2−	101.26	7/2+	[E1]		0.153 *4*	
(94.2[@a])		171.70	11/2+	77.52	5/2−	[E3]		450 *30*	B(E3)(W.u.)=14 *+12−9*.
100.4 *8*	0.2 *1*	274.8	9/2−	174.0	5/2−	[E2]		12.0 *5*	
106.6 *6*	6 *2*	218.3	7/2−	111.58	9/2+	[E1]		0.1023 *21*	
(108.0[@a])		300.95	15/2+	193.02	9/2−	[E3]		208 *12*	B(E3)(W.u.)=14 *+14−8*. Deduced Iγ=3.4×10^{-8} *+44−23* from B(E3)(W.u.) for 108.0γ and B(E2)(W.u.) and Iγ for 129.2γ.
110.20 *5*	100 *5*	168.72	11/2−	58.53	7/2−	[E2]		7.80 *11*	B(E2)(W.u.)=301 *24*. Eγ=110.2 *1*, Iγ=100 (1996Le01).
(111.6[@a])		111.58	9/2+	0.0	3/2−	[E3]		174 *10*	B(E3)(W.u.)=13 *+2−9*.
111.8 *2*	6.5 *6*	300.95	15/2+	189.10	13/2+	[M1]		3.04 *4*	M1 R.M.E. (from branching ratios)=1.00 *8*. B(M1)=0.063 *10*. B(M1)(W.u.)=0.035 *6*. B(M1)(W.u.)=0.0063 *+15−24*. This value is low by a factor of ≈6 compared to the transition probability from branching ratios.
115.5 *3*	1.6 *2*	193.02	9/2−	77.52	5/2−	[E2]		6.49 *12*	B(E2)(W.u.)=180 *+8−9*. Eγ=115.5 *2*, Iγ=2.8 *3* (1996Le01).
116.8 *8*	0.8 *4*	218.3	7/2−	101.26	7/2+	[E1]		0.342 *7*	
(121.1 *8*)		304.6	(9/2+)	183.4	5/2+				
126.3 *5*	0.4 *2*	344.5	11/2−	218.3	7/2−	[E2]		4.41 *10*	
127.7 *1*	10.2 *8*	316.80	17/2+	189.10	13/2+	[E2]		4.21 *6*	B(E2)(W.u.)=286 *+37−46*. Eγ=128.2 *2*, Iγ=4.5 *6* (1996Le01), placed from 536 level.
129.2 *1*	8.0 *7*	300.95	15/2+	171.70	11/2+	[E2]		4.00 *6*	B(E2)(W.u.)=276 *+98−36*.
(133.2[@])	1.4 *7*	525.14	13/2+	391.93	9/2+	[E2]		3.52 *8*	B(E2)(W.u.)=297 *+144−60*. Iγ=1.1 *+10−4* deduced from B(E2)(W.u.)(133.2γ)/B(E1)(W.u.)(356.2γ) and Iγ(356.2γ).
(134.2[@])	0.7 *5*	542.7	11/2+	408.49	7/2+	[E2]		3.41 *8*	B(E2)(W.u.)=277 *+143−127*. Iγ=0.42 *+88−25* deduced from B(E2)(W.u.)(134.2γ)/B(E1)(W.u.)(349.7γ) and Iγ(349.7γ).
134.4[d] *2*	1.2[d] *3*	193.02	9/2−	58.53	7/2−	(E2+M1)	4.0 *9*	3.70 *20*	M1 R.M.E. (from branching ratios)=0.040 *8*. B(M1)=1.6×10^{-4} *+7−6*. B(E2)(W.u.)=25 *5*. B(M1)(W.u.)=0.9×10^{-4} *+4−3*. δ: deduced by evaluators from E2 and M1 matrix elements. Eγ=134.3 *2*, Iγ=1.6 *2* (1996Le01), placed from 218 level only.
134.4[d] *2*	[d&]	218.3	7/2−	83.90	5/2+				
(135.7 *5*)		247.24	7/2+	111.58	9/2+				
(135.9[@a])		487.59	19/2+	351.71	13/2−	[E3]		58.8 *15*	B(E3)(W.u.)=15 *+11−6*. Iγ=2.4×10^{-8} *+24−11* deduced from B(E3)(W.u.)(135.9γ)/B(E2)(W.u.)(186.6γ) and Iγ(186.6γ).

Coulomb excitation 2003Wu03 (continued)

γ(^{231}Pa) (continued)

E_γ[†]	I_γ	E_i(level)	J^π_i	E_f	J^π_f	Mult.	δ	α[b]	Comments
(136.4 *3*)		319.9	3/2$^-$	183.4	5/2$^+$				γ from (p,2nγ).
[x]139.5 *5*	0.5 *3*								
139.75 *5*	48.2 *11*	328.85	15/2$^-$	189.10	13/2$^+$	[E1]		0.225 *3*	E1 R.M.E.=+4.955×10^{-3} *+110−40*. B(E1)=1.54×10^{-6} *+7−3*. B(E1)(W.u.)=6.3×10^{-5} *+3−1*. E1 R.M.E. (from branching ratios)=6.3×10^{-3} *4*. B(E1)=2.48×10^{-6} *+33−30*. B(E1)(W.u.)=10.2×10^{-5} *+14−3*. Eγ=139.8 *1*, Iγ=36.3 *15* (1996Le01).
(143.0[@a])		311.65	5/2$^+$	168.72	11/2$^-$	[E3]		45 *2*	B(E3)(W.u.)=38 *19*. Iγ=7×10^{-8} *+17−5* deduced from B(E3)(W.u.)(143γ)/B(E1)(W.u.)(253.2γ) and Iγ(253.2).
145.9 *2*	&	247.24	7/2$^+$	101.26	7/2$^+$				
[x]155.5 *3*	1.5 *3*								
158.5 *3*	10.5 *15*	351.71	13/2$^-$	193.02	9/2$^-$	[E2]		1.72 *3*	B(E2)(W.u.)=272 *+111−60*. Eγ=158.5 *3*, Iγ=17 *5* (1996Le01).
158.8 *5*	0.3 *2*	406.1	(11/2$^+$)	247.24	7/2$^+$	[E2]		1.71 *4*	
160.13 *5*	268 *15*	328.85	15/2$^-$	168.72	11/2$^-$	[E2]		1.650 *23*	B(E2)(W.u.)=299 *+21−22*. Eγ=160.1 *1*, Iγ=212 *9* (1996Le01).
162.4 *5*	1.0 *5*	351.71	13/2$^-$	189.10	13/2$^+$	[E1]		0.1577 *25*	E1 R.M.E. (from branching ratios)=3.3×10^{-3} *8*. B(E1)=0.8×10^{-6} *4*. B(E1)(W.u.)=3.3×10^{-5} *17*.
163.5[d] *3*	1.2[d] *3*	247.24	7/2$^+$	83.90	5/2$^+$	[M1]		5.02 *7*	Eγ=163.5 *6*, Iγ=0.5 *2* (1996Le01), placed from 247 level only.
163.5[d] *3*	1.2[d] *3*	274.8	9/2$^-$	111.58	9/2$^+$	[E1]		0.1552 *22*	
171.0 *2*	3.9 *3*	487.59	19/2$^+$	316.80	17/2$^+$	[M1]		4.42 *6*	M1 R.M.E. (from branching ratios)=1.25 *8*. B(M1)=0.078 *10*. B(M1)(W.u.)=0.043 *6*. B(M1)(W.u.)=0.016 *+3−6* from Coul. ex. matrix elements. The two values are in disagreement. Eγ=171.3 *2*, Iγ=1.3 *2* (1996Le01), unplaced.
173.5 *2*	1.4 *2*	274.8	9/2$^-$	101.26	7/2$^+$	[E1]		0.1348 *19*	Eγ=173.3 *2*, Iγ=1.4 *2* (1996Le01), placed from 717 level.
174.3	2.4 *10*	717.1	15/2$^+$	542.7	11/2$^+$	[E2]		1.181 *17*	B(E2)(W.u.)=303 *+205−54*. I_γ: 2.4 *10* deduced by evaluators from B(E2)(W.u.)(174.3γ)/B(E1)(W.u.)(365.4γ).
(176.9[@a])		728.4	23/2$^+$	551.51	17/2$^-$	[E3]		14.6 *2*	I_γ: 1.7×10^{-8} *9* deduced by evaluators from B(E2)(W.u.)(240.9γ)/B(E3)(W.u.)(176.9γ). B(E3)(W.u.)=14 *+9−5*.
177.96 *6*	16.5 *6*	494.77	21/2$^+$	316.80	17/2$^+$	[E2]		1.090 *15*	B(E2)(W.u.)=301 *+58−39*. Eγ=178.1 *1*, Iγ=3.0 *4* (1996Le01), unplaced.
180.0 *2*	2.3 *3*	351.71	13/2$^-$	171.70	11/2$^+$	[E1]		0.1236 *17*	E1 R.M.E. (from branching ratios)=5.2×10^{-3} *5*. B(E1)=1.9×10^{-6} *+4−3*. B(E1)(W.u.)=7.8×10^{-5} *+16−12*. Eγ=180.0 *2*, Iγ=1.3 *3* (1996Le01), placed from 705 level.
(180.1[@])	2.6 *12*	705.2	17/2$^+$	525.14	13/2$^+$	[E2]		1.041 *15*	B(E2)(W.u.)=305 *+176−130*. I_γ: 2.6 *12* deduced by evaluators from B(E2)(W.u.)(180.1γ)/B(E1)(W.u.)(376.4γ).
183.3 *2*	1.2 *2*	351.71	13/2$^-$	168.72	11/2$^-$	[M1+E2]	1.1 *+12−7*	2.2 *11*	M1 R.M.E. (from branching ratios)=0.12 *5*. B(M1)=0.0010

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

E_γ[†]	I_γ	E_i(level)	J_i^π	E_f	J_f^π	Mult.	δ	α[b]	Comments
									+11−6. B(M1)(W.u.)=0.00056 *+62−34*. B(E2)(W.u.)=6.1 *+29−41*. δ: deduced by evaluators from E2 and M1 matrix elements. Eγ=183.6 *3*, Iγ=0.6 *2* (1996Le01).
186.6 *1*	7.1 *3*	487.59	19/2+	300.95	15/2+	[E2]		0.909 *13*	B(E2)(W.u.)=295 *38*. Eγ=186.5 *1*, Iγ=2.2 *3* (1996Le01), unplaced.
196.8 *3*	1.5 *3*	525.14	13/2+	328.85	15/2−	[E1]		0.1002 *14*	Eγ=196.8 *2*, Iγ=1.2 *3* (1996Le01).
199.82 *6*	71.0 *25*	551.51	17/2−	351.71	13/2−	[E2]		0.704 *10*	B(E2)(W.u.)=328 *+14−13*. Eγ=199.8 *1*, Iγ=21.2 *11* (1996Le01).
(203.3 *3*)		304.6	(9/2+)	101.26	7/2+				
206.88 *5*	206 *10*	535.73	19/2−	328.85	15/2−	[E2]		0.619 *9*	B(E2)(W.u.)=308 *+18−16*. Eγ=207.1 *1*, Iγ=84 *4* (1996Le01).
215.5 *2*	1.3 *4*	408.49	7/2+	193.02	9/2−	[E1]		0.0810 *12*	Eγ=215.6 *2*, Iγ=1.6 *4* (1996Le01).
218.2 *2*	[&]	319.9	3/2−	101.8	3/2+				Eγ=217.6 *1*, Iγ=3.8 *3* (1996Le01).
218.93 *6*	47.2 *9*	535.73	19/2−	316.80	17/2+	[E1]		0.0781 *11*	E1 R.M.E.=+6.03×10^{-3} *+13−14*. B(E1)=1.82×10^{-6} *9*. B(E1)(W.u.)=7.5×10^{-5} *4*. E1 R.M.E. (from branching ratios)=8.0×10^{-3} *4*. B(E1)=3.2×10^{-6} *3*. B(E1)(W.u.)=1.32×10^{-4} *12*. Eγ=218.7 *1*, Iγ=21.4 *3* (1996Le01), placed from 351.5 level.
223.0[e] *3*	0.1[e] *1*	391.93	9/2+	168.72	11/2−	[E1]		0.0748 *11*	B(E1)(W.u.)=4.7×10^{-5} *+11−12*. Eγ=222.5 *3*, Iγ=1.5 *2* (1996Le01).
223.0[e] *3*	1.8[e] *5*	551.51	17/2−	328.85	15/2−	[M1+E2]	1.3 *+21−7*	1.1 *6*	B(E2)(W.u.)=4.6 *+22−24*. M1 R.M.E. (from branching ratios)=0.12 *6*. B(M1)=0.0008 *+10−6*. B(M1)(W.u.)=0.00045 *+56−34*. δ: from E2 and M1 matrix elements.
226.6 *1*	12.0 *6*	721.38	25/2+	494.77	21/2+	[E2]		0.447 *6*	B(E2)(W.u.)=261 *+60−130*. Eγ=226.7 *2*, Iγ=1.2 *2* (1996Le01), placed from 930 level.
(228.9[@])	4.3 *22*	946.0	19/2+	717.1	15/2+	[E2]		0.432 *6*	B(E2)(W.u.)=314 *+162−57*. Iγ=3.1 *+34−10* deduced from B(E2)(W.u.)(228.9γ)/B(E1)(W.u.)(394.5γ) and Iγ(394.5).
232.9 *2*	[&]	344.5	11/2−	111.58	9/2+				
233.2 *5*	2.8 *3*	728.4	23/2+	494.77	21/2+	[M1]		1.85 *3*	M1 R.M.E. (from branching ratios)=2.2 *2*. B(M1)=0.20 *+4−3*. B(M1)(W.u.)=0.112 *+22−17*. Eγ=233.2 *1*, Iγ=3.5 *4* (1996Le01), placed from 312 level.
234.5 *5*	0.8 *3*	551.51	17/2−	316.80	17/2+	[E1]		0.0666 *9*	E1 R.M.E.=−1.91×10^{-3} *+23−30*. B(E1)=0.20×10^{-6} *5*. B(E1)(W.u.)=8.2×10^{-5} *21*. E1 R.M.E. (from branching ratios)=1.4×10^{-3} *4*. B(E1)=0.11×10^{-6} *+7−5*. B(E1)(W.u.)=4.5×10^{-5} *+29−21*.
235.8[e] *2*	0.9[e] *5*	319.9	3/2−	83.90	5/2+	[E1]		0.0658 *9*	I_γ: total intensity of 4 *2* between the placements from 320 and 425 levels divided by evaluators from Iγ(236γ)/Iγ(217γ)=0.233 *9* in the Adopted Levels, Gammas dataset, using Iγ(217γ)=3.8 *3*.
235.8[e] *2*	3.1[e] *16*	424.90	13/2−	189.10	13/2+	[E1]		0.0658 *9*	I_γ: 4 *2*−0.9 *5*.

$^{231}_{91}Pa_{140}$-11

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

E_γ[†]	I_γ	E_i(level)	J^π_i	E_f	J^π_f	Mult.	α[b]	Comments
236.58 *8*	54.7 *15*	788.06	$21/2^-$	551.51	$17/2^-$	[E2]	0.385 *6*	B(E2)(W.u.)=310 *23*. Eγ=236.6 *2*, Iγ=10.6 *8* (1996Le01).
240.9[e] *5*	0.8[e] *3*	317.78	$3/2^+$	77.52	$5/2^-$	[E1]	0.0626 *10*	Eγ=240.3 *1*, Iγ=4.2 *4* (1996Le01), placed from 318 level only.
240.9[e] *5*	3.2[e] *3*	728.4	$23/2^+$	487.59	$19/2^+$	[E2]	0.362 *6*	B(E2)(W.u.)=307 *+60−69*.
249.6[‡] *3*		351.6	$5/2^-$	101.8	$3/2^+$			
249.8 *1*	100.7 *25*	785.56	$23/2^-$	535.73	$19/2^-$	[E2]	0.320 *5*	B(E2)(W.u.)=327 *+19−20*. Eγ=249.9 *1*, Iγ=21.3 *10* (1996Le01).
250.5[‡] *3*	&	351.6	$5/2^-$	101.26	$7/2^+$			
250.5 *2*	2.9 *3*	551.51	$17/2^-$	300.95	$15/2^+$	[E1]	0.0573 *8*	E1 R.M.E. (from branching ratios)=2.4×10^{-3} *7*. B(E1)=0.32×10^{-6} *+21−16*. B(E1)(W.u.)=1.3×10^{-5} *+9−7*.
252.1 *5*	1.8 *6*	788.06	$21/2^-$	535.73	$19/2^-$	[M1]	1.489 *21*	M1 R.M.E. (from branching ratios)=0.28 *6*. B(M1)=0.0036 *+17−14*. B(M1)(W.u.)=0.0020 *+10−8*.
253.2 *4*	3.2 *4*	311.65	$5/2^+$	58.53	$7/2^-$	[E1]	0.0559 *8*	B(E1)(W.u.)=6.0×10^{-5} *+44−33*. Eγ=253.3 *2*, Iγ=2.8 *4* (1996Le01).
253.2 *2*	2.3 *5*	424.90	$13/2^-$	171.70	$11/2^+$	[E1]	0.0559 *8*	
[x]258.9 *3*	0.4 *2*							Eγ=258.8 *2*, Iγ=2.7 *4* (1996Le01).
265.5 *10*	0.3 *2*	273.7	$1/2^+$	8.8	$1/2^-$	[E1]	0.0502 *9*	Eγ=264.6 *3*, Iγ=0.9 *6* (1996Le01).
267.8 *2*	&	351.6	$5/2^-$	83.90	$5/2^+$			Eγ=267.2 *3*, Iγ=1.8 *3* (1996Le01).
269.1 *1*	19.5 *6*	1057.11	$25/2^-$	788.06	$21/2^-$	[E2]	0.251 *4*	B(E2)(W.u.)=322 *+50−30*. Eγ=268.8 *3*, Iγ=3.5 *6* (1996Le01).
(270.4[@a])		328.85	$15/2^-$	58.53	$7/2^-$	[E4]	12.2 *3*	B(E4)(W.u.)=396 *+317−198*. Iγ=1.9×10^{-9} *+16−9* deduced from B(E4)(W.u.)(270.4γ)/B(E2)(W.u.)(160.13γ) and Iγ(160.13).
271.4 *3*	1.3 *4*	1057.11	$25/2^-$	785.56	$23/2^-$	[M1]	1.213 *17*	M1 R.M.E. (from branching ratios)=0.63 *9*. B(M1)=0.015 *+5−4*. B(M1)(W.u.)=0.0084 *+28−23*. Eγ=271.5 *2*, Iγ=3.6 *5* (1996Le01).
272.5 *2*	4.9 *4*	993.8	$29/2^+$	721.38	$25/2^+$	[E2]	0.241 *4*	
273.6 *3*	1.5 *5*	273.7	$1/2^+$	0.0	$3/2^-$	[E1]	0.0469 *7*	Eγ=273.7 *2*, Iγ=2.5 *5* (1996Le01).
279.1 *2*	0.7 *2*	450.54	$9/2^-$	171.70	$11/2^+$	[E1]	0.0449 *6*	Eγ=278.7 *4*, Iγ=0.9 *2* (1996Le01), unplaced.
280.6 *3*	&	631.9	$(5/2^-)$	351.6	$5/2^-$			
280.6 *5*	0.2 *1*	1355.5	$29/2^-$	1074.29	$27/2^-$	[M1]	1.106 *16*	M1 R.M.E. (from branching ratios)=0.7 *2*. B(M1)=0.016 *+11−8*. B(M1)(W.u.)=0.009 *+6−5*. B(M1)(W.u.)=0.0052 *+57−16* from matrix element.
284.1[d] *2*	0.3[d] *1*	395.75	$7/2^-$	111.58	$9/2^+$	[E1]	0.0431 *6*	Eγ=284.3 *4*, Iγ=0.8 *2* (1996Le01), unplaced.
284.1[d] *2*	0.3[d] *1*	604.0	$(3/2^-)$	319.9	$3/2^-$	[M1]	1.069 *15*	
288.7 *2*	28.0 *8*	1074.29	$27/2^-$	785.56	$23/2^-$	[E2]	0.201 *3*	I_γ: uncertainty of 0.3 (or 1.1%) in 2003Wu03 seems too low to be realistic. Evaluators assign 0.8 (or 3%), consistent with uncertainties for other strong γ rays. B(E2)(W.u.)=324 *+27−37*. E_γ: level-energy difference=289.78.
290.8 *2*	23.9 *7*	785.56	$23/2^-$	494.77	$21/2^+$	[E1]	0.0409 *6*	I_γ: uncertainty of 0.2 (or 0.8%) in 2003Wu03 seems too low to be realistic.

Coulomb excitation 2003Wu03 (continued)

γ(^{231}Pa) (continued)

E_γ[†]	I_γ	E_i(level)	J^π_i	E_f	J^π_f	Mult.	α[b]	Comments
								Evaluators assign 0.7 (or 3%), consistent with uncertainties for other strong γ rays.
								E1 R.M.E.=+7.02×10^{-3} +*15*−*11*. B(E1)=2.05×10^{-6} +*9*−*6*. B(E1)(W.u.)=8.4×10^{-5} +*4*−*3*.
								E1 R.M.E. (from branching ratios)=9.4×10^{-3} *4*. B(E1)=3.7×10^{-6} *3*. B(E1)(W.u.)=1.52×10^{-4} *12*.
								Eγ=290.7 *2*, Iγ=6.8 *6* (1996Le01), placed from 1076 level.
290.8 *3*	1.2 *2*	1019.2	27/2$^+$	728.4	23/2$^+$	[E2]	0.196 *3*	
293.1 *5*	0.8 *4*	788.06	21/2$^-$	494.77	21/2$^+$	[E1]	0.0402 *6*	E1 R.M.E. (from branching ratios)=1.9×10^{-3} *5*. B(E1)=0.16×10^{-6} +*10*−*7*. B(E1)(W.u.)=6.6×10^{-5} +*41*−*29*.
294.5[d] *2*	0.6[d] *2*	395.75	7/2$^-$	101.26	7/2$^+$	[E1]	0.0398 *6*	Eγ=294.9 *3*, Iγ=0.9 *2* (1996Le01), placed from 1351 level.
294.5[d] *2*	0.6[d] *2*	406.1	(11/2$^+$)	111.58	9/2$^+$	[M1]	0.968 *14*	
298.0 *5*	0.4 *2*	1019.2	27/2$^+$	721.38	25/2$^+$	[M1]	0.937 *13*	M1 R.M.E. (from branching ratios)=1.5 *4*. B(M1)=0.08 +*5*−*4*. B(M1)(W.u.)=0.045 +*28*−*23*.
298.6 *3*	4.6 *2*	1355.5	29/2$^-$	1057.11	25/2$^-$	[E2]	0.181 *3*	B(E2)(W.u.)=330 +*31*−*114*.
300.5 *3*	1.8 *2*	788.06	21/2$^-$	487.59	19/2$^+$	[E1]	0.0381 *5*	E1 R.M.E. (from branching ratios)=2.8×10^{-3} *8*. B(E1)=0.36×10^{-6} +*23*−*18*. B(E1)(W.u.)=1.5×10^{-5} +*10*−*8*. Eγ=300.5 *3*, Iγ=1.0 *2* (1996Le01), unplaced.
308.9 *3*	1.4 *2*	317.78	3/2$^+$	8.8	1/2$^-$	[E1]	0.0358 *5*	B(E1)(W.u.)=1.9×10^{-5} +*17*−*11*. Eγ=308.9 *2*, Iγ=3.5 *4* (1996Le01).
311.6 *3*	1.5 *2*	311.65	5/2$^+$	0.0	3/2$^-$	[E1]	0.0351 *5*	B(E1)(W.u.)=1.2×10^{-5} +*12*−*6*. Eγ=311.9 *2*, Iγ=3.0 *4* (1996Le01).
311.9[c] *2*		395.75	7/2$^-$	83.90	5/2$^+$			
311.9[c] *2*	&	631.9	(5/2$^-$)	319.9	3/2$^-$			
314.2 *3*	1.2 *3*	1307.8	33/2$^+$	993.8	29/2$^+$	[E2]	0.1548 *22*	
317.6 *3*	0.8 *3*	317.78	3/2$^+$	0.0	3/2$^-$	[E1]	0.0337 *5*	B(E1)(W.u.)=2.1×10^{-5} *13*. B(E3)(W.u.)=25 +*16*−*9*. Eγ=317.8 *2*, Iγ=3.5 *4* (1996Le01).
323.8 *2*	7.0 *6*	1398.1	31/2$^-$	1074.29	27/2$^-$	[E2]	0.1416 *20*	B(E2)(W.u.)=322 +*31*−*52*. Eγ=321.9 *3*, Iγ=1.2 *2* (1996Le01).
326.2 *3*	1.0 *2*	677.8	(7/2$^-$)	351.6	5/2$^-$	[M1]	0.730 *10*	
327.7 *3*	1.1 *5*	1683.2	33/2$^-$	1355.5	29/2$^-$	[E2]	0.1367 *19*	
328.7 *3*	1.2 *5*	1057.11	25/2$^-$	728.4	23/2$^+$	[E1]	0.0313 *5*	E1 R.M.E. (from branching ratios)=4.8×10^{-3} *11*. B(E1)=0.9×10^{-6} *4*. B(E1)(W.u.)=3.7×10^{-5} *16*.
330.9 *3*	2.2 *4*	408.49	7/2$^+$	77.52	5/2$^-$	[E1]	0.0308 *4*	B(E1)(W.u.)=3.4×10^{-5} +*12*−*19*. Eγ=330.9 *3*, Iγ=2.4 *3* (1996Le01).
331.4 *2*	&	520.5	(15/2$^-$)	189.10	13/2$^+$			
333.5 *2*	4.5 *5*	391.93	9/2$^+$	58.53	7/2$^-$	[E1]	0.0303 *4*	B(E1)(W.u.)=1.9×10^{-5} +*3*−*4*. Eγ=333.6 *2*, Iγ=3.8 *4* (1996Le01).
338.3[c] *3*	&	450.54	9/2$^-$	111.58	9/2$^+$			
338.3[c] *3*		734.0	(9/2$^-$)	395.75	7/2$^-$			
338.3[c] *3*	0.8 *2*	1357.5	31/2$^+$	1019.2	27/2$^+$	[E2]	0.1246 *18*	Eγ=338.3 *3*, Iγ=1.0 *2* (1996Le01).

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

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

E_γ[†]	I_γ	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α[b]	Comments
349.3 *2*	&	450.54	9/2⁻	101.26	7/2⁺			
349.7 *3*	2.3 *3*	542.7	11/2⁺	193.02	9/2⁻	[E1]	0.0273 *4*	B(E1)(W.u.)=4.1×10^{-5} *+14−20*. Eγ=349.5 *2*, Iγ=3.5 *4* (1996Le01).
352.6 *5*	0.6 *4*	1660.4	37/2⁺	1307.8	33/2⁺	[E2]	0.1107 *16*	Eγ=352.9 *3*, Iγ=2.3 *3* (1996Le01), unplaced.
352.8 *2*	7.2 *4*	1074.29	27/2⁻	721.38	25/2⁺	[E1]	0.0268 *4*	E_γ: level-energy difference=353.62. E1 R.M.E.=+8.64×10^{-3} *+9−148*. B(E1)=2.7×10^{-6} *+0−10*. B(E1)(W.u.)=1.1×10^{-4} *+0−4*. E1 R.M.E. (from branching ratios)=0.0114 *7*. B(E1)=4.6×10^{-6} *+6−5*. B(E1)(W.u.)=1.9×10^{-4} *+3−2*. Eγ=352.9 *3*, Iγ=2.3 *3* (1996Le01), unplaced.
355.8 *3*	0.9 *3*	1754.1	35/2⁻	1398.1	31/2⁻	[E2]	0.1079 *15*	B(E2)(W.u.)=0.03 *+76−0* or 0.03 *+29−0*.
356.2 *2*	2.8 *5*	525.14	13/2⁺	168.72	11/2⁻	[E1]	0.0263 *4*	B(E1)(W.u.)=1.9×10^{-5} *+6−4*. Eγ=356.0 *3*, Iγ=3.3 *3* (1996Le01).
357.2 *8*	0.4 *3*	2040.4	37/2⁻	1683.2	33/2⁻	[E2]	0.1068 *17*	
365.4 *2*	2.0 *3*	717.1	15/2⁺	351.71	13/2⁻	[E1]	0.0249 *4*	B(E1)(W.u.)=2.7×10^{-5} *6*. Eγ=365.4 *2*, Iγ=3.9 *4* (1996Le01).
(367.0[@a])		535.73	19/2⁻	168.72	11/2⁻	[E4]	2.49 *4*	B(E4)(W.u.)=428 *+428−238*. Iγ=0.19×10^{-7} *+19−9* deduced from B(E4)(W.u.)(367.0γ)/B(E2)(W.u.)(206.9γ) and Iγ(206.9γ).
376.4 *2*	2.9 *3*	705.2	17/2⁺	328.85	15/2⁻	[E1]	0.0234 *3*	B(E1)(W.u.)=3.5×10^{-5} *+11−6*. Eγ=376.4 *2*, Iγ=2.6 *3* (1996Le01).
385.1 *3*	0.5 *2*	2139.3	39/2⁻	1754.1	35/2⁻	[E2]	0.0868 *12*	Eγ=385.0 *5*, Iγ=0.5 *2* (1996Le01).
(391.9[@a])		391.93	9/2⁺	0.0	3/2⁻	[E3]	0.396 *6*	B(E3)(W.u.)=7.6 *38*. Iγ=3.1×10^{-5} *+27−18* deduced from B(E3)(W.u.)(391.9γ)/B(E1)(W.u.)(333.5γ) and Iγ(333.5).
394.5[d] *4*	1.6[d] *3*	930.2	21/2⁺	535.73	19/2⁻	[E1]	0.0212 *3*	Eγ=394.4 *3*, Iγ=1.6 *2* (1996Le01), placed from 930 level only.
394.5[d] *4*	1.6[d] *3*	946.0	19/2⁺	551.51	17/2⁻	[E1]	0.0212 *3*	B(E1)(W.u.)=4.4×10^{-5} *+9−12*.
[x]403.9 *2*	&							
404.2 *2*	3.2 *4*	1398.1	31/2⁻	993.8	29/2⁺	[E1]	0.0201 *3*	E1 R.M.E. (from branching ratios)=0.0178 *13*. B(E1)=9.9×10^{-6} *+15−14*. B(E1)(W.u.)=4.1×10^{-4} *6*.
408.1 *3*	0.9 *3*	1196.2	23/2⁺	788.06	21/2⁻	[E1]	0.0197 *3*	
(408.5[@a])		408.49	7/2⁺	0.0	3/2⁻	[E3]	0.340 *5*	B(E3)(W.u.)=6 *4*. Iγ=0.9×10^{-7} *+33−7* deduced from B(E3)(W.u.)(408.5γ)/B(E1)(W.u.)(330.9γ) and Iγ(330.9γ).
[x]415.5 *2*	3.1 *4*							
420.7 *2*	2.6 *4*	604.0	(3/2⁻)	183.4	5/2⁺	[E1]	0.0185 *3*	
[x]424.6 *3*	1.3 *2*							
446.9 *5*	0.3 *1*	1754.1	35/2⁻	1307.8	33/2⁺	[E1]	0.01636 *23*	E_γ: 445.9 in Fig. 4 of 2003Wu03. E1 R.M.E. (from branching ratios)=0.018 *4*. B(E1)=9×10^{-6} *4*. B(E1)(W.u.)=3.7×10^{-4} *16*.
(456.7[@a])		785.56	23/2⁻	328.85	15/2⁻	[E4]	0.903 *13*	I_γ: 2.7×10^{-8} *20* deduced by evaluators from B(E2)(W.u.)(249.8γ)/B(E4)(W.u.)(456.7γ).

Coulomb excitation 2003Wu03 (continued)

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

E_γ[†]	I_γ	E_i(level)	J^π_i	E_f	J^π_f	Mult.	α[b]	Comments
								B(E4)(W.u.)=475 *+370−317*. Upper limit of B(E4)(W.u.) is higher than expected from systematics (1999Sh28).
[x]458.5 *4*	0.7 *3*							
[x]460.7 *4*	0.9 *3*							
(465.2[@a])		542.7	11/2$^+$	77.52	5/2$^-$	[E3]	0.215 *3*	B(E3)(W.u.)=21 *8*. Iγ=0.60×10^{-4} *33* deduced from B(E3)(W.u.)(465.2γ)/B(E1)(W.u.)(349.7γ) and Iγ(349.7γ).
[x]474.1 *3*	0.0 *3*							
479.0 *6*	0.5 *3*	2139.3	39/2$^-$	1660.4	37/2$^+$	[E1]	0.01422 *20*	E1 R.M.E. (from branching ratios)=0.025 *9*. B(E1)=1.6×10^{-5} *+13−10*. B(E1)(W.u.)=6.6×10^{-4} *+54−41*.
[x]486.2 *3*	1.2 *2*							
[x]495.8 *3*	0.6 *2*							
[x]502.5 *3*	0.6 *2*							
[x]505.6 *3*	0.6 *2*							
(524.1[@a])	2.4×10^{-4} *12*	717.1	15/2$^+$	193.02	9/2$^-$	[E3]	0.145 *2*	B(E3)(W.u.)=22 *+24−8*. I_γ: 0.00024 *12* deduced by evaluators from B(E3)(W.u.)(524.1γ)/B(E1)(W.u.)(365.4γ).
[x]552.0 *3*	0.7 *2*							
[x]554.1 *3*	1.0 *2*							
[x]564.1 *2*	0.4 *2*							
[x]606.3 *2*	0.7 *2*							
[x]621.7 *4*	0.4 *2*							
[x]645.0 *2*	0.7 *2*							
[x]651.0 *4*	0.5 *2*							
[x]667.4 *2*	0.7 *2*							
[x]683.3 *2*	0.9 *2*							
[x]687.5 *2*	1.1 *2*							

† Eγ values given in Figs. 4 and 7 of 2003Wu03 are level-energy differences. The evaluators have quoted all Eγ data from authors′ Tables 1 and 2, except for some doublets where values have been taken from the level-scheme Figs. 4 and 7.

‡ From Fig. 7 in 2003Wu03; composite member for the doublet in Table 2: 250.2 *3*.

\# From Fig. 7 in 2003Wu03; for the doublet in Table 2 of 2003Wu03: composite Eγ=81.6 *3*, Iγ=1.7 *3*.

@ From level-energy difference, γ implied from reported matrix elements, but not observed.

& In Coul. ex. work of 2003Wu03, intensity could not be determined due to contribution from a closely spaced strong line. The γ ray is seen in (p,2nγ), and also expected in Coul. ex.

a This transition is not included in the Adopted Levels, Gammas dataset.

b Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

c Multiply placed.

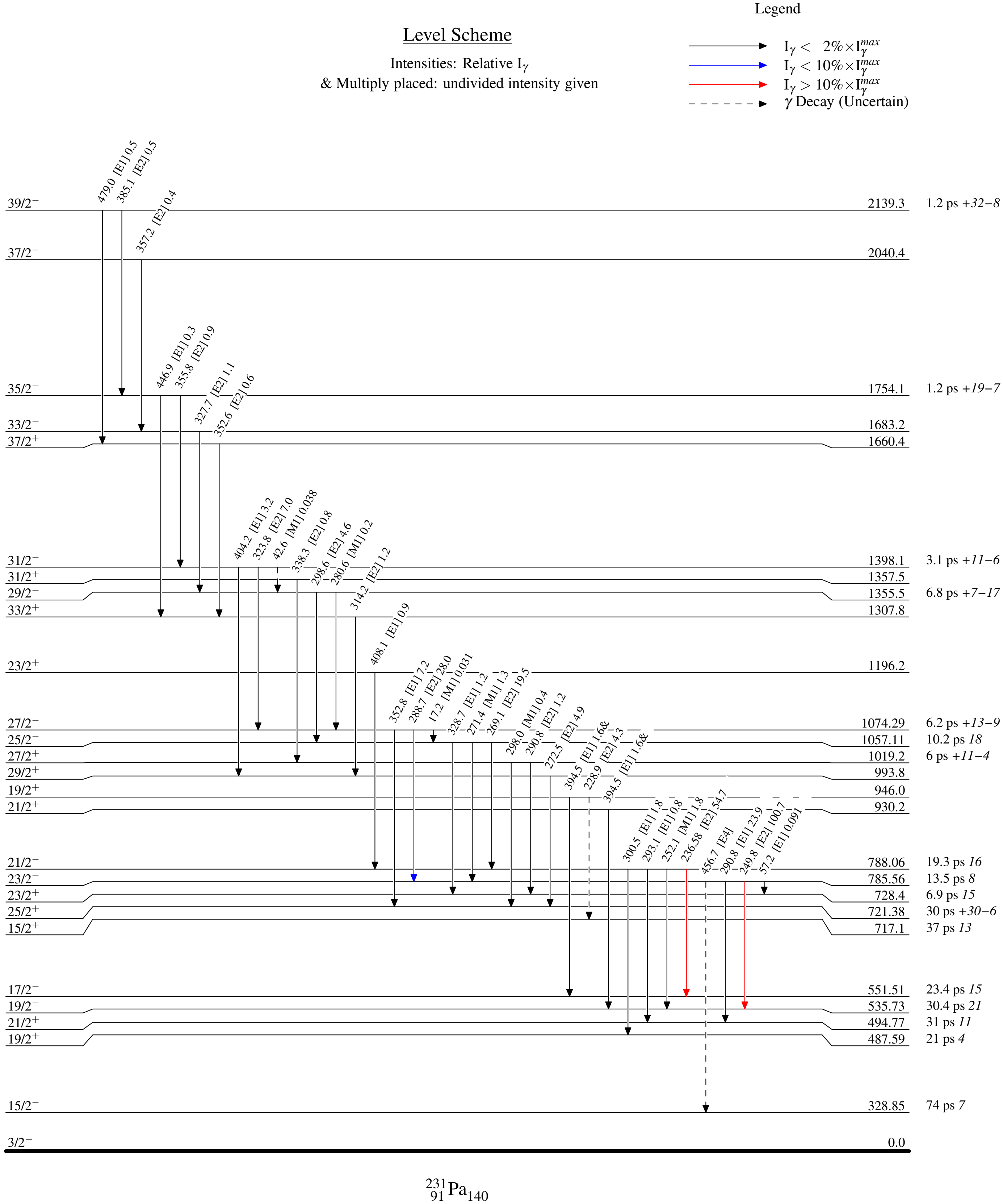
$^{231}_{91}Pa_{140}$-15

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

[d] Multiply placed with undivided intensity.
[e] Multiply placed with intensity suitably divided.
[f] Placement of transition in the level scheme is uncertain.
[x] γ ray not placed in level scheme.

$^{231}_{91}Pa_{140}$-16

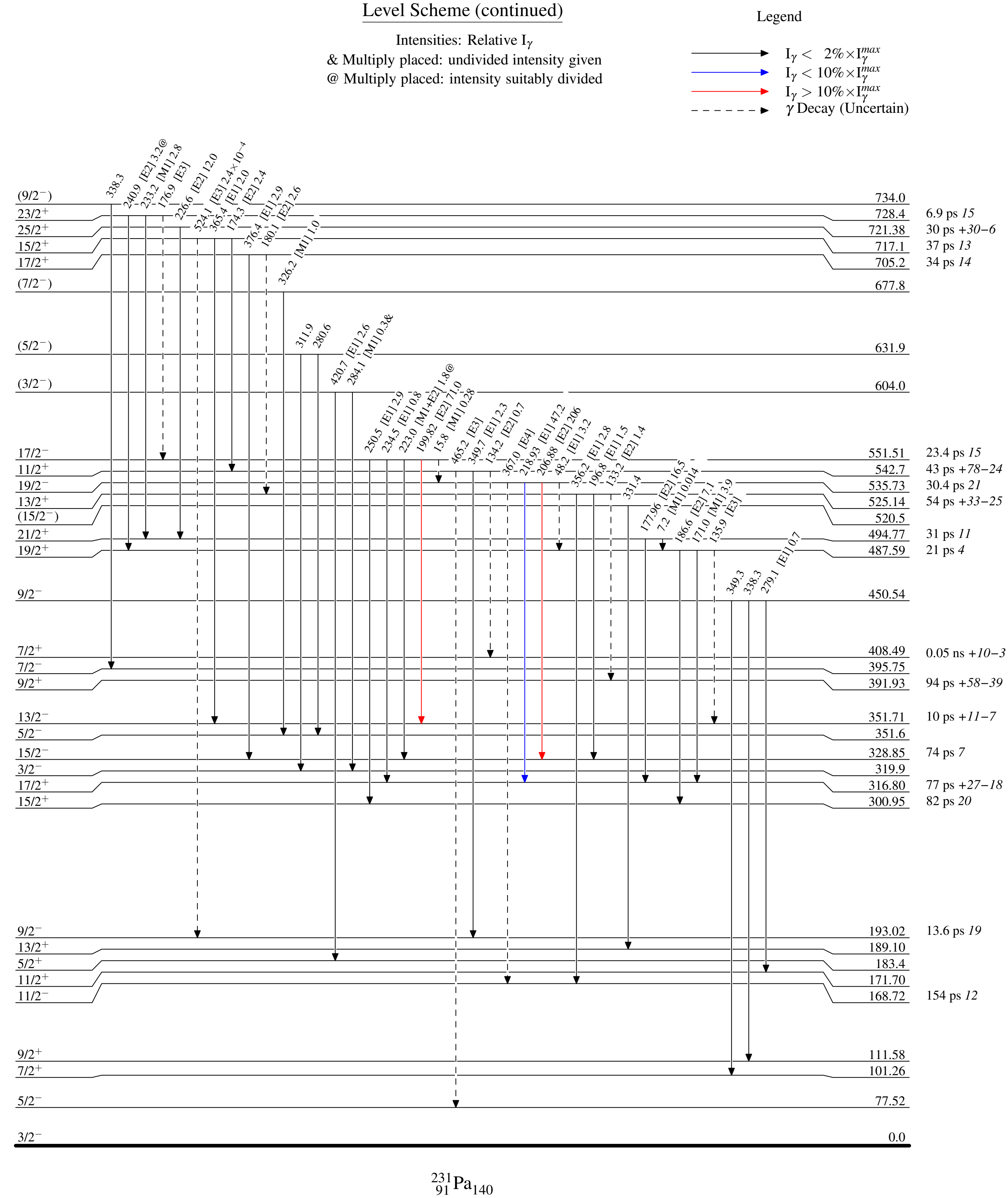
Coulomb excitation 2003Wu03



Coulomb excitation 2003Wu03

Level Scheme (continued)

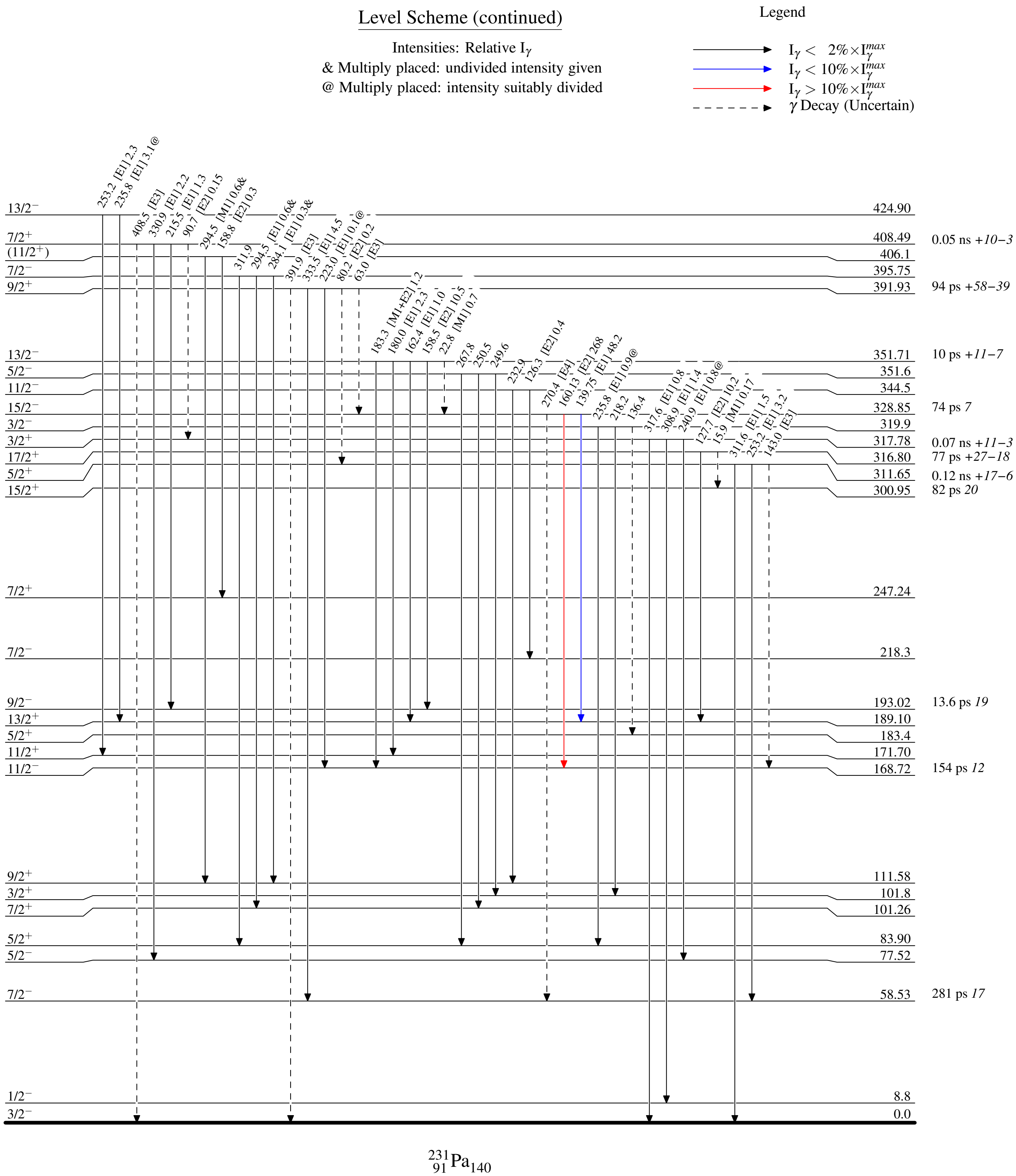
Intensities: Relative I_γ
& Multiply placed: undivided intensity given
@ Multiply placed: intensity suitably divided



Coulomb excitation 2003Wu03

Level Scheme (continued)

Intensities: Relative I_γ
& Multiply placed: undivided intensity given
@ Multiply placed: intensity suitably divided



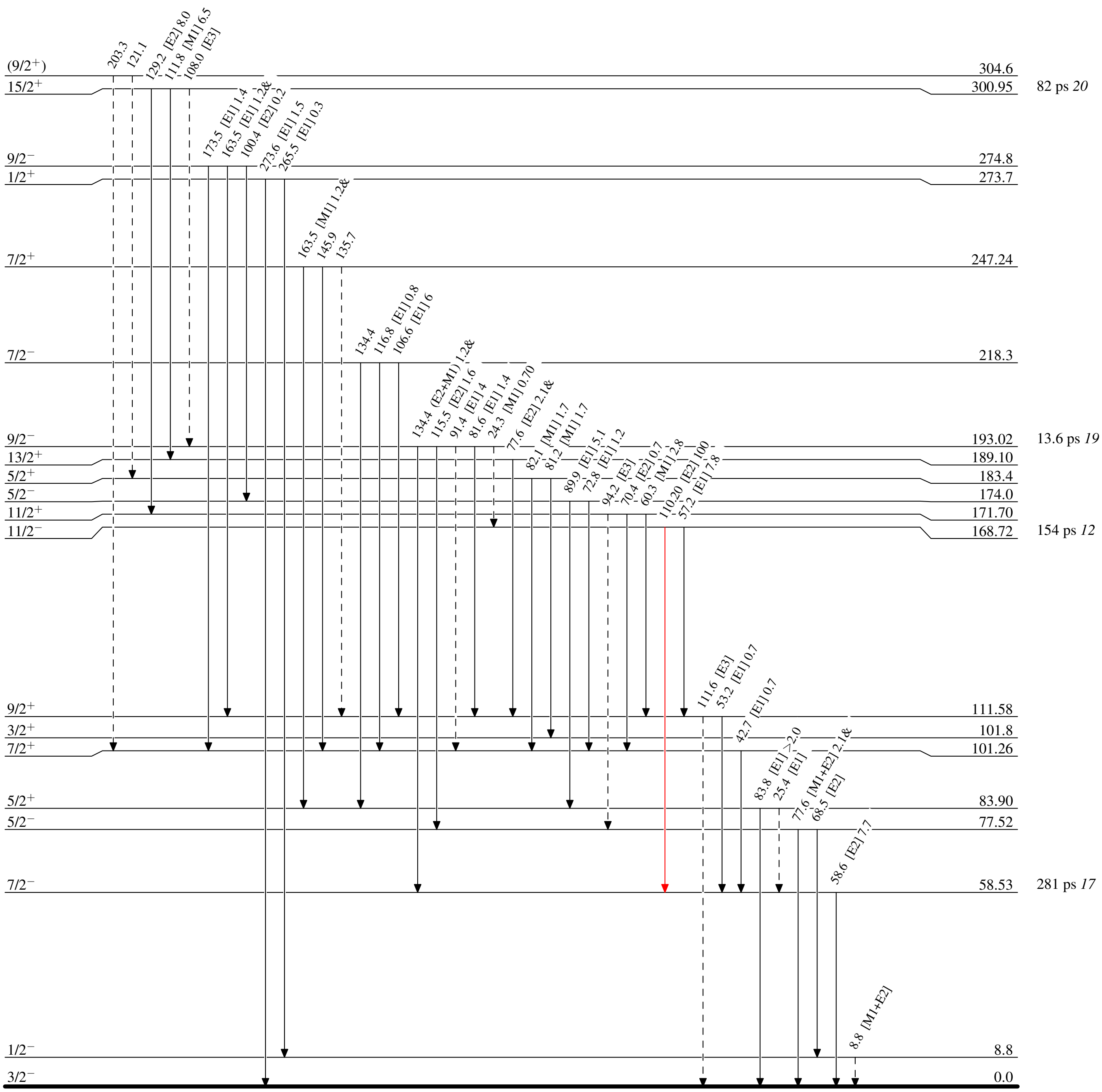
Coulomb excitation 2003Wu03

Level Scheme (continued)

Intensities: Relative I_γ
& Multiply placed: undivided intensity given
@ Multiply placed: intensity suitably divided

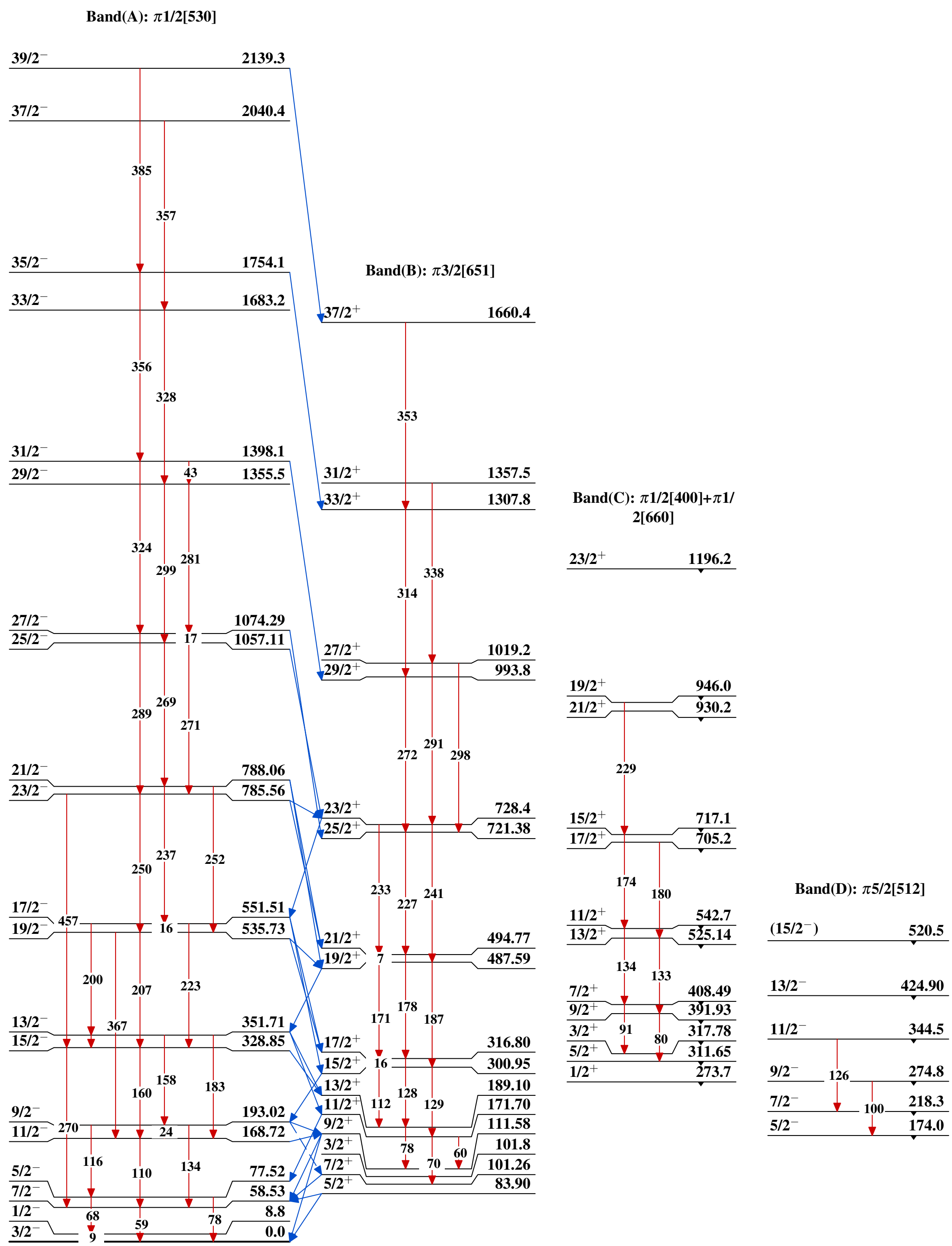
Legend

$I_\gamma < 2\% \times I_\gamma^{max}$
$I_\gamma < 10\% \times I_\gamma^{max}$
$I_\gamma > 10\% \times I_\gamma^{max}$
γ Decay (Uncertain)



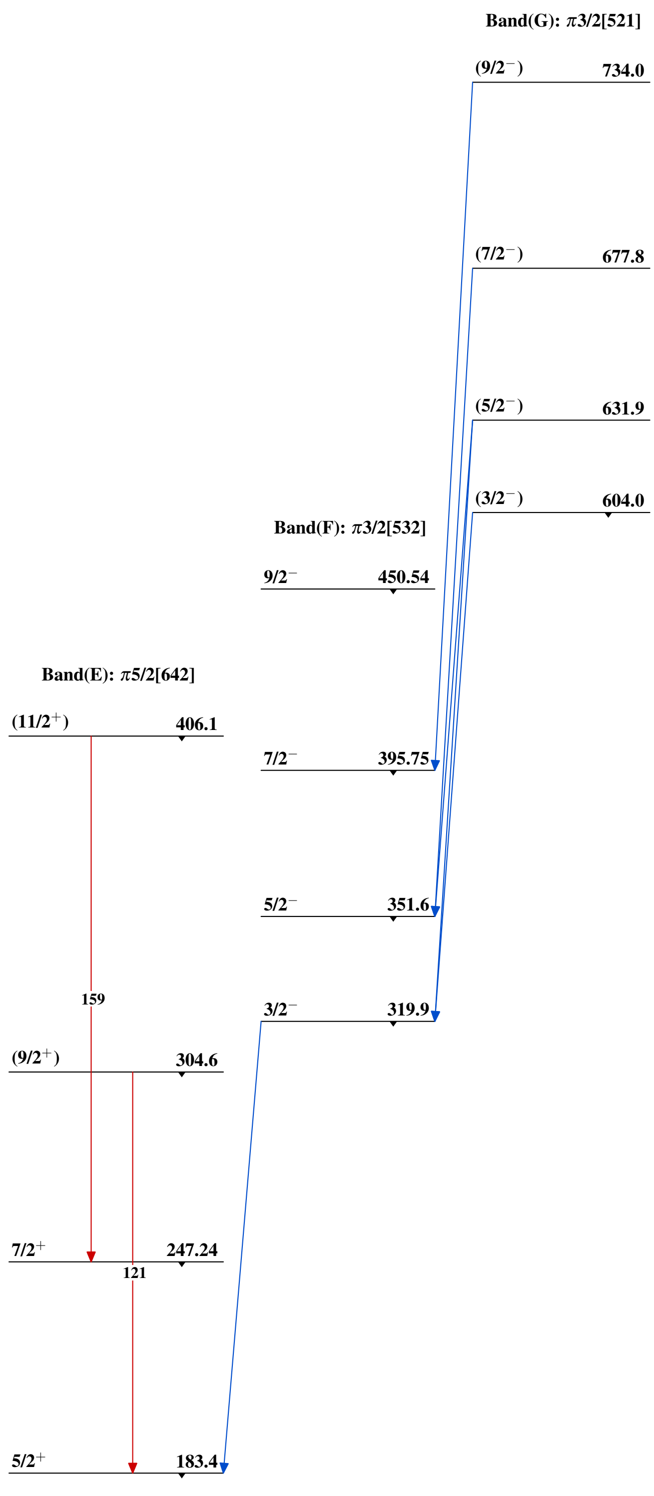
$^{231}_{91}Pa_{140}$

Coulomb excitation 2003Wu03



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

Coulomb excitation 2003Wu03 (continued)



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