Adopted Levels, Gammas

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	C. W. Reich	NDS 113, 2537 (2012)	1-Mar-2012

Q(β^-)=2452 *3*; S(n)=6336 *3*; S(p)=7181 *4*; Q(α)=−1.25×10^3 *3* 2017Wa10
S(2n)=14487 *3*; S(2p)=1.615×10^4 *4* 2017Wa10
Additional information 1.

Data are primarily from the ^{153}Eu(3n,γ) studies (1991Ba06). Several of the same levels are observed in the β^- decay of ^{156}Sm (1966Ha26 and others), and three levels reported from the ^{154}Eu(t,p) reaction.

Some model and theory calculations of possible interest:

1988Fr16: Survey of the properties of K=0 bands in strongly deformed nuclides.

1989HoZI: Empirical study of Newby energy shifts.

1990Af03: Interpretation of the level schemes of the Eu isotopes in terms of octupole deformation.

1992No04: Discussion of the ^{156}Eu level scheme. Authors conclude that there is no evidence for parity doublets and, hence, for octupole deformation.

1994No15: Thorough discussion of the residual p-n interaction in odd-odd nuclei.

1998Ja07: An excellent survey of nuclear-structure data for the odd-odd nuclides in the region from α=144 through α=194.

Considerable discussion of the level structure of the odd-odd Eu isotopes in terms of reflection asymmetry (e.g., octupole deformation) has appeared in the literature. 1990Af03 have interpreted the data on ^{153}Eu through ^{156}Eu in terms of octupole deformation, deducing values of the octupole-deformation parameter, β_3. In their capture gamma-ray study, 1991Ba06 interpret some of the bands as being parity doublets. From Δ<r^2> data for Eu isotopes from α=151 through α=159, however, 1990AlZK conclude that, while octupole deformation is likely present in ^{152}Eu and ^{154}Eu, it is not present in ^{156}Eu. In their review of the odd-odd nuclides, 1998Ja07 state that present theoretical results are not consistent with octupole deformation in ^{156}Eu. In the present evaluation, the evaluator has not used the ideas of reflection asymmetry to describe the ^{156}Eu levels.

^{156}Eu Levels

1991Ba06 rely heavily on those two-quasiparticle states expected to be among the lowest-lying in ^{156}Eu to assign configurations to the proposed bandheads.

From model calculations, 1991Ba06 give the computed mixing of configurations for each level. Some of the significant mixtures are noted for the associated bands or levels.

Additional information 2.

Cross Reference (XREF) Flags

A	^{153}Eu(3n,γ)
B	^{156}Sm β^- decay
C	^{154}Eu(t,p)

E(level)†	J$^\pi$	T$_{1/2}$‡	XREF	Comments
0.0#	0$^+$	15.19 d *8*	AB	%β^-=100 J$^\pi$: From atomic-beam, magnetic resonance (1981Ek03). The data would also be consistent with J≠0 if μ were negligibly small. π=+, from log *ft*=5.95 to 1$^+$, 22.6 level and mult=M1 for the γ from it to the g.s. Other: from $\gamma(\theta)$ following β^- decay of oriented ^{156}Eu nuclei, 1981Ch07 deduce J=1. T$_{1/2}$: Weighted average of 15.18 d *10* (1964Da08), 15.21 d *24* (1965CaZZ), 15.11 d *5* (1966Da19), 15.17 d *3* (1971Ba28), and 15.95 d *12* (1972Em01). Δ<r^2>(^{156}Eu−^{151}Eu)=0.72 fm^2 *4*, from collinear LASER spectroscopy (1985Al06 and, from the same group, 1986Al33). For λ, which is≈ Δ<r^2>, 1990Al34 report λ(^{156}Eu)-λ(^{151}Eu)=0.693 fm^2 *7*, from resonance ionization spectroscopy. From their compilation of optical isotope-shift data, 1987Au06 report λ(^{156}Eu)-λ(^{151}Eu)=0.63 fm^2

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{156}Eu Levels (continued)

E(level)[†]	J^π	$T_{1/2}$[‡]	XREF	Comments
				4. From an evaluation of data on nuclear rms charge radii, 2004An14 report $<r^2>^{1/2}$=5.124 fm *32*.
22.5176[#] *5*	1^+		AB	J^π: M1 to 0^+ g.s.
47.6728[#] *7*	2^+		AB	J^π: (M1) to 1^+ and expected band structure.
87.4897[@] *3*	1^-	12.0 ns *3*	AB	J^π: E1 to 0^+ g.s.
103.5942[#] *8*	3^+		A	J^π: M1 to 2^+ and expected band structure.
125.4568[@] *7*	2^-		AB	J^π: M1 to 1^-, E1 to 1^+ and expected band structure.
145.6816[&] *11*	5^+		A	J^π: E2 to 3^+ and the expected presence of this state at low energy in the level scheme (1991Ba06). The g.s. is the other coupling of these two Nilsson orbitals.
149.6725[a] *16*	5^-		A	J^π: E1 from 4^+, M1 from 5^- and the expected presence of this state (1991Ba06). The other coupling of these two orbitals is assigned to the $K^\pi=0^-$ bandhead at 217 keV.
159.7111[#] *12*	4^+		A	J^π: M1 to 3^+ and expected band structure.
175.1500[b] *10*	4^+		A	J^π: M1 to 3^+, E2 to 5^+ and the expected presence of this state (1991Ba06). The other coupling of these two Nilsson orbitals is assigned to the 1^+ bandhead at 291 keV (1991Ba06).
184.1966[@] *8*	3^-		A	J^π: M1 to 2^-, E1 to 2^+ and the expected band structure.
214.9306[c] *10*	4^-		A	J^π: E1 to 4^+ and the expected presence of the state with this configuration. The other coupling of these two Nilsson orbitals is assigned (1991Ba06) to the $K^\pi=1^-$ bandhead at 87 keV.
217.7761[d] *15*	0^-		A	J^π: E1 to 1^+ and expected band structure.
250.1646[#] *19*	5^+		A	J^π: M1 to 4^+ and expected band structure.
258.1440[@] *12*	4^-		A	J^π: E1 to 3^+ and expected band structure.
260.1834[e] *14*	4^+		A	J^π: M1 to 5^+, E1 from 3^-.
266.947[d] *3*	1^-		AB	J^π: E1 to 2^+, γ to 0^+ g.s.
268.7468[d] *11*	2^-		A	J^π: E1 γ's to 1^+ and 3^+.
268.7478?[b] *15*	5^+		A	J^π: M1 to 4^+ and expected band structure.
291.3037[f] *20*	1^+	≤0.2 ns	AB	J^π: log *ft*=5.30 from $J^\pi=0^+$ (^{156}Sm g.s.).
313.0984[c] *16*	5^-		A	J^π: E1 to 5^+ and expected band structure.
324.6951[f] *11*	2^+		A	J^π: E1 γ's to 1^- and 3^-.
343.3202[d] *19*	3^-		A	J^π: E1 γ's to 2^+ and 4^+.
353.4406[h] *11*	3^-		A	J^π: E1 to 4^+ and the expected presence of this two-quasiparticle state.
368.5352[g] *19*	(5^-)		A	J^π: E1 to 4^+, M1 to 5^- and the expected presence of the state with this configuration. This state may be mixed with the 5^- member of the $K^\pi=4^-$ band at 214.9 keV (1991Ba06).
375.3660[f] *20*	3^+		A	J^π: E1 γ's to 2^- and 4^-.
386.3223[d] *22*	4^-		A	J^π: E1 γ's to 3^+ and 5^+.
434.2302[i] *19*	3^-		A C	XREF: C(448). J^π: L=0 in (t,p) on a $J^\pi=3^-$ target.
435.5835[h] *20*	4^-		A	J^π: E1 to 4^+ and expected band structure.
441.635[f] *7*	4^+		A	J^π: E1 to 3^- and expected band structure.
513.2906 *28*	1^-		A	Assigned as a member of a $K^\pi=0^-$ band by 1991Ba06 (in ^{153}Eu(3n,γ)). See the discussion of this point in the ^{153}Eu(3n,γ) data set. J^π: M1 γ's to 0^- and 2^- levels.
524[i] *15*	(4^-)		C	E(level): From 1984La06, (t,p). J^π: Possible member of the $K^\pi=3^-$ band at 434.2 keV.
675 *16*			C	E(level): From 1984La06, (t,p).

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{156}Eu Levels (continued)

† From the ^{153}Eu(3n,γ) data, except two values from the ^{154}Eu(t,p) reaction.

‡ For excited states, from ^{156}Sm decay (1968An09).

Band(A): $K^\pi=0^+$ g.s. band. configuration=π5/2[413]-ν5/2[642]. For the even-spin members, α=7.93 keV, β=+2.86 eV. For the odd-spin members, α=8.09 keV, β=+1.26 eV. The energies of the odd-spin members are shifted upward from where they would be expected to be in a "normal" band by≈6.5 keV (related to the Newby shift).

@ Band(B): $K^\pi=1^-$ band. configuration=π5/2[413]-ν3/2[521]. α=9.66 keV, β=−4.6 eV, A_2=+69 eV.

& Band(C): $K^\pi=5^+$ bandhead. configuration=π5/2[413]+ν5/2[642].

[a] Band(D): $K^\pi=5^-$ bandhead. configuration=π5/2[532]+ν5/2[642].

[b] Band(E): $K^\pi=4^+$ band. configuration=π5/2[532]+ν3/2[521]. α=9.36 keV.

[c] Band(F): $K^\pi=4^-$ band. configuration=π5/2[413]+ν3/2[521]. α=9.82 keV.

[d] Band(G): $K^\pi=0^-$ band. configuration=π5/2[532]-ν5/2[642].

[e] Band(H): $K^\pi=4^+$ bandhead. configuration=π3/2[411]+ν5/2[642].

[f] Band(I): $K^\pi=1^+$ band. configuration=π5/2[532]-ν3/2[521]. α=8.39 keV, A_2=+19.5 eV. To explain the relatively low log *ft* value of the β^- transition to the bandhead, 1991Ba06 propose that there is an admixture of the configuration π7/2[523]-ν 5/2[523] in this band.

[g] Band(J): $K^\pi=5^-$ band. configuration=π5/2[413]+ν5/2[523]. 1991Ba06 propose that there is am admixture of the 5^- member of the $K^\pi=4^-$ band having configuration=π5/2[413]+ν3/2[521].

[h] Band(K): $K^\pi=3^-$ band. configuration=π3/2[411]+ν3/2[521]. α=10.27 keV.

[i] Band(L): $K^\pi=3^-$ band. configuration=π5/2[413]-ν11/2[505]. 1991Ba06 propose some admixture of the configuration π3/2[411]+ν3/2[521] in order to account for the γ decay of the band members.

Adopted Levels, Gammas (continued)

$\gamma(^{156}Eu)$

E_i(level)	J^{π}_i	E_γ[†]	I_γ[‡]	E_f	J^{π}_f	Mult.[#@]	α[&]	$I_{(\gamma+ce)}$	Comments
22.5176	1^+	22.525 *6*	100	0.0	0^+	M1	22.6		
47.6728	2^+	25.1550 *5*	100	22.5176	1^+	(M1)	16.31		
87.4897	1^-	39.7805[a] *4*	<6	47.6728	2^+	[E1]	0.606		I_γ: Most of the intensity of this doublet is placed elsewhere in the level scheme (see the discussion in the ^{153}Eu(3n,γ) data set).
		64.9725 *4*	7.8 *9*	22.5176	1^+	E1	0.900		B(E1)(W.u.)=4.28×10^{-6} *+42−15* B(E1)(W.u.): The range of values includes the uncertainty regarding the contribution of the 39 γ to the decay of this level.
		87.4897 *3*	100 *3*	0.0	0^+	E1	0.407		B(E1)(W.u.)=1.83×10^{-5} *+17−6* B(E1)(W.u.): The range of values includes the uncertainty regarding the contribution of the 39 γ to the decay of this level.
103.5942	3^+	55.9208 *6*	100	47.6728	2^+	M1	9.88		
125.4568	2^-	37.9681 *7*	100 *8*	87.4897	1^-	M1	4.82		
		102.9361 *15*	46 *11*	22.5176	1^+	E1	0.262		
145.6816	5^+	42.0879 *8*	100	103.5942	3^+	E2	76.6		
149.6725	5^-	(3.99)		145.6816	5^+	[E1]			E_γ: Computed from level energies. Placement deduced to explain decay of 149 level (1991Ba06).
159.7111	4^+	56.1179 *20*	100 *13*	103.5942	3^+	M1	9.78		
		112.0381 *13*	14.6 *18*	47.6728	2^+	[E2]	1.607		Mult.: Mult=M1,E2 from ce data, but placement requires E2.
175.1500	4^+	29.478 *5*		145.6816	5^+	E2	444	1.58×10^2 *4*	
		71.5555 *5*	100 *7*	103.5942	3^+	M1	4.84		
		127.478 *3*	9.4 *20*	47.6728	2^+	[E2]	1.015		Mult.: Mult=M1,E2 from ce data, but placement requires E2.
184.1966	3^-	58.7402 *6*	100 *8*	125.4568	2^-	M1	8.58		
		136.5234 *29*	26 *7*	47.6728	2^+	E1	0.1222		
214.9306	4^-	39.7805[a] *4*	100	175.1500	4^+	E1	0.606		
217.7761	0^-	195.2586 *15*	100	22.5176	1^+	E1	0.0467		
250.1646	5^+	90.4564 *18*	100 *16*	159.7111	4^+	M1	2.46		
		146.563 *4*	17 *4*	103.5942	3^+	E2	0.622		
258.1440	4^-	73.9501 *14*	100 *8*	184.1966	3^-	M1	4.40		
		132.6885 *23*	17 *4*	125.4568	2^-	E2	0.881		
		154.5454 *20*	69 *9*	103.5942	3^+	E1	0.0874		
260.1834	4^+	85.0345 *15*	18 *3*	175.1500	4^+	M1	2.94		
		110.5106 *8*	100 *3*	149.6725	5^-	E1	0.217		
		114.5018 *16*	14.8 *17*	145.6816	5^+	M1	1.253		
266.947	1^-	219.277 *3*	100 *7*	47.6728	2^+	E1	0.0344		
		266.937 *6*	38 *7*	0.0	0^+				
268.7468	2^-	165.1527 *7*	40 *3*	103.5942	3^+	E1	0.0734		
		246.223 *4*	100 *10*	22.5176	1^+	E1	0.0254		
268.7478?	5^+	93.5972[b] *12*	100	175.1500	4^+	M1	2.23		
291.3037	1^+	165.8452 *24*	60 *10*	125.4568	2^-	E1	0.0723		B(E1)(W.u.)≥7.4×10^{-5}
		203.818 *3*	100 *80*	87.4897	1^-	E1	0.0417		B(E1)(W.u.)≥6.7×10^{-5}

Adopted Levels, Gammas (continued)

$\gamma(^{156}Eu)$ (continued)

E_i(level)	J^π_i	E_γ[†]	I_γ[‡]	E_f	J^π_f	Mult.[#@]	α[&]	Comments
291.3037	1+	244.0 8	10 4	47.6728	2+	[M1,E2]	0.132 21	
		268.5 8	11 4	22.5176	1+	[M1,E2]	0.100 18	
		291.0 8	13 5	0.0	0+	[M1]	0.0954 15	B(M1)(W.u.)≥2.8×10^{-4}
313.0984	5−	137.9447 29	54 6	175.1500	4+			
		167.4175 13	100 18	145.6816	5+	E1	0.0705	
324.6951	2+	140.4983 8	33 5	184.1966	3−	E1	0.1130	
		237.218 6	100 15	87.4897	1−	E1	0.0280	
		302.177 7	19.8 19	22.5176	1+	M1	0.0863	
343.3202	3−	183.6048 23	39 4	159.7111	4+	E1	0.0550	
		295.6528 26	100 11	47.6728	2+	E1	0.0158 9	
353.4406	3−	138.5097 5	38.9 17	214.9306	4−	M1	0.731	
		178.2918 11	100 8	175.1500	4+	E1	0.0595	
368.5352	(5−)	99.7855 20	50 12	268.7478?	5+			
		193.3852 26	88 13	175.1500	4+	E1	0.0479	
		218.885 7	100 15	149.6725	5−	M1	0.205	
375.3660	3+	117.2242 20	15 3	258.1440	4−	E1	0.185	
		191.177 13	5.0 9	184.1966	3−			
		249.900 4	100 19	125.4568	2−	E1	0.0244	
386.3223	4−	43.0076 8	45 6	343.3202	3−			I_γ: If this placement is correct, the intensity is too large (1991Ba06).
		136.1584 13	16.1 24	250.1646	5+	E1	0.1231	
		282.717 5	100 11	103.5942	3+	E1	0.0178	
434.2302	3−	80.7893 28	74 16	353.4406	3−	M1	3.41	
		174.0466 19	100 13	260.1834	4+	E1	0.0635	
		259.082 5	52 10	175.1500	4+	E1	0.0223	
435.5835	4−	82.1396 28	24 5	353.4406	3−			
		220.6563 24	100 11	214.9306	4−	M1	0.201	
		260.425 7	75 9	175.1500	4+	E1	0.0220	
441.635	4+	257.438 7	100	184.1966	3−	E1	0.0226	
513.2906	1−	244.540 3	97 19	268.7468	2−	M1	0.1521	
		295.517 6	100 8	217.7761	0−	M1	0.0915	
		387.863 12	28 4	125.4568	2−	E2	0.0270	
		425.808 9	90 8	87.4897	1−	M1	0.0352	

[†] From the ^{153}Eu(3n,γ) data. Other: ^{156}Sm β^- decay.

[‡] From the ^{153}Eu(3n,γ) data, unless otherwise noted. Other: ^{156}Sm β^- decay.

[#] From ce data from ^{153}Eu(3n,γ) data primarily and ^{156}Sm β^- decay.

[@] Additional information 3.

[&] 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.

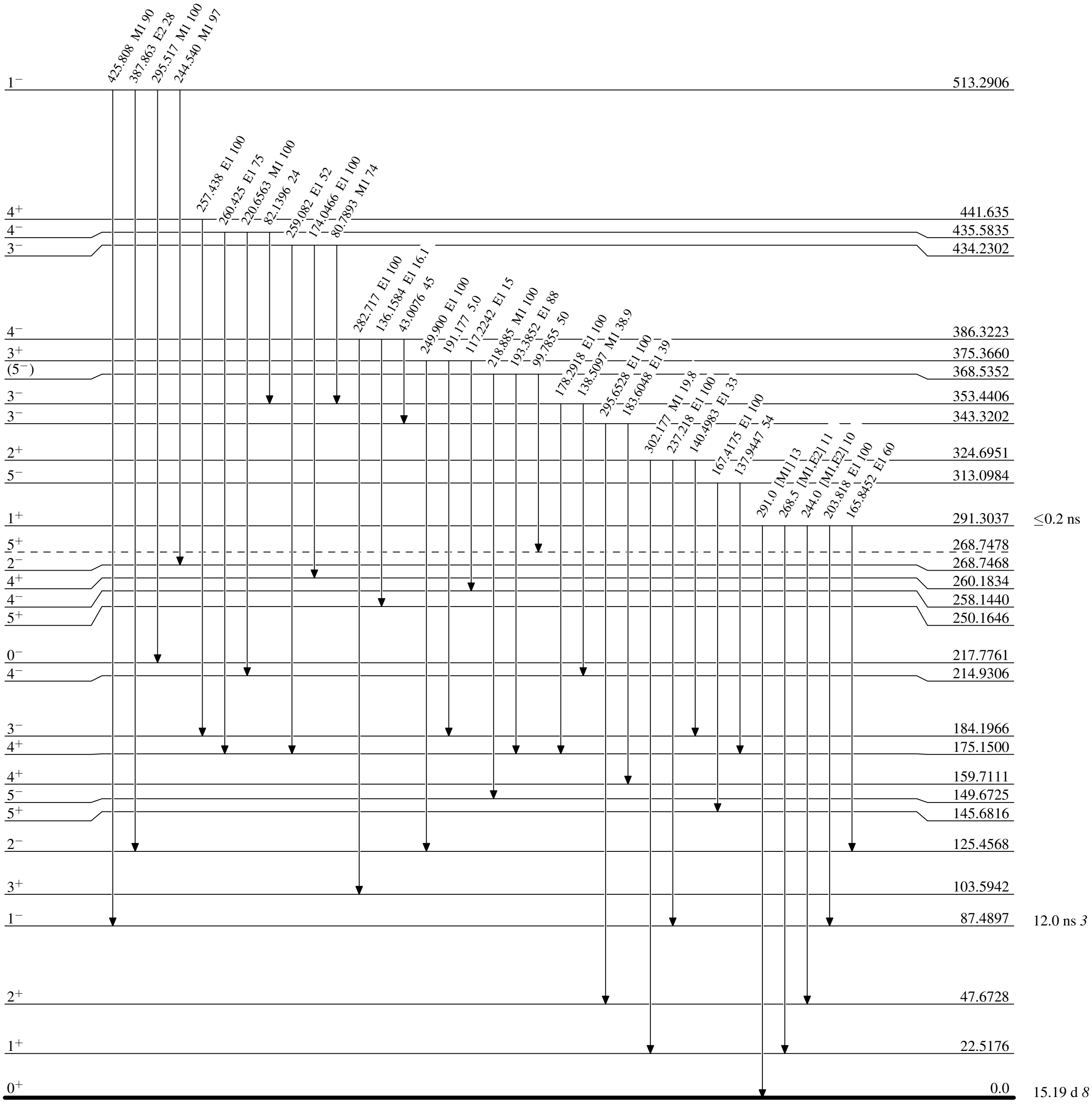
[a] Multiply placed.

[b] Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Level Scheme

Intensities: Relative photon branching from each level

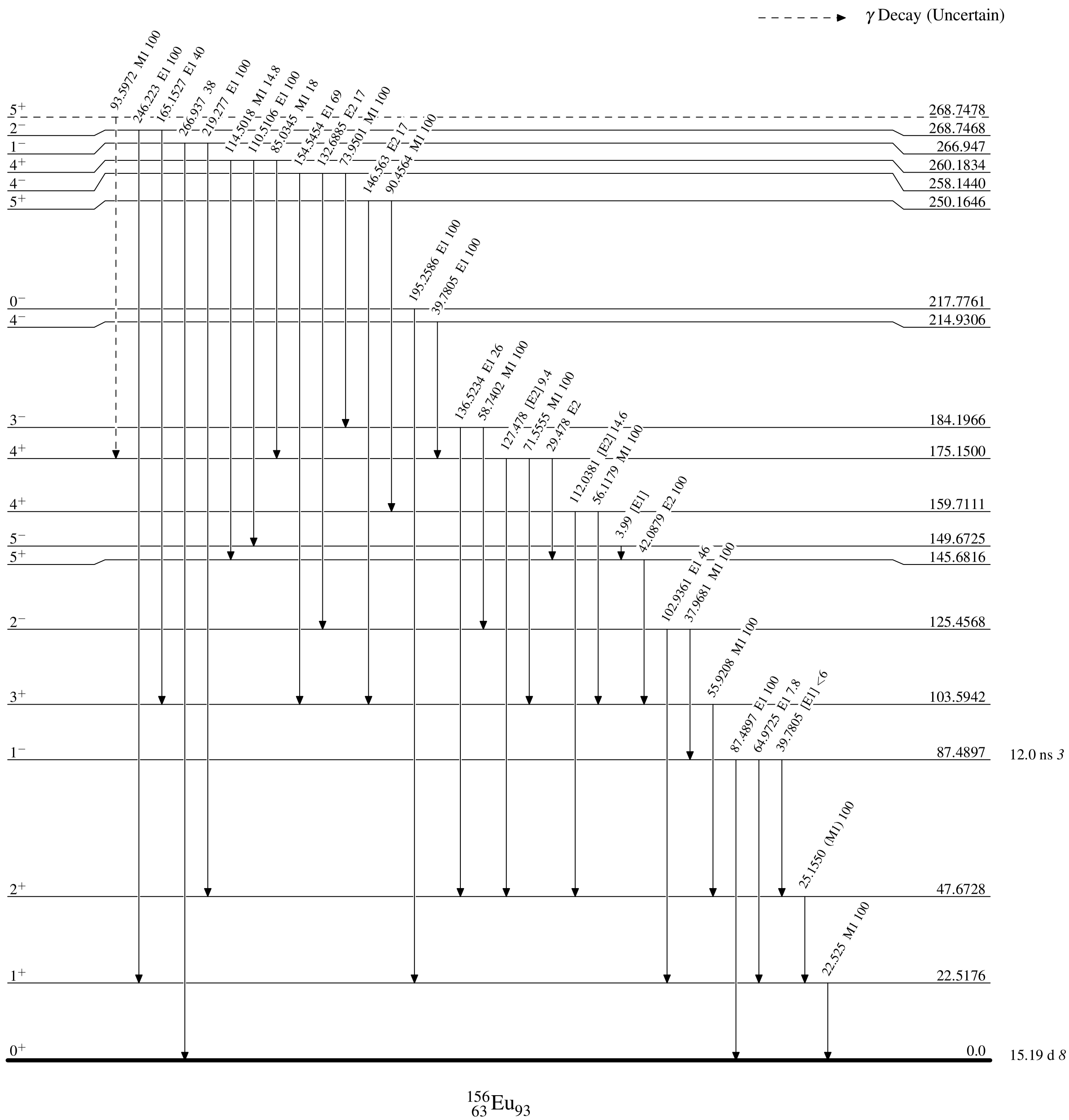


$^{156}_{63}Eu_{93}$

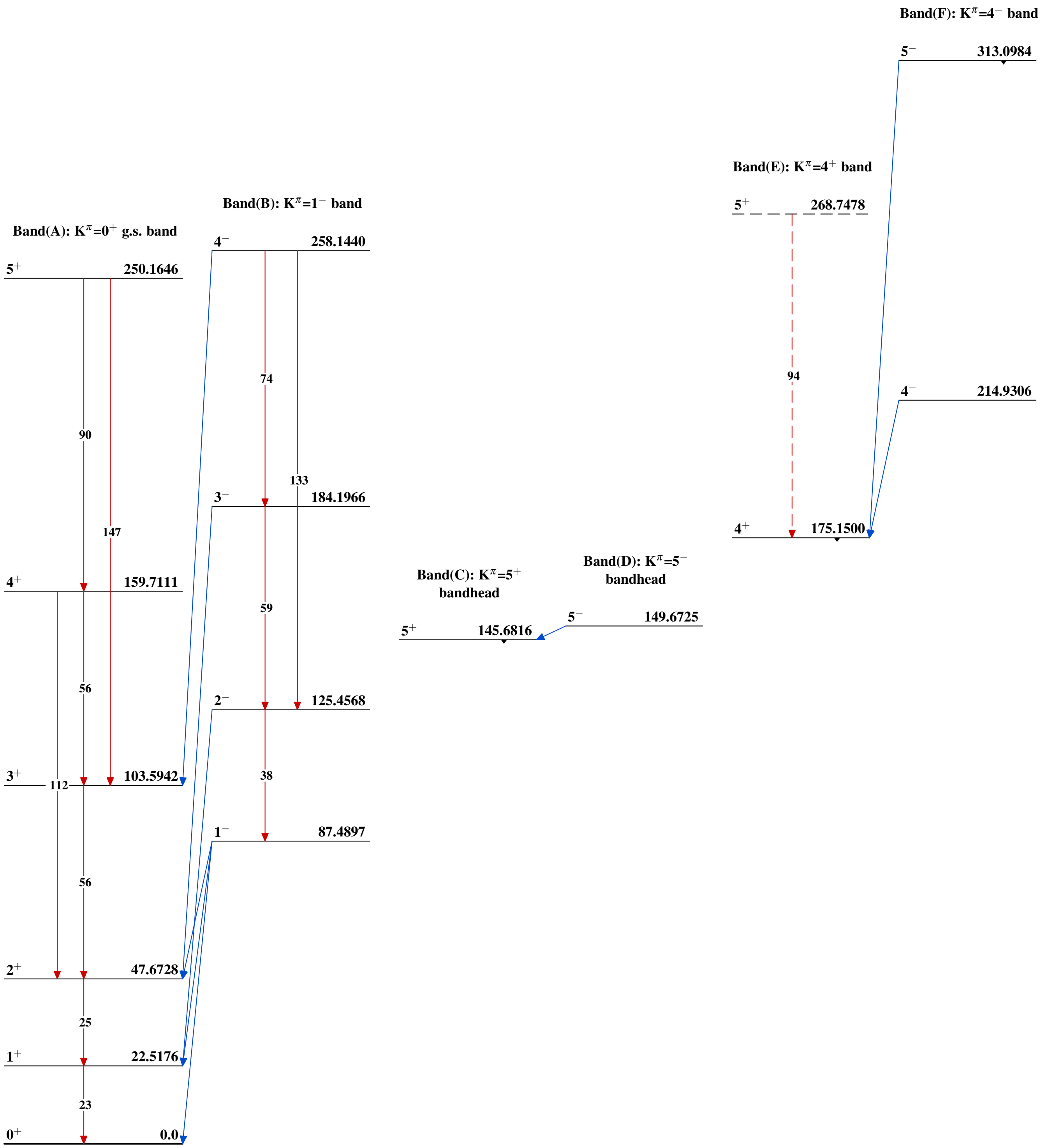
Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level

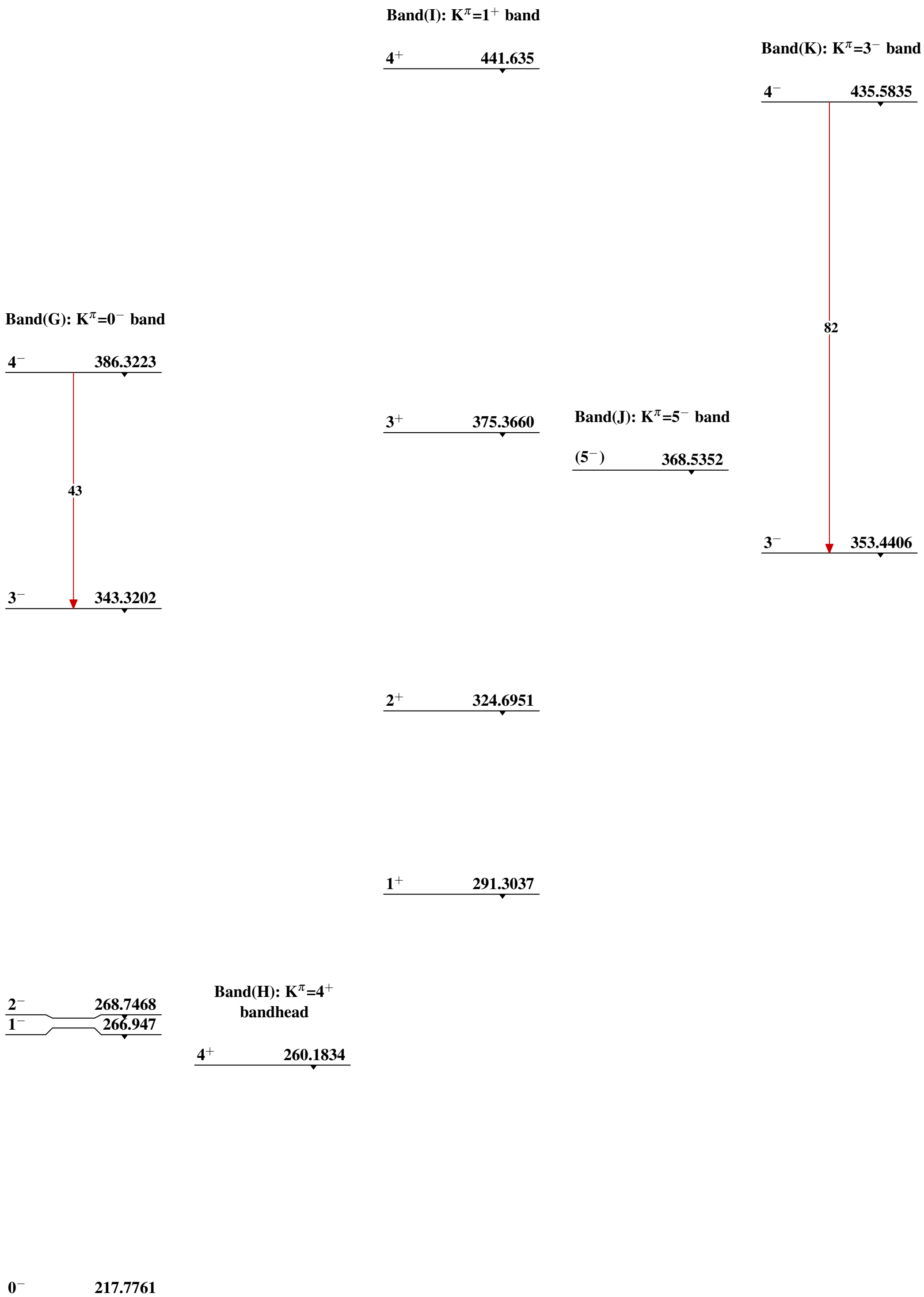


Adopted Levels, Gammas



$^{156}_{63}Eu_{93}$

Adopted Levels, Gammas (continued)



$^{156}_{63}Eu_{93}$

Adopted Levels, Gammas (continued)

$^{156}_{63}Eu_{93}$