Adopted Levels, Gammas

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	C. D. Nesaraja	NDS 146, 387 (2017)	31-Aug-2017

Q(β^-)=−73.2 *27*; S(n)=6019.9 *29*; S(p)=7.36×10^3 *SY*; Q(α)=4665.5 *10* 2017Wa10
ΔS(p)=30 (syst, 2017Wa10).

Identification:
1954St98: ^{244}Pu produced from ^{243}Pu(n,γ) reaction and possibly by electron capture of ^{244}Am. The reaction were studied via a multiple order neutron capture of ^{239}Pu in the pile irradiated plutonium experiment at the Material Testing Reactor at Argonne National Laboratory with integrated flux of ×10^4 neutrons. Plutonium was chemically separated and analyzed in a 12 inch, 60 ° mass spectrometer.

Systematic studies/Compilation/Evaluation:
2017He08: Review of properties of spontaneous fission.
2017Pr04: Systematics of B(E2) revisited using elemental data fit parameters.
2016Pr01: Compilation, evaluation for B(E2), $T_{1/2}$ and deformation parameter.
2011Ch65: Recommended $T_{1/2}$ of ^{244}Pu based on measurements published till 2010.
2000Ho27: Recommended $T_{1/2}$ SF based on measurement till April 1998.
1989Ho24: Recommended total $T_{1/2}$ and $T_{1/2}$(SF).
1975Me28, 1974VaYN: Properties of fission isomer.

Theoretical calculations:
2017Ph01, 2017Zh03, 2016Sa16, 2016Su09, 2014De43, 2014Is03, 2013Ra05, 2013Se17, 2013Is13, 2012Is08, 2011Qi06, 2011Qi12, 2011Zh36, 2009De32, 2009Ni06, 2008Xu06, 2007Pe30, 2006De05, 2005Sh42, 1996De19, 1979Po23: Calculated α decay half-life.
2015Ba24, 2015Sa15, 2010Sa09, 2008Xu06, 2005Re16, 2005Sh42, 2005Xu01, 2004Ro01, 1992Bh03, 1992Gr16, 1990Bh02, 1976Ra02, 1972Mo27, 1972We09: Calculated spontaneous fission half-lives.
1978Po01: Calculated properties of the SF isomer, its moment of inertia, pairing energy gap, and magnetic moment.
2000Se09: Description of long-range α emission during spontaneous fission.
2014Re05, 2002Hi06: Calculated $T_{1/2}(\beta\beta)$.
2014De43, 1998Bu18: Calculated energy levels and transition strengths.
2013De12, 1995Mo29, 1984Eg01, 1983Bo15, 1982Du16: Calculated deformation parameters.
2014Ji14, 2014Lu01, 2014Ro09, 2014Sh13, 2013Bo29, 2012Ja08, 2001YaZU, 1992Bh03, 1992Gr16, 1990Bh02, 1984Ro23, 1980Bj02, 1972Ma11, 1976Iw02, 2017Ba02, 1974MoYC, 1972We09, 1971Pa33: Calculated fission barriers heights.
2013Li30, 2010Wa34: Calculated two-quasiparticle high K-state with $\nu7/2^+[624]\otimes\nu9/2^-[734]$ configuration. Predicted the octupole deformed high K-isomeric state at 1.022 MeV in 2013Li30.
2010Wa23, 2010Wa31: Calculated relative intensities of α decay to rotational states.
2002Re31: Calculated g.s properties.
2012Zh14, 2005Al40, 2001Fa07, 1988ShZR, 1985Bo20, 1984Eg01, 1982Du16: Analysis of yrast states, backbending and alignment.
1983Bo15: Calculated equilibrium deformations and static electric moment.
2014Af04, 2013Af01, 1980Du07: Calculated moment of inertia.
2011Ne09, 2006Sh19, 2002Pr01, 1982L01, 1982Du16, 1971Ko31, 1970Ne08: Calculated octupole-vibrational states.
1969Wy02: Calculated nuclear mass parameter, an important characteristic of the collective motion of the nucleus.
1992Bh03, 1974MoYC, 1972Mo27, 1971Pa33: Calculated isomeric state energy.
1977VaYN: Review of properties of spontaneously fissioning isomers.
2014Mi26: Analyzed the influence of octupole mode on nuclear high K-isomer properties.

Adopted Levels, Gammas (continued)

^{244}Pu Levels

Cross Reference (XREF) Flags

A	^{248}Cm α decay	D	^{244}Pu(d,d′)
B	^{244}Np β^- decay	E	^{244}Pu(^{47}Ti,^{47}Ti′γ)
C	Coulomb excitation	F	^{244}Pu(^{208}Pb,^{208}Pb′γ)

E(level)[†]	Jπ[a]	$T_{1/2}$	XREF	Comments
0.0[‡]	0^+	8.13×10^7 y *3*	ABCD F	%SF=0.123 *6*; %α=99.877 *6* %SF is deduced from the adopted $T_{1/2}$=8.13 ×10^7 y *3* and $T_{1/2}$(SF)=6.6 ×10^{10} y *3*. $T_{1/2}$: From revised value of 8.12 ×10^7 y *3* (2006Ag15). Relative activity using thermal ionization mass spectrometry and α spectrometry was used in the 2006Ag15 measurement. The method was an improvement from previous measurements due to better isotope fraction as well as more accurate determination of alpha activity ratios using ^{240}Pu and ^{242}Pu as reference nuclides. The evaluator has however, revised the value given originally by 2006Ag15 using values of $T_{1/2}$(^{242}Pu)= 3.73 ×10^7 y *3* (from email reply of M. Martin on 14 May 2017), $T_{1/2}$(^{240}Pu)= 6561 y *7* (2008Si25), $T_{1/2}$(^{239}Pu)= 24110 y *29* (2014Br18), and $T_{1/2}$(^{241}Pu) α decay = 5.87 ×10^5 y *5* (deduced from $T_{1/2}$(^{241}Pu)= 14.329 y *29* (2015Ne16), and %α=2.44 ×10^{-3} *2* (2008BeZV). Other $T_{1/2}$: 2011Ch65: 8.00 ×10^7 y *12* (recommended half-life based on measurements published from 1956-2006). 1989Ho24: 8.00 ×10^7 y *9* (weighted average of several compiled and revised values till 1969). 1969Be06: 8.28 ×10^7 y *10* (specific activity relative to ^{239}Pu, measured with Si-Au surface barrier detector), 1966Fi07: 8.18 ×10^7 y *26* (specific activity relative to ^{240}Pu and ^{242}Pu, measured with Si surface barrier detector), 1956Bu92: 7.6 ×10^7 y *20* (specific activity of decay to ^{240}U and ^{240}Np, measured using end window Geiger Muller counter and proportional counter), 1956Di09: 7.6 ×10^7 y *20* (activity of ^{240} Np decay, measured using Geiger-Mueller counters in anticoincidence with proportional counter). $T_{1/2}$(SF)=6.6 ×10^{10} y *3* from the weighted average of: 6.56 ×^{10} y *30* (1983Mo02), 6.8 ×10^{10}y *8* (1977Go03), and 6.67 ×10^{10} y *32* (revised value of 1966Fi07 by 1989Ho24). Other $T_{1/2}$(SF): 2000Ho27: Recommended half-life 6.6 ×10^{10} y *2*. 1980Kh05: 7.32 ×10^{10} y. 1955Fi36: 2.5 ×10^{10} y *8*. $T_{1/2}$(2 β- decay) ≥ 1.1 ×10^{18} y (1992Mo25: detection of ^{244}Cm alpha activity with ≤ 0.24 counts per day. %(2 β-decay) ≤ 7 ×10^{-9} deduced from $T_{1/2}$(2 β-decay) ≥ 1.1 ×10^{18} y and total half-life of $T_{1/2}$=8.13 ×10^7 y *3*. 1998Se17, 1994Ve03: Observed emission of long-range alpha particles during spontaneous fission. The ratio of long-range alpha to fission rate was measured to be 2.62 ×10^{-3} *25*, from which the light particle emission to binary fission probability ratio was deduced as 2.96 ×10^{-3} *31* by 1994Ve03. Energy distribution and yields were measured by 1998Se17. 1985Ge08: Measured isotope shift relative to ^{242}Pu as 1.03 *2*.
44.2[‡] *4*	2^+	158 ps *11*	ABCD F	Additional information 1. E(level): Level energy is calculated from Eα=5034.89 keV to 2^+ state, observed in ^{248}Cm alpha decay.

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Adopted Levels, Gammas (continued)

^{244}Pu Levels (continued)

E(level)[†]	Jπ[a]	$T_{1/2}$	XREF	Comments
				$T_{1/2}$: Calculated from B(E2)=13.61 *18*, measured in Coulomb excitation with α=7.8×10^2 *4* (α calculated from BrICC).
149.9[‡] *6*	4^+		ABCDEF	B(E4)↑=0.09 *+55−9* Additional information 2. E(level): Level energy is calculated from Eα=4930.37 keV to 4^+ state, observed in ^{248}Cm alpha decay. B(E4) was deduced in Coulomb excitation. Jπ: From Coulomb excitation and (d,d′) data.
313.0[‡] *5*	6^+[b]		ABCDEF	
530.2[‡] *7*	8^+[b]		BCDEF	
708 *4*	(2^+,3^-)		C	Jπ: from Coulomb excitation. B(E2)=0.045 *13* if Jπ=2^+; B(E3)=0.30 *10* if Jπ=3^- (1974Mc15).
797.8[‡] *8*	10^+[b]		C F	
957[#] *2*	3^-[f]		CD	
1015 *2*	(2^+)[c]		CD	
1068[#] *4*	(5^-)[f]		D	E(level): 1068-keV level was doublet in (d,d′) spectrum; 1975Th11 suggested that one level of the doublet may be the 5^- member of a K=2^- octupole-vibrational band.
1068			D	
1108 *2*	(3^-)[e]		CD	
1111.4[‡] *9*	12^+[b]		C F	
1194 *3*	(5^-)[e]		D	
1201.5[#] *8*	7^-		C EF	
1210 *3*			D	
1211.2[@] *8*	8^-	1.75 s *12*	B EF	Jπ: From measurements of in-band M1/E2 branching ratios in ^{244}Pu(^{208}Pb,^{208}Pb′γ) deep inelastic reaction that was used to extract g_K-g_R/Q_0 values that verifies the assignment. In addition, systematics show a similar excitation energy and decay pattern of N=150 isotones with even Z for ^{246}Cm (2008Ro21), ^{248}Cf (2014Ma86),^{250}Fm (2008Gr17) and ^{252}No (2008Ro21). $T_{1/2}$: From decay curve measurements in ^{244}Pu(^{47}Ti,^{47}Ti′γ) (2016Ho13).
1321.1[&] *18*	9^-[d]		F	
1353 *4*			D	
1378 *3*			D	
1390.5[#] *8*	9^-		C F	
1434 *3*			D	
1442.2[@] *13*	10^-[d]		F	
1466.7[‡] *10*	14^+[b]		C F	
1575.1[&] *15*	11^-[d]		F	
1613 *3*	(3^-)[g]		D	
1623.3[#] *9*	11^-		C F	
1718.3[@] *15*	12^-[d]		F	
1783 *3*			D	
1805 *3*			D	
1847 *3*			D	
1859.2[‡] *10*	16^+[b]		C F	
1873.0[&] *16*	13^-[d]		F	
1896 *3*			D	
1898.9[#] *9*	13^-		C F	
2037.7[@] *16*	14^-[d]		F	
2213.8[&] *17*	15^-[d]		F	

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Adopted Levels, Gammas (continued)

^{244}Pu Levels (continued)

E(level)[†]	Jπ[a]	$T_{1/2}$	XREF	Comments
2214.9[#] *10*	15^-		C F	
2284.5[‡] *11*	18^+[b]		C F	
2398.8[@] *18*	16^-[d]		F	
≈2400		380 ps *80*		%SF≤100 E(level): The shape isomer′s energy was deduced as 2.43 MeV +*30*−*26* by 1971Au06 from intermediate structure observed in neutron-induced fission cross sections. Calculations of 1971Pa33, 1972Mo27, and 1992Bh03, 2013Gi06, yield E(level)= 3.2, 3.5, ≈ 2.4 MeV, and 2.47 respectively. $T_{1/2}$: Measured from decay of fission isomer observed in ^{244}Pu(d,pn). Theoretical calculations: $T_{1/2}$(SF)=137 ps (2005Re16). 1974MeYP. See 1975Me28 for systematics of SF isomer half-lives. 1974Ba28: Fission probability distributions were measured following ^{242}Pu(15-MeV t,pF) reaction, and the heights and curvatures of the two peaks in the fission barrier were deduced.
2567.8[#] *10*	17^-		C F	
2594.8[&] *18*	17^-[d]		F	
2737.9[‡] *12*	20^+[b]		C F	
2799.8[@] *19*	18^-[d]		F	
2952.2[#] *12*	19^-		C F	
3013.8[&] *19*	19^-[d]		F	
3211.0[‡] *13*	22^+		C F	
3236.8[@] *20*	20^-[d]		F	
3360.0[#] *13*	21^-		C F	
3467.8[&] *21*	21^-[d]		F	
3686.3[‡] *14*	24^+		C F	
3705.8[@] *22*	22^-[d]		F	
3784.0[#] *15*	23^-		C F	
3948.8[&] *23*	23^-[d]		F	
4145.2[‡] *15*	26^+[b]		C F	
4191.8[@] *24*	24^-[d]		F	
4227.2[#] *17*	25^-		C F	
4606.1[‡] *17*	28^+		C	
4690.2[#] *20*	27^-		C	
5085.7[‡] *20*	30^+		C	
5589.6[‡] *22*	32^+		C	
6119.7[‡] *24*	34^+		C	

[†] From least-squares fit to Eγ data by the evaluator, except as noted. E=44.2 keV, and 149.9 keV have been held fixed during the the least-squares fit. ΔE=1 keV for gammas without uncertainty is assumed.
[‡] Band(A): $K=0^+$ Ground-state band.
[#] Band(B): Octupole-vibrational band.
[@] Band(C): $K=8^-$,(ν9/2[734]⊗ν7/2[624]), α=0.
[&] Band(D): $K=8^-$,(ν9/2[734]⊗ν7/2[624]), α=1.
[a] Except as noted, assignments are based on band structure.
[b] In addition to the band structure arguments, J^π for levels observed in Coulomb Excitation by 1983Sp03 are from systematic impact-parameter dependence of the γ-ray yields, the particle-γ directional correlation, and the γ-multiplicity measurements.

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Adopted Levels, Gammas (continued)

^{244}Pu Levels (continued)

[c] In the (d,d′) measurement, 1975Th11 noted that J^π could also be a 3^-. However a comparison of the reduced transition probability B(E2)↑=0.30 *10* (1970Th11) that was extracted by normalizing the (d,d′) cross section with values from Coulomb Excitation measurement (1974Mc15): B(E3)=1.16 12 if $J^\pi=3^-$; B(E2)=0.195 *18*, if $J^\pi=2^+$ makes it a possible 2^+ rather than a 3^-.

[d] Assignments for the (^{244}Pu,^{244}Pu′γ) deep inelastic reaction are based on the band members built on the K isomer at 1211 keV except as noted.

[e] K=0^- or 1^- ? This assignment was suggested in 1975Th11 from (d,d′) data. The authors of 1975Th11 suggested also that the doublet at 1068 may contain the expected 1^- member of the band.

[f] K=2^- ? This assignment was suggested in 1975Th11 from (d,d′) data with $J^\pi=3^-$ at 957 level and that the doublet at 1068 may contain the expected 5^- member of the band.

[g] Based on the cross section pattern from the (d,d′) measurements

γ(^{244}Pu)

E_i(level)	J^π_i	E_γ[†]	I_γ	E_f	J^π_f	Mult.	α[a]	Comments
44.2	2^+	(44.2[&] *4*)		0.0	0^+	[E2]	7.8×10^2 *4*	α(L)=5.6×10^2 *3*; α(M)=157 *8* α(N)=43.2 *21*; α(O)=10.2 *5*; α(P)=1.59 *8*; α(Q)=0.00340 *15* B(E2)(W.u.)=3.0×10^2 *3*
149.9	4^+	(105.7[&] *7*)		44.2	2^+	[E2]	12.2 *5*	α(L)=8.9 *3*; α(M)=2.48 *9* α(N)=0.681 *24*; α(O)=0.161 *6*; α(P)=0.0256 *9*; α(Q)=9.5×10^{-5} *3* E_γ: 110.8γ was observed by 1987Mo29 but was considered questionable by the evalutor due to its indistinct peak and its close proximity to the Pu K-Xray line as shown in Fig.1 in 1987Mo29.
313.0	6^+	163.1[‡] *5*	100	149.9	4^+	[E2]	1.90 *4*	α(K)=0.189 *3*; α(L)=1.240 *25*; α(M)=0.346 *7* α(N)=0.0951 *19*; α(O)=0.0225 *5*; α(P)=0.00364 *7*; α(Q)=2.25×10^{-5} *4*
530.2	8^+	217.2[‡‡] *5*	100	313.0	6^+	[E2]	0.630 *11*	α(K)=0.1332 *20*; α(L)=0.361 *7*; α(M)=0.1001 *17* α(N)=0.0275 *5*; α(O)=0.00652 *12*; α(P)=0.001071 *19*; α(Q)=1.000×10^{-5} *16*
797.8	10^+	267.4[‡] *5*	100	530.2	8^+			
1111.4	12^+	313.5[‡] *5*	100	797.8	10^+			
1201.5	7^-	671.3 *5*		530.2	8^+			
1211.2	8^-	(10[&] *1*)		1201.5	7^-			
		681.0[@] *1*		530.2	8^+	[E1]	0.00802	α(K)=0.00649 *9*; α(L)=0.001158 *17*; α(M)=0.000277 *4* α(N)=7.50×10^{-5} *11*; α(O)=1.85×10^{-5} *3*; α(P)=3.44×10^{-6} *5*; α(Q)=2.07×10^{-7} *3*
1321.1	9^-	(110[&] *2*)		1211.2	8^-			
1390.5	9^-	189.0 *5*		1201.5	7^-			
		592.9 *5*		797.8	10^+			
		860.5 *5*		530.2	8^+			
1442.2	10^-	(121[&] *2*)		1321.1	9^-			
		231[#]		1211.2	8^-			
1466.7	14^+	355.1[‡] *5*		1111.4	12^+			
1575.1	11^-	133[#]		1442.2	10^-			
		254[#]		1321.1	9^-			
1623.3	11^-	233.1 *5*		1390.5	9^-			
		511.8 *5*		1111.4	12^+			
		825.4 *5*		797.8	10^+			

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Adopted Levels, Gammas (continued)

$\gamma(^{244}Pu)$ (continued)

E_i(level)	J_i^π	E_γ †	I_γ	E_f	J_f^π
1718.3	12⁻	143#		1575.1	11⁻
		276#		1442.2	10⁻
1859.2	16⁺	392.5‡ 5		1466.7	14⁺
1873.0	13⁻	155#	68 7	1718.3	12⁻
		298#	100 9	1575.1	11⁻
1898.9	13⁻	275.6 5		1623.3	11⁻
		432.1 5		1466.7	14⁺
		787.7 5		1111.4	12⁺
2037.7	14⁻	165#	65 8	1873.0	13⁻
		319#	100 9	1718.3	12⁻
2213.8	15⁻	176#	45 4	2037.7	14⁻
		341#	100 8	1873.0	13⁻
2214.9	15⁻	316.1 5		1898.9	13⁻
		355.9 5		1859.2	16⁺
		747.9 5		1466.7	14⁺
2284.5	18⁺	425.3‡ 5		1859.2	16⁺
2398.8	16⁻	185#	49 5	2213.8	15⁻
		361#	100 7	2037.7	14⁻
2567.8	17⁻	283.3 5		2284.5	18⁺
		353.1 5		2214.9	15⁻
		708.6 5		1859.2	16⁺
2594.8	17⁻	196#	41 5	2398.8	16⁻
		381#	100 11	2213.8	15⁻
2737.9	20⁺	453.4‡ 5		2284.5	18⁺

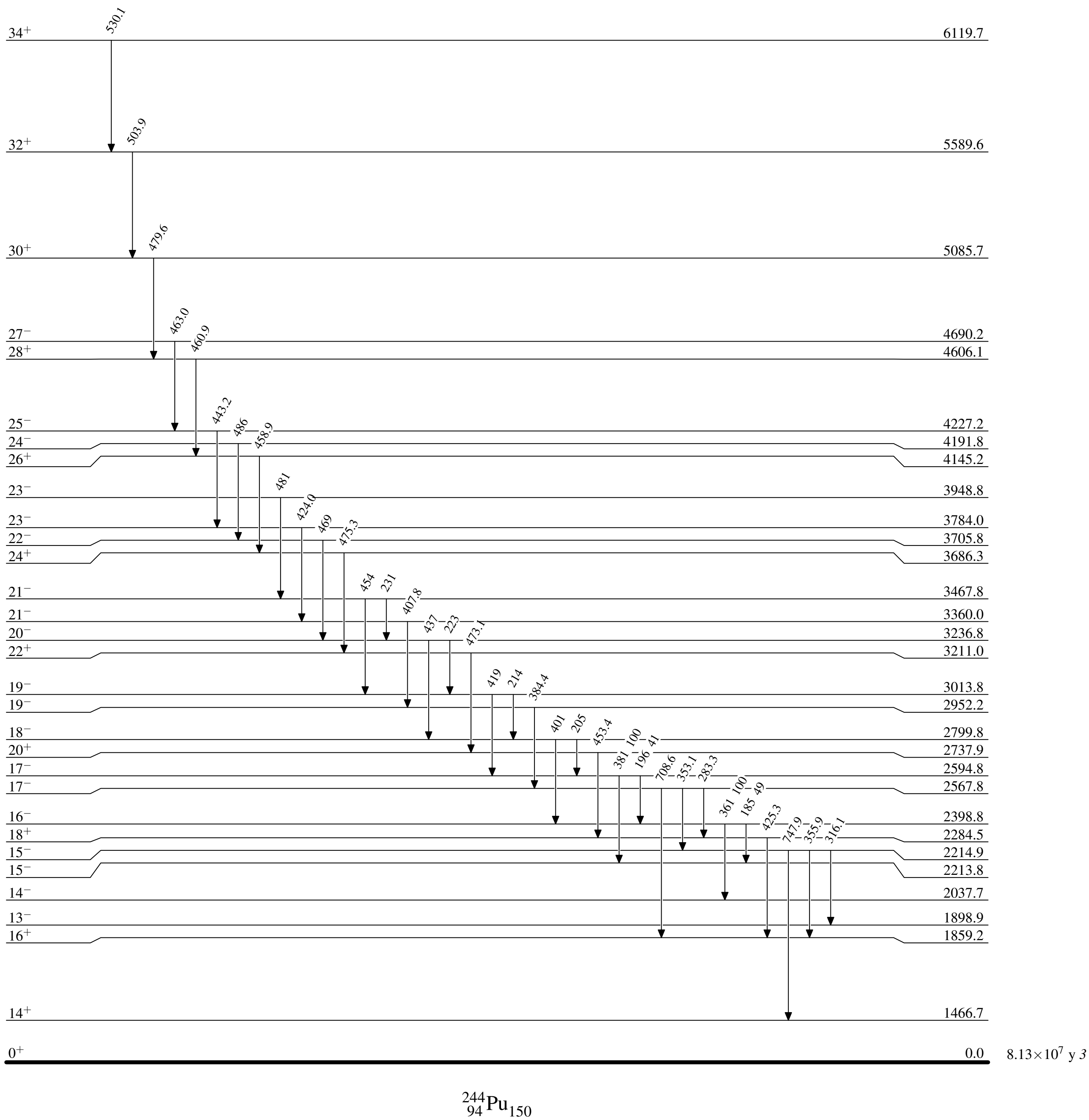
E_i(level)	J_i^π	E_γ †	E_f	J_f^π
2799.8	18⁻	205#	2594.8	17⁻
		401#	2398.8	16⁻
2952.2	19⁻	384.4 5	2567.8	17⁻
3013.8	19⁻	214#	2799.8	18⁻
		419#	2594.8	17⁻
3211.0	22⁺	473.1 5	2737.9	20⁺
3236.8	20⁻	223#	3013.8	19⁻
		437#	2799.8	18⁻
3360.0	21⁻	407.8 5	2952.2	19⁻
3467.8	21⁻	231#	3236.8	20⁻
		454#	3013.8	19⁻
3686.3	24⁺	475.3 5	3211.0	22⁺
3705.8	22⁻	469	3236.8	20⁻
3784.0	23⁻	424.0 8	3360.0	21⁻
3948.8	23⁻	481#	3467.8	21⁻
4145.2	26⁺	458.9‡ 5	3686.3	24⁺
4191.8	24⁻	486#	3705.8	22⁻
4227.2	25⁻	443.2 8	3784.0	23⁻
4606.1	28⁺	460.9 8	4145.2	26⁺
4690.2	27⁻	463.0 10	4227.2	25⁻
5085.7	30⁺	479.6 10	4606.1	28⁺
5589.6	32⁺	503.9 10	5085.7	30⁺
6119.7	34⁺	530.1	5589.6	32⁺

† From Coulomb Excitation (2016JaZZ, 1999Wi11), except as noted.
‡ From Coulomb Excitation that have also been measured by 1983Sp03.
# From $^{244}Pu(^{208}Pb,^{208}Pb'\gamma)$ deep inelastic data.
@ From ^{244}Np β- decay.
& Gamma has not been observed. Its energy is from level energy difference.
a Additional information 3.

Adopted Levels, Gammas

Level Scheme

Intensities: Relative photon branching from each level



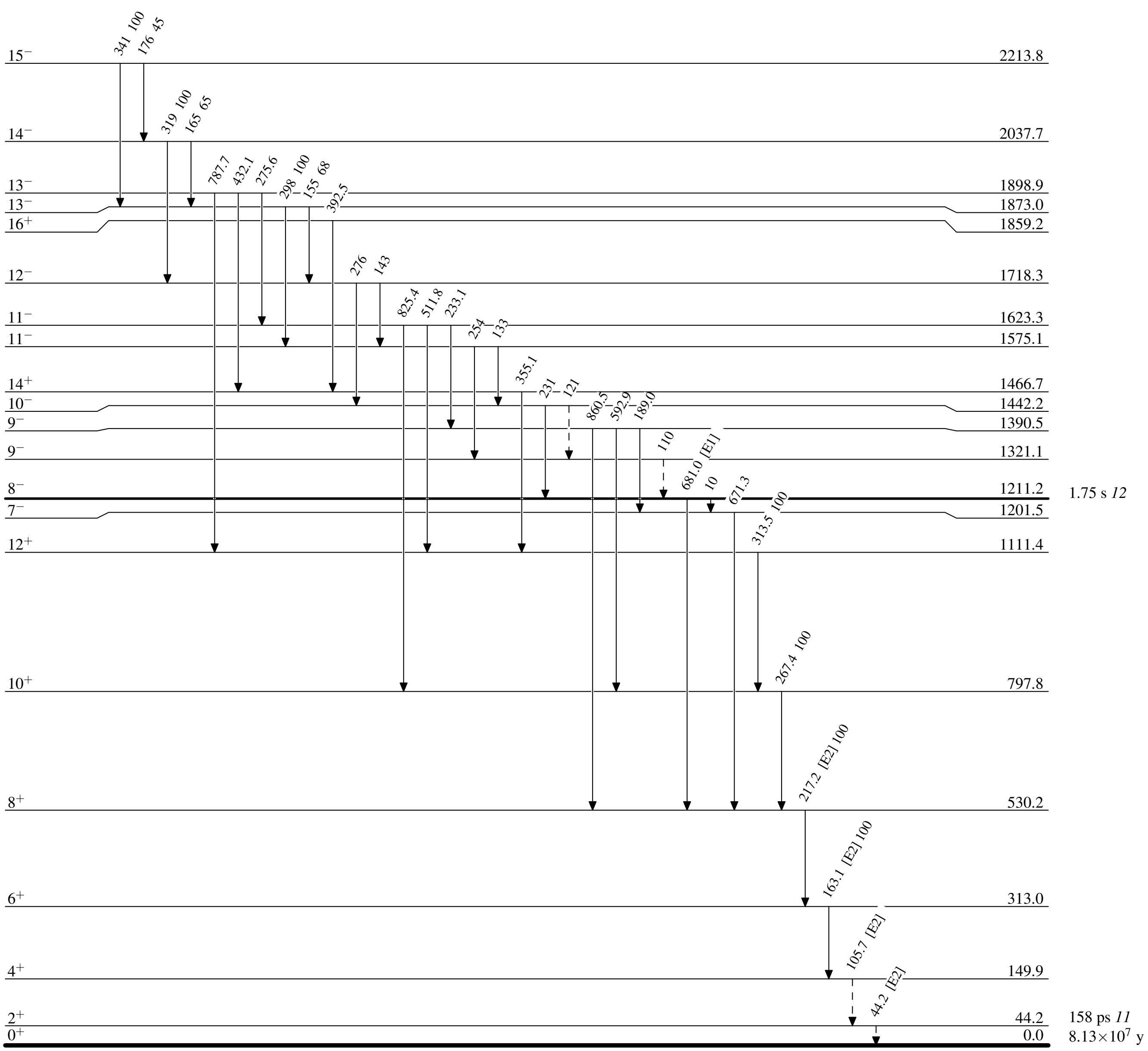
Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level

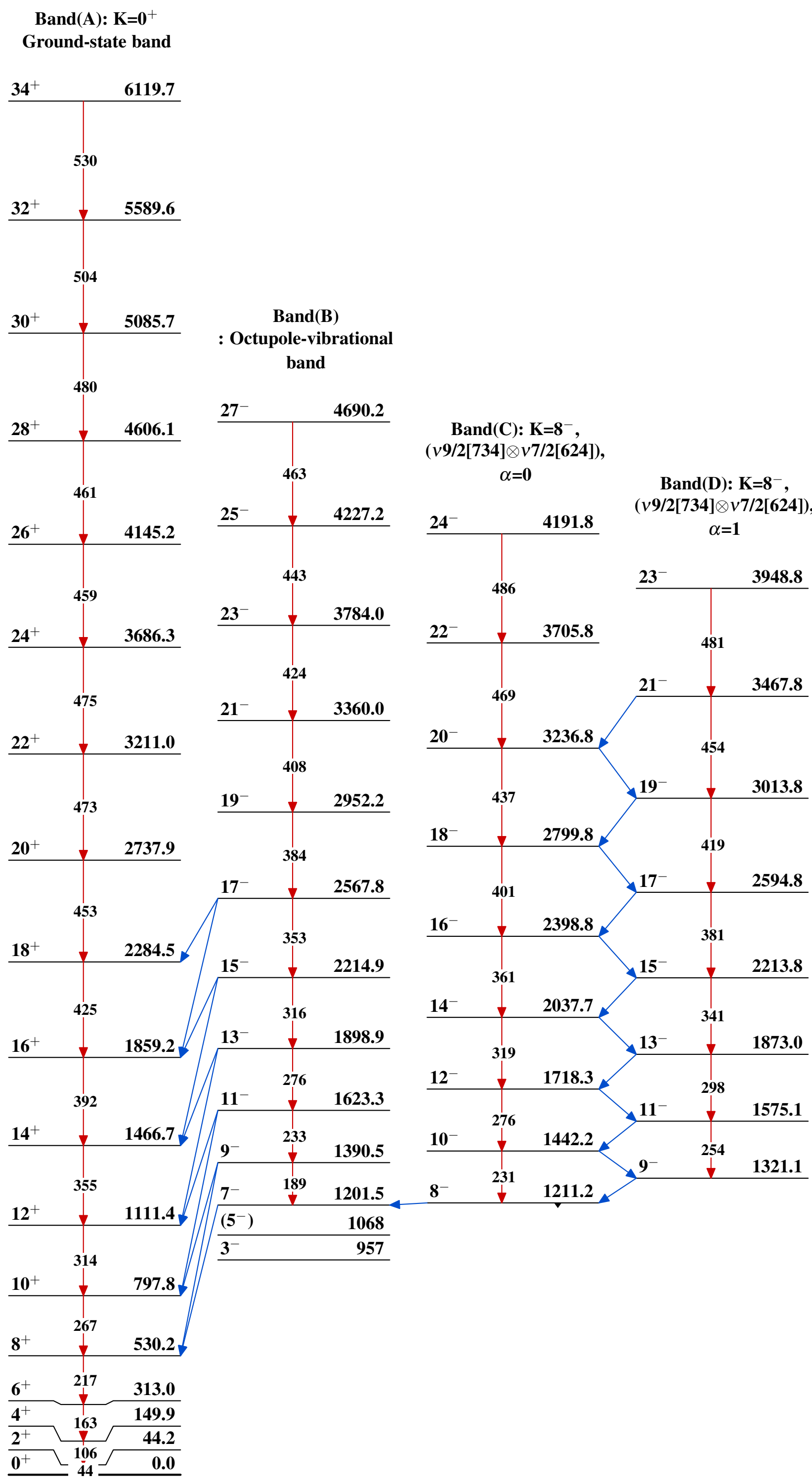
Legend

γ Decay (Uncertain)



$^{244}_{94}Pu_{150}$

Adopted Levels, Gammas



$^{244}_{94}Pu_{150}$