Adopted Levels, Gammas

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh, Sukhjeet Singh	ENSDF	08-Mar-2022

Q(β^-)=239 *10*; S(n)=5662 *8*; S(p)=4288 *4*; Q(α)=6326.9 *7* 2021Wa16
S(2n)=12530 *6*, S(2p)=10722 *8* (2021Wa16).
^{224}Ac identified and produced by 1948Gh01 in Th(d,X) at 80 MeV, with an estimated half-life of ≈2.5 h. Later studies of ^{224}Ac decay: 1951Me10, 1958Hi78, 1968Le17, 1976MiZR, 1987Mi10, 1992Li31.

Theoretical calculations: 24 references extracted from the NSR database are listed in document records.
Additional information 1.
All data are from ^{228}Pa α decay.
In this evaluation, the level scheme is essentially that proposed by 1994Ah03 with some modifications suggested in 2004Sh25. The band structures are taken essentially from 2004Sh25, but considered tentative at this stage. As pointed out in 1994Ah03 and 2004Sh25, the level scheme of ^{224}Ac is very complex and many additional levels are expected. Thus the level scheme presented here is considered as incomplete. Information about confirmed multipolarities, mixing ratios and other spectroscopic details is lacking. Further experiments on the decay of ^{228}Pa, and involving nuclear reactions are needed to confirm and elucidate the structure of this nucleus.
2004Sh25 suggest five other bands, not listed here, for which only one or two levels each are known.

^{224}Ac Levels

Cross Reference (XREF) Flags

A ^{228}Pa α decay (19.5 h)

E(level)	J$^\pi$[†]	$T_{1/2}$	XREF	Comments
0[‡]	(0$^-$)	2.78 h *16*	A	%ε=90.9 *+14−20*; %α=9.1 *+20−14* (1951Me10) %ε,%α: from ε/α=10 *2* (1951Me10). %β^-: No β^- branch observed; %β^-<1.6 from log *ft*>5.9 expected for a 0$^-$ to 0$^+$ ^{224}Th g.s. β^- transition. J$^\pi$: log *ft*=5.9 (1976MiZR) to 1$^-$ level in ^{224}Ra suggest probable allowed β^- transition; large hindrance factors (or non-observation) of α transitions to levels in ^{220}Fr which are connected by γ transitions implying change of one or two units of spin between these levels; possible K^π=0$^-$ bandhead of an octupole band. See also several arguments given in previous Nuclear Data Sheets evaluation (1986Ma45; same arguments in 1997Ar05) where J^π=0$^-$ was assigned. Based on theoretical considerations 1988Sh01 deduce J^π=0$^-$ or 3$^-$ for 3/2 proton and 3/2 neutron coupling with octupole deformation, and 2$^+$ or (2$^-$) with quadrupole deformation only. $T_{1/2}$: weighted average of 2.55 h *28* (1987Mi10) and 2.9 h *2* (1951Me10; their previous value ≈2.5 h reported in 1948Gh01).
17.60[‡] *15*	(1$^-$)		A	
23.40 *11*	(2$^-$)		A	
29.83[#] *9*	(1$^+$)		A	J$^\pi$: E1 γ to (0$^-$).
34.2? *8*			A	
37.17[‡] *9*	(2$^-$)		A	
44.2? *3*			A	
45.8? *4*	(−)		A	
47.4? *4*			A	
49.08 *13*	(3$^-$)		A	
52.20[#] *11*	(2$^+$)		A	
64.47 *14*	(3$^+$)		A	
65.2? *6*			A	

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Adopted Levels, Gammas (continued)

^{224}Ac Levels (continued)

E(level)	J^{π}[†]	XREF	Comments
75.9? *6*		A	
78.51[‡] *12*	(3^-)	A	A 48.6γ is omitted here due to unlikely M2 multipolarity implied from assigned J^{π} values.
80.49[#] *10*	(3^+)	A	
84.1? *4*		A	
90.56 *13*	($^+$)	A	
92.6? *4*		A	
100.44? *23*		A	
103.31 *13*	(4^+)	A	
105.1? *6*		A	
109.33 *17*	(4^-)	A	
110.53 *15*	($^+$)	A	
116.46[‡] *13*	(4^-)	A	
130.30[#] *11*	(4^+)	A	
133.4? *4*		A	
142.5 *3*	(5^+)	A	
146.6 *4*		A	E(level): this level may be the same as 142.4 level, but the energy matching is poor.
159.3 *4*		A	
169 *2*		A	
176.72[#] *14*	(5^+)	A	
183.40[‡] *13*	(5^-)	A	
212 *2*		A	
219.7 *4*		A	
236.5[‡] *4*	(6^-)	A	
252.68[#] *17*	(6^+)	A	
283.48 *13*	(3^-)	A	
300 *2*		A	
317.2 *5*		A	
333.04 *12*	(3^+)	A	
353.89[@] *11*	(3^-)	A	
360.25[&] *11*	(3^+)	A	
380.80 *16*	($^+$)	A	
395.84[@] *19*	(4^-)	A	
402.92[&] *16*	(4^+)	A	
448.08[@] *20*	(5^-)	A	
452.1[&] *4*	(5^+)	A	

[†] Assignments are mainly from 2004Sh25 based on interpretation of parity-doublets (reflection asymmetric) structures in ^{224}Ac. Some of the assignments are supported by transition multipolarities from conversion electron data for high energy transitions and E1 assignments from I(K-x ray)/Iγ ratios. For the K^{π}=0 and 1 bands, two scenarios are presented in their figures 4 and 5 of 2004Sh25. See detailed discussion by the authors. Assignments given here are arbitrarily taken from figure 4 in 2004Sh25. K^{π}=3^+ and 3^- parity- doublet bands are also supported by 1994Ah03 with minor differences in level assignments at high energy.

[‡] Band(A): Band based on (0^-). Mixture of K^{π}=0^- and K^{π}=1^- bands from $\pi 3/2 \otimes \nu 3/2$ and $\pi 5/2 \otimes \nu 3/2$ configurations (2004Sh25).

[#] Band(B): Band based on 1^+. Mixture of K^{π}=0^+ and K^{π}=1^+ bands from $\pi 3/2 \otimes \nu 3/2$ and $\pi 5/2 \otimes \nu 3/2$ configurations (2004Sh25).

[@] Band(C): Band based on (3^-). Mixture of K^{π}=2^- and K^{π}=3^- bands from $\pi 5/2 \otimes \nu 1/2$ configuration (2004Sh25).

[&] Band(D): Band based on (3^+). Mixture of K^{π}=2^+ and K^{π}=3^+ bands from $\pi 5/2 \otimes \nu 1/2$ configuration (2004Sh25).

Adopted Levels, Gammas (continued)

$\gamma(^{224}Ac)$

E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.	δ	$\alpha^\dagger$	Comments
29.83	(1^+)	29.8 *1*	100	0	(0^-)	E1		2.83 *5*	
37.17	(2^-)	37.2# *1*	100	0	(0^-)	[E2]		1200 *24*	
52.20	(2^+)	(22)		29.83	(1^+)				
		28.8 *1*	42 *7*	23.40	(2^-)	E1		3.10 *6*	
		34.6 *1*	100 *11*	17.60	(1^-)	E1		1.91	A 52.1γ is omitted here due to unlikely M2 multipolarity implied from assigned J^π values.
64.47	(3^+)	41.1 *1*	100	23.40	(2^-)				Mult.: (M1) listed in 1993Sh07, but no argument given.
78.51	(3^-)	26.3 *1*	100 *14*	52.20	(2^+)	E1		3.93 *7*	
80.49	(3^+)	28.3 *1*	≈4.2	52.20	(2^+)				
		43.3 *1*	100 *13*	37.17	(2^-)	E1		1.054 *17*	
90.56	$(^+)$	67.2 *1*	100	23.40	(2^-)	(E1)		0.327	
103.31	(4^+)	54.2 *1*	100	49.08	(3^-)	(E1)		0.580	
109.33	(4^-)	60.3‡ *2*	100‡	49.08	(3^-)				
110.53	$(^+)$	61.5 *1*	100	49.08	(3^-)				
116.46	(4^-)	36.0 *1*	100 *15*	80.49	(3^+)	(E1)		1.72 *3*	
		52.0 *2*	87 *15*	64.47	(3^+)				
130.30	(4^+)	49.8 *1*	20 *4*	80.49	(3^+)				
		51.8 *1*	100 *11*	78.51	(3^-)	(E1)		0.654	
		78.6# *3*	8 *4*	52.20	(2^+)				
		81.2 *1*	89 *15*	49.08	(3^-)				
146.6		62.5# *1*	100 *17*	84.1?					
159.3		66.3# *3*	≈50	92.6?					
		75.5# *3*	≈100	84.1?					
176.72	(5^+)	46.5 *2*	≈30	130.30	(4^+)				
		60.3‡ *2*	<125‡	116.46	(4^-)	(E1)		0.436 *8*	
		67.4 *2*	100 *15*	109.33	(4^-)				
		73.4 *2*	21 *9*	103.31	(4^+)				
183.40	(5^-)	53.1 *1*	100 *15*	130.30	(4^+)	(E1)		0.612	
		74.1 *3*	38 *10*	109.33	(4^-)				
		80.1 *1*	85 *15*	103.31	(4^+)	(E1)		0.205	
219.7		77.2 *2*	≈100	142.5	(5^+)				
		86.3# *2*	≈67	133.4?					
236.5	(6^-)	59.8 *3*	100	176.72	(5^+)				
252.68	(6^+)	69.3 *2*	100 *17*	183.40	(5^-)	(E1)		0.301	
		76.0 *2*	43 *12*	176.72	(5^+)				
		110.3 *4*	86 *17*	142.5	(5^+)				
		122.5 *5*	≈23	130.30	(4^+)				
283.48	(3^-)	140.8 *4*	20 *5*	142.5	(5^+)				
		193.0 *2*	11 *4*	90.56	$(^+)$				
		237.7# *3*	26 *5*	45.8?	$(^-)$	(M1)		1.473	
		246.2 *2*	36 *8*	37.17	(2^-)				
		260.1 *1*	100 *11*	23.40	(2^-)				
317.2		280.0 *5*	≈100	37.17	(2^-)				
		283.0# *5*	≈100	34.2?					
333.04	(3^+)	202.7 *1*	88 *13*	130.30	(4^+)	M1(+E2)	<0.6	2.07 *23*	
		222.7 *2*	≈16	110.53	$(^+)$				
		232.6# *2*	59 *9*	100.44?					
		242.6 *2*	47 *8*	90.56	$(^+)$	(M1)		1.392	
		252.6 *2*	63 *13*	80.49	(3^+)	(M1)		1.244	
		267.8# *5*	33 *11*	65.2?					

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Adopted Levels, Gammas (continued)

γ(^{224}Ac) (continued)

E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.	δ	α[†]
333.04	(3$^+$)	280.8 *4*	≈31	52.20	(2$^+$)			
		283.4 *4*	≈47	49.08	(3$^-$)			
		285.8[#] *5*	≈16	47.4?				
		288.9[#] *5*	≈47	44.2?				
		295.5 *4*	≈31	37.17	(2$^-$)			
		303.2 *2*	100 *18*	29.83	(1$^+$)			
353.89	(3$^-$)	237.5 *2*	18.9 *23*	116.46	(4$^-$)	(M1)		1.476
		244.7 *5*	9.6 *23*	109.33	(4$^-$)	(M1)		1.359
		248.8[#] *5*	7.7 *27*	105.1?				
		269.1[#] *4*	13 *3*	84.1?				
		278.0[#] *5*	≈9	75.9?				
		290.0 *5*	≈23	64.47	(3$^+$)			
		309.6[#] *3*	≈23	44.2?				
		316.8 *1*	100 *14*	37.17	(2$^-$)	(M1)		0.666
		330.4[‡] *1*	<50[‡]	23.40	(2$^-$)	(M1)		0.593
360.25	(3$^+$)	230.0 *1*	45 *8*	130.30	(4$^+$)	M1(+E2)	<0.7	1.41 *21*
		268.7[#] *5*	9 *2*	90.56	(+)			
		279.5 *4*	9.3 *23*	80.49	(3$^+$)			
		308.0 *1*	100 *10*	52.20	(2$^+$)	M1(+E2)	<0.4	0.68 *4*
		312.8[#] *4*	≈5.0	47.4?				
		330.4[‡] *1*	<28[‡]	29.83	(1$^+$)			
380.80	(+)	250.5 *2*	59 *12*	130.30	(4$^+$)	(M1)		1.273
		300.3 *3*	≈17	80.49	(3$^+$)			
		328.6 *2*	100 *14*	52.20	(2$^+$)			
		351.0 *4*	≈17	29.83	(1$^+$)			
395.84	(4$^-$)	212.5 *5*	≈42	183.40	(5$^-$)			
		253.4 *5*	≈67	142.5	(5$^+$)			
		317.2 *2*	≈580	78.51	(3$^-$)			
		347.0 *3*	100 *42*	49.08	(3$^-$)			
402.92	(4$^+$)	226.3 *2*	≈17	176.72	(5$^+$)			
		299.5 *3*	≈33	103.31	(4$^+$)			
		312.3 *3*	≈17	90.56	(+)			
		322.4 *2*	100 *13*	80.49	(3$^+$)	M1(+E2)	<0.7	0.55 *9*
448.08	(5$^-$)	195.5 *2*	100 *30*	252.68	(6$^+$)			
		317.8 *3*	≈300	130.30	(4$^+$)			
		344.3 *4*	≈100	103.31	(4$^+$)			
452.1	(5$^+$)	335.6 *3*	100	116.46	(4$^-$)			

[†] 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 with undivided intensity.

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

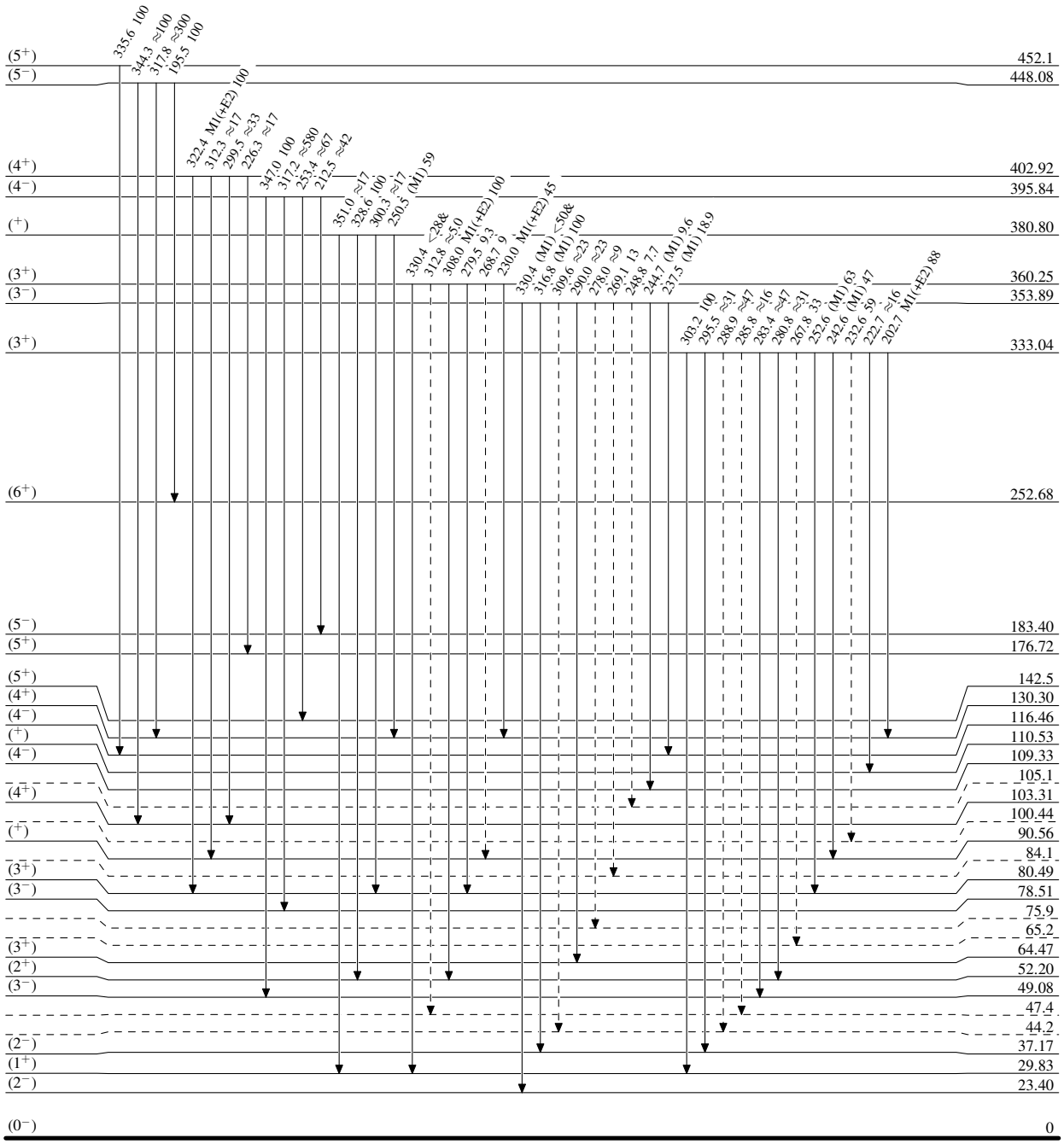
Adopted Levels, Gammas

Legend

Level Scheme

Intensities: Relative photon branching from each level
& Multiply placed: undivided intensity given

- - - - - - ► γ Decay (Uncertain)



$^{224}_{89}Ac_{135}$

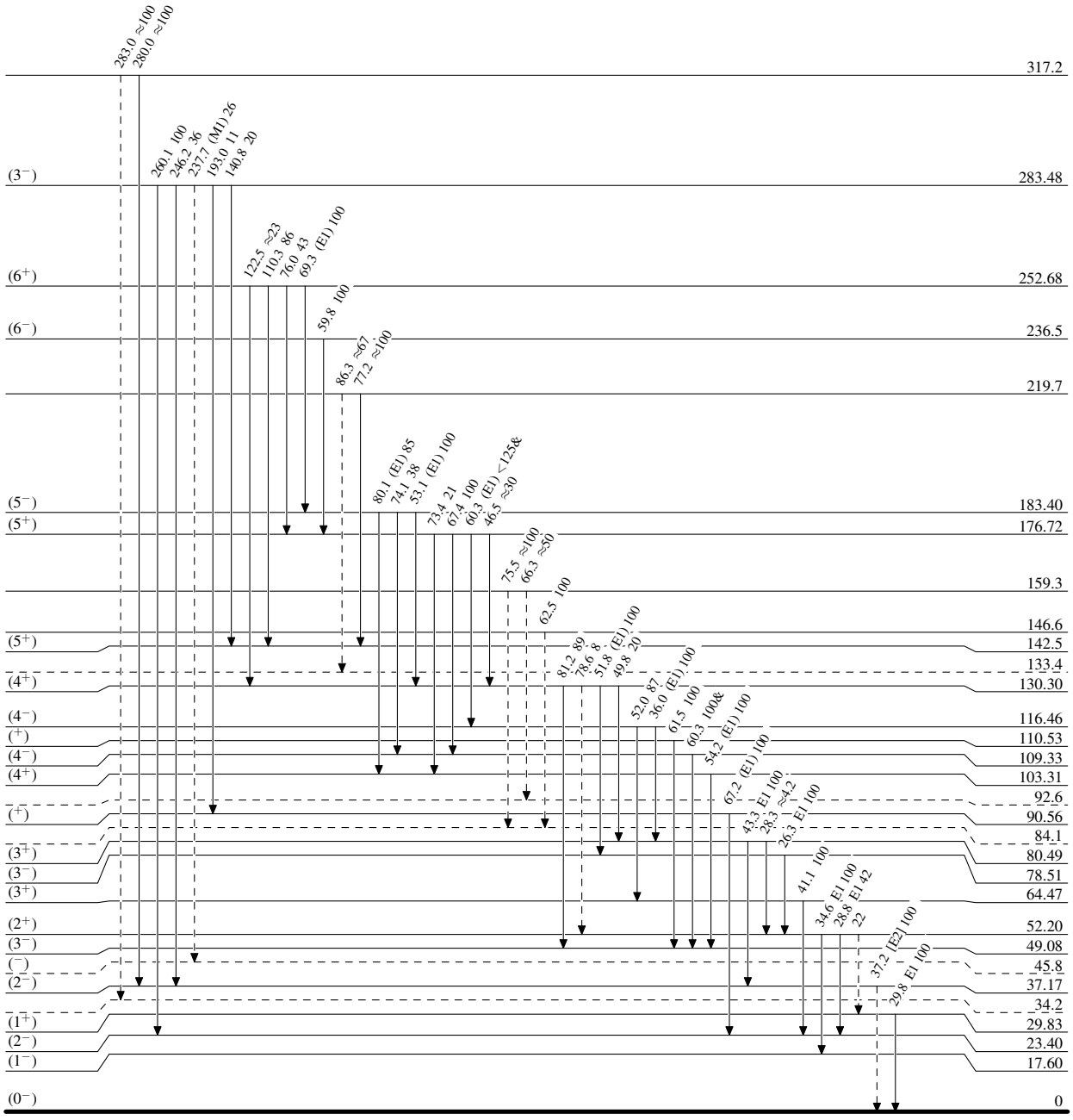
Adopted Levels, Gammas

Legend

Level Scheme (continued)

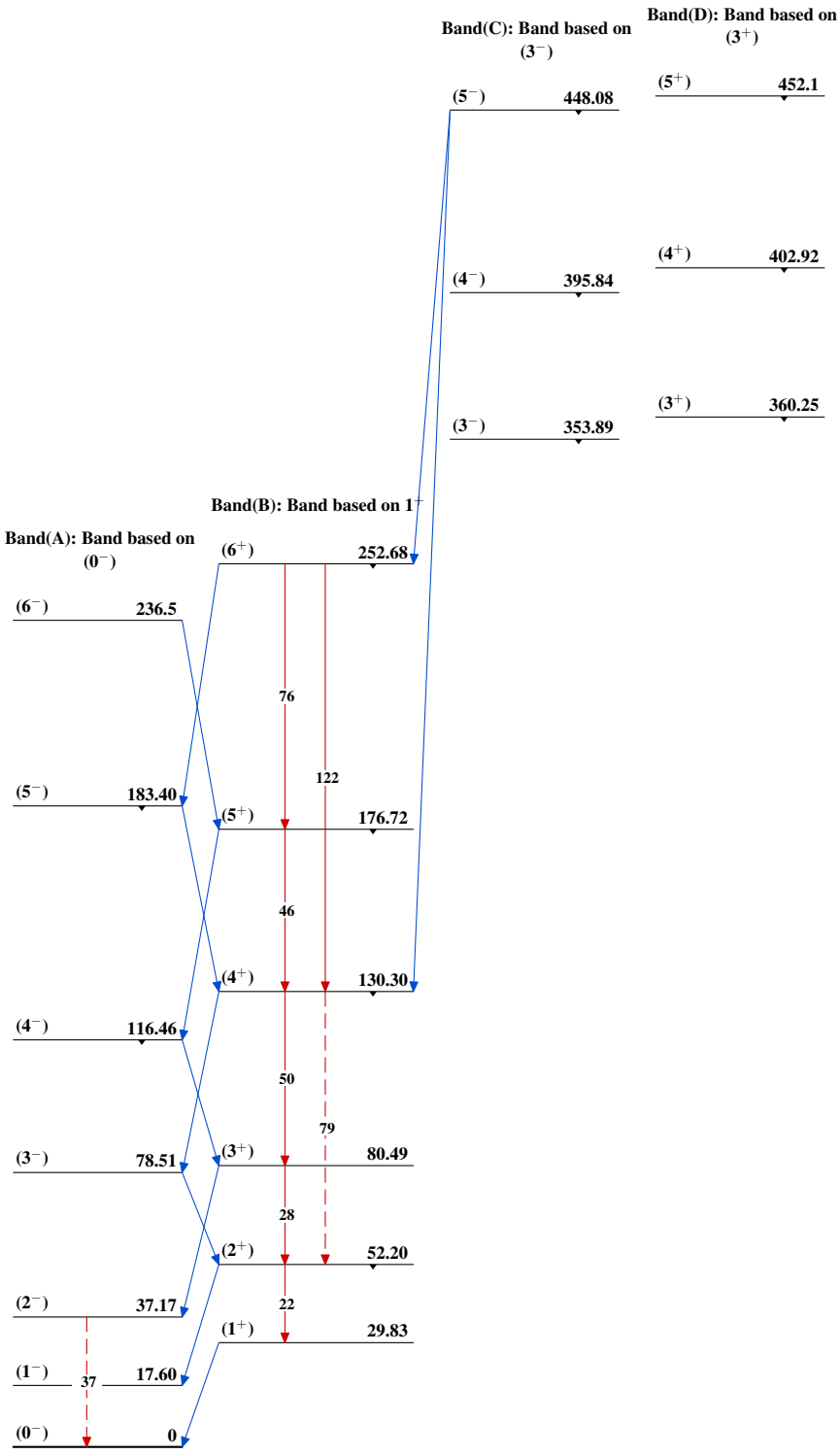
Intensities: Relative photon branching from each level
& Multiply placed: undivided intensity given

- - - - - - ► γ Decay (Uncertain)



$^{224}_{89}Ac_{135}$

Adopted Levels, Gammas



$^{224}_{89}Ac_{135}$