Adopted Levels, Gammas

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Y. Akovali	NDS 94,131 (2001)	1-Aug-2001

Q(β^-)=−2.06×10^3 *syst*; S(n)=6625.3 *17*; S(p)=5967.6 *22*; Q(α)=6128.44 *19* 2012Wa38
Note: Current evaluation has used the following Q record −2100 syst 6624.6 *23* 5966.2 *27* 6128.4419 1995Au04.

Theoretical studies:
1998Co23 calculated level energies of K=2$^+$ γ-band, K=0$^-$, K=1$^-$ and K=2$^-$ octupole-vibrational band; and B(E3; 0$^+$ to 3$^-$) strengths. The interacting boson approximation was utilized. See also 1990Co26 for analysis of level structure and octupole state fragmentation dependence on β(2) deformation.
See 1992So22 for the calculated B(E3) octupole strengths and energies of K,J^π=0,3$^-$ and 1,3$^-$ states.
Energies, B(EL) values and structures were calculated by 1991So15 for low-energy nonrotational states in the framework of a quasiparticle-phonon model. See also earlier calculations in 1976Iv04 and 1973Iv01, 1971Ko31, 1970Ne08, 1969Pa08, 1965So04.
Ground-state deformations were calculated by 1995Mo29 based on the finite-range droplet macroscopic model and the folded YUKAWA single-particle microscopic model. Their calculations yielded β(2)=0.245, β(4)=0.026, β(6)=−0.038.
The equilibrium deformations and the static electric moment were calculated by 1983Bo15 with use of dynamic model.
The quadrupole moment for various proton and neutron states were calculated by 1992Bh04 by using WOODS-Saxon and Nilsson models. The fermion dynamical symmetry and pseudo su(3) models were used also to calculate the B(E2; 0$^+$ to 2$^+$) values, and comparisons were made.
The static electric quadrupole and hexadecapole moments were calculated by 1978Ne13 by using Strunsky shell-correction method.
Properties of the γ-vibrational state was studied and B(E2) value was calculated by 1965Be40.
Systematics of E(first 2$^+$ levels) and B(E2; 0$^+$ to 2$^+$) were studied by 1993Sa05 as a function of N(n)N(p), products of valence proton and neutron numbers.
From a correlation plot of known B(E2; 2$^+$ to 0$^+$)′s with N(n)N(p), the products of valence proton and neutron numbers, 1995Za10 deduced a range for the hexadecapole deformation for ^{250}Cf as β(4)≈−0.05 to −0.10.
The average neutron and proton pairing gaps were calculated by 1988Ma04.
The energies of the ground-state band were calculated by 1988Ri07 by using the interacting boson model, and by 1978To13 by using the collective HAMILTONIAN with β-vibration plus rotation.
For calculation of partial α half-life, see, for example, 1997Mo25, 1979Po23, 1976Ra02.
Potential energy surface and shape of the fissioning nucleus were calculated by 1996Py02. Analysis were made by considering heavy-ion clustering. See 1976Iw02, 1971Sc03 also for calculations of potential energy surface for fission.
For calculations and systematics of $T_{1/2}$(SF), see, 1992Bh03, 1989St20, 1988Io03, 1978Po09.
For calculated fission barriers, see 1992Bh03, 1987Gu03, 1984Ku05, 1980Ku14, 1977Pr10, 1973Ba19, 1972Ma11.
Average total kinetic energy of fission fragments was calculated by 1995Ef04.
Yield for ^{40}S in spontaneous fission relative to yield for α decay was calculated by 1993Gr15.
Partial half-life for decay by pion emission was calculated by 1988Io02.
Emission probabilities for decay by heavy-ion were calculated by 1980Sa36.

^{250}Cf Levels

Cross Reference (XREF) Flags

A	^{254}Fm α decay	E	^{250}Cf(d,d′)
B	^{250}Bk β^- decay	F	^{249}Cf(d,p)
C	^{250}Es ε decay (2.22 h)	G	^{249}Bk(α,t)
D	^{250}Es ε decay (8.6 h)		

E(level)	J$^\pi$	$T_{1/2}$	XREF	Comments
0.0†	0$^+$	13.08 y *9*	ABCDE G	%α=99.923 *3*; %SF=0.077 *3* $T_{1/2}$: measurement of 1969Me01. Other measurement: 10.9 y *8* (1957Ea01). Branchings are from unweighted average of the measured α/SF=1330 *45* (1963Ph01), 1260 *40* (1965Me02).

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Adopted Levels, Gammas (continued)

^{250}Cf Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$	XREF	Comments
				Cross sections for α, t, and p emission following fission were measured by 1985Wi10. Cross sections of fission fragments in ^{238}U(^{12}C,F) were measured and effective moment of inertia at saddle point was deduced by 1990Li26. The angular distribution of fission fragments in ^{238}U(^{12}C,F) were measured by 1986Ka12 and 1985Ja14. Neutron multiplicity was measured by 1980Ho01 from fragment-neutron coincidences. Average number of neutron emitted in SF decay was measured by 1971Or03. Fission-fragment kinetic energy distribution was measured by 1973Ho02.
42.721[†] *5*	2$^+$	96 ps *10*	ABCDE G	T$_{1/2}$: calculated from B(E2)=16.0 *16*, deduced in (d,d′).
141.875[†] *10*	4$^+$		ABCDE G	
296.22[†] *6*	6$^+$		A DE G	
≈500[†]	8$^+$		G	J$^{\pi}$: energy fit to g.s. band.
871.57[‡] *3*	2$^-$		BCD G	J$^{\pi}$: E1 transition to 2$^+$ of g.s. band, no gammas to the 0$^+$ or 4$^+$.
905.89[‡] *2*	3$^-$		B DE G	B(E3)↑=20.2 *20* J$^{\pi}$: E1 transitions to 2$^+$, 4$^+$ levels.
951.98[‡] *2*	4$^-$		B D G	J$^{\pi}$: M1+E2 and E2 to 3$^-$ and 2$^-$ members of the K=2$^-$ band, respectively; E1 transition to 4$^+$ state.
1008.51[‡] *2*	5$^-$		DE G	J$^{\pi}$: M1+E2 and E2 transitions to 4$^-$ and 3$^-$ members of the band, respectively.
1031.852[#] *21*	2$^+$	0.94 ps *10*	BC E	J$^{\pi}$: E2 transition to 0$^+$ g.s. T$_{1/2}$: calculated from B(E2)=0.11 *1*, deduced in (d,d′), and adopted γ branchings from the level.
≈1070[‡]	(6$^-$)		G	J$^{\pi}$: energy fit to the 2$^-$ octupole-vibrational band.
1071.37[#] *2*	3$^+$		BCD	J$^{\pi}$: M1 transition from 2$^+$ state at 1658 keV; γ to 4$^-$.
1123[#] *1*	(4$^+$)		E	J$^{\pi}$: from (d,d′) data.
1154.24[@] *10*	0$^+$		BC	J$^{\pi}$: E0 transition to 0$^+$ g.s.
1175.52[&] *3*	1$^-$		BC E	J$^{\pi}$: E1 to 0$^+$ g.s.
1189.39[@] *3*	2$^+$		BC	J$^{\pi}$: E0+E2 transition to 2$^+$.
1209.97[a] *4*	(2)$^-$		BC F	J$^{\pi}$: E1 to 2$^+$; no 1210γ to g.s.; ε decay from 1$^{(-)}$ ^{250}Es suggests J^{π} Ne 3$^-$. Almost pure 2$^-$,(n 9/2[734]-n 5/2[622]) configuration was suggested in 1980Ah01. The ε decay transition from the 1$^-$,(n 7/2[633]-n 9/2[734]) ^{250}Es parent could Be via the p 7/2[633] to p 5/2[622] transition. The n 5/2[622] state is a hole state, close to the 9/2[734] state; some admixture of 1$^-$,(n 9/2[734]-n 5/2[622]) configuration in 2.22-h ^{250}Es can explain this ε transition. The decay from the 2$^-$,(p 3/2[521]+n 1/2[620]) ^{250}Bk g.s., however, is not consistent with a β transition to an almost pure 2$^-$,(n 9/2[734]-n 5/2[622]) state; this β branch requires configuration admixtures in ^{250}Bk g.s. or in this 1209.97-keV level, or both. The log *ft* of 9.30 for this 2$^-$ to 2$^-$ β transition and population of the same level in 1$^{(-)}$ ^{250}Es ε decay with a log *ft* oF 7.36 would only Be consistent with some admixture. Therefore, its structure should Be quite mixed, not almost pure two-neutron state as proposed. If the 1209.97 level is indeed a mixed state, the level at 1210 keV, seen in (α,t) reaction (which populates two proton states), could also Be the same level. Because of insufficient data, the level populated in (α,t) is listed here with the level seen in (d,d′) at 1211 keV.
1211[&] *1*	(3$^-$)		B E G	B(E3)↑=19.3 *19* J$^{\pi}$: from (d,d′); large B(E3) suggests octupole vibration.

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Adopted Levels, Gammas (continued)

^{250}Cf Levels (continued)

E(level)	Jπ	XREF	Comments
			The level observed in (α,t) is assumed to populate a two-proton component of this collective state. Population of this level in ^{250}Bk β^- decay is not established.
≈1218.2?		B	
1244.50 *8*	2^+	BC	Jπ: γ transitions to 0^+, 2^+, 4^+ states.
1247[a] *2*	(3^-)	E	Jπ: from (d,d′) data, 1980Ah01 suggested that this level is the 3^- member of a K=2 band, based at 1209.97 keV level.
1255.39[b] *4*	4^-	D FG	Jπ: M1+E2 transitions to 3^-, 5^- states.
1266.6[c] *2*	0^+	BC	Jπ: E0 to g.s. Configuration of (n 7/2[624],n 7/2[613]) was assigned by 1979Ah02.
1272 *2*		E	
1296.60[c] *4*	2^+	BC E	Jπ: 1253.84γ to 2^+ is E0+E2.
1311.00[b] *4*	5^-	D F	Jπ: 55.6γ to 4^- state is M1+E2; band parameter; (d,p) data.
1313[&] *2*	(5^-)	E	
1335 *2*	(3^-)	E	B(E3)↑=4.6 *5* Jπ: K,Jπ=0,3^- was tentatively assigned by 1980Ah01 from their (d,d′) work.
1377.76[b] *4*	6^-	D FG	Jπ: M1(+E2) transition to the 5^- member of the 4^- band; energy fit to band; (d,p) data.
1385.50 *10*	$1,2^+$	B	Jπ: γ′s to 0^+, 2^+ states.
1396.09[d] *7*	$(5)^-$	D FG	Jπ: M1 transitions to the 4^-, 5^- levels; (α,t) and (d,p) reactions.
1411.33 *6*	$(1,2^+)$	B	Jπ: 1368.62γ to 2^+ state; 1411.6γ probably goes to 0^+ g.s.
1426.86[g] *12*	(3^-)	B E	B(E3)↑=13.3 *13* Jπ: from (d,d′). Large B(E3) suggests octupole vibration.
1457.76[d] *4*	$(6)^-$	D FG	Jπ: 146.9 and 80.00 M1 transitions to the 5^- and $(6)^-$ states of 4^- band; band parameter.
1478.37[e] *4*	$(5)^-$	D FG	Jπ: M1 transitions to 4^-, $(5)^-$ states; (d,p), (α,t) data.
1499.53[f] *4*	$(6)^-$	D F	Jπ: M1 transitions to $(5)^-$, $(6)^-$ states; (d,p) data.
≈1530[d]	(7^-)	FG	Jπ: (d,p) and (α,t) data.
1541[g] *2*	(5^-)	E	
≈1550[e]	(6^-)	FG	Jπ: (d,p) data.
1570 *2*		E	
≈1575[f]	(7^-)	F	Jπ: (d,p) data.
≈1600	(6^-)	F	K=6, two-neutron state was assigned by 1976Ya02.
1626 *3*		E	
1658.00[h] *4*	2^+	BC	Jπ: E2 to g.s. From the absence of any 0^+ and 1^+ levels in the vicinity of this level, 1980Ah03 suggested K=2 for this state.
1695.15[h] *10*	(3^+)	B	Jπ: γ′s to 2^+, 4^+; β feeding from 2^- ^{250}Bk. The tentative assignment of this level to K=2 rotational band is based on its energy difference with the 1658-keV level.
1735 *2*		E	
1915 *3*		E	
2015 *3*		E	

† Band(A): K=0^+ g.s. band. Spin and parities of band members are based on multipolarities of intraband transitions, α hindrance factors, and on energy fit to the rotational band.

‡ Band(B): K=2^- octupole-vibrational band. Assignment of levels to this band was based on the multipolarities of intraband transitions, and on level spacings. The large (d,d′) cross section in population of the 3^- member suggests octupole-vibrational state. The band was populated in (α,t) reaction through its two-proton component, (p 3/2[521],p 7/2[633]), and it was not seen in (d,p).

\# Band(C): K=2^+ γ-vibrational band.

@ Band(D): K=0^+ band 1980Ah01 pointed out that similar energies of the first 0^+ states in ^{248}Cm (at 1084 keV) and in ^{250}Cf (1154 keV) may suggest predominantly neutron configurations for them, and that neutron pair vibration character was deduced by 1977Fl06 for the 1084-keV level in ^{248}Cm from (t,p) reaction.

& Band(E): K=1^- octupole-vibrational band. 1980Ah01 suggested that the major components of this band are probably the (n

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Adopted Levels, Gammas (continued)

^{250}Cf Levels (continued)

9/2[734], n 7/2[613]) and (n 9/2[734], n 7/2[624]) configurations, and that the Coriolis interaction with the K=2$^-$ band at 1209.97 would take place through the n 7/2[613] state of this band and the n 5/2[622] state of the K=2$^-$ band. See 1980Ah01 for further discussions.

[a] Band(F): K=2−? band.

[b] Band(G): K=4$^-$ band. The two-neutron structure,4$^-$, (n 9/2[734],n 1/2[620]), was proposed by 1976Ya02 from (d,p) data. See 1976Ya02 for a discussion on Coriolis interaction with the K=5$^-$ bands.

[c] Band(H): K=0$^+$ band.

[d] Band(I): K=5$^-$ band. (p 3/2[521],p 7/2[633]) + (n 9/2[734],n 1/2[620]) structure was deduced by 1976Ya02 from observation of this band in (d,p) reaction. This admixture explain also the strong γ transitions to the K=4$^-$ (n 9/2[734],n 1/2[620]) band and gammas from the K=5$^-$ (n 9/2[734],n 1/2[620]) band.

[e] Band(J): K=5$^-$ (n 9/2[734],n 1/2[620]) band. See also the note for K=5$^-$ (p 3/2[521],p 7/2[633]) band.

[f] Band(K): K=6$^-$ (n 9/2[734],n 3/2[622]) band.

[g] Band(L): K=3?

[h] Band(M): K=2$^+$ band?

γ(^{250}Cf)

E_i(level)	J_i^π	E_γ†	I_γ‡	E_f	J_f^π	Mult.†	δ	α#	Comments
42.721	2+	42.721 *5*		0.0	0+	E2		1293	B(E2)(W.u.)=3.4×10^2 *4*
141.875	4+	99.160 *10*		42.721	2+	E2		23.8	
296.22	6+	154.35 *6*		141.875	4+	E2		3.33	
871.57	2−	828.81 *3*		42.721	2+	E1		0.00657	
905.89	3−	34.325 *5*	1.3 *2*	871.57	2−	M1+E2	0.42 *5*	7.4×10^2 *11*	
		764.2 *1*	78 *4*	141.875	4+	E1		0.00758	
		863.2 *1*	100 *6*	42.721	2+	E1		0.00613	
951.98	4−	46.093 *5*	2.1 *3*	905.89	3−	M1+E2	0.40 *2*	200 *10*	
		80.412 *10*	3.2 *4*	871.57	2−	E2		63.3	
		810.2 *1*	100 *6*	141.875	4+	E1		0.00684	
1008.51	5−	56.527 *13*	6.7 *8*	951.98	4−	M1+E2	0.37 *+20−10*	80 *40*	
		102.623 *10*	15.7 *23*	905.89	3−	E2		20.28	
		712.3 *1*	100 *7*	296.22	6+	[E1]		0.00859	
		866.7 *1*	97 *8*	141.875	4+	[E1]		0.00608	
1031.852	2+	126.01 *3*	0.0140 *12*	905.89	3−	[E1]		0.0834	B(E1)(W.u.)=6.8×10^{-6} *10*
		160.26 *4*	0.063 *4*	871.57	2−	[E1]		0.1859	B(E1)(W.u.)=1.50×10^{-5} *19*
		889.956 *22*	3.40 *5*	141.875	4+	[E2]		0.01961	B(E2)(W.u.)=0.211 *23*
		989.125 *21*	100	42.721	2+	E2		0.01603	B(E2)(W.u.)=3.7 *4*
		1031.852 *21*	79.1 *12*	0.0	0+	E2		0.01480	B(E2)(W.u.)=2.3 *3*
1071.37	3+	119.4 *3*	0.014 *5*	951.98	4−	[E1]		0.0956	
		165.44 *15*	0.028 *4*	905.89	3−	[E1]		0.1726	
		199.72 *20*	0.022 *3*	871.57	2−	[E1]		0.1127	
		929.468 *22*	25.1 *4*	141.875	4+	[E2]		0.0180	
		1028.654 *25*	100 *3*	42.721	2+	(E2)		0.0148 *9*	
1154.24	0+	1111.50 *10*	100	42.721	2+	[E2]		0.0129	
		1154.3 *2*		0.0	0+	E0			$I_{(\gamma+ce)}$: Iγ(1111.5γ)/total Ice(1154.3 transition)=2.5 *5*.
1175.52	1−	303.95 *20*	11.9 *14*	871.57	2−	[M1,E2]		1.0 *8*	
		1132.80 *3*	100 *6*	42.721	2+	[E1]		0.00385	
		1175.5 *2*	200 *20*	0.0	0+	E1		0.00362	
1189.39	2+	1047.51 *6*	18.0 *13*	141.875	4+	[E2]		0.0144	
		1146.67 *3*	100 *5*	42.721	2+	E0+E2		0.10 *3*	
1209.97	(2)−	1167.25@ *4*		42.721	2+	E1		0.00366	If the 1209.97 level belongs to K=2 band, the 1167.25γ is a K-forbidden transition.
1211	(3−)	1068.27& *17*		141.875	4+				Existence of this transition is not certain.
		1167.25@& *4*		42.721	2+				
≈1218.2?		≈1175.5&		42.721	2+				
1244.50	2+	1103.0 *3*	7.2 *24*	141.875	4+	[E2]		0.01306	
		1201.79 *4*	100 *6*	42.721	2+	[M1,E2]		0.027 *16*	
		1244.42 *8*	25 *3*	0.0	0+	[E2]		0.01045	

$^{250}_{98}$Cf$_{152}$-5

$\gamma(^{250}Cf)$ (continued)

E_i(level)	J^{π}_i	E_{γ}†	I_{γ}‡	E_f	J^{π}_f	Mult.†	δ	α#	$I_{(\gamma+ce)}$	Comments
1255.39	4⁻	184.2 *2*	2.1 *4*	1071.37	3⁺	[E1]		0.1352		
		246.92 *6*	17.0 *9*	1008.51	5⁻	M1+E2	1.00 *6*	1.86 *9*		
		303.41 *3*	100 *5*	951.98	4⁻	M1+E2	0.92 *7*	1.09 *10*		
		349.4 *1*	91 *5*	905.89	3⁻	E2+M1	4.6 *5*	0.223 *12*		
		383.7 *1*	63 *4*	871.57	2⁻	E2		0.135		
1266.6	0⁺	1223.8 *2*		42.721	2⁺	[E2]		0.0108	101 *10*	
		1266.6 *2*		0.0	0⁺	E0				Total Ice(1266.6 transition)/Iγ(1223.8γ)=188 *10*/100 *10*.
1296.60	2⁺	1154.77 *3*	100 *5*	141.875	4⁺	[E2]		0.0120		
		1253.82 *7*	23.3 *19*	42.721	2⁺	E0+E2			177 *43*	
		1296.54 *13*	9.4 *13*	0.0	0⁺	[E2]		0.00969		
1311.00	5⁻	55.602 *5*		1255.39	4⁻	M1+E2	0.59 *5*	133 *9*		
1377.76	6⁻	66.759 *10*		1311.00	5⁻	M1(+E2)	≤0.5	37 *7*		
1385.50	1,2⁺	1342.87 *8*	93 *7*	42.721	2⁺					
		1385.42 *6*	100 *7*	0.0	0⁺					
1396.09	(5)⁻	85.086 *7*	22.8 *20*	1311.00	5⁻	M1(+E2)	≤0.27	15.4 *16*		
		140.694 *10*	100 *7*	1255.39	4⁻	M1(+E2)	<0.1	15.6		
1411.33	(1,2⁺)	1368.61 *6*	100 *8*	42.721	2⁺					
		1411.6& *4*	19 *5*	0.0	0⁺					
1426.86	(3⁻)	555.22& *10*		871.57	2⁻					
1457.76	(6)⁻	61.667 *5*	100 *9*	1396.09	(5)⁻	M1+E2	0.20 *3*	45.1 *16*		
		80.00 *3*	13 *4*	1377.76	6⁻	M1(+E2)	<0.3	18.7 *11*		
		146.9 *1*	26 *8*	1311.00	5⁻	M1(+E2)	<0.6	13.0 *18*		
1478.37	(5)⁻	82.282 *6*	100 *8*	1396.09	(5)⁻	M1(+E2)	<0.06	16.33 *11*		
		222.993 *20*	71 *5*	1255.39	4⁻	M1+E2	0.42 *7*	3.71 *15*		
1499.53	(6)⁻	41.775 *5*	41 *4*	1457.76	(6)⁻	M1(+E2)	0.14 *+7−14*	144 *30*		
		103.440 *10*	100 *9*	1396.09	(5)⁻	M1(+E2)	0.25 *+15−10*	9.1 *9*		
1658.00	2⁺	586.43 *7*	14 *2*	1071.37	3⁺	M1(+E2)		0.24 *1*		
		626.11 *4*	54 *6*	1031.852	2⁺	M1(+E2)		0.24 *1*		
		786.26 *14*	11 *2*	871.57	2⁻	[E1]		0.00721		
		1516.22 *7*	2.6 *2*	141.875	4⁺	[E2]		0.00727		
		1615.29 *4*	100 *5*	42.721	2⁺	E2		0.00498		
		1658.00 *4*	59 *3*	0.0	0⁺	E2				
1695.15	(3⁺)	1553.37 *18*	55 *14*	141.875	4⁺					
		1652.40 *10*	100 *9*	42.721	2⁺					

† From ^{250}Bk β^- decay and 8.6-h, 2.22-h ^{250}Es ε decays.

‡ Relative intensities deexciting each level, adopted from ^{250}Bk β^- and ^{250}Es ε decays.

Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned

$\gamma(^{250}Cf)$ (continued)

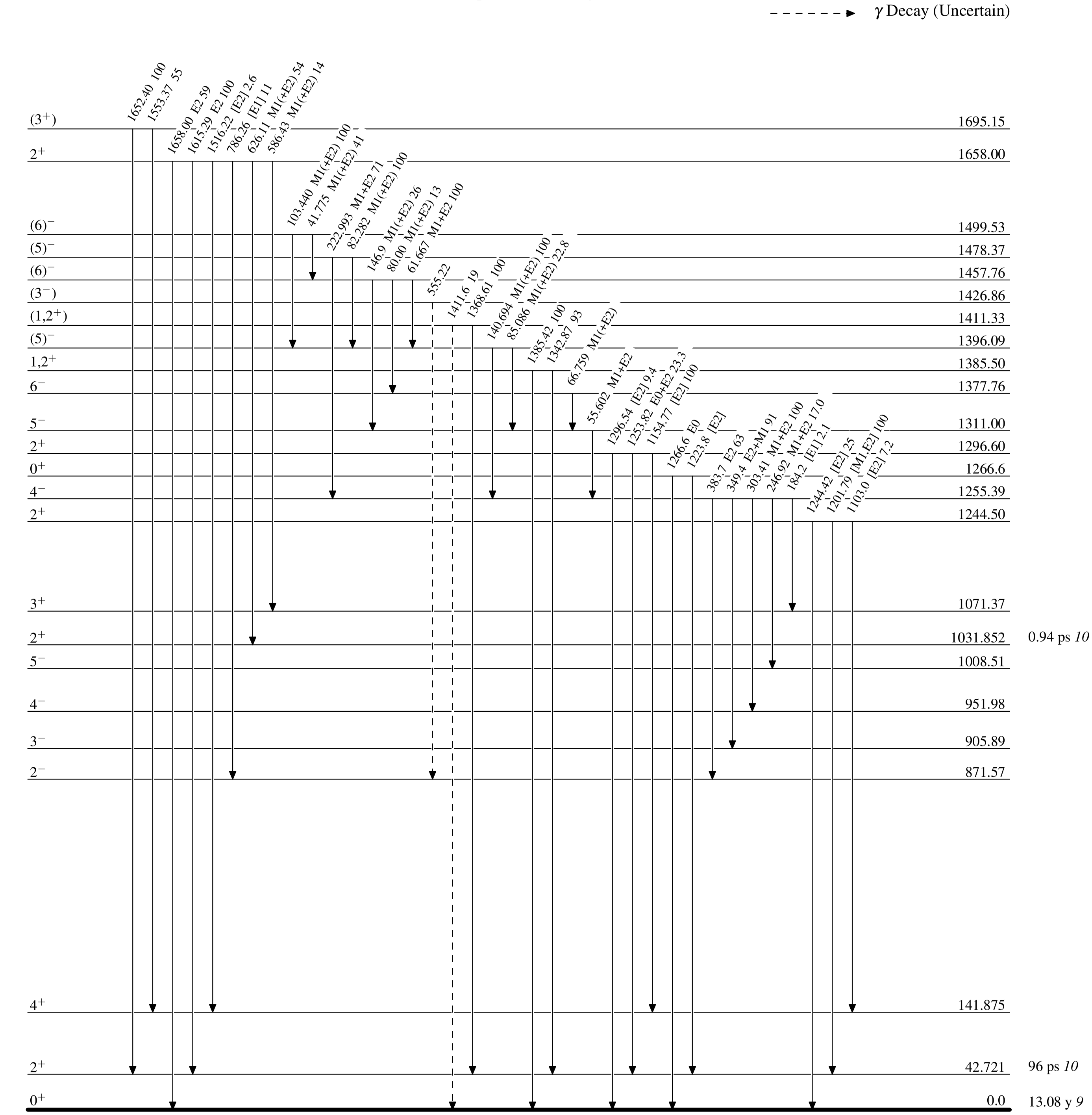
multipolarities, and mixing ratios, unless otherwise specified.
@ Multiply placed.
& Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Legend

Level Scheme

Intensities: Relative photon branching from each level



$^{250}_{98}Cf_{152}$

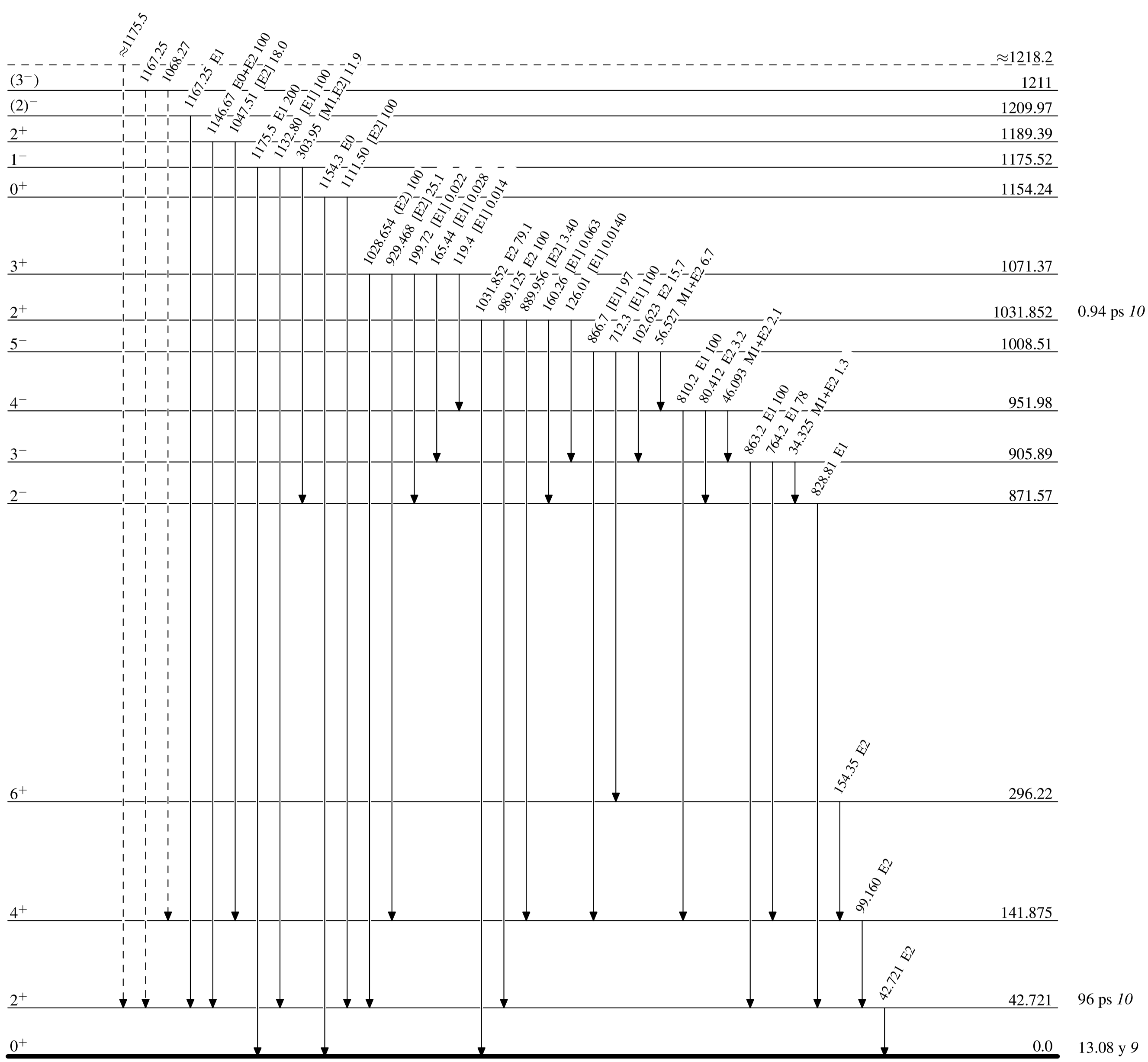
Adopted Levels, Gammas

Legend

Level Scheme (continued)

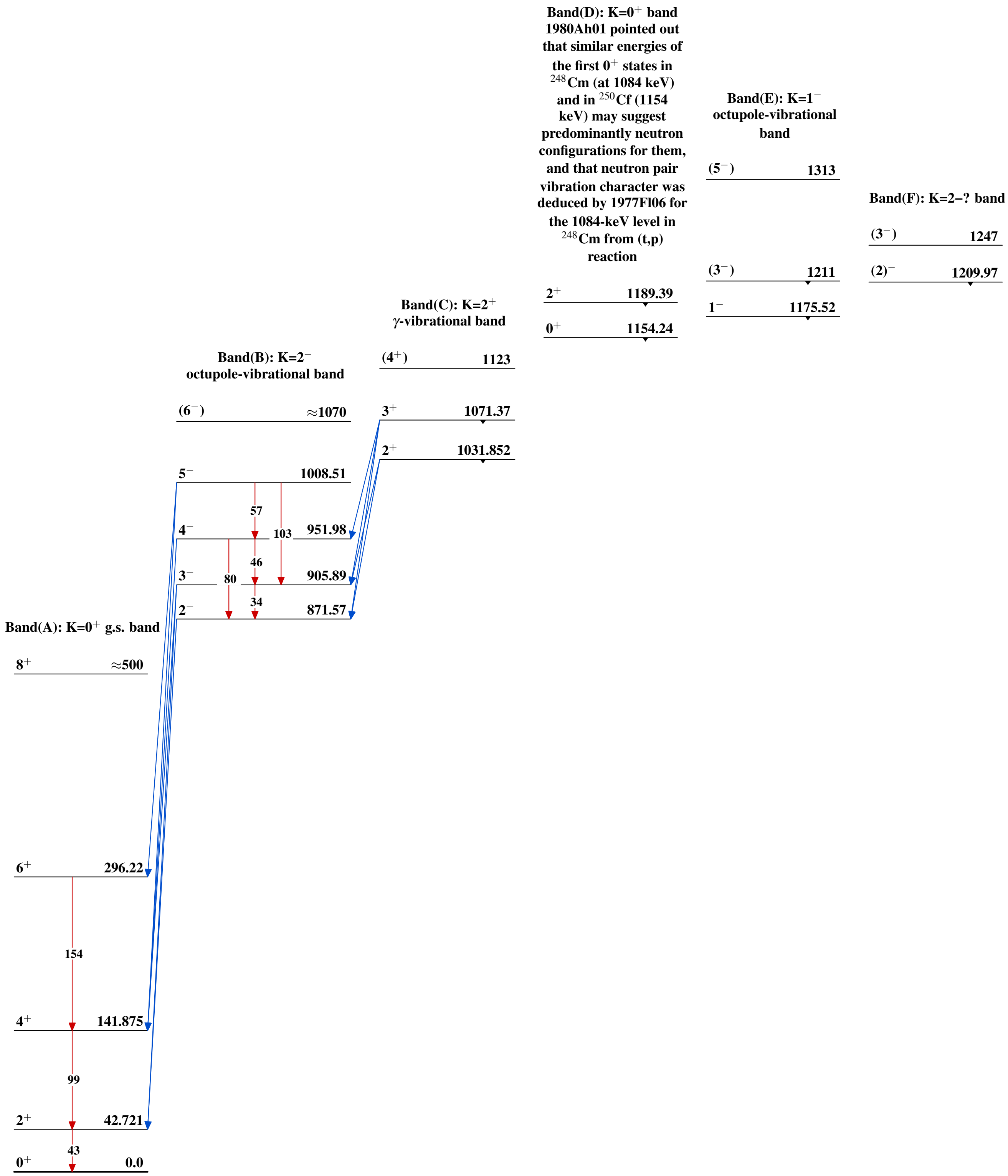
Intensities: Relative photon branching from each level

- - - - - ▸ γ Decay (Uncertain)



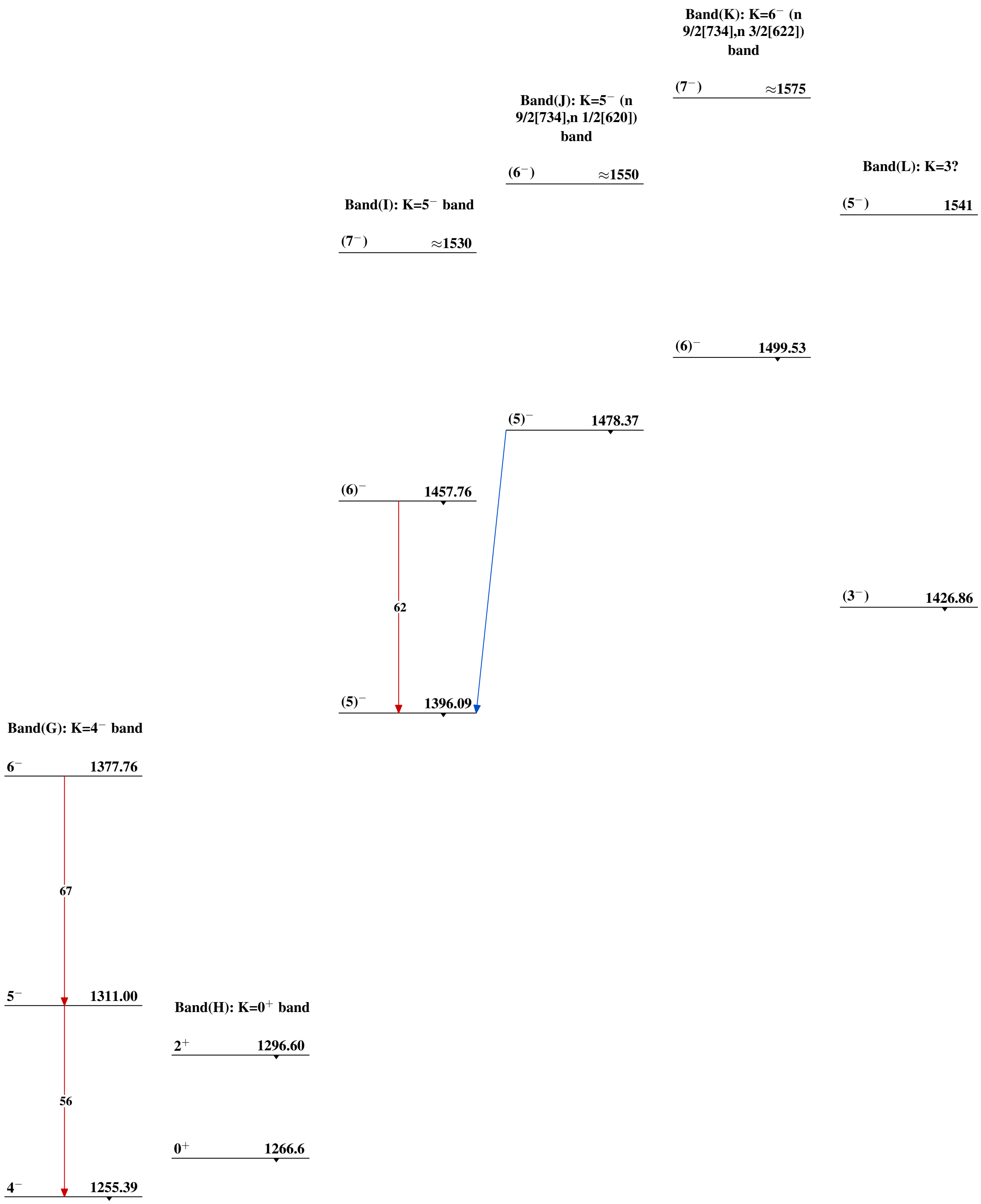
$^{250}_{98}Cf_{152}$

Adopted Levels, Gammas



$^{250}_{98}Cf_{152}$

Adopted Levels, Gammas (continued)



$^{250}_{98}Cf_{152}$

Adopted Levels, Gammas (continued)

Band(M): K=2^+ band?

$^{250}_{98}Cf_{152}$