Adopted Levels, Gammas

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh, M. S. Basunia, Murray Martin et al. ,	NDS 160, 405 (2019)	30-Oct-2019

Q(β^-)=−4190 *50*; S(n)=7310 *13*; S(p)=4952 *13*; Q(α)=8546 *6* 2017Wa10
S(2n)=12783 *14*, S(2p)=8180 *13* (2017Wa10).
Additional information 1.
Theory references: consult NSR database (www.nndc.bnl.gov/nsr/) for 62 primary references for nuclear structure, and 42 for calculations of half-lives of radioactive decays.
From lifetime measurements, 1988Ga33 conclude that higher spin states exhibit enhanced B(E1) rates of about 0.006 which may be a result of collective dipole deexcitations from a reflection- asymmetric intrinsic state.

^{218}Ra Levels

Cross Reference (XREF) Flags

A ^{222}Th α decay (1.964 ms)
B ^{208}Pb(^{13}C,3nγ),(^{14}C,4nγ),

E(level)[†]	J$^\pi$[‡]	$T_{1/2}$[#]	XREF	Comments
0.0[&]	0$^+$	25.91 μs *14*	AB	%α=100 Additional information 2. $T_{1/2}$: weighted average of 25.99 μs *10* (E. Parr et al., Phys Rev. C 100, 044323 (2019)), 25.2 μs *3* (2001Ku07), 26 μs *2* (1992Wi14) and 25.6 μs *11* (1986To02). Others: 15.6 μs *10* (1991AnZZ), 14 μs *2* (1970Va13).
388.90[&] *10*	2$^+$	29.8 ps *28*	AB	J$^\pi$: E2 γ to 0$^+$.
741.10[&] *14*	4$^+$	19.4 ps *35*	B	J$^\pi$: ΔJ=2, E2 γ to 2$^+$.
793.21[a] *18*	(3$^-$)		AB	J$^\pi$: ΔJ=1, D γ to 2$^+$.
853[a] *6*	(1$^-$)		A	E(level): from Eα and Q(α) values. J$^\pi$: on the basis of the similarity in the hindrance factor for the 853 level with that of the 793 level, and the γ to 0$^+$, 2016Pa28 propose that the 853 level is the bandhead of the octupole band.
1038.32[a] *18*	5$^-$		B	J$^\pi$: ΔJ=1, E1 γ to 4$^+$.
1122.04[&] *20*	6$^+$	13.2 ps *28*	B	J$^\pi$: ΔJ=2, E2 γ to 4$^+$; E1 γ to 5$^-$.
1340.85[a] *21*	7$^-$	[@]	B	J$^\pi$: ΔJ=1, E1 γ to 6$^+$; ΔJ=2, E2 γ to 5$^-$.
1546.70[&] *23*	8$^+$	[@]	B	J$^\pi$: ΔJ=1, E1 γ to 7$^-$; ΔJ=2, E2 γ to 6$^+$.
1573.01 *19*	(3$^-$,4,5$^-$)		B	J$^\pi$: γ rays to (3$^-$) and 5$^-$.
1694.35[a] *25*	9$^-$	[@]	B	J$^\pi$: γ to 8$^+$; ΔJ=2, E2 γ to 7$^-$.
1714.60 *25*			B	J$^\pi$: γ to 4$^+$.
1725.8 *3*			B	J$^\pi$: γ to 5$^-$.
1803.60 *24*			B	J$^\pi$: γ rays to 6$^+$ and 7$^-$.
1855.9 *3*			B	J$^\pi$: γ to 6$^+$.
1896.8 *3*			B	J$^\pi$: γ to 8$^+$.
1961.7[&] *3*	10$^+$	[@]	B	J$^\pi$: ΔJ=1, E1 γ to 9$^-$; ΔJ=2, E2 γ to 8$^+$.
2031.8 *3*			B	J$^\pi$: γ to 9$^-$.
2109.3[a] *3*	11$^-$	[@]	B	J$^\pi$: ΔJ=2, E2 γ to 9$^-$; ΔJ=1, D γ to 10$^+$.
2328.3 *4*			B	
2390.8[&] *3*	12$^+$	<1.4 ps	B	J$^\pi$: ΔJ=1, E1 γ to 11$^-$; ΔJ=2, E2 γ to 10$^+$.
2420.0[b] *3*	(12$^-$)		B	J$^\pi$: ΔJ=1, (M1+E2) γ to 11$^-$.
2442.4 *4*			B	
2465.6 *3*			B	J$^\pi$: γ to 10$^+$.
2526.3[a] *3*	13$^-$	<4.9 ps	B	J$^\pi$: ΔJ=1, E1 γ to 12$^+$; ΔJ=2, E2 γ to 11$^-$.

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Adopted Levels, Gammas (continued)

^{218}Ra Levels (continued)

E(level)[†]	J^{π}[‡]	$T_{1/2}$[#]	XREF	Comments
2825.5[&] *3*	14^+	<1.4 ps	B	J^{π}: ΔJ=1, E1 γ to 13^-; ΔJ=2, E2 γ to 12^+.
2966.4[a] *4*	15^-	<1.4 ps	B	J^{π}: ΔJ=1, E1 γ to 14^+; ΔJ=2, E2 γ to 13^-. $T_{1/2}$: This $T_{1/2}$ leads to B(E2)(W.u)>218, a factor of about 3 larger than any of the other E2 or E1 reduced transition probabilities. The $T_{1/2}$ limit may be a typo.
2967.2[b] *4*	(14^-)		B	J^{π}: ΔJ=2, E2 γ to (12^-); γ to 13^-.
3285.1[&] *4*	16^+		B	J^{π}: γ rays to 14^+ and 15^-.
3387.7[b] *7*	(16^-)		B	J^{π}: γ to (14^-).
3388.8[a] *4*	17^-	<13 ps	B	J^{π}: ΔJ=2, E2 γ to 15^-; γ to 16^+.
3719.8[b] *7*	(18^-)		B	J^{π}: γ rays to (16^-) and 17^-.
3756.0[&] *7*	18^+		B	J^{π}: γ to 17^-, and member of g.s. band.
3805.9[a] *8*	19^-		B	J^{π}: γ rays to 17^-, (18^-) and 18^+.
4117.7[b] *9*	(20^-)		B	J^{π}: γ rays to (18^-) and 19^-.
4191.1?[&] *11*	(20^+)		B	J^{π}: γ rays to 18^+ and 19^-.
4212.6[a] *10*	(21^-)		B	J^{π}: γ to 19^-.
4391.6[c] *11*	(21^+)		B	J^{π}: γ to (20^-).
4588.3[&] *11*	(22^+)		B	J^{π}: γ to (21^-).
4675.3[a] *10*	(23^-)		B	J^{π}: γ rays to (21^-) and (22^+).
4682.6[b] *10*	(22^-)		B	J^{π}: γ rays to (20^-) and (21^-).
4835.5[c] *11*	(23^+)		B	J^{π}: γ rays to (21^+), (22^+) and (22^-).
5020.3[&] *12*	(24^+)		B	J^{π}: γ rays to (22^+) and (23^-).
5125.4[a] *13*	(25^-)		B	J^{π}: γ rays to (23^-) and (24^+).
5139.4[b] *11*	(24^-)		B	J^{π}: γ rays to (22^-) and (23^+).
5363.5[c] *13*	(25^+)		B	J^{π}: γ rays to (23^+) and (24^-).
5470.1[&] *13*	(26^+)		B	J^{π}: γ rays to (24^+) and (25^-).
5588.1[a] *13*	(27^-)		B	J^{π}: γ rays to (25^-) and (26^+).
5901.7[&] *14*	(28^+)		B	J^{π}: γ rays to (26^+) and (27^-).
6134.9[a] *15*	(29^-)		B	J^{π}: γ rays to (27^-) and (28^+).
6343.8[&] *15*	(30^+)		B	J^{π}: γ rays to (28^+) and (29^-).
6678.8[a] *16*	(31^-)		B	J^{π}: γ rays to (29^-) and (30^+).

† From a least-squares fit to the adopted Eγ data except for the 853 level which comes from the E(α) branch to that level.

‡ From γ(θ) and γ(lin pol) data in ^{208}Pb(^{13}C,3nγ), and association of levels in bands or sequences. Additional γ mult arguments are given explicitly.

\# From recoil-distance Doppler-shift method in inverse kinematic reaction: ^{13}C(^{208}Pb,3nγ)(1988Ga33). No delayed component with a half-life longer than 5 ns was observed for any of the transitions (1986Go21).

@ 1988Ga33 deduced $T_{1/2}$=3.1 ps *4* for 1341, 7^-; 2.3 ps *3* for 1547, 8^+; 5.9 ps *6* for 1694, 9^-; 2.6 ps *4* for 1962, 10^+; and 4.2 ps *5* for 2109, 11^- levels using average B(E2) for transitions from some of the above levels.

& Band(A): $K^{\pi}=0^+$ g.s. band.

a Band(B): Octupole band.

b Seq.(C): γ sequence based on 12^-.

c Seq.(D): γ sequence based on (21^+).

Adopted Levels, Gammas (continued)

$\gamma(^{218}Ra)$

E_i(level)	J_i^π	E_γ†	I_γ†	E_f	J_f^π	Mult.‡	α#	Comments
388.90	2^+	388.9 *1*	100	0.0	0^+	E2	0.0727	B(E2)(W.u.)=25.5 *24*
741.10	4^+	352.2 *1*	100	388.90	2^+	E2	0.0954	B(E2)(W.u.)=63 *12*
793.21	(3^-)	404.3 *2*	100	388.90	2^+	D		
853	(1^-)	853		0.0	0^+			
1038.32	5^-	245.1 *2*		793.21	(3^-)			
		297.3 *2*		741.10	4^+	E1	0.0359	
1122.04	6^+	83.7 *2*	35 *7*	1038.32	5^-	(E1)	0.177 *3*	B(E1)(W.u.)=0.0057 *17*
		380.9 *2*	100 *6*	741.10	4^+	E2	0.0769	B(E2)(W.u.)=46 *11*
1340.85	7^-	218.8 *1*	100 *5*	1122.04	6^+	E1	0.0729	
		302.6 *2*	8.7 *22*	1038.32	5^-	E2	0.1482	
1546.70	8^+	205.8 *2*	100 *7*	1340.85	7^-	E1	0.0843	
		424.6 *2*	71 *20*	1122.04	6^+	E2	0.0578	
1573.01	$(3^-,4,5^-)$	534.7 *2*		1038.32	5^-			
		779.8 *2*		793.21	(3^-)			
		831.9 *2*		741.10	4^+			
1694.35	9^-	147.5& *2*	100& *45*	1546.70	8^+		0.190	
		353.6 *2*	58 *20*	1340.85	7^-	E2	0.0943	
1714.60		973.5 *2*		741.10	4^+			
1725.8		687.5 *2*	100	1038.32	5^-			
1803.60		462.7 *2*		1340.85	7^-			
		681.6 *2*		1122.04	6^+			
1855.9		733.9 *2*	100	1122.04	6^+			
1896.8		350.1 *2*	100	1546.70	8^+			
1961.7	10^+	267.3 *1*	100 *5*	1694.35	9^-	E1	0.0457	
		415.0& *2*	36& *9*	1546.70	8^+	E2	0.0613	
2031.8		337.5 *2*	100	1694.35	9^-			
2109.3	11^-	77.5 *2*		2031.8				
		147.5& *2*	42& *42*	1961.7	10^+		0.190	
		415.0& *2*	100& *25*	1694.35	9^-	E2	0.0613	
2328.3		472.4 *2*	100	1855.9				
2390.8	12^+	281.4 *2*	100 *7*	2109.3	11^-	E1	0.0407	B(E1)(W.u.)>0.004
		429.3 *2*	33 *7*	1961.7	10^+	E2	0.0562	B(E2)(W.u.)>84
2420.0	(12^-)	310.6 *2*	100	2109.3	11^-	(M1+E2)	0.4 *3*	
2442.4		410.6 *2*	100	2031.8				
2465.6		503.9 *2*		1961.7	10^+			
		568.8 *2*		1896.8				
2526.3	13^-	106.1 *2*		2420.0	(12^-)			
		135.6 *2*	33 *3*	2390.8	12^+	E1	0.230	B(E1)(W.u.)>0.0034
		416.9 *2*	100 *27*	2109.3	11^-	E2	0.0606	B(E2)(W.u.)>80
2825.5	14^+	299.3 *2*	100 *28*	2526.3	13^-	E1	0.0354	B(E1)(W.u.)>0.0035
		434.8@ *2*	<45	2390.8	12^+	E2	0.0544	E_γ: double placement, with intensity not divided.
2966.4	15^-	140.9 *2*	32 *5*	2825.5	14^+	E1	0.210	B(E1)(W.u.)>0.011
		440.0 *2*	100 *5*	2526.3	13^-	E2	0.0528	B(E2)(W.u.)>218
2967.2	(14^-)	142		2825.5	14^+			
		440.8 *2*		2526.3	13^-			
		547.3 *2*		2420.0	(12^-)	E2	0.0313	
3285.1	16^+	318.7	100 *20*	2966.4	15^-			
		459.7	60 *20*	2825.5	14^+			
3387.7	(16^-)	420.5	100	2967.2	(14^-)			
3388.8	17^-	104		3285.1	16^+			
		422.4 *2*		2966.4	15^-	E2	0.0586	
3719.8	(18^-)	331		3388.8	17^-			
		332.1 *3*		3387.7	(16^-)			

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Adopted Levels, Gammas (continued)

$\gamma(^{218}Ra)$ (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Comments
3756.0	18^+	367		3388.8	17^-	
		471[a]		3285.1	16^+	
3805.9	19^-	50		3756.0	18^+	
		86		3719.8	(18^-)	
		417		3388.8	17^-	
4117.7	(20^-)	312		3805.9	19^-	
		398		3719.8	(18^-)	
4191.1?	(20^+)	385		3805.9	19^-	
		434.8[@] 2		3756.0	18^+	E_γ: double placement, with intensity not divided.
4212.6	(21^-)	406.6	100	3805.9	19^-	
4391.6	(21^+)	274	100	4117.7	(20^-)	
4588.3	(22^+)	376		4212.6	(21^-)	
		397[a]		4191.1?	(20^+)	
4675.3	(23^-)	87		4588.3	(22^+)	
		462.7[@]		4212.6	(21^-)	
4682.6	(22^-)	291[a]		4391.6	(21^+)	
		470		4212.6	(21^-)	
		565		4117.7	(20^-)	
4835.5	(23^+)	153		4682.6	(22^-)	
		247		4588.3	(22^+)	
		444		4391.6	(21^+)	
5020.3	(24^+)	345[@]		4675.3	(23^-)	
		432[@]		4588.3	(22^+)	
5125.4	(25^-)	105		5020.3	(24^+)	
		450[@]		4675.3	(23^-)	
5139.4	(24^-)	304		4835.5	(23^+)	
		457		4682.6	(22^-)	
		464[a]		4675.3	(23^-)	
5363.5	(25^+)	224		5139.4	(24^-)	
		528		4835.5	(23^+)	
5470.1	(26^+)	345[@]		5125.4	(25^-)	
		450[@]		5020.3	(24^+)	
5588.1	(27^-)	118		5470.1	(26^+)	
		463[@]		5125.4	(25^-)	
5901.7	(28^+)	313		5588.1	(27^-)	
		432[@]		5470.1	(26^+)	
6134.9	(29^-)	233		5901.7	(28^+)	
		547		5588.1	(27^-)	
6343.8	(30^+)	209		6134.9	(29^-)	
		442		5901.7	(28^+)	
6678.8	(31^-)	335		6343.8	(30^+)	
		544		6134.9	(29^-)	

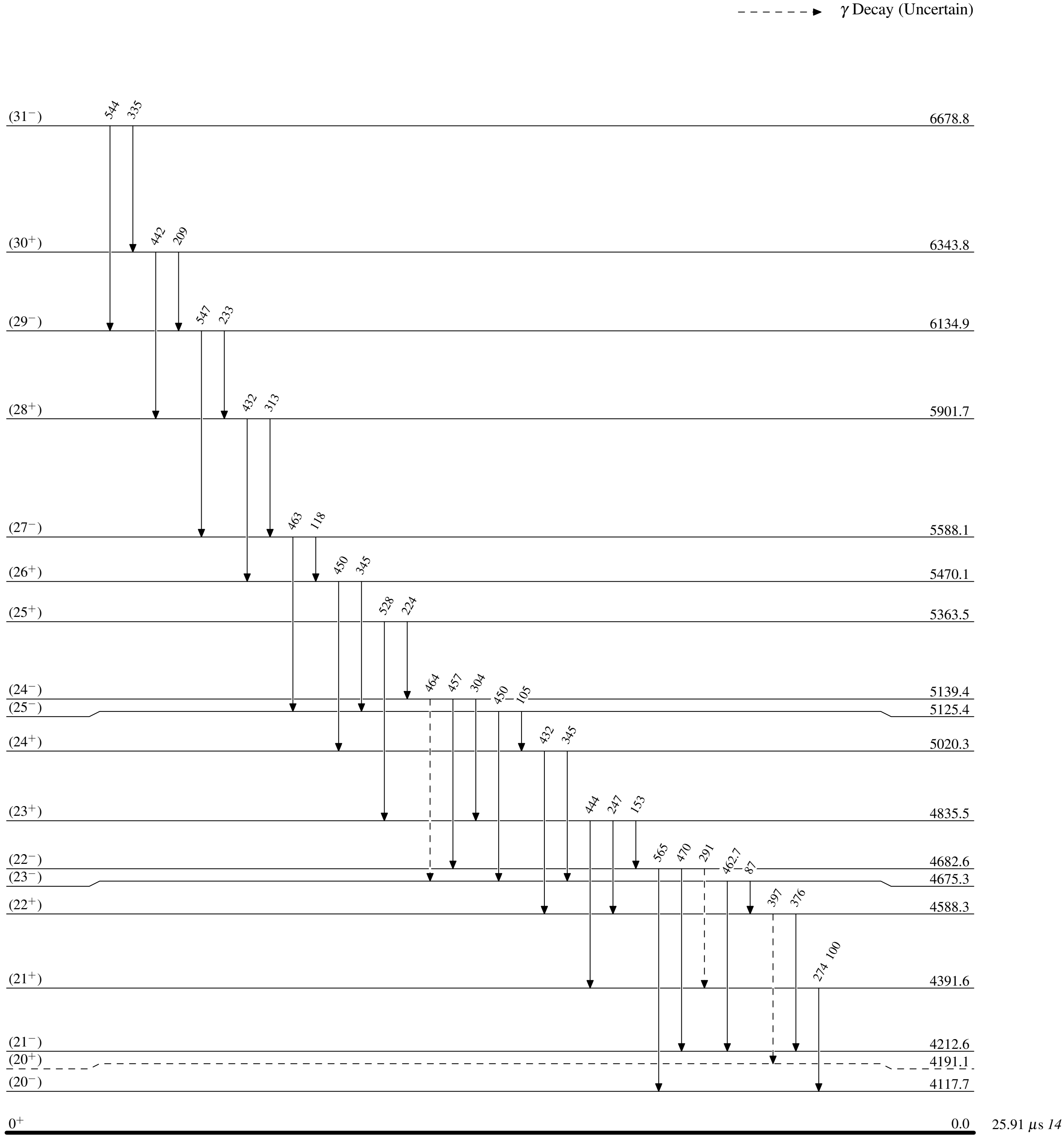
† From $^{208}Pb(^{13}C,3n\gamma),(^{14}C,4n\gamma)$ dataset.
‡ From $\gamma(\theta)$ and γ(lin pol) data in $^{208}Pb(^{13}C,3n\gamma)$.
\# Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.
@ Multiply placed.
& Multiply placed with intensity suitably divided.
a Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Legend

Level Scheme

Intensities: Relative photon branching from each level

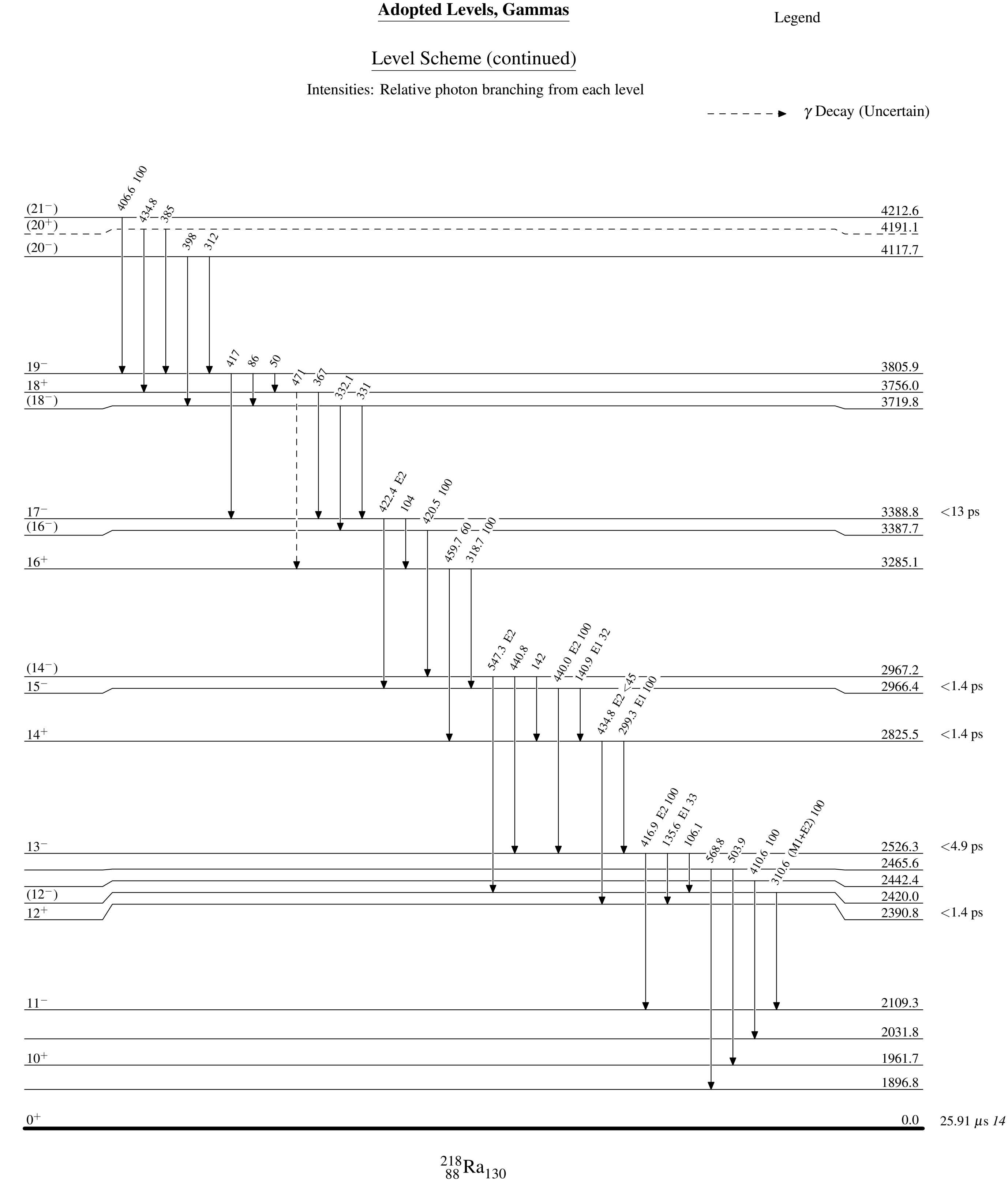


$^{218}_{88}Ra_{130}$

Adopted Levels, Gammas

Level Scheme (continued)

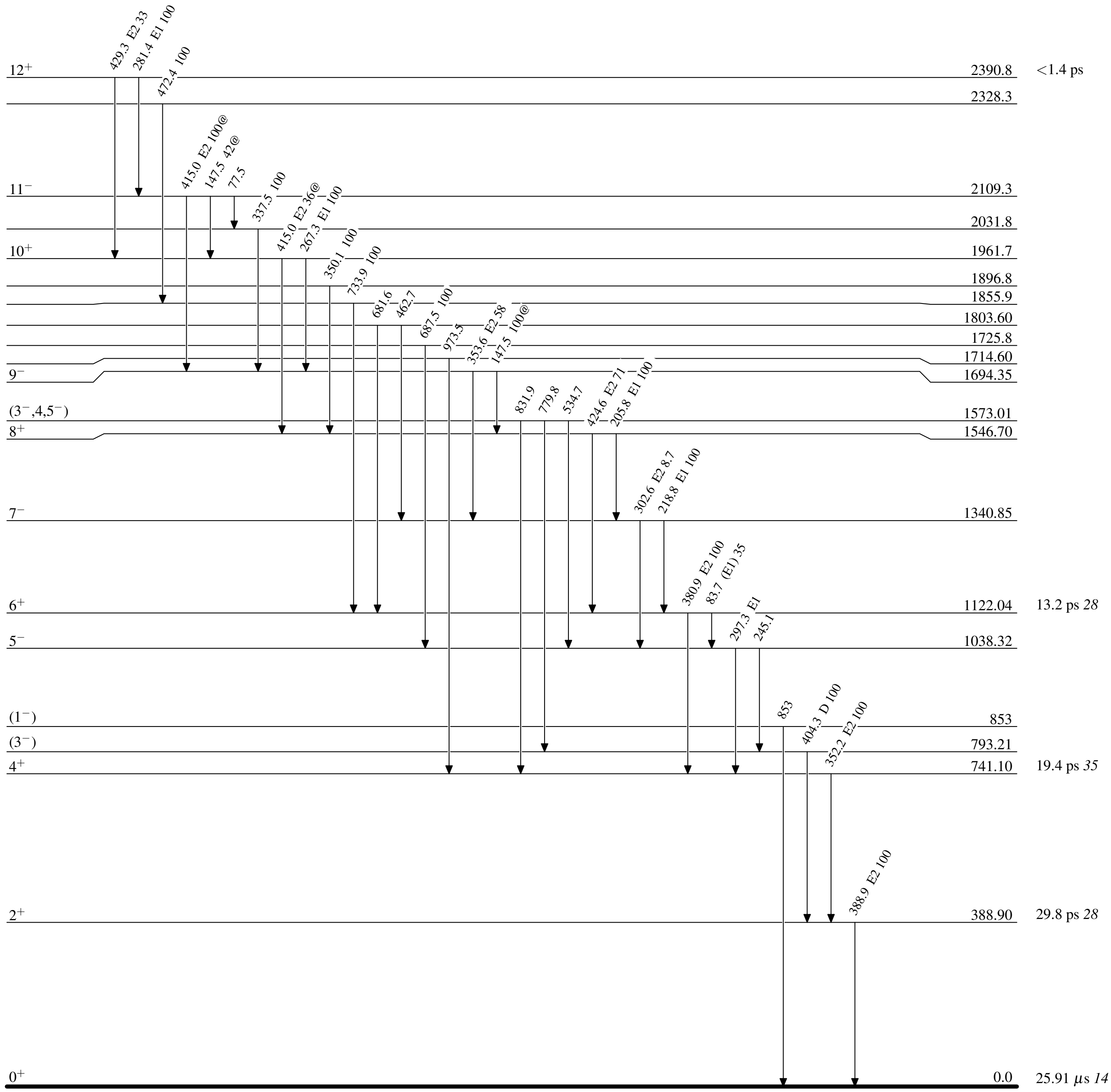
Intensities: Relative photon branching from each level



Adopted Levels, Gammas

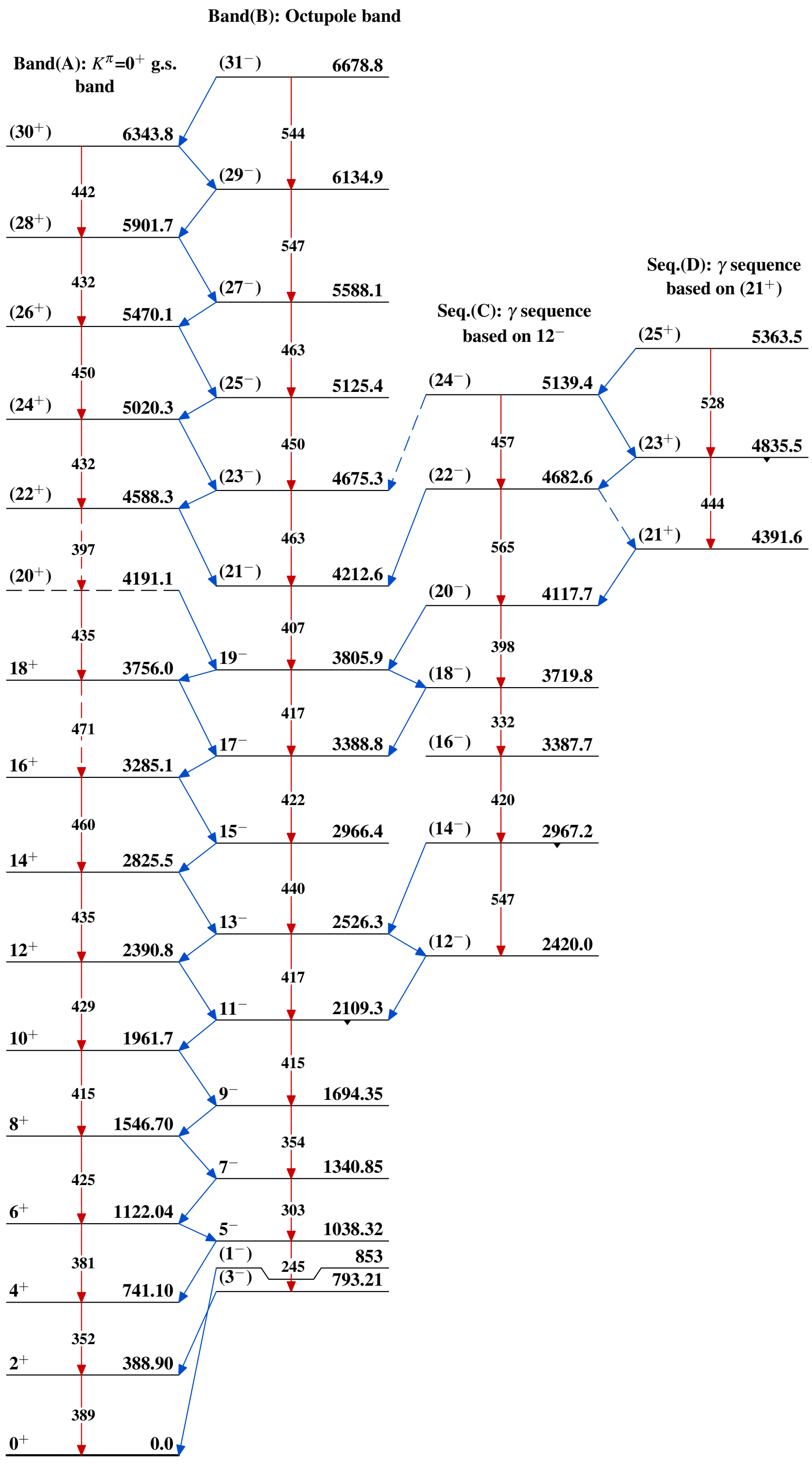
Level Scheme (continued)

Intensities: Relative photon branching from each level
@ Multiply placed: intensity suitably divided



$^{218}_{88}Ra_{130}$

Adopted Levels, Gammas



Adopted Levels, Gammas

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	E. Browne, J. K. Tuli	NDS 112,1115 (2011)	31-Oct-2010

Q(β^-)=−3474 *11*; S(n)=7195 *12*; S(p)=5637 *11*; Q(α)=7592 *6* 2012Wa38
Note: Current evaluation has used the following Q record −3471 11 *7193* 12 *5635* 12 *7592* 6 2009AuZZ,2003Au03.
Additional information 1.

Calculations, compilations, systematics:
^{14}C decay rate: 1986De32.
Spontaneous emission of heavy ions: 1986Po06.
α decay Γ: 1995De59, 1992De44.
Binding energy, deformation role: 1986Ch23.
Cluster model for α decay, Geiger-Nuttall plot: 1991Bu05, 1986Ir01.
Equilibrium deformation: 1995Ru10, 1994Cw01, 1991Sk01, 1989Eg02, 1988So08, 1984Na22.
K^π=0$^+$ and K^π=0$^-$ bands: 1980Sh07.
Levels, $\beta(\lambda)$ ratios: 1995De13, 1995Mi22, 1993Am07, 1993Dz01, 1991Eg01, 1987En05, 1986Da03, 1986Le05.
Octupole shapes and shape changes: 1987Na10.
p-n interaction energy: 1990Mo11.
Super- and hyperdeformed configurations: 1995We02.
Quasi-bands in even-even nuclei: 1984Sa37.
Yrast band parity splitting: 1995Jo11, 1993Sc11.
Fission: 1999Po19, 1997An08.

^{220}Ra Levels

Cross Reference (XREF) Flags

- A ^{220}Fr β^- decay
- B ^{224}Th α decay
- C ^{208}Pb(^{14}C,2nγ)
- D ^{208}Pb(^{18}O,α2nγ)

E(level)[†]	J$^\pi$[‡]	T$_{1/2}$	XREF	Comments
0[#]	0$^+$	18 ms *2*	ABCD	%α=100 T$_{1/2}$: weighted average of 17 ms *2* (1990An19) and 23 ms *5* (1961Ru06); other: 31 ms *8* (1978IbZZ). Isotope shift: Δ<r^2>=+0.68 *7* relative to ^{214}Ra (1988Ah02).
178.47[#] *12*	2$^+$		ABCD	J$^\pi$: E2 γ ray to 0$^+$. T$_{1/2}$: from 2Z-N=44 systematics 1992Ro02 predict T$_{1/2}$=670 ps.
410.07[#] *23*	4$^+$		CD	J$^\pi$: stretched E2 γ ray to 2$^+$.
412.98[@] *10*	(1$^-$)		ABC	J$^\pi$: γ rays to 0$^+$, 2$^+$. Probable bandhead of K^π=0$^-$ band.
474.17[@] *23*	(3$^-$)		BC	J$^\pi$: γ ray to 2$^+$. Probable member of K^π=0$^-$ band.
634.8[@] *4*	(5)$^-$		CD	J$^\pi$: E1 γ ray to 4$^+$.
688.1[#] *3*	6$^+$		CD	J$^\pi$: E2 γ ray to 4$^+$.
873.0[@] *4*	(7)$^-$		CD	J$^\pi$: E1 γ ray to 6$^+$.
1001.2[#] *4*	8$^+$		CD	J$^\pi$: E1 γ ray to 7$^-$; E2 γ ray to 6$^+$.
1163.8[@] *4*	(9)$^-$		CD	J$^\pi$: E1 γ ray to 8$^+$.
1342.7[#] *5*	10$^+$		CD	
1496.1[@] *5*	(11)$^-$		CD	J$^\pi$: E1 γ ray to 10$^+$.

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Adopted Levels, Gammas (continued)

^{220}Ra Levels (continued)

E(level)[†]	J^{π}[‡]	XREF	Comments
1711.2[#] *5*	12^+	CD	J^{π}: E1 γ ray to $(11)^-$.
1863.7[@] *5*	$(13)^-$	CD	J^{π}: E1 γ ray to 12^+.
2105.7[#] *5*	14^+	CD	
2262.5[@] *5*	$(15)^-$	CD	J^{π}: E1 γ ray to 14^+.
2523.5[#] *6*	16^+	CD	
2690.1[@] *6*	$(17)^-$	CD	J^{π}: E1 γ ray to 16^+.
2961.9[#] *6*	18^+	CD	
3144.5[@] *6*	(19^-)	CD	
3417.6[#] *6*	(20^+)	D	
3624.0[@] *6*	(21^-)	CD	
3888.6[#] *7*	(22^+)	D	
4122.7[@] *7*	(23^-)	D	
4374.7[#] *7*	(24^+)	D	
4636.3[@] *7*	(25^-)	D	
4873.6[#] *7*	(26^+)	D	
5164.1[@] *8*	(27^-)	D	
5384.5[#] *8*	(28^+)	D	
5703.0[@] *9*	(29^-)	D	
5912.0?[#] *9*	(30^+)	D	
6255.5? *10*	(31^-)	D	

† Deduced by evaluators from a least-squares fit to γ-ray energies.
‡ From bands structure in (^{14}C,2nγ) and (^{18}O,α2nγ). The assignments up to $J^{\pi}=24^+$ have been confirmed by stretched Q and stretched D γ-ray transitions from $\gamma(\theta)$ experiments in (^{18}O,α2nγ). In addition, arguments based on γ-ray multipolarities are given here.
# Band(A): $K^{\pi}=0^+$ g.s. rotational band.
@ Band(B): $K^{\pi}=0^-$ band.

$\gamma(^{220}$Ra)

E_i(level)	J^{π}_i	E_{γ}[‡]	I_{γ}[‡]	E_f	J^{π}_f	Mult.[#]	α[†]	Comments
178.47	2^+	178.4[@] *2*		0	0^+	E2	0.892	α(K)=0.200 *3*; α(L)=0.509 *8*; α(M)=0.1379 *21*; α(N+..)=0.0454 *7* α(N)=0.0364 *6*; α(O)=0.00779 *12*; α(P)=0.001149 *17*; α(Q)=9.99×10^{-6} *15*
410.07	4^+	231.6 *2*		178.47	2^+	E2	0.350	α(K)=0.1209 *17*; α(L)=0.1684 *25*; α(M)=0.0452 *7*; α(N+..)=0.01491 *22* α(N)=0.01195 *18*; α(O)=0.00257 *4*; α(P)=0.000384 *6*; α(Q)=5.19×10^{-6} *8*
412.98	(1^-)	234.5[@] *1*	72[@] *20*	178.47	2^+			
		413.0[@] *1*	100[@] *13*	0	0^+			
474.17	(3^-)	295.7[&] *2*		178.47	2^+			
634.8	$(5)^-$	224.6 *3*		410.07	4^+	E1	0.0685	α(K)=0.0548 *8*; α(L)=0.01042 *15*; α(M)=0.00249 *4*; α(N+..)=0.000821 *12* α(N)=0.000651 *10*; α(O)=0.0001447 *21*; α(P)=2.38×10^{-5} *4*; α(Q)=1.456×10^{-6} *21*

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Adopted Levels, Gammas (continued)

$\gamma(^{220}Ra)$ (continued)

E_i(level)	J_i^π	E_γ[‡]	I_γ[‡]	E_f	J_f^π	Mult.[#]	α[†]	Comments
688.1	6+	278.1 2		410.07	4+	E2	0.192	α(K)=0.0830 12; α(L)=0.0806 12; α(M)=0.0215 3; α(N+..)=0.00709 11 α(N)=0.00568 9; α(O)=0.001224 18; α(P)=0.000185 3; α(Q)=3.36×10^{-6} 5
873.0	(7)−	184.9 2	100 10	688.1	6+	E1	0.1088	α(K)=0.0865 13; α(L)=0.01695 25; α(M)=0.00406 6; α(N+..)=0.001335 19 α(N)=0.001059 16; α(O)=0.000235 4; α(P)=3.83×10^{-5} 6; α(Q)=2.24×10^{-6} 4
		237.9 4	8 2	634.8	(5)−	(E2)[a]	0.319	α(K)=0.1145 17; α(L)=0.1508 24; α(M)=0.0405 7; α(N+..)=0.01334 21 α(N)=0.01069 17; α(O)=0.00230 4; α(P)=0.000344 6; α(Q)=4.86×10^{-6} 7
1001.2	8+	128.1 3	100 10	873.0	(7)−	E1	0.264	α(K)=0.206 4; α(L)=0.0436 7; α(M)=0.01049 16; α(N+..)=0.00343 6 α(N)=0.00273 5; α(O)=0.000599 10; α(P)=9.55×10^{-5} 15; α(Q)=5.10×10^{-6} 8
		313.3 3	57 11	688.1	6+	E2	0.1336	α(K)=0.0648 10; α(L)=0.0509 8; α(M)=0.01348 20; α(N+..)=0.00445 7 α(N)=0.00356 6; α(O)=0.000770 12; α(P)=0.0001177 17; α(Q)=2.55×10^{-6} 4
1163.8	(9)−	162.5 2	100 10	1001.2	8+	E1	0.1485	α(K)=0.1174 17; α(L)=0.0236 4; α(M)=0.00565 9; α(N+..)=0.00185 3 α(N)=0.001473 22; α(O)=0.000325 5; α(P)=5.27×10^{-5} 8; α(Q)=2.99×10^{-6} 5
		290.8 4	13 4	873.0	(7)−	(E2)[a]	0.1673	α(K)=0.0756 11; α(L)=0.0677 11; α(M)=0.0180 3; α(N+..)=0.00594 9 α(N)=0.00476 8; α(O)=0.001027 16; α(P)=0.0001560 24; α(Q)=3.03×10^{-6} 5
1342.7	10+	178.6 3	100 20	1163.8	(9)−	(E1)[a]	0.1183	α(K)=0.0939 14; α(L)=0.0185 3; α(M)=0.00443 7; α(N+..)=0.001457 22 α(N)=0.001157 17; α(O)=0.000256 4; α(P)=4.17×10^{-5} 6; α(Q)=2.42×10^{-6} 4
		341.5 3	33 7	1001.2	8+	(E2)[a]	0.1040	α(K)=0.0542 8; α(L)=0.0369 6; α(M)=0.00972 14; α(N+..)=0.00321 5 α(N)=0.00257 4; α(O)=0.000557 8; α(P)=8.57×10^{-5} 13; α(Q)=2.10×10^{-6} 3
1496.1	(11)−	153.6 3	100 20	1342.7	10+	E1	0.170	α(K)=0.1342 20; α(L)=0.0272 4; α(M)=0.00653 10; α(N+..)=0.00214 4 α(N)=0.00170 3; α(O)=0.000376 6; α(P)=6.06×10^{-5} 9; α(Q)=3.39×10^{-6} 5
		332.7 3	40 8	1163.8	(9)−	(E2)[a]	0.1121	α(K)=0.0572 8; α(L)=0.0406 6; α(M)=0.01072 16; α(N+..)=0.00354 6 α(N)=0.00283 4; α(O)=0.000614 9; α(P)=9.42×10^{-5} 14; α(Q)=2.23×10^{-6} 4
1711.2	12+	215.1 3	100 20	1496.1	(11)−	E1	0.0759	α(K)=0.0606 9; α(L)=0.01160 17; α(M)=0.00277 4; α(N+..)=0.000913 14 α(N)=0.000724 11; α(O)=0.0001610 24; α(P)=2.65×10^{-5} 4; α(Q)=1.601×10^{-6} 23
		368.2 3	44 9	1342.7	10+	(E2)[a]	0.0843	α(K)=0.0465 7; α(L)=0.0281 4; α(M)=0.00737 11; α(N+..)=0.00244 4 α(N)=0.00195 3; α(O)=0.000423 6; α(P)=6.55×10^{-5} 10; α(Q)=1.78×10^{-6} 3
1863.7	(13)−	152.4 3	100 20	1711.2	12+	E1	0.173	α(K)=0.1368 21; α(L)=0.0278 5; α(M)=0.00667 10; α(N+..)=0.00219 4

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Adopted Levels, Gammas (continued)

$\gamma(^{220}Ra)$ (continued)

E_i(level)	J^π_i	E_γ[‡]	I_γ[‡]	E_f	J^π_f	Mult.[#]	α[†]	Comments
								α(N)=0.00174 *3*; α(O)=0.000383 *6*; α(P)=6.18×10^{-5} *10*; α(Q)=3.45×10^{-6} *5*
1863.7	(13)$^-$	367.6 *3*	78 *16*	1496.1	(11)$^-$	(E2)[a]	0.0847	α(K)=0.0466 *7*; α(L)=0.0282 *4*; α(M)=0.00741 *11*; α(N+..)=0.00245 *4* α(N)=0.00196 *3*; α(O)=0.000425 *6*; α(P)=6.58×10^{-5} *10*; α(Q)=1.79×10^{-6} *3*
2105.7	14$^+$	241.9 *3*	100 *20*	1863.7	(13)$^-$	(E1)[a]	0.0576	α(K)=0.0462 *7*; α(L)=0.00868 *13*; α(M)=0.00207 *3*; α(N+..)=0.000684 *10* α(N)=0.000542 *8*; α(O)=0.0001207 *18*; α(P)=2.00×10^{-5} *3*; α(Q)=1.238×10^{-6} *18*
		394.4 *3*	40 *8*	1711.2	12$^+$	(E2)[a]	0.0701	α(K)=0.0404 *6*; α(L)=0.0220 *4*; α(M)=0.00575 *9*; α(N+..)=0.00190 *3* α(N)=0.001519 *22*; α(O)=0.000331 *5*; α(P)=5.15×10^{-5} *8*; α(Q)=1.530×10^{-6} *22*
2262.5	(15)$^-$	156.7 *3*	72 *14*	2105.7	14$^+$	E1	0.1621	α(K)=0.1280 *19*; α(L)=0.0259 *4*; α(M)=0.00620 *10*; α(N+..)=0.00204 *3* α(N)=0.001618 *24*; α(O)=0.000357 *6*; α(P)=5.76×10^{-5} *9*; α(Q)=3.24×10^{-6} *5*
		399.1 *3*	100 *20*	1863.7	(13)$^-$	(E2)[a]	0.0679	α(K)=0.0394 *6*; α(L)=0.0211 *3*; α(M)=0.00552 *8*; α(N+..)=0.00183 *3* α(N)=0.001457 *21*; α(O)=0.000317 *5*; α(P)=4.95×10^{-5} *7*; α(Q)=1.492×10^{-6} *21*
2523.5	16$^+$	261.1 *3*	100 *20*	2262.5	(15)$^-$	(E1)[a]	0.0483	α(K)=0.0388 *6*; α(L)=0.00721 *11*; α(M)=0.001721 *25*; α(N+..)=0.000568 *9* α(N)=0.000450 *7*; α(O)=0.0001004 *15*; α(P)=1.665×10^{-5} *24*; α(Q)=1.049×10^{-6} *15*
		417.6 *3*	37 *7*	2105.7	14$^+$	(E2)[a]	0.0604	α(K)=0.0360 *5*; α(L)=0.0181 *3*; α(M)=0.00471 *7*; α(N+..)=0.001558 *23* α(N)=0.001243 *18*; α(O)=0.000271 *4*; α(P)=4.25×10^{-5} *6*; α(Q)=1.352×10^{-6} *19*
2690.1	(17)$^-$	166.6 *3*	78 *16*	2523.5	16$^+$	E1	0.1398	α(K)=0.1107 *17*; α(L)=0.0221 *4*; α(M)=0.00530 *8*; α(N+..)=0.00174 *3* α(N)=0.001382 *21*; α(O)=0.000305 *5*; α(P)=4.95×10^{-5} *8*; α(Q)=2.83×10^{-6} *5*
		427.6 *3*	100 *20*	2262.5	(15)$^-$	(E2)[a]	0.0568	α(K)=0.0343 *5*; α(L)=0.01669 *24*; α(M)=0.00434 *7*; α(N+..)=0.001436 *21* α(N)=0.001145 *17*; α(O)=0.000250 *4*; α(P)=3.92×10^{-5} *6*; α(Q)=1.286×10^{-6} *19*
2961.9	18$^+$	271.6 *3*	100 *20*	2690.1	(17)$^-$	(E1)[a]	0.0441	α(K)=0.0354 *5*; α(L)=0.00656 *10*; α(M)=0.001564 *23*; α(N+..)=0.000517 *8* α(N)=0.000409 *6*; α(O)=9.13×10^{-5} *13*; α(P)=1.517×10^{-5} *22*; α(Q)=9.64×10^{-7} *14*
		438.4 *3*	92 *18*	2523.5	16$^+$	(E2)[a]	0.0533	α(K)=0.0327 *5*; α(L)=0.01535 *22*; α(M)=0.00398 *6*; α(N+..)=0.001318 *19* α(N)=0.001051 *15*; α(O)=0.000230 *4*; α(P)=3.61×10^{-5} *6*; α(Q)=1.219×10^{-6} *18*
3144.5	(19$^-$)	182.4 *3*	88 *18*	2961.9	18$^+$	(E1)[a]	0.1124	α(K)=0.0893 *13*; α(L)=0.0175 *3*; α(M)=0.00420 *7*; α(N+..)=0.001381 *21* α(N)=0.001097 *16*; α(O)=0.000243 *4*; α(P)=3.96×10^{-5} *6*; α(Q)=2.31×10^{-6} *4*
		454.6 *3*	100 *20*	2690.1	(17)$^-$	(E2)[a]	0.0487	α(K)=0.0304 *5*; α(L)=0.01362 *20*; α(M)=0.00352 *5*; α(N+..)=0.001167 *17* α(N)=0.000930 *14*; α(O)=0.000204 *3*; α(P)=3.21×10^{-5} *5*; α(Q)=1.128×10^{-6} *16*

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Adopted Levels, Gammas (continued)

$\gamma(^{220}Ra)$ (continued)

E_i(level)	J^π_i	E_γ[‡]	I_γ[‡]	E_f	J^π_f	Mult.[#]	α[†]	Comments
3417.6	(20+)	273.2 *3*	100 *20*	3144.5	(19−)	(E1)[a]	0.0435	α(K)=0.0350 *5*; α(L)=0.00647 *10*; α(M)=0.001542 *22*; α(N+..)=0.000509 *8* α(N)=0.000403 *6*; α(O)=9.01×10−5 *13*; α(P)=1.497×10−5 *22*; α(Q)=9.52×10−7 *14*
		455.8 *3*	46 *9*	2961.9	18+	(E2)[a]	0.0484	α(K)=0.0302 *5*; α(L)=0.01350 *20*; α(M)=0.00349 *5*; α(N+..)=0.001156 *17* α(N)=0.000922 *13*; α(O)=0.000202 *3*; α(P)=3.18×10−5 *5*; α(Q)=1.122×10−6 *16*
3624.0	(21−)	206.4 *3*	100 *20*	3417.6	(20+)	(E1)[a]	0.0837	α(K)=0.0668 *10*; α(L)=0.01285 *19*; α(M)=0.00307 *5*; α(N+..)=0.001012 *15* α(N)=0.000803 *12*; α(O)=0.000178 *3*; α(P)=2.92×10−5 *5*; α(Q)=1.75×10−6 *3*
		479.4 *3*	90 *18*	3144.5	(19−)	(E2)[a]	0.0428	α(K)=0.0274 *4*; α(L)=0.01146 *17*; α(M)=0.00295 *5*; α(N+..)=0.000978 *14* α(N)=0.000779 *11*; α(O)=0.0001709 *25*; α(P)=2.71×10−5 *4*; α(Q)=1.009×10−6 *15*
3888.6	(22+)	264.4 *3*	100 *20*	3624.0	(21−)	(E1)[a]	0.0469	α(K)=0.0377 *6*; α(L)=0.00700 *10*; α(M)=0.001669 *24*; α(N+..)=0.000551 *8* α(N)=0.000436 *7*; α(O)=9.74×10−5 *14*; α(P)=1.616×10−5 *23*; α(Q)=1.021×10−6 *15*
		471.0 *3*	67 *13*	3417.6	(20+)	(E2)[a]	0.0446	α(K)=0.0284 *4*; α(L)=0.01213 *18*; α(M)=0.00313 *5*; α(N+..)=0.001037 *15* α(N)=0.000826 *12*; α(O)=0.000181 *3*; α(P)=2.87×10−5 *4*; α(Q)=1.047×10−6 *15*
4122.7	(23−)	233.8 *3*	100 *20*	3888.6	(22+)	(E1)[a]	0.0624	α(K)=0.0500 *8*; α(L)=0.00944 *14*; α(M)=0.00225 *4*; α(N+..)=0.000743 *11* α(N)=0.000589 *9*; α(O)=0.0001312 *19*; α(P)=2.16×10−5 *4*; α(Q)=1.334×10−6 *19*
		498.9 *4*	63 *19*	3624.0	(21−)	(E2)[a]	0.0389	α(K)=0.0253 *4*; α(L)=0.01010 *15*; α(M)=0.00259 *4*; α(N+..)=0.000860 *13* α(N)=0.000684 *10*; α(O)=0.0001503 *22*; α(P)=2.39×10−5 *4*; α(Q)=9.28×10−7 *13*
4374.7	(24+)	252.0 *3*	100 *20*	4122.7	(23−)	(E1)[a]	0.0524	α(K)=0.0420 *6*; α(L)=0.00786 *12*; α(M)=0.00188 *3*; α(N+..)=0.000619 *9* α(N)=0.000490 *7*; α(O)=0.0001093 *16*; α(P)=1.81×10−5 *3*; α(Q)=1.133×10−6 *17*
		486.3 *3*	57 *11*	3888.6	(22+)	(E2)[a]	0.0413	α(K)=0.0266 *4*; α(L)=0.01095 *16*; α(M)=0.00282 *4*; α(N+..)=0.000934 *14* α(N)=0.000744 *11*; α(O)=0.0001632 *23*; α(P)=2.59×10−5 *4*; α(Q)=9.79×10−7 *14*
4636.3	(25−)	261.9 *4*	57 *17*	4374.7	(24+)			
		513.6 *4*	100 *30*	4122.7	(23−)			
4873.6	(26+)	237.6 *4*	100 *30*	4636.3	(25−)			
		498.7 *4*	67 *20*	4374.7	(24+)			
5164.1	(27−)	290.7 *4*		4873.6	(26+)			
		527.7 *4*		4636.3	(25−)			
5384.5	(28+)	220.5 *4*	71 *28*	5164.1	(27−)			
		510.8 *4*	100 *30*	4873.6	(26+)			
5703.0	(29−)	318.2[b] *4*	25	5384.5	(28+)			
		538.9 *4*	100 *30*	5164.1	(27−)			
5912.0?	(30+)	209.7[b] *4*		5703.0	(29−)			
		527.0[b] *4*		5384.5	(28+)			
6255.5?	(31−)	552.5[b] *4*		5703.0	(29−)			

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Adopted Levels, Gammas (continued)

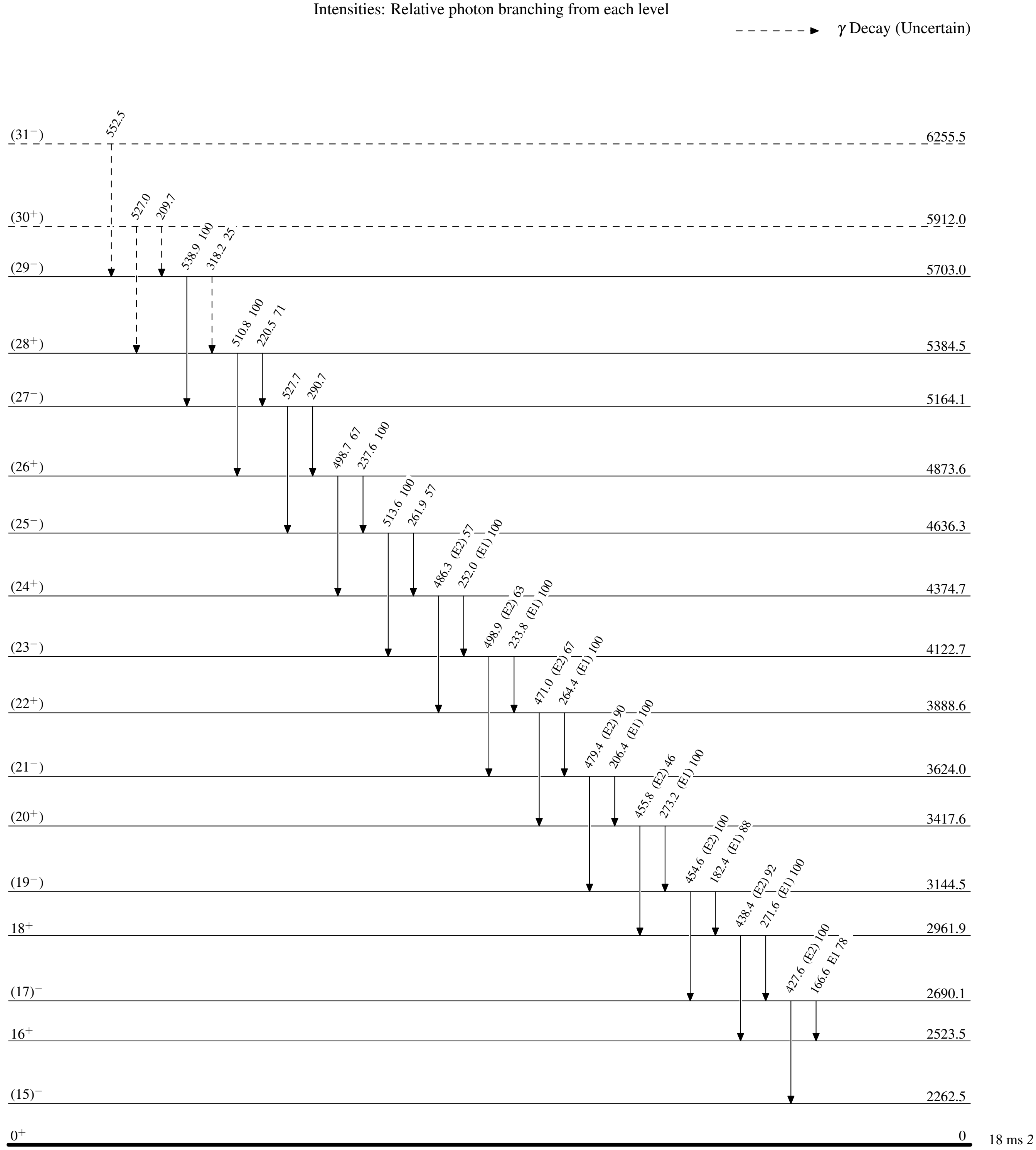
$\gamma(^{220}Ra)$ (continued)

† Additional information 2.
‡ From (^{18}O,α2nγ), unless otherwise noted.
# From (^{14}C,2nγ) and (^{18}O,α2nγ).
@ From ^{220}Fr β^- decay.
& From (^{14}C,2nγ).
[a] From $\gamma(\theta)$ (^{18}O,α2nγ), assuming stretched Q are E2 and stretched D are E1.
[b] Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Level Scheme

Intensities: Relative photon branching from each level

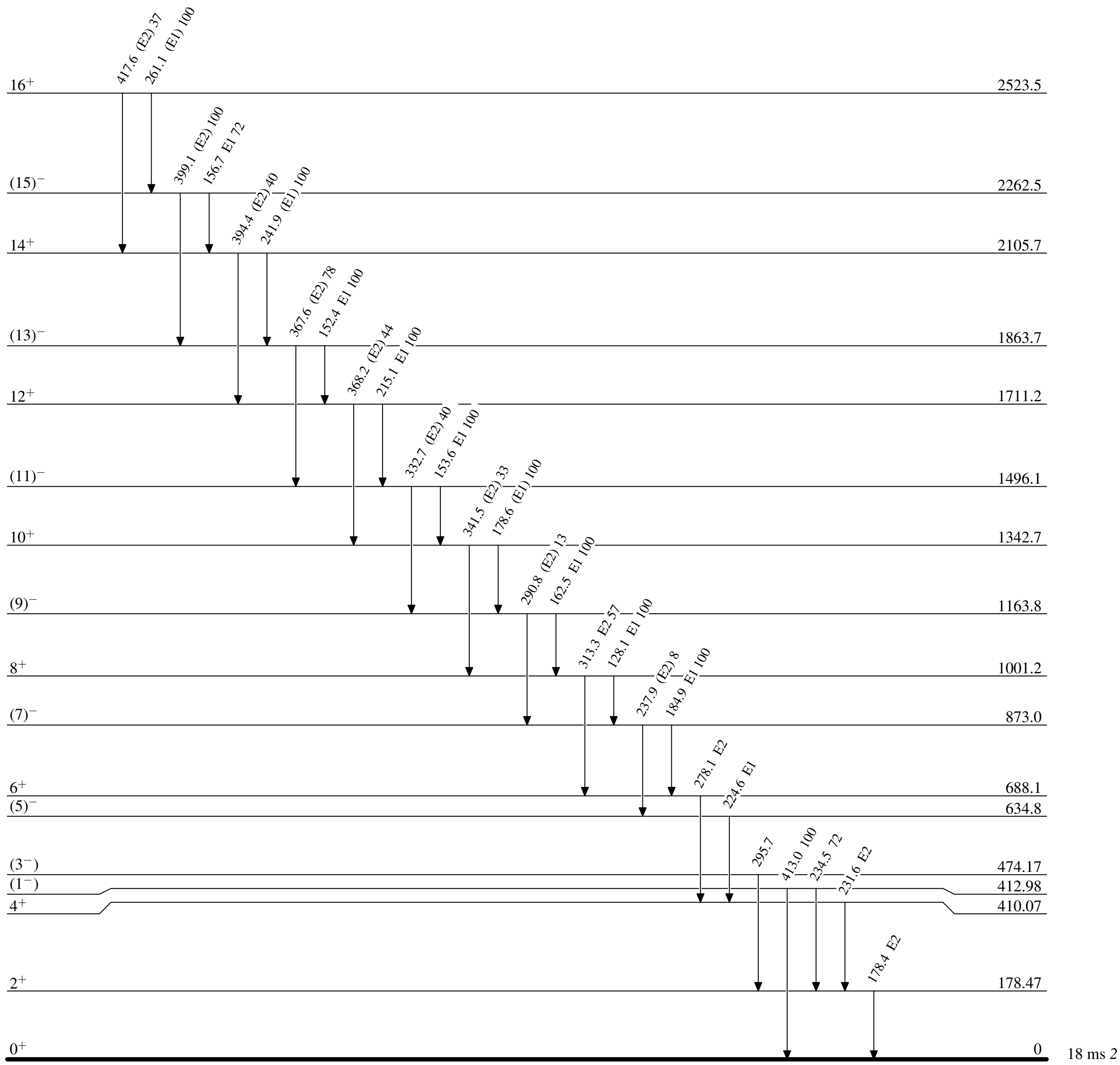


$^{220}_{88}Ra_{132}$

Adopted Levels, Gammas

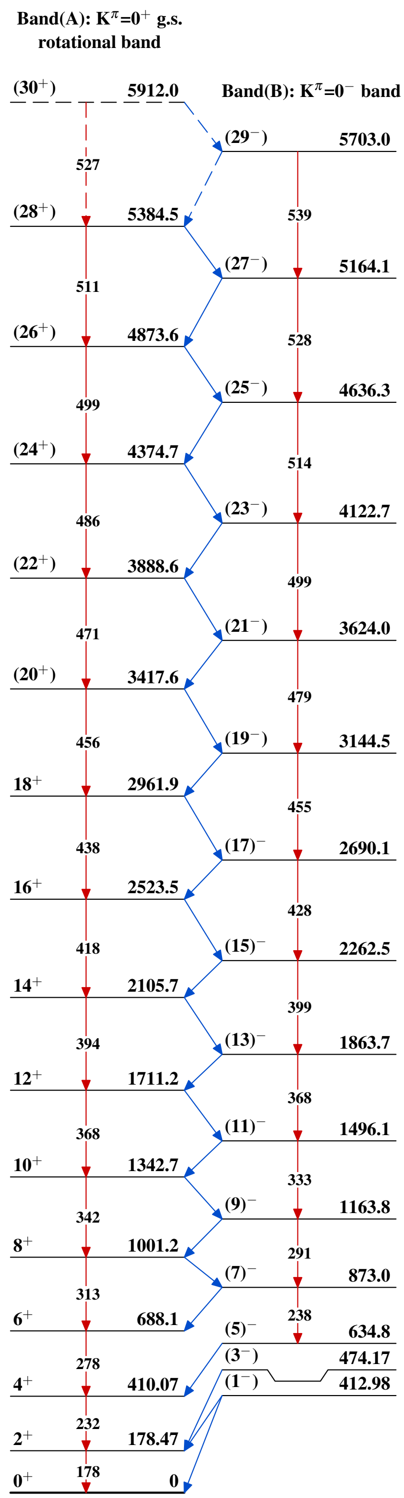
Level Scheme (continued)

Intensities: Relative photon branching from each level



$^{220}_{88}Ra_{132}$

Adopted Levels, Gammas



$^{220}_{88}Ra_{132}$

Adopted Levels, Gammas

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh, M. S. Basunia, Jun Chen et al. ,	NDS 192,315 (2023)	25-Sep-2023

Q(β^-)=−2302 *6*; S(n)=6715 *6*; S(p)=6246 *6*; Q(α)=6678 *4* 2021Wa16
S(2n)=12095 *9*, S(2p)=10870 *5* (2021Wa16).

Dataset by Balraj Singh, Jun Chen, and IAEA-ICTP-workshop participants: Diwanshu, S. Leblond, A. Rathi, P.S. Rawat, B. Rohila, and V. Vallet.

1948St42: ^{222}Rn identified in ^{230}U → ^{226}Th →^{222}Rn α-decay chain; ^{230}U produced in the bombardment of Th with 19-MeV deuterons and 38-MeV He ions at the Berkeley cyclotron facility. Measured half-life of the decay of ^{222}Rn from α decay. Later works on the study of ^{222}Rn decay: 1956As38 (also at Berkeley) and 1958To25 (at Gustaf Werner cyclotron facility in Uppsala).

Theoretical structure calculations:

2023Zh13: calculated $T_{1/2}$ and branching ratios for α, 2α, and ^{14}C cluster decays, quadrupole, octupole and hexadecupole deformation-energy surfaces using relativistic Hartree-Bogoliubov model with the DD-PC1 functional and a separable pairing force.

2022Ta16: calculated neutron and proton energy gaps, quadrupole and octupole deformation parameters using Hartree-Fock-Bogolyubov approximation with Skyrme forces.

2022Uz01: calculated quadrupole and octupole deformation parameters, rms proton matter radii, the total energy, and ^{14}C cluster decay rate using Skyrme Hartree−Fock+BCS theory with SLy4 and SkM* interactions.

2021Ku31: calculated energy differences, neutron and proton energy gaps, deformation parameters using Hartree-Fock-Bogoliubov theory with an effective Skyrme interaction.

2020No13: calculated potential energy surfaces in (β_2,β_3) plane using self-consistent mean-field (SCMF), and interacting boson model (IBM), energies of yrast positive-parity and negative-parity states, and relative energy splitting between positive- and negative-parity yrast bands, B(E1), B(E2), B(E3), transition quadrupole and octupole moments using Hartree-Fock-Bogoliubov approximation, based on Gogny-D1M energy density functional, and *sdf* interacting boson model (IBM) Hamiltonian for quadrupole-octupole coupling and collective excitations.

2019Zh50: calculated empirical proton-neutron interaction, B(E2), B(E3), binding energy, contour plot of total energy in (β_2,β_3) plane, neutron and proton single-particle levels by using the covariant density functional theory and the quadrupole-octupole collective Hamiltonian approach.

2015Bo05: calculated levels, J^π, B(E1), BE(2), B(E3) using analytic quadrupole octupole axially (AQOA) symmetric model using Davidson potential. Bohr collective Hamiltonian, and quadrupole plus octupole deformation.

2013De12: calculated β_2 and deformation parameter, CSM parameter, α-core QQ coupling parameter, Iα to 2$^+$, 4$^+$ and 6$^+$ states from ^{222}Ra decay in daughter nuclei, B(E2), rigidity parameter, E(4$^+$)/E(2$^+$) and E(6$^+$)/E(4$^+$) ratios, effective charge, hindrance factors using coherent state model.

2001Ch02: calculated rotational bands energy vs spin using reflection-asymmetric shell model for octupole-deformed nuclei.

1998Ra05: calculated high-spin levels, J^π, ground state and K^π=0$^-$ bands using phenomenological model.

1997Bu07, 1997Bu28: calculated levels, J^π, B(λ), deformation parameters, using mixed Saxon-Woods plus cubed Saxon-Woods cluster-core interaction.

1993Yo02, 1986Le05: calculations of B(E1)/B(E2) transition probabilities from the K^π=0$^-$ band.

1989Eg02: calculated octupole barrier energies, pairing energy, deformation parameters β_2, β_4 and β_6, dipole moment vs constrained quadrupole moment using microscopic model.

1988Ro02, 1987Ro08: calculated E1, E3 transition probabilities and the 0$^+$, 1$^-$ energy splitting, barrier heights, single particle and pairing energies vs octupole deformation, dipole vs octupole moments, B(E1)/B(E2) using constrained HF plus BCS method.

1988Ba48: calculated rotational band wave functions, quadrupole, and octupole deformations, energy splitting between the even- and odd-parity rotational bands using a collective Hamiltonian.

1987Na10: calculated levels, J^π, routhians, rotational bands, B(E1)/B(E2) ratios, shape dependence using cranking model.

1986Bo19: calculated quadrupole-octupole deformation energy surface, nonzero octupole moment using self-consistent Hartree-Fock plus BCS calculations.

Theoretical calculations for decay characteristics:

2023Zh13: calculated $T_{1/2}$ and branching ratios for α, 2α and ^{14}C cluster decays using relativistic Hartree-Bogoliubov model with the DD-PC1 functional and a separable pairing force, and proximity potential model for deformed nuclei.

2022Ka09: calculated $T_{1/2}$ for bare nuclei and He-like ions using adiabatic approach.

2020Ni01: calculated α-branching ratio to vibrational states, and α-decay half-life using multichannel cluster model.

2010Ro08: calculated HFB mean-field energies and octupole collective inertial parameters as function of octupole moment, particle-particle correlation energies, B(E1) and B(E3) probabilities, and dipole moments using Hartree-Fock-Bogoliubov

Adopted Levels, Gammas (continued)

approximation, and Barcelona-Catania-Paris energy density functionals.

Additional information 1.

Consult the NSR database for about 120 references for theoretical structure calculations, and about 230 theory references for α, 2α and ^{14}C decays, and other cluster decay characteristics of ^{222}Ra.

^{222}Ra Levels

B(E1)(W.u.) and B(E2)(W.u.) deduced by evaluators from measured matrix elements in Coulomb excitation, except as noted.
The $K^{\pi}=0^{+}$ g.s. band and the $K^{\pi}=0^{-}$ band at 242.11 keV have been interpreted as octupole parity-doublet bands.

Cross Reference (XREF) Flags

- A ^{222}Fr β^{-} decay (14.2 min)
- B ^{226}Th α decay (30.72 min)
- C $^{232}Th(^{136}Xe,X\gamma)$
- D Coulomb excitation

E(level)†	J^{π}	$T_{1/2}$‡	XREF	Comments
0.0#	0^{+}	33.6 s *4*	ABCD	%α=100; %^{14}C=3.0×10^{-8} *10* Evaluated rms charge radius $<r^2>^{1/2}$=5.687 fm *24* (2013An02). Evaluated $\delta<r^2>(^{222}Ra-^{214}Ra)$=+0.8950 fm^2 *2* (2013An02). $T_{1/2}$: from 2012Po13, from analysis of 42 α-decay curves, and with detailed discussion of uncertainties. Others: 36.17 s *10* (1995Ko54); 43 s *4* (1982Bo04); 39 s *4* (1958To25); 37.5 s *5* (1956As38); 38.0 s (1948St42). ^{14}C branching from measured values of I(^{14}C)/I(α)= 3.7×10^{-10} *6* (1985Pr01), 3.1×10^{-10} *10*(1985Ho21), and 2.3×10^{-10} *3* (1991Hu02). 1991Hu02 searched also for any ^{14}C branching to the 3^{-} state in ^{208}Pb at 2614 keV and deduced an upper limit of 2×10^{-10}% for its branch. Measured change in rms radius: $\delta<r^2>(^{214}Ra,^{222}Ra)$=+1.0449 fm^2 *2*(stat) *524*(syst) (2018Ly01). Measured isotope shifts: $\delta\nu(^{214}Ra,^{222}Ra)$=−29260 MHz *4*; $\delta\nu(^{226}Ra,^{222}Ra)$=+12483 MHz *3* (2018Ly01). Isotope shifts and change in rms charge radius deduced from the measurement of hyperfine-structure spectra of the $7s^2$ $^1S^0\rightarrow 7s7p\,^3P_1$ atomic transition using Collinear Resonance Ionization Spectroscopy at ISOLDE-CERN (2018Ly01). The isotope shift relative to ^{214}Ra was measured by 1988Ah02; the change in the nuclear mean square charge radius and the change in the quadrupole deformation parameter were deduced as $\Delta<r^2>$=−0.198, and $\Delta<\beta^2>^{1/2}$=0.191. See also 1987We03, 1985Ne09.
111.137# *20*	2^{+}	0.52 ns *4*	ABCD	Q=−0.75 *29* J^{π}: E2 γ to 0^{+}. $T_{1/2}$: from (α)(ce 111γ)(t) in ^{226}Th α decay. Q: from diagonal E2 matrix element (111,2^{+} → 111,2^{+})=−1.3 *5* (2020Bu01) in Coulomb excitation.
242.157@ *17*	1^{-}	9.5 ps *+21−16*	AB D	J^{π}: E1 γ to 0^{+}. $T_{1/2}$: other: <1.2 ns from (α)(242γ)(t) in ^{226}Th α decay.
301.495# *34*	4^{+}	135 ps *+17−14*	ABCD	Q=−1.59 *29* J^{π}: E2 γ to 2^{+}; band member. $T_{1/2}$: other: <1.4 ns from (α)(190γ)(t) in ^{226}Th α decay. Q: from diagonal E2 matrix element (301,4^{+} → 301,4^{+})=−1.3 *5* (2020Bu01) in Coulomb excitation.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{222}Ra Levels (continued)

E(level)†	J$^{\pi}$	T$_{1/2}$‡	XREF	Comments
317.330@ *22*	(3)$^-$	4.7 ps *+26−14*	AB D	J$^{\pi}$: E1 206γ to 2$^+$; 75γ to 1$^-$; band member. The nuclear electric dipole moment was deduced by 1992Ru01 as 0.036 *6* fm from the branching ratio for E1, E2 transitions deexciting the level. The electric quadrupole moment of 6.74 b *28* for both the g.s. and the K^{π}=0$^-$ band was assumed.
473.87@ *4*	(5$^-$)	24 ps *+5−9*	ABCD	J$^{\pi}$: γ to 4$^+$; no β feeding from 2$^-$ parent; band member.
549.97# *19*	(6$^+$)	34 ps *+6−5*	CD	J$^{\pi}$: gammas to 4$^+$ and (5$^-$); band member.
702.92@ *27*	(7$^-$)	15 ps *5*	CD	J$^{\pi}$: gammas to (6$^+$) and (5$^-$); band member.
842.93# *25*	(8$^+$)	11.1 ps *+31−24*	CD	J$^{\pi}$: gammas to (6$^+$) and (7$^-$); band member.
914.174& *26*	(0$^+$)		B	J$^{\pi}$: gammas to 2$^+$ and 1$^-$; analogy to the 916, 0$^+$ level in ^{224}Ra.
992.12@ *33*	(9$^-$)	5.1 ps *+17−13*	CD	J$^{\pi}$: gammas to (8$^+$) and (7$^-$); band member.
1024.920& *23*	(2$^+$)		AB	J$^{\pi}$: gammas to 0$^+$ and 4$^+$.
1170.99 *4*	(3$^-$,4$^+$)		A	J$^{\pi}$: gammas to (3)$^-$, 4$^+$ and (5$^-$); log *ft*=8.25 *+39−22* from 2$^-$ parent.
1171.55 *4*	(1,2$^+$)		A	J$^{\pi}$: γ to 0$^+$.
1173.02# *30*	(10$^+$)	5.0 ps *+24−17*	CD	J$^{\pi}$: gammas to (8$^+$) and (9$^-$); band member.
1225.23 *5*	(1,2$^+$)		A	J$^{\pi}$: γ to 0$^+$.
1265.05 *4*	(2$^+$,3)		A	J$^{\pi}$: gammas to 2$^+$ and 4$^+$; log *ft*=7.40 *9* from 2$^-$ parent.
1310.24 *8*	(0$^+$,1,2,3$^-$)		A	J$^{\pi}$: gamma to 1$^-$; log *ft*=8.52 *13* from 2$^-$ parent.
1330.5@ *4*	(11$^-$)	3.6 ps *+18−12*	CD	J$^{\pi}$: gammas to (10$^+$) and (9$^-$); band member.
1360.88 *9*	(1$^-$,2,3)		A	J$^{\pi}$: gammas to 2$^+$ and (3)$^-$; log *ft*=8.03 *10* from 2$^-$ parent.
1375.77 *8*	(1,2,3$^-$)		A	J$^{\pi}$: gamma to 1$^-$; log *ft*=8.15 *11* from 2$^-$ parent.
1402.596 *31*	(2$^+$,3$^-$)		A	J$^{\pi}$: gammas to 1$^-$ and 4$^+$.
1432.73 *6*	(1,2,3$^-$)		A	J$^{\pi}$: gammas to 2$^+$ and 1$^-$; log *ft*=7.42 *9* from 2$^-$ parent.
1439.994 *34*	(3$^-$)		A	J$^{\pi}$: gammas to 1$^-$ and (5$^-$); log *ft*=7.05 *10* from 2$^-$ parent.
1499.49 *5*	(1$^-$,2,3$^-$)		A	J$^{\pi}$: gammas to 1$^-$ and (3)$^-$; log *ft*=7.34 *9* from 2$^-$ parent.
1536.8# *5*	(12$^+$)	4.6 ps *+26−16*	CD	J$^{\pi}$: gammas to (10$^+$) and (11$^-$); band member.
1556.04 *7*	(2$^+$)		A	J$^{\pi}$: gammas to 0$^+$ and 4$^+$.
1619.62 *9*	(1,2,3$^-$)		A	J$^{\pi}$: gammas to 2$^+$ and 1$^-$; log *ft*=7.38 *12* from 2$^-$ parent.
1644.88 *4*	(2$^+$,3$^-$)		A	J$^{\pi}$: gammas to 1$^-$ and 4$^+$; log *ft*=6.91 *+34−22* from 2$^-$ parent.
1710.0@ *5*	(13$^-$)		C	J$^{\pi}$: gammas to (12$^+$) and (11$^-$); band member.
1754.36 *5*	(3$^-$)		A	J$^{\pi}$: gammas to 2$^+$, 4$^+$, and (5$^-$); log *ft*=6.55 *12* from 2$^-$ parent.
1821.56 *20*	(1,2,3$^-$)		A	J$^{\pi}$: γ to 1$^-$; log *ft*=7.0 *+19−16* from 2$^-$ parent.
1841.20 *6*	(1,2,3$^-$)		A	J$^{\pi}$: γ to 1$^-$; log *ft*=6.09 *+37−25* from 2$^-$ parent. If J^{π}(1645 level)=3$^-$, then J^{π}(1841)≠1$^+$.
1932.9# *6*	(14$^+$)		C	J$^{\pi}$: gamma to (12$^+$); band member.
2125.0@ *6*	(15$^-$)		C	J$^{\pi}$: gammas to (14$^+$) and (13$^-$); band member.
2358.4# *7*	(16$^+$)		C	J$^{\pi}$: gamma to (14$^+$); band member.
2569.8@ *7*	(17$^-$)		C	J$^{\pi}$: gammas to (16$^+$) and (15$^-$); band member.
2810.7# *9*	(18$^+$)		C	J$^{\pi}$: gamma to (16$^+$); band member.
3040.6@ *9*	(19$^-$)		C	J$^{\pi}$: gamma to (17$^-$); band member.
3287.4# *10*	(20$^+$)		C	J$^{\pi}$: gamma to (18$^+$); band member.

† From a least-squares fit to Eγ values. Uncertainties of some Eγ values have been increased (as specified under comment at each γ) in the fitting due to poor fit and the resulting reduced χ^2=2.2, compared to 4.9 without those ΔEγ adjustments.

‡ For levels above 111.1, half-lives have been deduced by evaluators from measured matrix elements in Coulomb excitation, and adopted γ-ray branching ratios.

Band(A): K^{π}=0$^+$ g.s. band.

@ Band(B): K^{π}=0$^-$ octupole vibrational band. Weighted averaged of D$_0$/Q$_0$=0.00402 b$^{1/2}$ *11* (1999Co02). Average electric dipole moment D$_0$=0.027 eb$^{1/2}$ *4* from J=7-15 (1999Co02).

& Band(C): K^{π}=(0$^+$) band.

Adopted Levels, Gammas (continued)

$\gamma(^{222}Ra)$

E_i(level)	J_i^π	E_γ ‡	I_γ ‡	E_f	J_f^π	Mult. #	α &	Comments
111.137	2^+	111.15 *3*	100	0.0	0^+	E2	6.12 *9*	B(E2)(W.u.)=112.8 *+96−82* E_γ: unweighted average of 111.11 *1* from ^{222}Fr β^- decay, 111.15 *1* from ^{226}Th α decay, and 111.2 *2* from (^{136}Xe,Xγ).
242.157	1^-	131.01 *3*	31.2 *15*	111.137	2^+	(E1)	0.2500 *35*	B(E1)(W.u.)=0.00186 *+40−34* E_γ: unweighted average of 130.98 *1* from ^{222}Fr β^- decay and 131.04 *1* from ^{226}Th α decay. I_γ: from ^{226}Th α decay. Other: 31.8 *31* from ^{222}Fr β^- decay. Mult.: from intensity balance in ^{226}Th α decay.
		242.13 *2*	100.0 *30*	0.0	0^+	E1	0.0575 *8*	B(E1)(W.u.)=0.00095 *+19−17* E_γ: unweighted average of 242.11 *1* from ^{222}Fr β^- decay and 242.14 *1* from ^{226}Th α decay. I_γ: from ^{226}Th α decay. Other: 100 *10* from ^{222}Fr β^- decay.
301.495	4^+	190.42 *14*	100	111.137	2^+	E2	0.700 *10*	B(E2)(W.u.)=123 *14* E_γ: unweighted average of 190.24 *2* from ^{222}Fr β^- decay, 190.31 *1* from ^{226}Th α decay, and 190.7 *2* from (^{136}Xe,Xγ).
317.330	$(3)^-$	75.13 *2*	0.017 *4*	242.157	1^-	[E2]	36.8 *5*	B(E2)(W.u.)=98 *+49−40*
		206.22 *4*	100.0 *32*	111.137	2^+	E1	0.0839 *12*	B(E1)(W.u.)=0.0041 *+17−14* E_γ: unweighted average of 206.18 *2* from ^{222}Fr β^- decay and 206.25 *1* from ^{226}Th α decay. I_γ: from ^{226}Th α decay. Other: 100 *10* from ^{222}Fr β^- decay.
473.87	(5^-)	(156.5 *1*)	4.3 *23*	317.330	$(3)^-$	[E2]	1.480 *21*	B(E2)(W.u.)=109 *+30−26* E_γ: from level-energy difference. I_γ: from B(E2,157γ)/B(E1,172γ) ratio in Coulomb excitation; this γ has not been observed.
		172.37 *2*	100	301.495	4^+	[E1]	0.1288 *18*	B(E1)(W.u.)=0.00123 *+60−24* E_γ: others: 172.3 *2* from ^{226}Th α decay and 172.2 *5* from (^{136}Xe,Xγ).
549.97	(6^+)	77	29 *4*	473.87	(5^-)	[E1]	0.2211 *31*	B(E1)(W.u.)=0.00211 *+44−40* E_γ,I_γ: from Coulomb excitation.
		248.4@ *2*	100	301.495	4^+	[E2]	0.276 *4*	B(E2)(W.u.)=135 *+24−21* I_γ: from Coulomb excitation.
702.92	(7^-)	153.1@ *5*	100@ *32*	549.97	(6^+)	[E1]	0.1715 *28*	B(E1)(W.u.)=0.0024 *+12−7*
		229.3@ *5*	18@ *6*	473.87	(5^-)	[E2]	0.362 *6*	B(E2)(W.u.)=95 *+74−38*
842.93	(8^+)	140.1@ *2*	100@ *18*	702.92	(7^-)	[E1]	0.2126 *31*	B(E1)(W.u.)=0.00265 *+75−66*
		292.9@ *2*	92@ *8*	549.97	(6^+)	[E2]	0.1636 *23*	B(E2)(W.u.)=119 *+36−28*
914.174	(0^+)	672.02 *2*	100 *7*	242.157	1^-			
		802.7† *1*	13 *8*	111.137	2^+			E_γ: uncertainty multiplied by a factor of 2 in the fitting; level-energy difference=803.036.
992.12	(9^-)	149.3@ *5*	100@ *16*	842.93	(8^+)	[E1]	0.1822 *30*	B(E1)(W.u.)=0.0049 *+18−14*
		289.0@ *5*	88@ *10*	702.92	(7^-)	[E2]	0.1705 *26*	B(E2)(W.u.)=2.7×10^2 *+10−7*

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Adopted Levels, Gammas (continued)

$\gamma(^{222}Ra)$ (continued)

E_i(level)	J^π_i	E_γ [‡]	I_γ [‡]	E_f	J^π_f	Mult.[#]	α [&]	Comments
1024.920	(2+)	707.54 *3*	100 *5*	317.330	(3)−			E_γ: other: 707.52 *9* from ^{226}Th α decay. I_γ: other: 100 *9* from ^{226}Th α decay.
		723.45 *6*	3.4 *5*	301.495	4+			E_γ: weighted average of 723.45 *4* from ^{222}Fr β^- decay and 722.9 *4* from ^{226}Th α decay. I_γ: other: 15 *6* from ^{226}Th α decay is discrepant.
		782.77 *3*	98 *9*	242.157	1−			E_γ: other: 783.0 *5* from ^{226}Th α decay. I_γ: other: 112 *25* from ^{226}Th α decay.
		913.69 *5*	16.9 *23*	111.137	2+			E_γ: other: 913.9 *4* from ^{226}Th α decay. I_γ: other: 66 *33* from ^{226}Th α decay is discrepant.
		1025.02 *8*	6.7 *11*	0.0	0+			
1170.99	(3−,4+)	696.88[†] *5*	29 *5*	473.87	(5−)			E_γ: uncertainty multiplied by a factor of 2 in the fitting; level-energy difference=697.13.
		853.78 *8*	100 *6*	317.330	(3)−			
		869.6 *2*	81 *25*	301.495	4+			
1171.55	(1,2+)	929.47 *8*	15 *2*	242.157	1−			
		1060.33 *5*	100 *8*	111.137	2+			
		1171.69 *8*	53 *6*	0.0	0+			
1173.02	(10+)	180.9[@] *2*	100[@] *23*	992.12	(9−)	[E1]	0.1147 *16*	B(E1)(W.u.)=0.0032 *+16−11*
		330.1[@] *2*	75[@] *7*	842.93	(8+)	[E2]	0.1147 *16*	B(E2)(W.u.)=139 *+76−48*
1225.23	(1,2+)	982.90 *8*	97 *19*	242.157	1−			
		1114.26 *8*	100 *19*	111.137	2+			
		1225.24 *8*	38 *7*	0.0	0+			
1265.05	(2+,3)	963.61 *6*	26 *4*	301.495	4+			
		1153.87 *5*	100 *10*	111.137	2+			
1310.24	(0+,1,2,3−)	1068.08 *8*		242.157	1−			
1330.5	(11−)	157.4[@] *5*	64[@] *10*	1173.02	(10+)	[E1]	0.1604 *26*	B(E1)(W.u.)=0.0046 *+24−16*
		338.3[@] *5*	100[@] *10*	992.12	(9−)	[E2]	0.1069 *16*	B(E2)(W.u.)=2.4×10^2 *+13−8*
1360.88	(1−,2,3)	1043.60 *9*	100 *12*	317.330	(3)−			
		1249.1[†] *1*	60 *11*	111.137	2+			E_γ: uncertainty multiplied by a factor of 3 in the fitting; level-energy difference=1249.74.
1375.77	(1,2,3−)	1133.61 *8*		242.157	1−			
1402.596	(2+,3−)	231.7 *2*	15.2 *16*	1170.99	(3−,4+)			
		377.64 *4*	24 *2*	1024.920	(2+)			
		1085.20 *5*	92 *12*	317.330	(3)−			
		1101.09 *5*	100 *10*	301.495	4+			
		1160.52 *8*	14.4 *14*	242.157	1−			
		1291.61 *8*	9.6 *16*	111.137	2+			
1432.73	(1,2,3−)	1190.4 *1*	8.5 *15*	242.157	1−			
		1321.65 *6*	100 *8*	111.137	2+			
1439.994	(3−)	268.99 *4*	13 *3*	1170.99	(3−,4+)			
		415.05 *4*	11 *2*	1024.920	(2+)			
		966.24 *9*	23 *5*	473.87	(5−)			
		1122.41[†] *9*	40 *7*	317.330	(3)−			E_γ: uncertainty multiplied by a

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Adopted Levels, Gammas (continued)

$\gamma(^{222}Ra)$ (continued)

E_i(level)	J^π_i	E_γ[‡]	I_γ[‡]	E_f	J^π_f	Mult.[#]	α[&]	Comments
								factor of 2 in the fitting; level-energy difference=1122.661.
1439.994	(3⁻)	1138.47 *5*	100 *10*	301.495	4⁺			
		1197.99 *8*	30 *5*	242.157	1⁻			
1499.49	(1⁻,2,3⁻)	474.45 *9*	100 *10*	1024.920	(2⁺)			
		1182.05 *8*	87 *10*	317.330	(3)⁻			
		1257.5 *1*	33 *6*	242.157	1⁻			
		1388.5 *1*	76 *10*	111.137	2⁺			
1536.8	(12⁺)	206.2[@] *5*	64[@] *12*	1330.5	(11⁻)	[E1]	0.0839 *13*	B(E1)(W.u.)=0.00164 *+93−62*
		363.9[@] *5*	100[@] *10*	1173.02	(10⁺)	[E2]	0.0871 *13*	B(E2)(W.u.)=136 *+78−48*
1556.04	(2⁺)	1238.60 *8*	100 *13*	317.330	(3)⁻			
		1254.4 *2*	26 *3*	301.495	4⁺			
		1445.2 *2*	69 *11*	111.137	2⁺			
		1556.5 *2*	59 *11*	0.0	0⁺			
1619.62	(1,2,3⁻)	1377.4 *1*	100 *15*	242.157	1⁻			
		1508.7 *2*	24 *7*	111.137	2⁺			
1644.88	(2⁺,3⁻)	619.95 *4*	31 *4*	1024.920	(2⁺)			
		1327.58 *6*	100 *9*	317.330	(3)⁻			
		1343.3 *1*	10.4 *17*	301.495	4⁺			
		1402.5 *2*	27 *3*	242.157	1⁻			
		1534.1 *2*	17 *3*	111.137	2⁺			
1710.0	(13⁻)	173.1[@] *5*	82[@] *12*	1536.8	(12⁺)	[E1]	0.1275 *20*	
		379.6[@] *5*	100[@] *9*	1330.5	(11⁻)	[E2]	0.0776 *11*	
1754.36	(3⁻)	351.75 *4*	52 *11*	1402.596	(2⁺,3⁻)			
		1280.99[†] *9*	34 *7*	473.87	(5⁻)			E_γ: uncertainty multiplied by a factor of 3 in the fitting; level-energy difference=1280.49.
		1436.4[†] *1*	100 *10*	317.330	(3)⁻			E_γ: uncertainty multiplied by a factor of 3 in the fitting; level-energy difference=1437.03.
		1453.4[†] *1*	45 *9*	301.495	4⁺			E_γ: uncertainty multiplied by a factor of 3 in the fitting; level-energy difference=1452.86.
		1643.9[†] *2*	44 *11*	111.137	2⁺			E_γ: uncertainty multiplied by a factor of 2 in the fitting; level-energy difference=1643.22.
1821.56	(1,2,3⁻)	1579.4 *2*	100	242.157	1⁻			
1841.20	(1,2,3⁻)	196.31 *4*	100 *13*	1644.88	(2⁺,3⁻)			
		1599.6[†] *2*	16 *5*	242.157	1⁻			E_γ: uncertainty multiplied by a factor of 2 in the fitting; level-energy difference=1599.04.
1932.9	(14⁺)	396.0[@] *5*	100	1536.8	(12⁺)	[E2]	0.0693 *10*	
2125.0	(15⁻)	192.1[@] *5*	68[@] *30*	1932.9	(14⁺)	[E1]	0.0993 *15*	
		415.0[@] *5*	100[@] *12*	1710.0	(13⁻)	[E2]	0.0613 *9*	
2358.4	(16⁺)	425.5[@] *5*	100	1932.9	(14⁺)	[E2]	0.0575 *8*	
2569.8	(17⁻)	211.4[@] *5*		2358.4	(16⁺)			
		444.8[@] *5*	100[@]	2125.0	(15⁻)	[E2]	0.0514 *7*	
2810.7	(18⁺)	452.3[@] *5*	100	2358.4	(16⁺)	[E2]	0.0493 *7*	
3040.6	(19⁻)	470.8[@] *5*	100	2569.8	(17⁻)	[E2]	0.0447 *6*	
3287.4	(20⁺)	476.7[@] *5*	100	2810.7	(18⁺)	[E2]	0.0434 *6*	

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Adopted Levels, Gammas (continued)

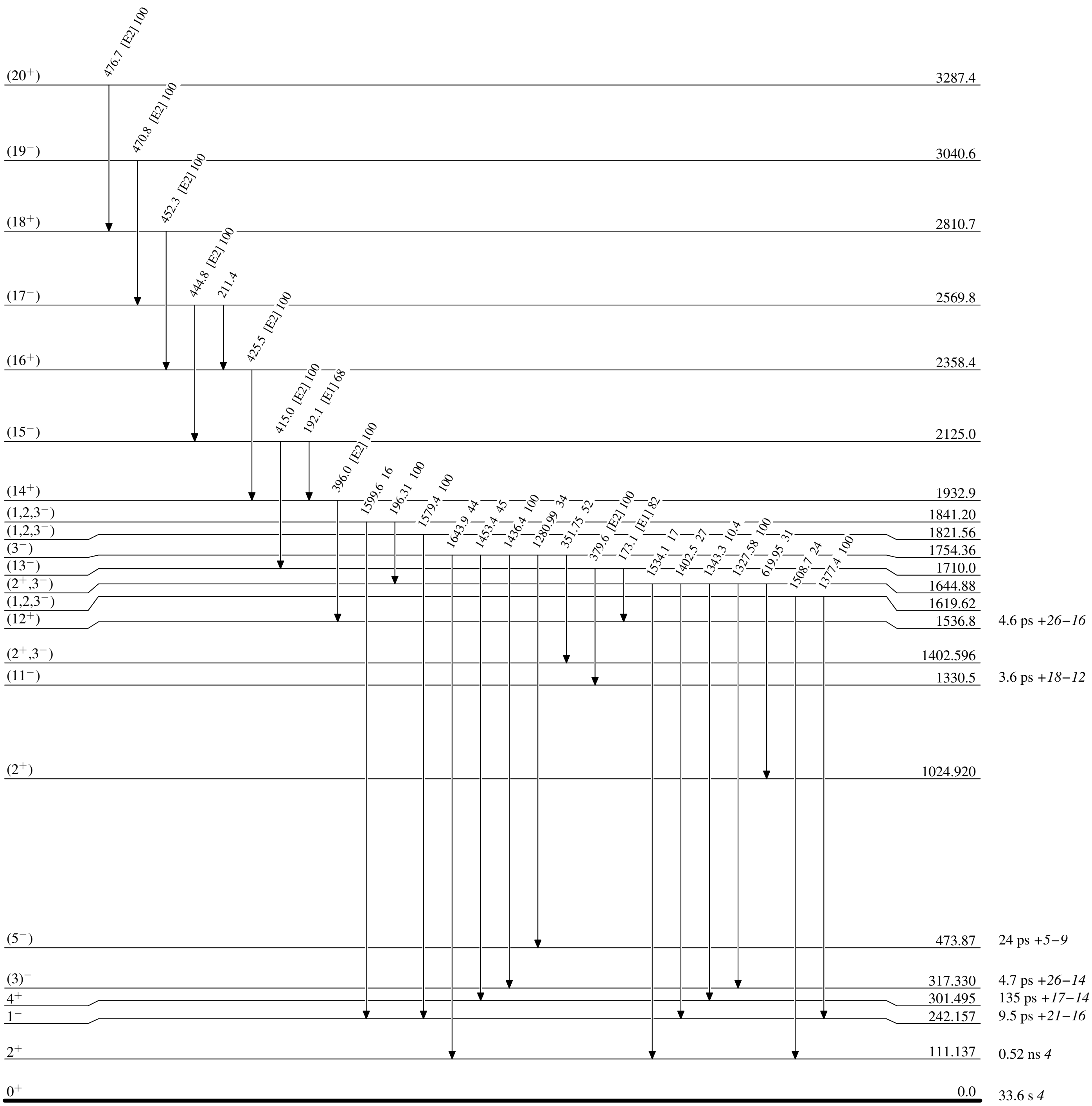
$\gamma(^{222}Ra)$ (continued)

† Poor fit; uncertainty multiplied by a factor in the fitting.
‡ From ^{222}Fr β^- decay, unless otherwise noted.
# From ce data in ^{226}Th α decay, unless otherwise noted.
@ From $^{232}Th(^{136}Xe,X\gamma)$.
& 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.

Adopted Levels, Gammas

Level Scheme

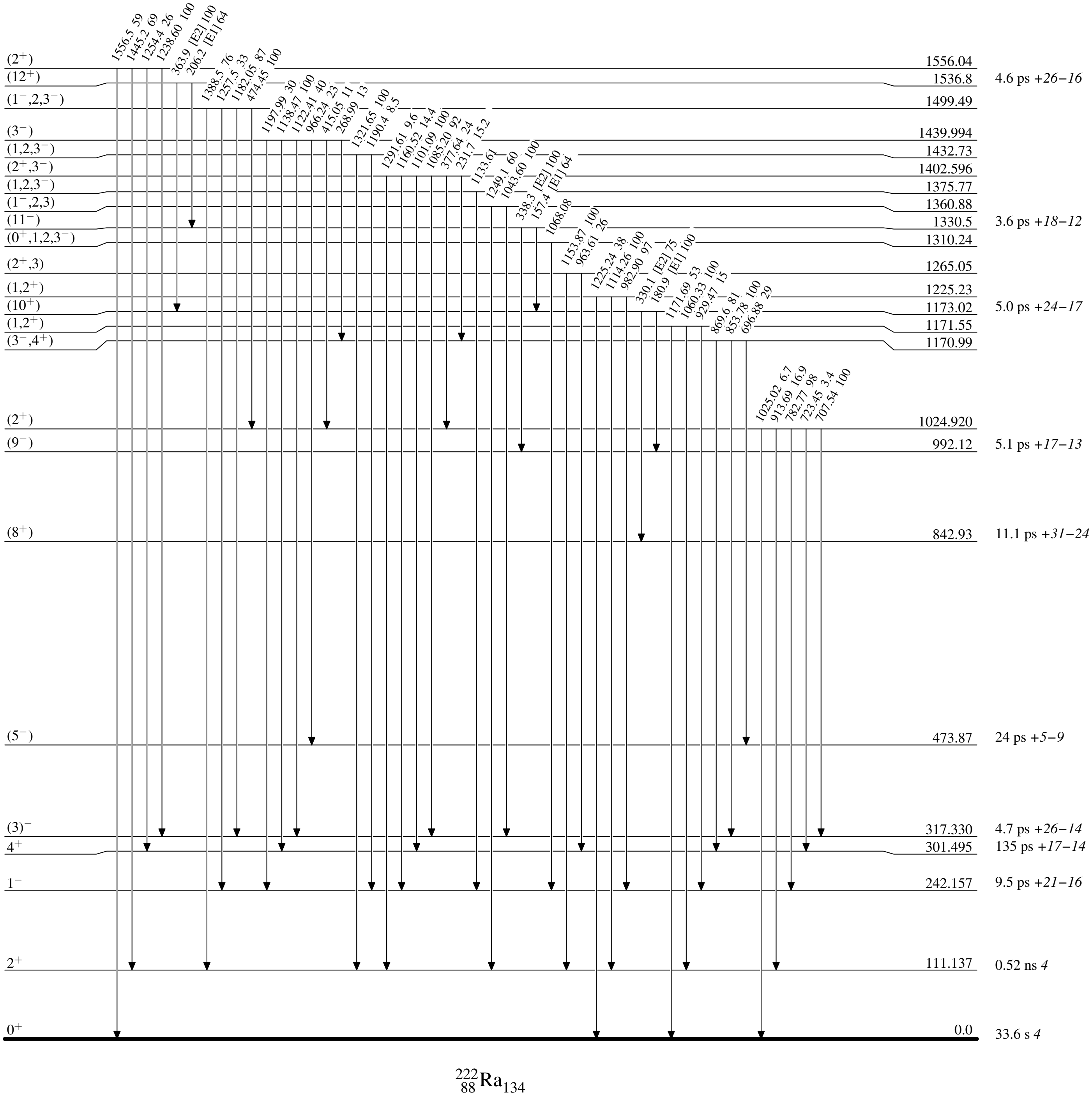
Intensities: Relative photon branching from each level



Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level

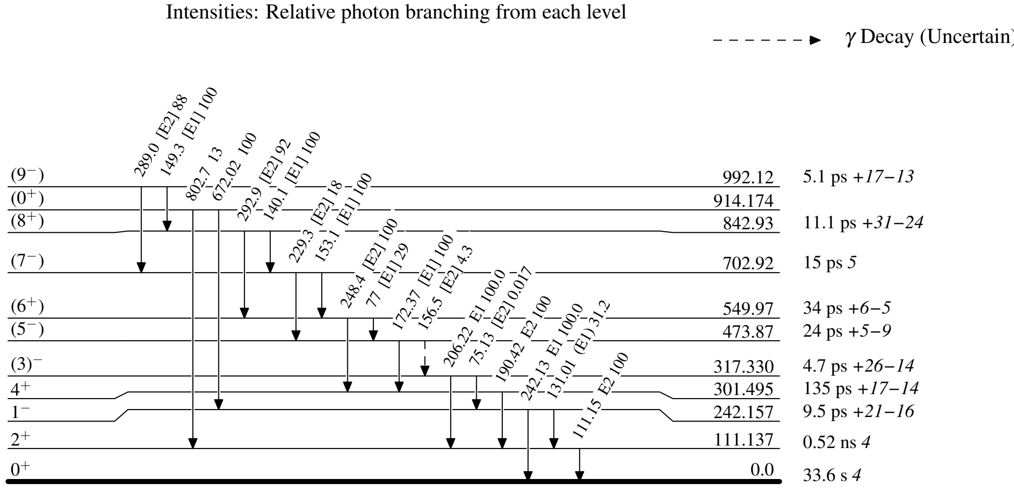


Adopted Levels, Gammas

Legend

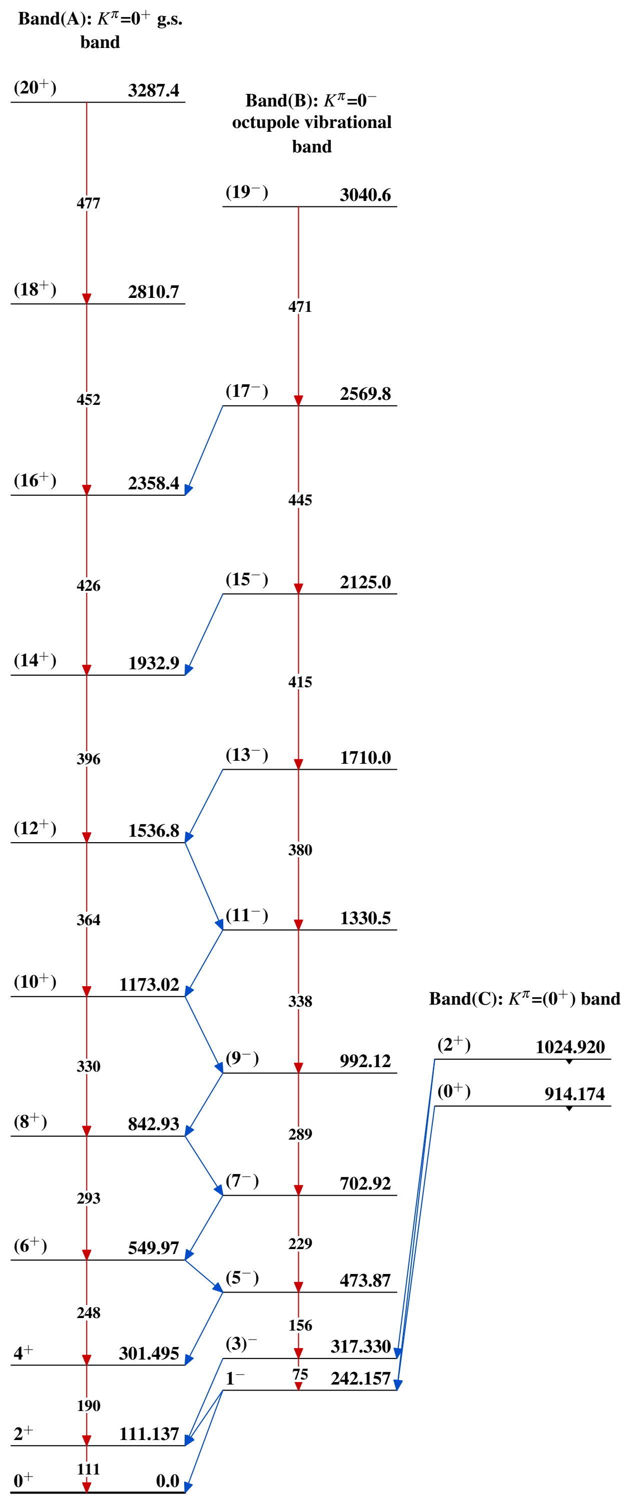
Level Scheme (continued)

Intensities: Relative photon branching from each level



$^{222}_{88}Ra_{134}$

Adopted Levels, Gammas



$^{222}_{88}Ra_{134}$

Adopted Levels, Gammas

History

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

Q(β^-)=−1408 *4*; S(n)=6478.7 *23*; S(p)=6845.5 *21*; Q(α)=5788.92 *15* 2021Wa16

S(2n)=11637 *5*, S(2p)=12124.1 *19* (2021Wa16).

In the past, ^{224}Ra was called ThX, and was first identified by Rutherford and Soddy, Phil. Mag. 4, 370 (1902), extracted from thorium with an estimated half-life of ≈4 d. Later studies of decay of ^{224}Ra: 1938Le07, 1962Ll02, 1962Wa28, 1971Jo14, 1977Ku15, 2004Sc04.

2014Bo26: mass determination with Penning-trap mass spectrometer ISOLTRAP facility at ISOLDE, CERN. Measured mass excess=18826 *28*.

Theoretical calculations: 132 references extracted from the NSR database are listed in document records.
Additional information 1.

^{224}Ra Levels

Cross Reference (XREF) Flags

A	^{224}Fr β^- decay (3.33 min)	E	^{226}Ra(p,t)
B	^{224}Ac ε decay (2.78 h)	F	^{226}Ra(α,α'2nγ)
C	^{228}Th α decay (1.9125 y)	G	^{226}Ra(^{58}Ni,^{60}Niγ)
D	Coulomb excitation	H	^{232}Th(^{136}Xe,Xγ)

E(level)[†]	J$^\pi$	T$_{1/2}$	XREF	Comments
0[#]	0$^+$	3.6316 d *23*	ABCDEFGH	%α=100; %^{14}C=4.0×10^{-9} *10* (1992Ar02) %^{14}C=4.0×10^{-9} *10* (1992Ar02), 6.5×10^{-9} *10* (1991Ho15,1991Ho24), 4.3×10^{-9} *12* (1985Pr01); fine structure looked for, but not observed (1991Ho15). Evaluated rms charge radius=5.705 fm *26* (2013An02). Measured change in rms radius: δ<r^2>(^{214}Ra,^{224}Ra)=+1.2680 fm^2 *2* (stat) *636* (syst) (2018Ly01, hyperfine structure by collinear laser resonance ionization spectroscopy at ISOLDE-CERN). Measured isotope shifts: $\delta\nu$(^{214}Ra,^{224}Ra)=−35652 MHz *4*; $\delta\nu$(^{226}Ra,^{224}Ra)=+6092 MHz *3* (2018Ly01, hyperfine structure by collinear laser resonance ionization spectroscopy at ISOLDE-CERN). δ<r^2>=+1.09 *11*, relative to ^{214}Ra (1988Ah02); other: 1989Ne03. T$_{1/2}$: weighted average of 3.6262 d *48* (2021Be13, National Physical Laboratory, U.K., from 238.6γ, 241.0γ and 583.2γ decay curves using HPGe detector); 3.6323 d *27* (2021Be13, NIST, from 238.6γ, 241.0γ and 583.2γ decay curves using HPGe detector); 3.6321 d *28* (2021Be13, NIST using an ionization chamber); and 3.6319 d *23* (2004Sc04, 4π ionization chamber at the Physikalisch-Technische Bundesanstalt-PTB). Other measurements: 3.66 d *4* (1971Jo14), 3.62 d *1* (1962Ll02), 3.64 d (1938Le07) are in agreement with the recommended value but much less precise.
84.372[#] *3*	2$^+$	0.748 ns *19*	ABCDEFGH	μ=+0.92 *22* (1973He13,2020StZV) J$^\pi$: E2 γ to 0$^+$. μ: from IPAC in ^{228}Th α decay (1973He13). B(E2)=3.96 *12* from Coul. ex. (2013Ga23,2012GaZV). Q$_2$=6.32 *10*, β_2=0.154 (2012GaZV,2013Ga23). T$_{1/2}$: from $\alpha\gamma$(t) in ^{228}Th α decay.
215.985[@] *4*	1$^-$		ABCDE GH	J$^\pi$: E1 γ to 0$^+$.
250.782[#] *5*	4$^+$	0.181 ns *9*	ABCD FGH	J$^\pi$: $\alpha\gamma(\theta)$ from 0$^+$ parent (^{228}Th α decay, 1989Po19). T$_{1/2}$: from $\alpha\gamma$(t) in ^{228}Th α decay.
290.352[@] *21*	3$^-$		ABCD FGH	J$^\pi$: E1 γ to 2$^+$; no γ to 0$^+$; HF=47 for α branch from 0$^+$; no β^- decay from 1$^-$

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{224}Ra Levels (continued)

E(level)†	Jπ	T1/2	XREF	Comments
				^{224}Fr; member of $K^{\pi}=0^-$ octupole band.
433.02@ *7*	$(5)^-$		A CD FGH	Jπ: E1 γ to 4+; no γ to levels with J<3; member of $K^{\pi}=0^-$ octupole band. γ-ray branching ratio is in disagreement in various experiments.
479.12# *10*	6^+	52.7 ps *42*	CDEFGH	Jπ: γ to 4+; member of g.s. band. T1/2: from 2012GaZV.
640.69@ *18*	(7^-)		D FGH	Jπ: (E2) γ to (5)−; member of $K^{\pi}=0^-$ octupole band.
754.88# *20*	8^+	20.8 ps *+49−55*	D FGH	Jπ: γ to (6+); member of g.s. band. T1/2: from 2012GaZV.
906.17@ *25*	(9^-)		D FGH	Jπ: γ to (7−); member of $K^{\pi}=0^-$ octupole band.
916.38 *6*	0^+		A C E	Jπ: L(p,t)=0.
965.65 *6*	2^+		A D	Jπ: γ rays to 0+ and 2+; populated in Coulomb excitation. Possible bandhead of $K^{\pi}=2^+$ γ-vibrational band.
992.70 *6*	(2^+)		A C	Jπ: γ rays to 2+ and 4+; possible γ to 0+; HF≈6.8 for α branch from 0+.
1053.041 *23*	1^-		A	Jπ: 1+E2 γ to 1−; γ to 0+.
1068.5# *3*	10^+		D FGH	Jπ: γ to (8+); member of g.s. band.
1090.087 *24*	$(2,3)^-$		A	Jπ: M1(+E2) γ to (3)−; γ rays to 1− and 2+.
1187.1 *4*	0^+,1,2		A	Jπ: γ rays to 1− and 2+; log ft=8.2 from $1^{(-)}$.
1216.89 *19*	$(1^-,2)$		A	Jπ: γ rays to 1− and (3)−; log ft=8.1 from $1^{(-)}$.
1220.7@ *4*	(11^-)		FGH	Jπ: γ to (9−); member of $K^{\pi}=0^-$ octupole band.
1223 *4*	0^+		E	Jπ: L(p,t)=0.
1348.22 *9*	$2^+,3^+$		A	Jπ: γ rays to 2+ and 4+; log ft=7.76 *11*, log $f^{1u}t$=8.5 from $1^{(-)}$.
1378.41 *3*	1^-		A	Jπ: M1 γ to 1−; γ rays to 0+ and 2+.
1379.04 *6*	$(1^+,2^+)$		A	Jπ: M1 γ to (2+); γ to 1−; log ft=6.87 from $1^{(-)}$.
1389.93 *15*	$(0^+,1,2)$		A	Jπ: γ rays to 1− and 2+; log ft=7.59 from $1^{(-)}$.
1413.7# *4*	(12^+)		FGH	Jπ: possible member of g.s. band.
1425.152 *20*	$(0,1,2)^-$		A	Jπ: M1 γ rays to 1− and (2,3)−.
1435.54 *3*	1^-		A	Jπ: M1 γ to 1−; γ to 0+.
1437.11 *6*	2^+		A	Jπ: γ rays to 0+ and 4+.
1553.67 *14*	$1,2^+$		A	Jπ: γ to 0+ g.s.
1573.6@ *6*	(13^-)		GH	Jπ: possible member of $K^{\pi}=0^-$ octupole band.
1614.42 *17*	$(1^-,2)$		A	Jπ: γ rays to (3)− and 1−; log ft=7.80 from $1^{(-)}$.
1627 *3*			E	
1652.49 *4*	2^+		A	Jπ: γ rays to 0+ and 4+.
1658.49 *9*	$1^{(-)},2^+$		A	Jπ: γ rays to 0+ and (3)−.
1736.44 *16*	$1,2^+$		A	Jπ: γ to 0+ g.s.
1754.84 *9*	0^+,1,2‡		A	Jπ: γ rays to 1− and 2+.
1761 *4*			E	E(level): possibly the same as the 1755 level.
1787.5# *6*	(14^+)		H	
1789.61 *6*	$1,2^+$		A	Jπ: γ rays to 0+ and 2+.
1796.71 *9*	$(1^-,2)$‡		A	Jπ: γ rays to 1− and (3)−.
1818.06 *19*	$(1^-,2)$‡		A	Jπ: γ rays to 1− and (3)−.
1838.53 *10*	0,1,2‡		A	Jπ: γ to 1− level.
1896.3 *3*	$(1^-,2)$‡		A	Jπ: γ rays to 1− and (3)−.
1949 *4*			E	
1964.7@ *8*	(15^-)		H	
1969.92 *10*	(0,1,2)‡		A	Jπ: γ to 1−.
2000.26 *17*	$(1^-,2)$‡		A	Jπ: γ to 1− and (3)−.
2043.0 *3*	0,1,2‡		A	Jπ: γ to 1−.
2052.3 *4*	2^+‡		A	Jπ: γ rays to 4+ and 1−.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{224}Ra Levels (continued)

E(level)†	J^π	XREF	Comments
2077.3 *4*	0^+,1,2‡	A	J^π: γ rays to 1^- and 2^+.
2117.4 *4*	1,2^+	A	J^π: γ to 0^+ g.s.
2135.3 *5*	0,1,2‡	A	J^π: γ to 1^-.
2187.7# *8*	(16^+)	H	
2229.4 *4*	(1^-,2)‡	A	J^π: γ rays to 1^- and $(3)^-$.
2246.5 *3*	1,2^+	A	J^π: γ to 0^+ g.s.
2368.7 *4*	1,2^+	A	J^π: γ to 0^+ g.s.
2384.1@ *9*	(17^-)	H	
2612.1# *10*	(18^+)	H	
2827.0@ *11*	(19^-)	H	
3059.2# *11*	(20^+)	H	
3289.8@ *12*	(21^-)	H	
3526.3# *12*	(22^+)	H	
3769.6@ *13*	(23^-)	H	
4011.4# *13*	(24^+)	H	
4266.4@ *14*	(25^-)	H	
4512.2# *14*	(26^+)	H	
4778.0?@ *15*	(27^-)	H	
5030.4?# *15*	(28^+)	H	

† From least-squares fit to Eγ data for levels deduced from γ-ray data.
‡ log *ft*<7.8, log $f^{1u}t$<7.8 from 1^- ^{224}Fr rules out J=3.
# Band(A): $K^\pi=0^+$ g.s. band.
@ Band(B): $K^\pi=0^-$ band.

$\gamma(^{224}Ra)$

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[#]	α[@]	Comments
84.372	2^+	84.373 *3*	100	0	0^+	E2[‡]	21.2	α(L)=15.57 *22*; α(M)=4.24 *6* α(N)=1.119 *16*; α(O)=0.238 *4*; α(P)=0.0343 *5*; α(Q)=0.0001015 *15* B(E2)(W.u.)=99 *3*
215.985	1^-	131.613 *4*	51.4 *6*	84.372	2^+	E1[‡]	0.247	α(K)=0.194 *3*; α(L)=0.0406 *6*; α(M)=0.00977 *14* α(N)=0.00254 *4*; α(O)=0.000559 *8*; α(P)=8.92×10^{-5} *13*; α(Q)=4.80×10^{-6} *7*
		215.983 *5*	100.0 *4*	0	0^+	E1[‡]	0.0752	α(K)=0.0600 *9*; α(L)=0.01148 *16*; α(M)=0.00274 *4* α(N)=0.000717 *10*; α(O)=0.0001593 *23*; α(P)=2.62×10^{-5} *4*; α(Q)=1.587×10^{-6} *23*
250.782	4^+	166.410 *4*	100	84.372	2^+	E2[‡]	1.164	B(E2)(W.u.)=140 *7* α(K)=0.225 *4*; α(L)=0.691 *10*; α(M)=0.187 *3* α(N)=0.0495 *7*; α(O)=0.01056 *15*; α(P)=0.001553 *22*; α(Q)=1.200×10^{-5} *17*
290.352	3^-	74.4 *1*	1.4 *4*	215.985	1^-	[E2]	38.5	α(L)=28.3 *5*; α(M)=7.70 *12* α(N)=2.03 *4*; α(O)=0.431 *7*; α(P)=0.0621 *10*; α(Q)=0.0001645 *25* I_γ: averaging by LWM.
		205.936 *27*	100.0 *10*	84.372	2^+	E1	0.0841	α(K)=0.0671 *10*; α(L)=0.01293 *19*; α(M)=0.00309 *5* α(N)=0.000807 *12*; α(O)=0.000179 *3*; α(P)=2.94×10^{-5} *5*; α(Q)=1.763×10^{-6} *25*
		290.5		0	0^+	[E3]	1.084	α(K)=0.196 *3*; α(L)=0.647 *9*; α(M)=0.180 *3* α(N)=0.0481 *7*; α(O)=0.01035 *15*; α(P)=0.001552 *22*; α(Q)=1.88×10^{-5} *3* E_γ: from Coulomb excitation.
433.02	$(5)^-$	142.66 *10*	56 *13*	290.352	3^-	[E2]	2.14	α(K)=0.279 *4*; α(L)=1.370 *20*; α(M)=0.372 *6* α(N)=0.0984 *15*; α(O)=0.0210 *3*; α(P)=0.00307 *5*; α(Q)=1.83×10^{-5} *3* I_γ: from Coulomb excitation based on extensive data for yield measurements. This value agrees with 54 *19* from (^{58}Ni,^{60}Niγ), but not with 26 *10* from α decay and 139 *39* from (^{136}Xe,Xγ). Weighted average of all four measurements is 43 *13* with reduced χ^2=3.4 as compared to critical χ^2=2.6.
		182.29 *10*	100 *12*	250.782	4^+	[E1]	0.1126	α(K)=0.0894 *13*; α(L)=0.01757 *25*; α(M)=0.00421 *6* α(N)=0.001098 *16*; α(O)=0.000243 *4*; α(P)=3.96×10^{-5} *6*; α(Q)=2.31×10^{-6} *4*
		348.5		84.372	2^+	[E3]	0.508	α(K)=0.1352 *19*; α(L)=0.273 *4*; α(M)=0.0753 *11* α(N)=0.0200 *3*; α(O)=0.00433 *6*; α(P)=0.000656 *10*; α(Q)=1.039×10^{-5} *15* E_γ: from Coulomb excitation.
479.12	6^+	228.3 *1*	100	250.782	4^+	[E2]	0.367	α(K)=0.1245 *18*; α(L)=0.179 *3*; α(M)=0.0480 *7* α(N)=0.01269 *18*; α(O)=0.00273 *4*; α(P)=0.000407 *6*; α(Q)=5.37×10^{-6} *8* B(E2)(W.u.)=157 *13*
640.69	(7^-)	160.5 *5*	13 *4*	479.12	6^+	[E1]	0.1530 *25*	α(K)=0.1209 *20*; α(L)=0.0243 *4*; α(M)=0.00583 *10* α(N)=0.001521 *25*; α(O)=0.000336 *6*; α(P)=5.43×10^{-5} *9*; α(Q)=3.07×10^{-6} *5* E_γ,I_γ: from (^{136}Xe,Xγ).
		207.8 *2*	100 *19*	433.02	$(5)^-$	[E2]	0.510	α(K)=0.1502 *22*; α(L)=0.265 *4*; α(M)=0.0714 *11* α(N)=0.0189 *3*; α(O)=0.00404 *6*; α(P)=0.000601 *9*; α(Q)=6.77×10^{-6} *10*
754.88	8^+	113.9 *5*	<11	640.69	(7^-)	[E1]	0.350 *7*	α(K)=0.272 *5*; α(L)=0.0594 *11*; α(M)=0.0143 *3* α(N)=0.00372 *7*; α(O)=0.000813 *15*; α(P)=0.0001285 *23*; α(Q)=6.64×10^{-6} *12*

From ENSDF

$^{224}_{88}Ra_{136}$-4

γ(^{224}Ra) (continued)

E_i(level)	J^π_i	E_γ†	I_γ†	E_f	J^π_f	Mult.#	δ#	α@	Comments
									B(E1)(W.u.)=0.0003 *3* E_γ: uncertainty assigned by evaluators.
754.88	8^+	275.8 *2*	100 *5*	479.12	6^+	[E2]		0.197	α(K)=0.0844 *12*; α(L)=0.0833 *12*; α(M)=0.0222 *4* α(N)=0.00587 *9*; α(O)=0.001265 *18*; α(P)=0.000191 *3*; α(Q)=3.42×10^{-6} *5* B(E2)(W.u.)=1.7×10^2 *5*
906.17	(9^-)	151.2 *5*	<15	754.88	8^+	[E1]		0.177 *3*	α(K)=0.1394 *23*; α(L)=0.0284 *5*; α(M)=0.00681 *12* α(N)=0.00177 *3*; α(O)=0.000391 *7*; α(P)=6.30×10^{-5} *11*; α(Q)=3.51×10^{-6} *6*
		265.5 *2*	100 *8*	640.69	(7^-)	[E2]		0.223	α(K)=0.0914 *13*; α(L)=0.0968 *14*; α(M)=0.0259 *4* α(N)=0.00683 *10*; α(O)=0.001472 *21*; α(P)=0.000222 *4*; α(Q)=3.74×10^{-6} *6*
916.38	0^+	700.5‡ *5*	≈21‡	215.985	1^-				
		832.01 *8*	100‡ *17*	84.372	2^+				
965.65	2^+	881.32 *7*	100 *6*	84.372	2^+				
		965.56 *10*	63 *7*	0	0^+				
992.70	(2^+)	741.9 *2*	88 *19*	250.782	4^+				
		908.10 *10*	100 *8*	84.372	2^+				
		992.9& *10*	≈88	0	0^+				
1053.041	1^-	762.63 *4*	23.4 *12*	290.352	3^-	(E2)		0.01536	α(K)=0.01137 *16*; α(L)=0.00300 *5*; α(M)=0.000745 *11* α(N)=0.000197 *3*; α(O)=4.38×10^{-5} *7*; α(P)=7.23×10^{-6} *11*; α(Q)=3.96×10^{-7} *6*
		837.03 *7*	100 *5*	215.985	1^-	M1+E2	1.6 *+18−4*	0.0219 *66*	α(K)=0.0172 *55*; α(L)=0.0035 *9*; α(M)=0.00086 *20* α(N)=0.00023 *6*; α(O)=5.1×10^{-5} *12*; α(P)=8.7×10^{-6} *22*; α(Q)=6.0×10^{-7} *20*
		968.62 *13*	3.4 *4*	84.372	2^+				
		1053.01 *8*	2.2 *3*	0	0^+				
1068.5	10^+	313.6 *2*	100	754.88	8^+	[E2]		0.1332	α(K)=0.0646 *9*; α(L)=0.0507 *8*; α(M)=0.01343 *19* α(N)=0.00355 *5*; α(O)=0.000768 *11*; α(P)=0.0001172 *17*; α(Q)=2.55×10^{-6} *4* E_γ: NRM average of three values. Weighted average gives 313.3 *4* with reduced χ^2=9.2.
1090.087	$(2,3)^-$	799.705 *37*	100 *6*	290.352	3^-	M1(+E2)		0.033 *19*	α(K)=0.026 *16*; α(L)=0.0050 *24*; α(M)=0.00121 *56* α(N)=3.2×10^{-4} *15*; α(O)=7.2×10^{-5} *34*; α(P)=1.25×10^{-5} *61*; α(Q)=9.1×10^{-7} *55* α: for δ(E2/M1)=1. α: overlaps M1 and E2.
		874.10 *7*	39 *3*	215.985	1^-				
		1005.5 *5*	5.5 *7*	84.372	2^+				
1187.1	0^+,1,2	970.9 *5*	86 *9*	215.985	1^-				
		1103.0 *5*	100 *27*	84.372	2^+				
1216.89	$(1^-,2)$	926.5 *2*	100 *24*	290.352	3^-				

From ENSDF

$\gamma(^{224}Ra)$ (continued)

E_i(level)	J^π_i	E_γ†	I_γ†	E_f	J^π_f	Mult.#	δ#	α@	Comments
1216.89	$(1^-,2)$	1001.1 *5*	71 *9*	215.985	1^-				
1220.7	(11^-)	314.5 *2*	100	906.17	(9^-)				
1348.22	$2^+,3^+$	1097.6 *2*	100 *27*	250.782	4^+				
		1263.80 *10*	81 *11*	84.372	2^+				
1378.41	1^-	325.348 *19*	34.9 *17*	1053.041	1^-	M1(+E2)	<0.3	0.549 *20*	α(K)=0.441 *18*; α(L)=0.0821 *20*; α(M)=0.0196 *5* α(N)=0.00518 *12*; α(O)=0.00118 *3*; α(P)=0.000205 *6*; α(Q)=1.58×10^{-5} *7*
		461.98 *8*	11.2 *6*	916.38	0^+				
		1294.21 *6*	28.2 *31*	84.372	2^+				
		1378.45 *10*	100 *6*	0	0^+				
1379.04	$(1^+,2^+)$	386.4 *10*	27.9 *23*	992.70	(2^+)				
		413.40 *5*	94 *6*	965.65	2^+	M1(+E2)	<0.5	0.272 *24*	α(K)=0.218 *21*; α(L)=0.041 *3*; α(M)=0.0098 *6* α(N)=0.00259 *15*; α(O)=0.00059 *4*; α(P)=0.000102 *7*; α(Q)=7.8×10^{-6} *8*
		1163.04 *10*	100 *7*	215.985	1^-				
1389.93	$(0^+,1,2)$	1173.89 *23*	100 *15*	215.985	1^-				
		1305.6 *2*	48 *7*	84.372	2^+				
1413.7	(12^+)	345.2 *2*	100	1068.5	10^+				
1425.152	$(0,1,2)^-$	335.056 *19*	22.9 *9*	1090.087	$(2,3)^-$	M1(+E2)	<0.5	0.48 *5*	α(K)=0.39 *4*; α(L)=0.073 *4*; α(M)=0.0176 *9* α(N)=0.00465 *22*; α(O)=0.00106 *6*; α(P)=0.000183 *11*; α(Q)=1.39×10^{-5} *14*
		372.08 *4*	14.4 *7*	1053.041	1^-	M1(+E2)	<1.1	0.308 *86*	α(K)=0.243 *75*; α(L)=0.049 *9*; α(M)=0.0120 *19* α(N)=0.0032 *5*; α(O)=0.00072 *12*; α(P)=0.000123 *23*; α(Q)=8.7×10^{-6} *27*
		1209.2 *2*	1.50 *15*	215.985	1^-				
		1340.800 *25*	100 *7*	84.372	2^+				
1435.54	1^-	382.511 *25*	45.9 *22*	1053.041	1^-	M1(+E2)	<0.7	0.32 *5*	α(K)=0.25 *5*; α(L)=0.049 *5*; α(M)=0.0118 *11* α(N)=0.0031 *3*; α(O)=0.00070 *7*; α(P)=0.000122 *13*; α(Q)=9.1×10^{-6} *15*
		442.78 *8*	24 *3*	992.70	(2^+)				
		519.5 *2*	7.9 *6*	916.38	0^+				
		1219.42 *10*	20.8 *24*	215.985	1^-				
		1350.9 *2*	38 *11*	84.372	2^+				
		1435.60 *10*	100 *10*	0	0^+				
1437.11	2^+	1186.35 *10*	34 *4*	250.782	4^+				
		1352.60 *10*	86 *12*	84.372	2^+				
		1437.20 *10*	100 *10*	0	0^+				
1553.67	$1,2^+$	1338.0 *5*	≈100	215.985	1^-				
		1469.4 *2*	100 *12*	84.372	2^+				
		1553.5 *2*	48 *6*	0	0^+				
1573.6	(13^-)	356.7 *5*	100	1220.7	(11^-)	[E2]		0.0920	α(K)=0.0496 *7*; α(L)=0.0315 *5*; α(M)=0.00827 *13* α(N)=0.00218 *4*; α(O)=0.000475 *7*; α(P)=7.33×10^{-5} *11*;

$\gamma(^{224}Ra)$ (continued)

E_i(level)	J^π_i	E_γ†	I_γ†	E_f	J^π_f	Mult.#	α@	Comments
								α(Q)=1.91×10^{-6} *3* E_γ: 348.5 *2* in (^{58}Ni,^{60}Niγ) is discrepant.
1614.42	(1$^-$,2)	1323.9 *3*	42 *7*	290.352	3$^-$			
		1398.5 *2*	100 *13*	215.985	1$^-$			
1652.49	2$^+$	659.64 *10*	11.5 *21*	992.70	(2$^+$)			
		1401.6 *2*	7.0 *10*	250.782	4$^+$			
		1568.18 *6*	55 *7*	84.372	2$^+$			
		1652.47 *5*	100 *12*	0	0$^+$			
1658.49	1$^{(-)}$,2$^+$	1368.1 *2*	68 *16*	290.352	3$^-$			
		1442.3 *2*	40 *5*	215.985	1$^-$			
		1658.54 *10*	100 *20*	0	0$^+$			
1736.44	1,2$^+$	1520.6 *2*	22 *3*	215.985	1$^-$			
		1736.19 *25*	100 *17*	0	0$^+$			
1754.84	0$^+$,1,2	702.0 *2*	51 *16*	1053.041	1$^-$			
		1538.4 *2*	22 *3*	215.985	1$^-$			
		1670.53 *10*	100 *16*	84.372	2$^+$			
1787.5	(14$^+$)	373.8 *5*	100	1413.7	(12$^+$)	[E2]	0.0809	α(K)=0.0450 *7*; α(L)=0.0266 *4*; α(M)=0.00697 *11* α(N)=0.00184 *3*; α(O)=0.000401 *6*; α(P)=6.21×10^{-5} *10*; α(Q)=1.721×10^{-6} *25*
1789.61	1,2$^+$	1573.73 *8*	100 *12*	215.985	1$^-$			
		1705.12 *10*	49 *8*	84.372	2$^+$			
		1789.4 *2*	76 *12*	0	0$^+$			
1796.71	(1$^-$,2)	1506.4 *2*	43 *6*	290.352	3$^-$			
		1580.8 *2*	39 *6*	215.985	1$^-$			
		1712.30 *10*	100 *17*	84.372	2$^+$			
1818.06	(1$^-$,2)	1527.7 *2*	89 *17*	290.352	3$^-$			
		1602.1 *5*	100 *17*	215.985	1$^-$			
1838.53	0,1,2	1622.54 *10*	100	215.985	1$^-$			
1896.3	(1$^-$,2)	1607.1 *5*	100 *17*	290.352	3$^-$			
		1679.5 *5*	61 *17*	215.985	1$^-$			
		1811.6 *5*	72 *17*	84.372	2$^+$			
1964.7	(15$^-$)	391.1 *5*	100	1573.6	(13$^-$)	[E2]	0.0717	α(K)=0.0411 *6*; α(L)=0.0227 *4*; α(M)=0.00593 *9* α(N)=0.001565 *23*; α(O)=0.000341 *5*; α(P)=5.30×10^{-5} *8*; α(Q)=1.559×10^{-6} *23*
1969.92	(0,1,2)	1753.93 *10*	100	215.985	1$^-$			
2000.26	(1$^-$,2)	947.2 *2*	100 *12*	1053.041	1$^-$			
		1784.3 *3*	70 *12*	215.985	1$^-$			
2043.0	0,1,2	1827.05 *27*	100	215.985	1$^-$			
2052.3	2$^+$	1801.3 *5*	100 *19*	250.782	4$^+$			
		1836.5 *5*	63 *19*	215.985	1$^-$			
2077.3	0$^+$,1,2	1862.0 *5*	47 *9*	215.985	1$^-$			
		1992.4 *4*	100 *17*	84.372	2$^+$			
2117.4	1,2$^+$	2033.2 *5*	65 *12*	84.372	2$^+$			
		2117.3 *5*	100 *14*	0	0$^+$			
2135.3	0,1,2	1919.3 *5*	100	215.985	1$^-$			

$^{224}_{88}Ra_{136}$-7

$\gamma(^{224}Ra)$ (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[#]	α[@]	Comments
2187.7	(16^+)	400.2 *5*	100	1787.5	(14^+)	[E2]	0.0674	α(K)=0.0392 *6*; α(L)=0.0209 *3*; α(M)=0.00546 *8* α(N)=0.001442 *22*; α(O)=0.000314 *5*; α(P)=4.90×10^{-5} *8*; α(Q)=1.483×10^{-6} *22*
2229.4	$(1^-,2)$	1938.3 *10*	73 *18*	290.352	3^-			
		2013.4 *5*	91 *18*	215.985	1^-			
		2145.2 *5*	100 *18*	84.372	2^+			
2246.5	$1,2^+$	2030.5 *5*	100 *16*	215.985	1^-			
		2162.0 *5*	93 *15*	84.372	2^+			
		2246.6 *5*	14 *3*	0	0^+			
2368.7	$1,2^+$	2152.5 *5*	100 *16*	215.985	1^-			
		2368.8 *5*	53 *11*	0	0^+			
2384.1	(17^-)	419.4 *5*	100	1964.7	(15^-)	[E2]	0.0597	α(K)=0.0357 *5*; α(L)=0.0178 *3*; α(M)=0.00464 *7* α(N)=0.001224 *18*; α(O)=0.000267 *4*; α(P)=4.19×10^{-5} *6*; α(Q)=1.340×10^{-6} *19*
2612.1	(18^+)	424.4 *5*	100	2187.7	(16^+)	[E2]	0.0579	α(K)=0.0349 *5*; α(L)=0.01712 *25*; α(M)=0.00445 *7* α(N)=0.001175 *18*; α(O)=0.000257 *4*; α(P)=4.02×10^{-5} *6*; α(Q)=1.306×10^{-6} *19*
2827.0	(19^-)	442.9 *5*	100	2384.1	(17^-)	[E2]	0.0520	α(K)=0.0320 *5*; α(L)=0.01484 *22*; α(M)=0.00385 *6* α(N)=0.001015 *15*; α(O)=0.000222 *4*; α(P)=3.50×10^{-5} *5*; α(Q)=1.193×10^{-6} *17*
3059.2	(20^+)	447.1 *5*	100	2612.1	(18^+)	[E2]	0.0508	α(K)=0.0314 *5*; α(L)=0.01438 *21*; α(M)=0.00372 *6* α(N)=0.000983 *15*; α(O)=0.000215 *4*; α(P)=3.39×10^{-5} *5*; α(Q)=1.169×10^{-6} *17*
3289.8	(21^-)	462.8 *5*	100	2827.0	(19^-)	[E2]	0.0466	α(K)=0.0293 *5*; α(L)=0.01284 *19*; α(M)=0.00332 *5* α(N)=0.000876 *13*; α(O)=0.000192 *3*; α(P)=3.03×10^{-5} *5*; α(Q)=1.087×10^{-6} *16*
3526.3	(22^+)	467.1 *5*	100	3059.2	(20^+)	[E2]	0.0456	α(K)=0.0288 *4*; α(L)=0.01246 *18*; α(M)=0.00322 *5* α(N)=0.000849 *13*; α(O)=0.000186 *3*; α(P)=2.94×10^{-5} *5*; α(Q)=1.066×10^{-6} *16*
3769.6	(23^-)	479.8 *5*	100	3289.8	(21^-)	[E2]	0.0427	α(K)=0.0273 *4*; α(L)=0.01143 *17*; α(M)=0.00294 *5* α(N)=0.000777 *12*; α(O)=0.0001705 *25*; α(P)=2.70×10^{-5} *4*; α(Q)=1.007×10^{-6} *15*
4011.4	(24^+)	485.1 *5*	100	3526.3	(22^+)	[E2]	0.0416	α(K)=0.0268 *4*; α(L)=0.01104 *16*; α(M)=0.00284 *4* α(N)=0.000750 *11*; α(O)=0.0001645 *24*; α(P)=2.61×10^{-5} *4*; α(Q)=9.84×10^{-7} *14*
4266.4	(25^-)	496.8 *5*	100	3769.6	(23^-)	[E2]	0.0393	α(K)=0.0255 *4*; α(L)=0.01023 *15*; α(M)=0.00263 *4* α(N)=0.000694 *10*; α(O)=0.0001524 *22*; α(P)=2.42×10^{-5} *4*; α(Q)=9.37×10^{-7} *14*
4512.2	(26^+)	500.8 *5*	100	4011.4	(24^+)	[E2]	0.0385	α(K)=0.0251 *4*; α(L)=0.00998 *15*; α(M)=0.00256 *4* α(N)=0.000676 *10*; α(O)=0.0001485 *22*; α(P)=2.36×10^{-5} *4*; α(Q)=9.21×10^{-7} *13*
4778.0?	(27^-)	511.6[&] *5*		4266.4	(25^-)			
5030.4?	(28^+)	518.2[&] *5*		4512.2	(26^+)			

[†] From weighted averages of available data.
[‡] From ^{228}Th α decay.
[#] From ce data in ^{224}Fr β^- decay, unless otherwise noted.
[@] 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.
[&] Placement of transition in the level scheme is uncertain.

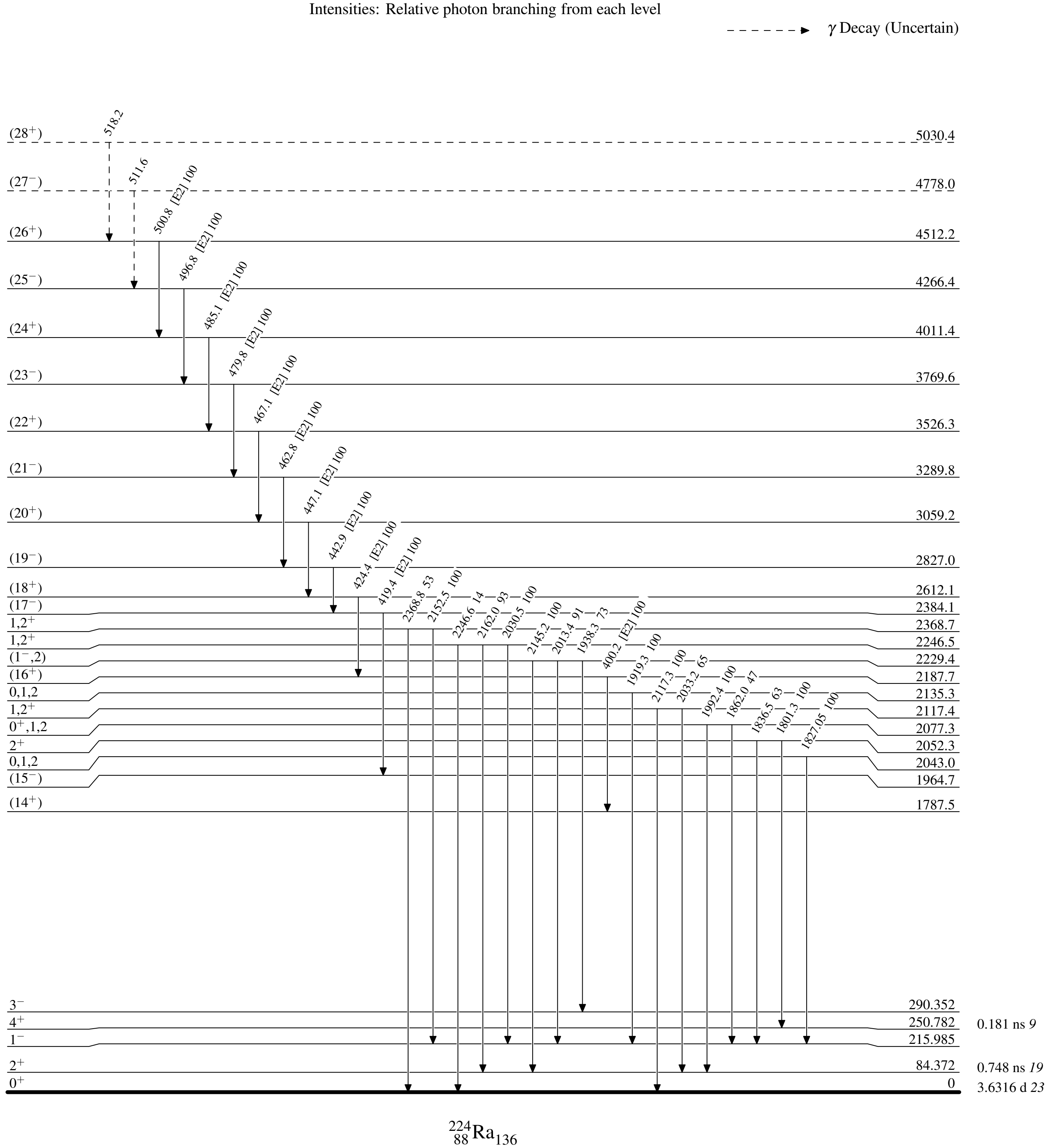
From ENSDF

$^{224}_{88}Ra_{136}$-8

Adopted Levels, Gammas

Level Scheme

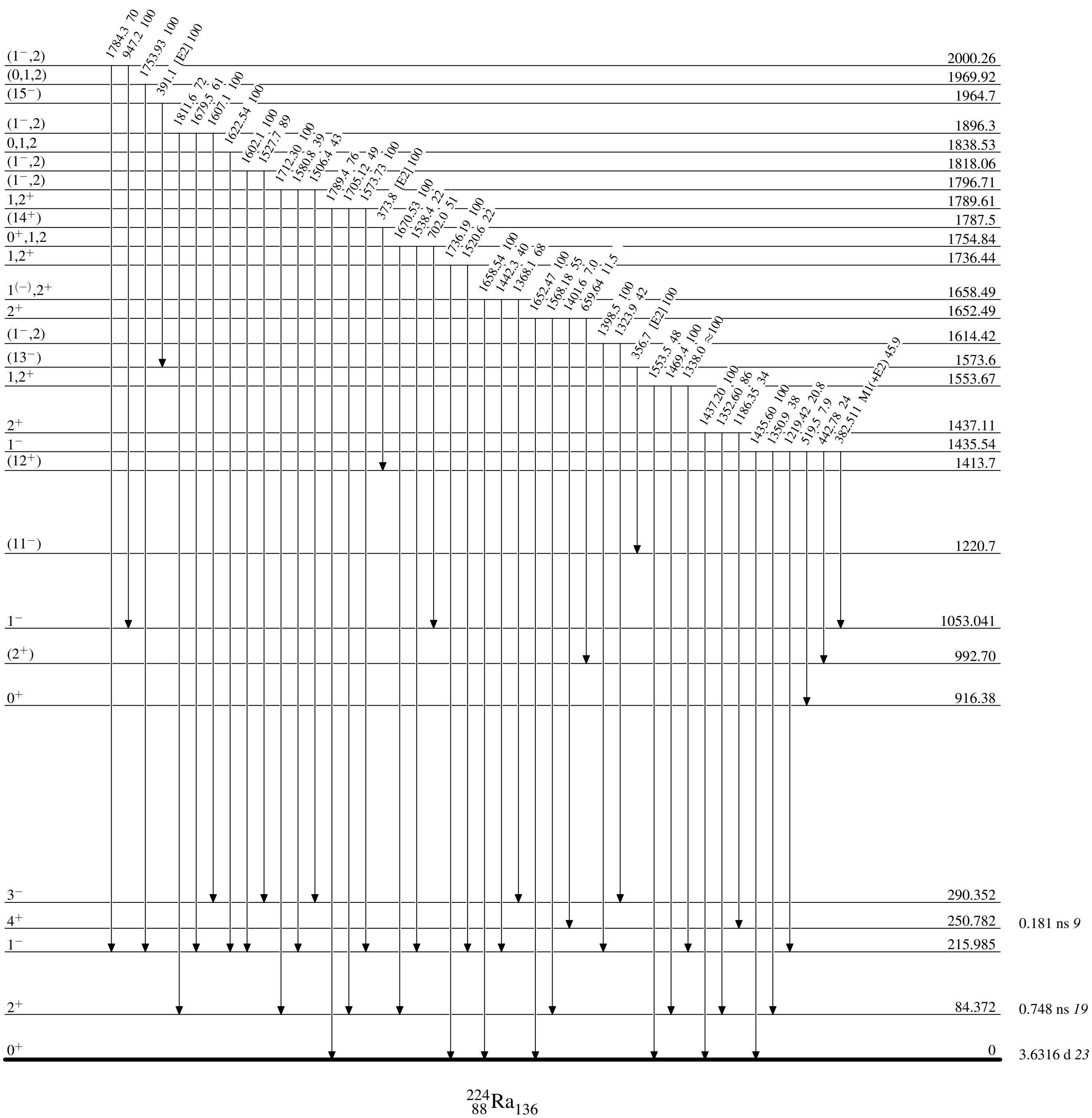
Intensities: Relative photon branching from each level



Adopted Levels, Gammas

Level Scheme (continued)

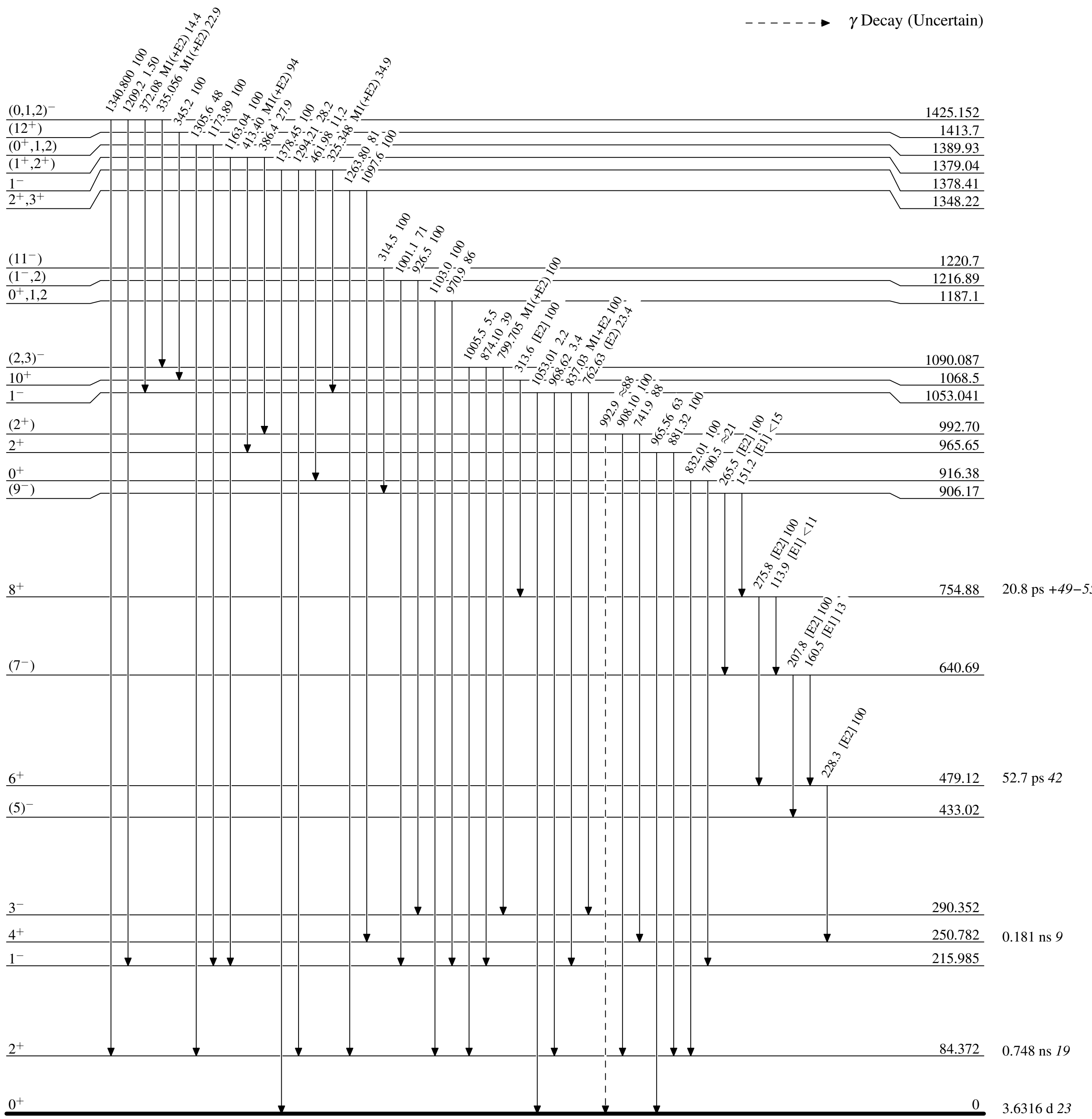
Intensities: Relative photon branching from each level



Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level

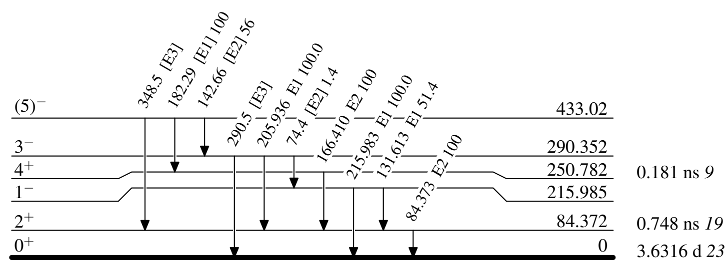


$^{224}_{88}Ra_{136}$

Adopted Levels, Gammas

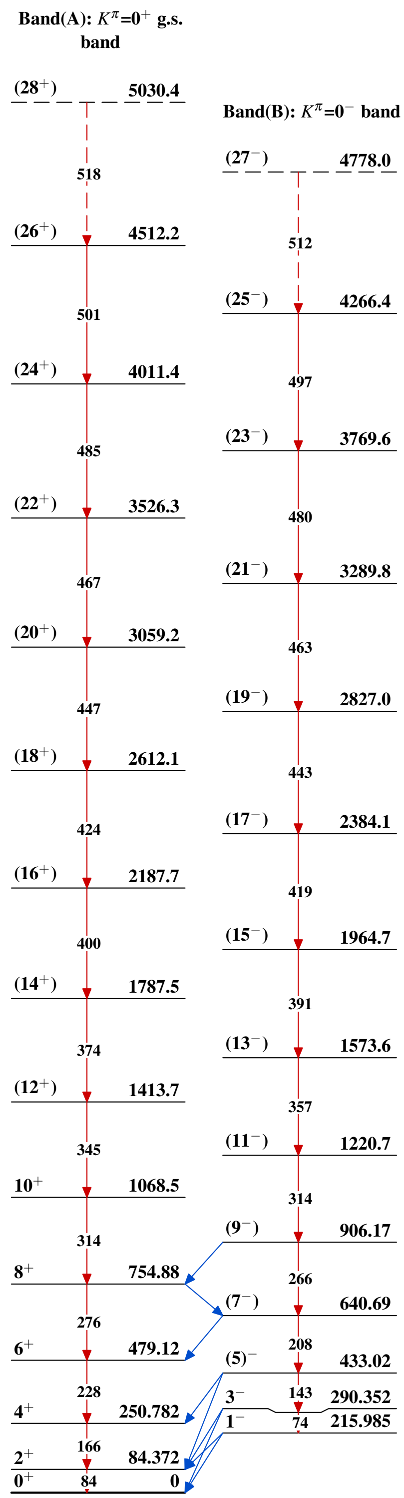
Level Scheme (continued)

Intensities: Relative photon branching from each level



$^{224}_{88}Ra_{136}$

Adopted Levels, Gammas



$^{224}_{88}Ra_{136}$

Adopted Levels, Gammas

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Y. A. Akovali	NDS 77,433 (1996)	1-Feb-1996

Q(β^-)=−641 *4*; S(n)=6396 *3*; S(p)=7440 *13*; Q(α)=4870.62 *25* 2012Wa38

Note: Current evaluation has used the following Q record −640 3 *6396* 3 *7479* 104870.63 *25* 1995Au04.

Energies and wave functions of K^π=0$^-$, 2$^+$, 2$^-$, 3$^-$ and second 0$^-$ octupole-vibrational states were calculated by 1975Iv03. See 1983Pi04 for calculations of K^π=0$^-$, 0$^+$ octupole-vibrational state energies; see 1970Ne08 for calculated energies of K^π=0$^-$,1$^-$,2$^-$ and 3$^-$ bands; and 1982Zi02 for calculated energies of K^π=0$^-$ band. The energies of the rotational states of the 0$^+$ and 0$^-$ bands were calculated by 1995Al06, 1995De13 and 1995Jo11 and compared with the experimental level energies.

For calculations of equilibrium deformation parameters see, for example, 1975Iv03, 1982Du16, 1982Le19, 1983Ro14 and 1984Na22.

For calculations of electric quadrupole and hexadecapole moments see, for example, 1975Iv03 and 1983Ro14.

Effects of the Coriolis and centrifugal forces for nuclei with stable octupole deformation were examined; B(E3; 0$^+$ to 3$^-$,K=0) value and effective moments of inertia for g.s. and K^π=0$^-$ bands were calculated as a function of octupole deformation by 1983Ro15. See also 1970Ne08 for calculated B(E3; 0$^+$ to 3$^-$) and 1977Ba45 for calculated B(E3; 0$^+$ to 3$^-$), B(E1; 0$^+$ to 1$^-$) values for K^π=0$^-$ band.

See 1995De13 for calculated branching ratios for E1, E2, E3 transitions and comparisons with the experimental values.

Partial $T_{1/2}$ for heavy ion emission were calculated by 1984Po08, 1985Po11 and 1995Si05. See 1995Na13 for discussions on multiclustering.

^{226}Ra Levels

Cross Reference (XREF) Flags

A	^{226}Fr β^- decay	E	^{226}Ra(d,d′)
B	^{226}Ac ε decay	F	^{230}Th(d,^{6}Li)
C	^{230}Th α decay	G	(HI,xnγ)
D	Coulomb excitation		

E(level)	J$^\pi$&	$T_{1/2}$	XREF	Comments
0.0†	0$^+$	1600 y *7*	ABCDEFG	%α=100; %^{14}C=3.2×10^{-9} *16* %^{14}C/%α=3.2×10^{-11} *16* (1985Ho21). Other measurement: %^{14}C/%α≤1×10^{-10} (1985Al28). $T_{1/2}$: weighted average of 1622 y *13* (1949Ko01), 1617 y *12* (1956Se10), 1577 y *9* (1959Go80), 1602 y *8* (1959Ma12), 1599 y *7* (1966Ra13). Earlier measurement: 1590 y (1931Cu01).
67.67† *1*	2$^+$	0.63 ns *2*	ABCDEFG	J$^\pi$: 67.67γ to 0$^+$ is E2. $T_{1/2}$: by (α)(ce 68γ)(t) in ^{230}Th α decay.
211.54† *2*	4$^+$	≈0.17 ns	A CDEFG	J$^\pi$: 143.87γ to 2$^+$ is E2; level is Coulomb excited. $T_{1/2}$: by (α)(143γ)(t) in ^{230}Th α decay.
253.73‡ *1*	1$^-$		ABCDEFG	J$^\pi$: the 253.73γ to 0$^+$ is E1.
321.54‡ *6*	3$^-$		A CDEFG	B(E3)↑=1.10 *11*
416.5† *3*	6$^+$		CDEFG	
446.3‡ *2*	5$^-$		A CDEFG	
626.7‡ *2*	7$^-$		D G	
650	(0$^+$)		D F	J$^\pi$: 1984Va13 report that a 0$^+$ state at 650 keV was identified by R. Zimmerman on the basis of a multiple-Coulomb excitation study. The level was weakly populated, if at all, in (d,^{6}Li).
669.4† *3*	8$^+$		D G	
824.6# *1*	0$^+$		A C F	J$^\pi$: L=0 in (d,^{6}Li); the α-hindrance factor in ^{230}Th α decay; γ transition to 1$^-$ state and the nonobservation of any γ to 3$^-$ state of K=0$^-$ band are consistent with the assignment.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{226}Ra Levels (continued)

E(level)	J^{π}[&]	XREF	Comments
857.6[‡] 3	9⁻	D G	
873.7[#] 1	2⁺	A C F	J^{π}: the γ transitions to the 1⁻ and 3⁻ states of the K=0⁻ band; the α hindrance factor; L=2 in (d,^{6}Li).
959.9[†] 3	10⁺	D G	
1048.8[@] 1	1⁻	A F	J^{π}: the γ transitions to the 0⁺, 2⁺ states of g.s. band suggest 1 or 2⁺. L=1 in ^{230}Th(d,^{6}Li) determines π=−.
1070.5[@] 2	(2⁻)	A	J^{π}: gammas to 2⁺ and 1⁻ levels and log ft=7.2 for the β branch from 1⁻ ^{226}Fr suggest J^{π}=0⁺,1,2. The J^{π}=2⁻ of K=1 band assignment was proposed by 1981Ku02 from spacing relative to the 1⁻ state at 1048.8 keV.
1077.2 2	1⁻,2	A	J^{π}: gammas to 2⁺, 1⁻, 3⁻ states and log ft=7.1 for the β decay from 1⁻ ^{226}Fr suggest J^{π}=2,1⁻.
1107 3	2⁺,3⁻	E	J^{π}: assigned by 1990Th02 from (d,d′) data, based on their observed deuteron-angular distributions, and on cross sections.
1122.4 3	(2⁺)	A E	J^{π}: γ to 4⁺ and log ft=8.6 for the β^{-} feeding from 1⁻ ^{226}Fr suggest J^{π}=2⁺ or 3⁺. From the (d,d′) data, 1990Th02 assigned 2⁺,3⁻. By assuming that the levels populated in the β^{-} decay and in the (d,d′) reaction are the same, J^{π}=(2⁺) is adopted.
1133.1[‡] 3	11⁻	D G	
1140	[a]	F	
1156.2 1	2⁺	A E	J^{π}: gammas to 0⁺ and 4⁺.
1220		F	
1238.9 5	(2)	A	Gammas to 2⁺, 3⁻ states and β^{-} decay from 1⁻ ^{226}Fr are consistent with J^{π}=1⁻,2. The Alaga rule and absence of a γ to the g.s. imply J=2.
1280.5[†] 4	12⁺	D G	
1330		F	
1390.0 1	2⁺	A E	J^{π}: gammas to 0⁺, 2⁺ states suggest J^{π}=1, 2⁺; the authors of 1990Th02 assign 2⁺ from their (d,d′) data.
1420	[a]	F	This level might be the same level observed in ^{226}Fr β^{-} decay at 1422.5.
1422.5 10	0,1,2	A	J^{π}: γ to 1⁻ and the log ft of 8.0 for the β^{-} decay from the 1⁻, ^{226}Fr suggest J^{π}=0, 1 or 2.
1437.8 7	1⁻,2	A	Gammas to 1⁻, 3⁻ states and the log ft of 8.2 from 1⁻ ^{226}Fr suggest J^{π}=1⁻ or 2.
1446[‡]	13⁻	D	
1540	[a]	F	
1587.3 5	1,2⁺	A	J^{π}: gammas to 0⁺, 1⁻ levels.
1621.3 5	1⁻,2⁺	A	J^{π}: gammas to 0⁺, 3⁻ states.
1625[†]	14⁺	D	
1723.4 3	2⁺	A E	J^{π}: from the gammas to 0⁺ and 1⁻ levels, J^{π} is 1 or 2⁺; the authors of 1990Th02 assign J^{π}=2⁺ from their (d,d′) data.
1738.5 10	1,2⁺	A	J^{π}: gammas to 0⁺ and 1⁻ levels.
1756.2 10	1,2⁺	A	J^{π}: gammas to 0⁺, 1⁻ levels.
1767.1 10	0,1,2	A	J^{π}: log ft=7.2 for the β^{-} decay from the 1⁻ ^{226}Fr parent.
1778.4 10	0,1,2	A	J^{π}: log ft=7.2 for the β^{-} decay from the 1⁻ parent.
1786.1 10	1⁻,2⁺	A	J^{π}: gammas to 0⁺, 3⁻ levels.
1793[‡]	15⁻	D	
1865.0 10	1,2⁺	A	J^{π}: gammas to 0⁺, 2⁺ levels.
1882.3 7	0,1,2	A	J^{π}: log ft=7.6 for the β branch from ^{226}Fr, 1⁻ parent;
1888.4 15	0,1,2	A	J^{π}: log ft=7.8 for the β^{-} decay from the 1⁻ parent.
1897.4 10	1⁻,2⁺	A	J^{π}: gammas to 0⁺, 3⁻ levels.
1907.8 10	1,2⁺	A	J^{π}: γ to 0⁺ g.s.
1945.6 10	1,2⁺	A	J^{π}: γ to 0⁺ g.s.
1951.0 10	1⁻,2⁺	A	J^{π}: gammas to 0⁺, 3⁻ levels.
1970.8 5	1⁻,2⁺	A	J^{π}: gammas to 0⁺, 3⁻ levels.
1982.7 10	0⁺,1	A	J^{π}: from log ft=7.3 for β^{-} decay from 1⁻ ^{226}Fr, J≤2; from γ to 2⁺ state J^{π} Ne 0⁻; γ to 1⁻ of octupole-vibrational band but not to the 3⁻ member of this band suggests J Ne 2.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{226}Ra Levels (continued)

E(level)	J$^{\pi}$[&]	XREF	Comments
1993[†]	16$^+$	D	
2006.7 *15*	0,1,2	A	log *ft*=7.3 for the β^- decay from 1$^-$ ^{226}Fr parent.
2015.2 *15*	0,1,2	A	log *ft*=7.5 for the β branch from 1$^-$ ^{226}Fr parent.
2056.8 *5*	1,2$^+$	A	J$^{\pi}$: γ to 0$^+$ g.s.
2086.1 *10*	1,2$^+$	A	J$^{\pi}$: γ to 0$^+$ g.s.
2170[‡]	17$^-$	D	
2182.3 *15*	0,1,2	A	log *ft*=7.5 for the β branch from 1$^-$ ^{226}Fr parent.
2189.4 *10*	2$^+$	A E	J$^{\pi}$: (d,d′) data and γ to 0$^+$ g.s..
2269.7 *10*	1,2$^+$	A	J$^{\pi}$: γ to 0$^+$ g.s.
2382[†]	18$^+$	D	

[†] Band(A): K=0 g.s. band.
[‡] Band(B): K=0 octupole vibrational band.
[#] Band(C): K=0 band.
[@] Band(D): K=1 band.
[&] The J^{π} assignments for all levels of the g.s. band and the K=0 octupole-vibrational band are from the Coulomb excitation, γ-decay pattern, and the (HI,xnγ) data. The arguments for the 2$^+$ and the 1$^-$ states of these two bands are given explicitly. Assignments made from (d,d′) data are based on deuteron angular distributions and on measured cross sections.
[a] From J^{π}=L^{-1}, deduced in (d,^{6}Li).

γ(^{226}Ra)

E$_i$(level)	J$^{\pi}_i$	E$_{\gamma}$[†]	I$_{\gamma}$[‡]	E$_f$	J$^{\pi}_f$	Mult.[#]	α[@]	Comments
67.67	2$^+$	67.67 *1*	100	0.0	0$^+$	E2	61.9	B(E2)(W.u.)=123 *5*
211.54	4$^+$	143.87 *1*	100	67.67	2$^+$	E2	2.11	B(E2)(W.u.)≈212
253.73	1$^-$	186.05 *1*	73 *4*	67.67	2$^+$	E1	0.108	
		253.73 *1*	100 *7*	0.0	0$^+$	E1	0.0520	
321.54	3$^-$	67.81 *20*		253.73	1$^-$			
		110.00 *5*	10 *3*	211.54	4$^+$			
		253.9 *1*	100 *11*	67.67	2$^+$			
416.5	6$^+$	204.9 *3*	100	211.54	4$^+$			
446.3	5$^-$	124.8 *2*	3.3 *11*	321.54	3$^-$			
		234.8 *2*	100	211.54	4$^+$			
626.7	7$^-$	180.4 *2*	8.5 *10*	446.3	5$^-$			
		210.3 *2*	100	416.5	6$^+$			
650	(0$^+$)	396		253.73	1$^-$			E$_{\gamma}$: from Coulomb excitation.
669.4	8$^+$	252.8 *2*	100	416.5	6$^+$			
824.6	0$^+$	570.9 *1*	100	253.73	1$^-$			
857.6	9$^-$	188.2 *2*	100	669.4	8$^+$			
		231.0 *2*	54 *5*	626.7	7$^-$			
873.7	2$^+$	552.2 *1*	91 *7*	321.54	3$^-$			
		620.0 *1*	100 *10*	253.73	1$^-$			
959.9	10$^+$	290.6 *2*	100	669.4	8$^+$			
1048.8	1$^-$	795.1 *1*	32 *3*	253.73	1$^-$			
		980.6 *5*	100 *10*	67.67	2$^+$			
		1048.1 *5*	79 *9*	0.0	0$^+$			
1070.5	(2$^-$)	816.9 *2*	14.7 *14*	253.73	1$^-$			
		1002.2 *5*	100 *10*	67.67	2$^+$			
1077.2	1$^-$,2	755.8 *2*	9.5 *10*	321.54	3$^-$			
		823.5 *3*	7.8 *8*	253.73	1$^-$			
		1009.0 *5*	100 *10*	67.67	2$^+$			

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

$\gamma(^{226}Ra)$ (continued)

E_i(level)	J^π_i	E_γ †	I_γ ‡	E_f	J^π_f
1122.4	(2^+)	910.9 2	100	211.54	4^+
1133.1	11^-	173.2 2	70 7	959.9	10^+
		275.5 2	100	857.6	9^-
1156.2	2^+	834.7 1	56 4	321.54	3^-
		902.6 3	16.0 12	253.73	1^-
		944.6 3	100 10	211.54	4^+
		1087.9 5	42 4	67.67	2^+
		1155.8 5	60 6	0.0	0^+
1238.9	(2)	917.3 5	50 10	321.54	3^-
		1171.7 10	100 15	67.67	2^+
1280.5	12^+	320.6 2		959.9	10^+
1390.0	2^+	516.30 5	10.4 8	873.7	2^+
		565.4 1	8.2 8	824.6	0^+
		1322.5 5	100 9	67.67	2^+
		1390.7 10	57 6	0.0	0^+
1422.5	0,1,2	1168.8 10	100	253.73	1^-
1437.8	1^-,2	1117.0 10	100 25	321.54	3^-
		1183.5 8	86 9	253.73	1^-
1446	13^-	166		1280.5	12^+
		313		1133.1	11^-
1587.3	1,2^+	1333.6 5	100 19	253.73	1^-
		1587.0 15	15 4	0.0	0^+
1621.3	1^-,2^+	1299.6 5	100 14	321.54	3^-
		1368.3 10	53 14	253.73	1^-
		1554.4 15	25 6	67.67	2^+
		1620.9 15	29 4	0.0	0^+
1625	14^+	179		1446	13^-
		345		1280.5	12^+
1723.4	2^+	646.2 3	13 3	1077.2	1^-,2
		1471.1 10	100 16	253.73	1^-
		1655.0 10	53 7	67.67	2^+
		1722.1 15	26 4	0.0	0^+
1738.5	1,2^+	1486.2 15	18 3	253.73	1^-
		1670.4 10	52 7	67.67	2^+
		1738.3 10	100 10	0.0	0^+
1756.2	1,2^+	1503.2 10	29 4	253.73	1^-
		1755.4 10	100 15	0.0	0^+
1767.1	0,1,2	1513.4 10		253.73	1^-
1778.4	0,1,2	1524.7 10		253.73	1^-
1786.1	1^-,2^+	1465.2 15	64 14	321.54	3^-
		1532.4 10	100 19	253.73	1^-
		1785.2 15	17 4	0.0	0^+
1793	15^-	168		1625	14^+
		347		1446	13^-
1865.0	1,2^+	991.4 8	23 4	873.7	2^+

E_i(level)	J^π_i	E_γ †	I_γ ‡	E_f	J^π_f
1865.0	1,2^+	1610.7 10	100 11	253.73	1^-
		1797.2 15	26 4	67.67	2^+
		1865.5 10	58 6	0.0	0^+
1882.3	0,1,2	444.50 5		1437.8	1^-,2
1888.4	0,1,2	1634.7 15		253.73	1^-
1897.4	1^-,2^+	1576.0 10	100 29	321.54	3^-
		1685.2 15	57 12	211.54	4^+
		1897.8 15	72 15	0.0	0^+
1907.8	1,2^+	1083.6 8	63 12	824.6	0^+
		1839.6 10	100 10	67.67	2^+
		1907.4 15	44 9	0.0	0^+
1945.6	1,2^+	1692.6 10	100 12	253.73	1^-
		1944.0 15	14 4	0.0	0^+
1951.0	1^-,2^+	1628.2 15	24 4	321.54	3^-
		1697.3 10	82 12	253.73	1^-
		1883.9 10	100 12	67.67	2^+
		1951.1 15	31 1	0.0	0^+
1970.8	1^-,2^+	848.3 5	13.4 20	1122.4	(2^+)
		1648.9 15	16.1 22	321.54	3^-
		1716.8 10	78 8	253.73	1^-
		1903.4 10	100 10	67.67	2^+
		1971.1 10	32 5	0.0	0^+
1982.7	0^+,1	1109.7 10	36 8	873.7	2^+
		1728.4 10	100 10	253.73	1^-
		1914.8 15	38 6	67.67	2^+
1993	16^+	200&		1793	15^-
		368		1625	14^+
2006.7	0,1,2	1753.0 15		253.73	1^-
2015.2	0,1,2	1761.5 15		253.73	1^-
2056.8	1,2^+	1231.9 5	100 10	824.6	0^+
		1990.3 10	96 10	67.67	2^+
		2056.9 15	43 7	0.0	0^+
2086.1	1,2^+	2017.6 10	100 17	67.67	2^+
		2087.8 15	18 5	0.0	0^+
2170	17^-	177		1993	16^+
		377		1793	15^-
2182.3	0,1,2	1928.6 15		253.73	1^-
2189.4	2^+	1365.0 10	75 30	824.6	0^+
		2120.9 10	100 14	67.67	2^+
		2190.9 15	31 5	0.0	0^+
2269.7	1,2^+	2014.4 15	60 12	253.73	1^-
		2202.2 10	100 11	67.67	2^+
		2272.0 20	27 9	0.0	0^+
2382	18^+	389		1993	16^+

† From ^{226}Fr β^- decay, ^{230}Th α decay and (HI,xnγ), except where noted.

‡ Relative photon intensity deexciting each level, adopted from ^{226}Fr β^- decay, ^{230}Th α decay and (HI,xnγ) data.

\# From ce work in ^{230}Th α decay and ^{226}Ac ε decay.

@ 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.

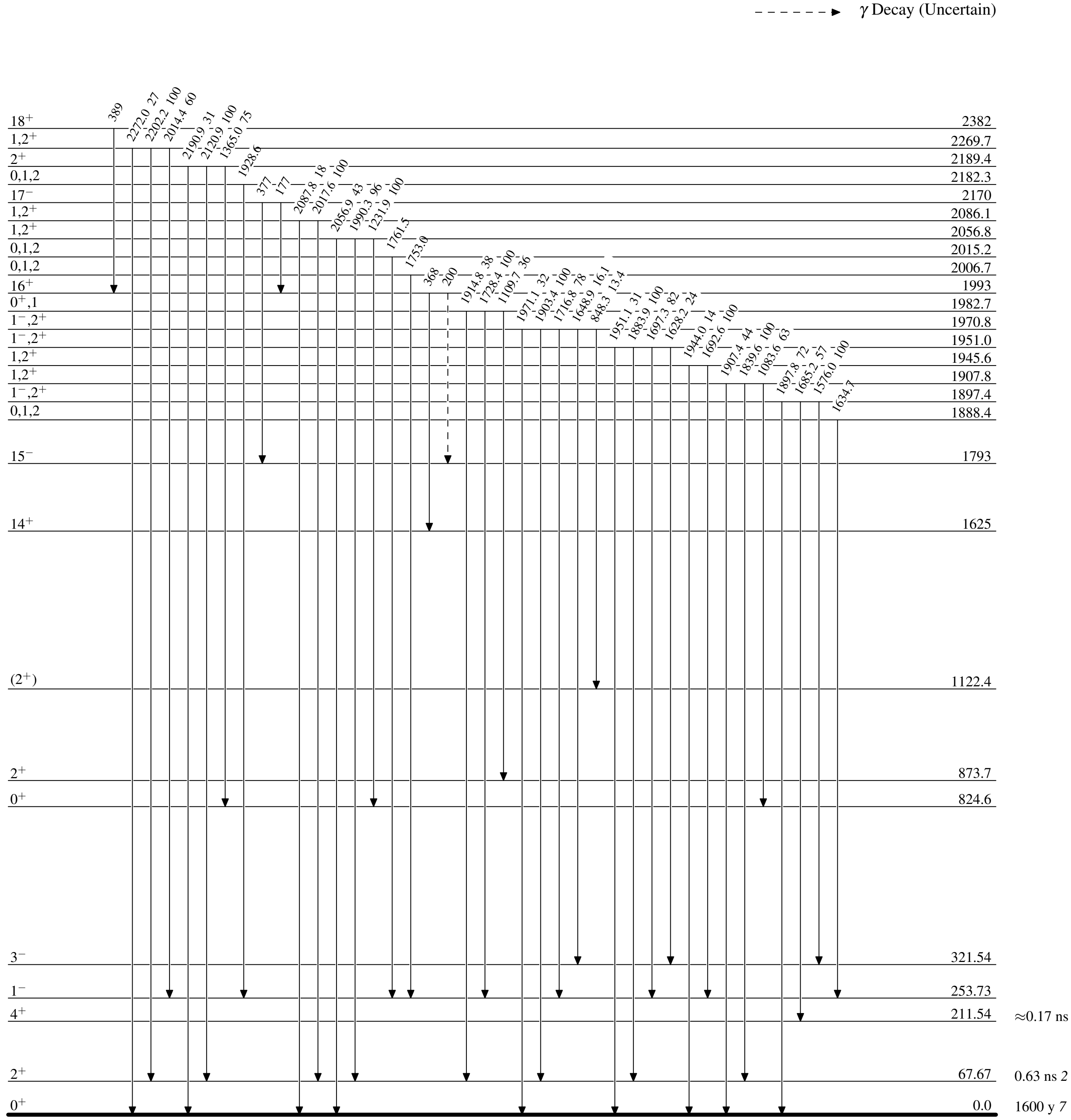
& Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Legend

Level Scheme

Intensities: Relative photon branching from each level

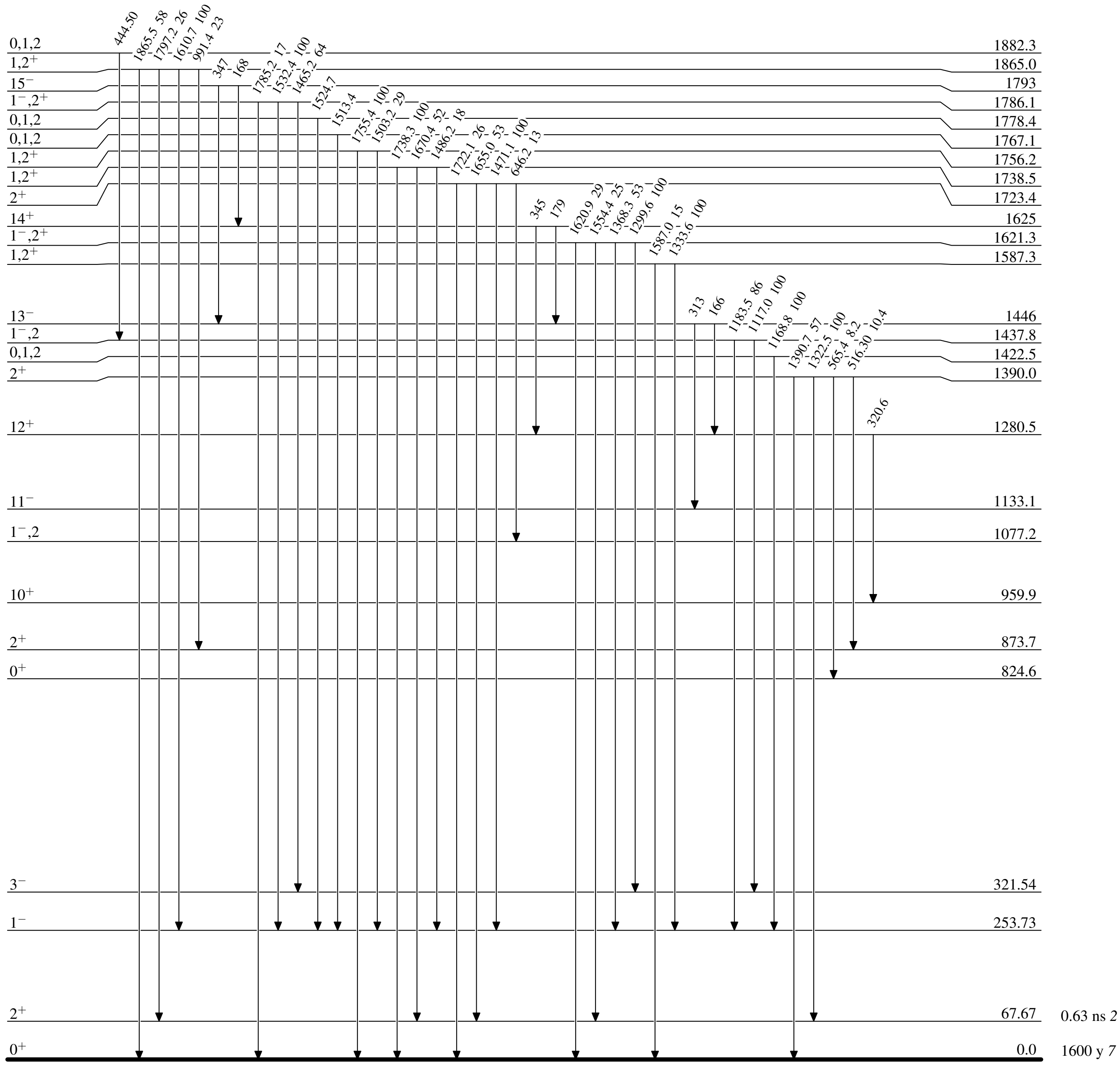


$^{226}_{88}Ra_{138}$

Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Relative photon branching from each level

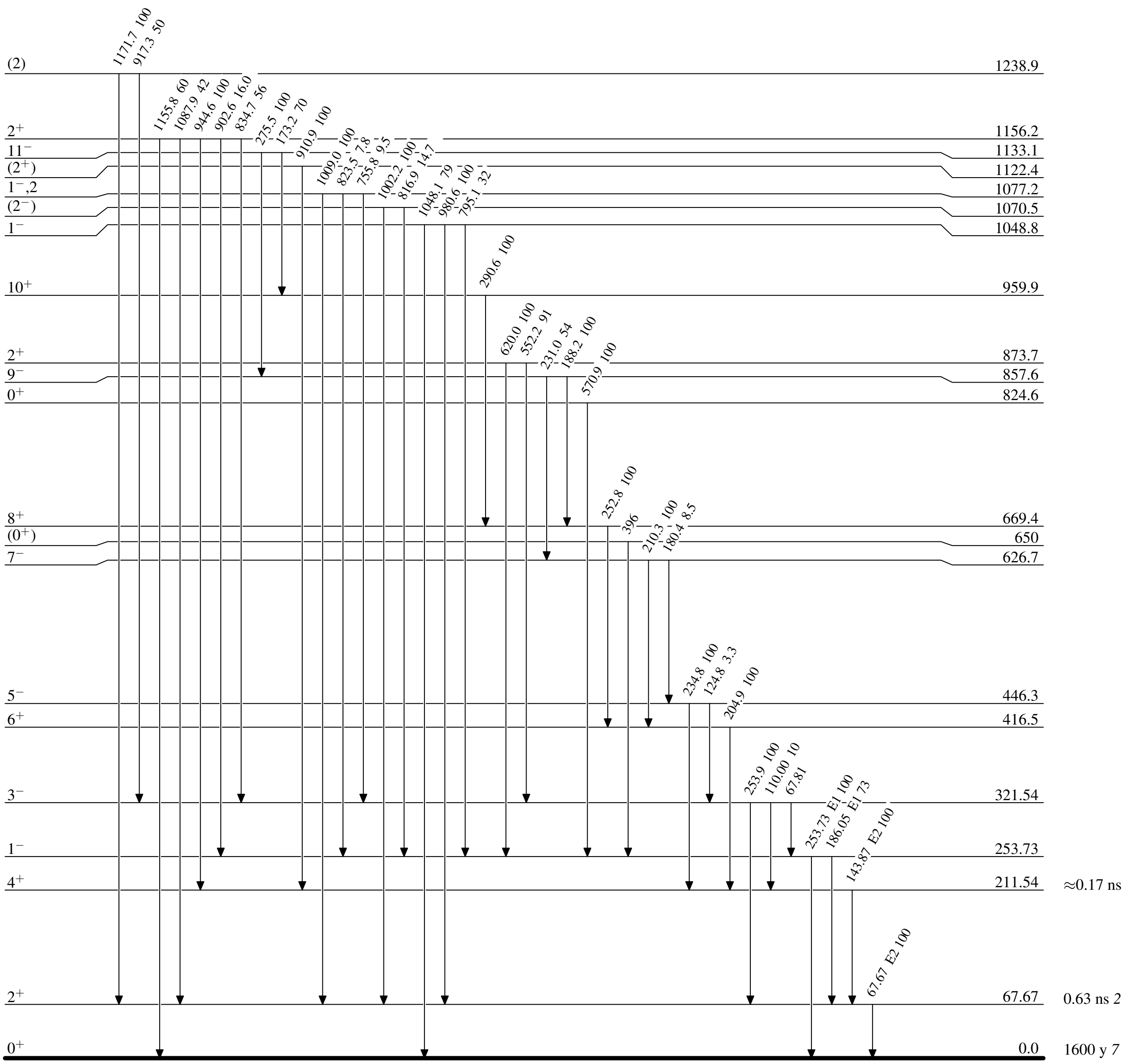


$^{226}_{88}Ra_{138}$

Adopted Levels, Gammas

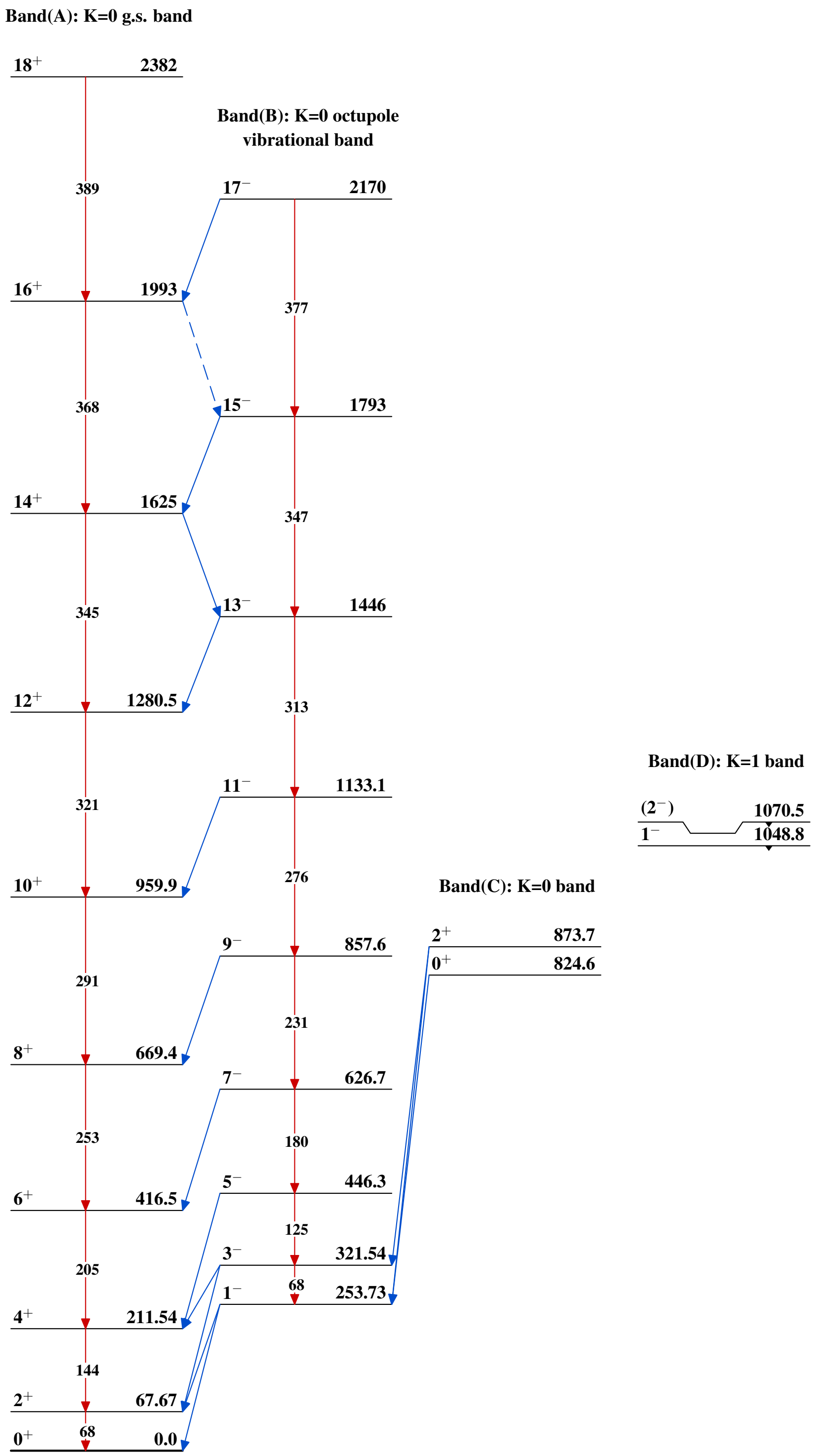
Level Scheme (continued)

Intensities: Relative photon branching from each level



$^{226}_{88}Ra_{138}$

Adopted Levels, Gammas



$^{226}_{88}Ra_{138}$

Adopted Levels, Gammas

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Khalifeh Abusaleem	NDS 116, 163 (2014)	31-Dec-2012

Q(β^-)=45.8 *7*; S(n)=6308.6 *23*; S(p)=8033 *13*; Q(α)=4072 *10* 2012Wa38

Calculations, compilations, systematics:
α-decay, Geiger-Nuttall plot: 1991Bu05, 2009De32, 2010Wa31.
Bound state β^- decay of highly ionized atoms: 1987Ta16.
Binding energies, deformation role: 1986Ch23, 2010Ro08.
Clustering in nuclei: 1986Da03, 2000Bu02.
E1 transition, octupole deformation: 1989De11, 2008Bi03, 2001Ch02, 2000Ku42.
Equilibrium deformation energy, shapes: 1995Ru10, 1988So08, 1984Na22.
Ground state rotational band, excited bands: 2001Sa54, 1993Am07, 1988Ab07.
Selection rule, β^- decay: 1992So06.
Intrinsic structures and associated rotational bands: 1992So10.
Levels, B(λ): 1995De13, 1988Ri07, 1986Go07, 2007Bo46.
Levels, octupole deformed nuclei: 1991Eg01, 2008Ro11, 2006Le09, 2001Za09, 2001Za04, 2010Bo12.
Octupole deformation, octupole vibration: 2005Bo18.
Fission barrier: 2004Mo06.
Quadruple, octupole moment: 2002Ts01.
Quasi-bands in even-even nuclei: 1984Sa37.
Super- and hyper-deformed configurations: 1995We02.
Alpha-decay half life: 2005Sh42, 2006Me15.
Relativistic mean field interaction: 2005La04.
$T_{1/2}$: 2010Sa09.

^{228}Ra Levels

Cross Reference (XREF) Flags

A	^{228}Fr β^- decay
B	^{232}Th α decay
C	^{232}Th(d,^{6}Li)
D	^{232}Th(^{136}Xe,Xγ)

E(level)[†]	J^{π}[#]	$T_{1/2}$[‡]	XREF	Comments
0[&]	0^+[@]	5.75 y *3*	ABCD	%β^-=100 $T_{1/2}$: from 1962Ma58. Others: 6.7 y (1931Cu01), 5.7 y *2* (1960Du11). Isotope shift: Δ<r^2>=+1.46 *15* relative to ^{214}Ra (1988Ah02). Calculated $T_{1/2}$(^{12}C emission)=4.4×10^{19} y (1986De32).
63.823[&] *20*	2^+[@]	550 ps *20*	ABCD	J^{π}: E2 γ to 0^+; member of g.s. band. $T_{1/2}$: From ^{228}Fr β^- decay using $\beta\gamma\gamma$(t) method. Others: 550 ps *20* (shape de-convolusion in ^{228}Fr β^- decay); 0.55 ns *4* (^{232}Th α-decay).
204.702[&] *22*	4^+[@]	181 ps *3*	ABCD	J^{π}: E2 γ to 2^+; no γ to 0^+; member of g.s. band. $T_{1/2}$: From ^{228}Fr β^- decay using $\beta\gamma\gamma$(t) method.
411.69[&] *5*	(6^+)		A CD	J^{π}: γ only to 4^+, probable member of g.s. band.
474.18[a] *4*	1^-[@]	≤7 ps	A CD	J^{π}: E1 γ to 2^+; γ to 0^+. Probable head of $K^{\pi}=0^-$ octupole vibrational band from systematics. $T_{1/2}$: Represents average of four independent measurements in ^{228}Fr β^- decay. 2σ limit.

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Adopted Levels, Gammas (continued)

^{228}Ra Levels (continued)

E(level)[†]	Jπ[#]	$T_{1/2}$[‡]	XREF	Comments
537.50[a] *4*	3^-	≤6 ps	A CD	Jπ: E1 γ to 4^+; γ to 2^+; probable member of K=0 octupole band. $T_{1/2}$: Represents average of ten time-delayed measurements in ^{228}Fr β^- decay. 2 σ limit.
655.98[a] *5*	(5^-)[@]		A CD	Jπ: γ's to 4^+ and (6^+). Probable member of K=0 octupole band.
674.29[&] *11*	(8^+)[@]		D	Jπ: (E2) γ to 6^+; member of g.s. band.
721.19[b] *8*	0^+		A C	Jπ: L(d,^{6}Li)=0 for even-even nucleus. Bandhead of second $K^\pi=0^+$ band; E0 γ-ray to 0^+.
770.71[b] *4*	2^+		A C	Jπ: Strong E0 component of E0+M1+E2 γ-ray to 2^+ state of the g.s. band.
830.1[a] *5*	(7^-)[@]		D	Jπ: (E1) γ to (6^+).
846.15[c] *9*	2^+		A C	Jπ: E0 γ-ray from 2^+; possible head of $K^\pi=2^+$ band.
880.31[b] *6*	4^+		A C	Jπ: Strong E0 component of E0+M1+E2 γ-ray to 4^+ level of the g.s. band.
898.86[c] *8*	(3^+)		A	Jπ: γ's to 2^+ and 4^+. Probable member of $K^\pi=2^+$ band.
967.11 *20*	$(2^+,4^+)$		A C	Jπ: L=(2,4) in (d,^{6}Li); γ to 4^+; γ's from 2^+.
983.29[&] *15*	(10^+)[@]		D	Jπ: (E2) γ to (8^+).
1013.24[d] *14*	2^+		A C	Jπ: E0 γ-ray to 2^+. Possible head of second $K^\pi=2^+$ band.
1042.01 *11*	$(0^+,1,2,3^-)$		A	Jπ: γ to 1^-. log *ft*=8.4 (log $f^{1u}t$=9.8) from 2^- ^{228}Fr. Suggested as head of third $K^\pi=0^+$ band (1982Ru04), in which case the 1050 (d,^{6}Li) peak, which is not consistent with L=0, must correspond to the 1052.78 level.
1052.79 *13*	$(2^+,3,4^+)$		A C	XREF: C(1050). Jπ: γ's to 2^+ and (4^+); L(d,^{6}Li)=(2,4) for E=1050.
1055.0[a] *5*	(9^-)[@]		D	Jπ: γ's to 8^+ and 7^-; member of a rotational band.
1070.24[d] *7*	(3^+)		A C	Jπ: probable E0 component in γ to (3^+). γ's to 2^+ and 4^+. Possible member of second $K^\pi=2^+$ band.
1087.29 *7*	$(1^-,2,3^-)$		A	Jπ: γ's to (1^-) and (3^-). Suggested by 1982Ru04 as a member of the third $K^\pi=0^+$ band.
1109.12 *19*	$(2^+,3)$		A	Jπ: γ to 4^+. log *ft*=7.91 (log $f^{1u}t$=9.35) from 2^-.
1140	(4^+)		C	Jπ: L(d,^{6}Li)=(4). Possibly same level as 1157.
1157.61 *21*	$(2^+,3,4^+)$		A	Jπ: γ's to 2^+ and 4^+.
1182.28 *8*	(3^-)		A	Jπ: γ's to (3^-) and (5^-). log *ft*=7.89 (log $f^{1u}t$=9.3) from 2^- ^{228}Fr.
1200	(2^+)		C	Jπ: L(d,^{6}Li)=(2). Possibly same level as 1220.
1219.98 *13*	(2^+)		A	Jπ: γ's to 0^+ and 4^+.
1238.5 *3*	$(1,2,3^-)$		A	Jπ: γ's to (1^-) and 2^+. log *ft*=7.44 (log $f^{1u}t$=8.8) from 2^- ^{228}Fr.
1327.0[a] *4*	(11^-)[@]		D	Jπ: (E2) γ to (9^-).
1331.1[&] *4*	(12^+)[@]		D	Jπ: (E2) γ to (10^+).
1349.5 *4*	(4^+)		A	Jπ: γ's to 4^+ and (6^+). log *ft*=7.9 (log $f^{1u}t$=9.3) from 2^- ^{228}Fr.
1420			C	Jπ: L(d,^{6}Li)=(2,4).
1471.75 *12*	$(1^-,2,3,4^+)$		A	Jπ: γ's to 2^+ and (3^-). log *ft*=7.7 (log $f^{1u}t$=9.0) from 2^- ^{228}Fr.
1495.35 *13*	$(1^+,2,3,4^+)$		A	Jπ: γ's to (3^+) and 2^+.
1507.14 *17*	$(2^+,3^-)$		A	Jπ: γ's to (1^-) and 4^+.
1518.88? *21*	$(0^+,1,2,3^-)$		A	Jπ: γ's to 2^+ and (1^-).
1579.8 *3*	$(1^-,2,3^-)$		A	Jπ: γ's to (1^-) and (3^-).
1639.3[a] *5*	(13^-)[@]		D	Jπ: (E2) γ to (11^-).
1710.0[&] *5*	(14^+)[@]		D	Jπ: (E2) γ to (12^+).
1911.82 *16*	$1^+,2^+$		A	Jπ: γ to 721 0^+ level.
1974.62 *24*	$1,2^+$		A	Jπ: γ to 0^+ g.s.
1987.7[a] *6*	(15^-)[@]		D	Jπ: (E2) γ to (13^-).
2041.1 *3*	(2^+)		A	Jπ: γ's to 721-keV 0^+ and (4^+).
2107.93 *19*	$(2^+,3)$		A	Jπ: γ's to 2^+, 4^+. (log $f^{1u}t$=8.2 from 2^- ^{228}Fr).
2110.8 *4*	$(2,3^-)$		A	γ's to (1^-), (3^+), (3^-); log *ft*=6.36 from 2^- ^{228}Fr.
2113.6[&] *7*	(16^+)[@]		D	Jπ: (E2) γ to (16^+).
2138.3 *6*	(2^+)		A	Jπ: γ's to 0^+ and 4^+.

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Adopted Levels, Gammas (continued)

^{228}Ra Levels (continued)

E(level)[†]	Jπ[#]	XREF	Comments
2161.3 *5*	(2$^+$)	A	Jπ: γ′s to 0$^+$ and 4$^+$.
2168.2 *7*	(2$^+$,3)	A	Jπ: γ′s to 2$^+$ and 4$^+$. log *ft*=7.10 (log $f^{1u}t$=8.2 *2*) from 2$^-$ ^{228}Fr.
2368.0[a] *7*	(17$^-$)[@]	D	Jπ: γ to (15$^-$).
2536.0[&] *8*	(18$^+$)[@]	D	Jπ: γ to (16$^+$).
2776.6[a] *9*	(19$^-$)[@]	D	Jπ: γ to (17$^-$).
2972.1[&] *10*	(20$^+$)[@]	D	Jπ: γ to (18$^+$).
3418.9[&] *11*	(22$^+$)[@]	D	Jπ: γ to (20$^+$).

† From a least-squares fit to Eγ.

‡ From 1998Gu09 using βγγ(t) method, except otherwise noted.

\# Based on multipolarity extracted in β^- decay from conversion electron intensities and fast timing data (1998Gu09). The agreement between the theoretical predictions and the measured CC confirm the previously tentatively assigned spins in 1982Ru04. 1982Ru04: show a comparison of experimental branching ratios with those expected from the Alaga rule as modified to account for Coriolis interaction between the K^π=0$^-$ and the (unobserved) K^π=1$^-$ bands. These calculated branching ratios for the E1 transitions between the K^π=0$^-$ and K^π=0$^+$, K^π=2$^+$ bands are in good agreement with experiment.

@ Band structure and band parameters; member of a rotational band in particle transfer reaction.

& Band(A): K^π=0$^+$ g.s. band. α=6.80 keV *23*.

a Band(B): K^π=0$^-$ octupole-vibrational band. α=6.15 keV *7*.

b Band(C): second K^π=0$^+$ band.

c Band(D): K^π=2$^+$ band,γ-vibrational.

d Band(E): K^π=second 2$^+$ band.

$\gamma(^{228}Ra)$

E_i(level)	J_i^π	E_γ[‡]	I_γ[#]	E_f	J_f^π	Mult.[@]	α[†]	Comments
63.823	2^+	63.83 2	100	0	0^+	E2	80.3 12	B(E2)(W.u.)=142 6 α(L)=59.0 9; α(M)=16.03 23; α(N+..)=5.25 8 α(N)=4.23 6; α(O)=0.897 13; α(P)=0.1289 19; α(Q)=0.000306 5 Mult.: from (L1+L2)/L3/M/(N+...)=100/83.5/60/18.7 in agreement with theoretical prediction (100/82.5/50/15.6) for E2 γ-ray (1998Gu09).
204.702	4^+	140.88 1	100	63.823	2^+	E2	2.26 4	B(E2)(W.u.)=207 4 α(K)=0.283 4; α(L)=1.450 21; α(M)=0.394 6; α(N+..)=0.1295 19 α(N)=0.1041 15; α(O)=0.0222 4; α(P)=0.00324 5; α(Q)=1.90×10^{-5} 3 Mult.: (L1+L2)/L3/M/(N+...)=100/57.4/39.6/13.6; theory:(100/56.9/37.7/15.1), α(K)exp=0.27 5;α(K)theory=0.29 for E2 (1998Gu09).
411.69	(6^+)	206.97 4	100	204.702	4^+	[E2]	0.517	α(K)=0.154; α(L)=0.274; α(M)=0.0737; α(N+..)=0.0264
474.18	1^-	410.40 6	82 4	63.823	2^+	E1	0.0177	B(E1)(W.u.)$\geq1.5\times10^{-4}$ α(K)=0.0145; α(L)=0.00255; α(M)=0.00060; α(N+..)=0.00021 Mult.: α(K)exp=0.017 3;α(K)theory=0.015 for E1 (1998Gu09).
		474.0 1	100 19	0	0^+	[E1]	0.0133	B(E1)(W.u.)$\geq1.2\times10^{-4}$ α(K)=0.0108; α(L)=0.00187; α(M)=0.00044; α(N+..)=0.00015
537.50	3^-	332.91 5	25.1 16	204.702	4^+	E1	0.0279	B(E1)(W.u.)$\geq1.5\times10^{-4}$ α(K)=0.0226; α(L)=0.00409; α(M)=0.00097; α(N+..)=0.00034 Mult.: α(K)exp=0.032 7; α(K)theory=0.023 for E1 (1998Gu09).
		473.7 1	100 11	63.823	2^+	[E1]	0.0133	B(E1)(W.u.)$\geq2.2\times10^{-4}$ α(K)=0.0108; α(L)=0.00187; α(M)=0.00044; α(N+..)=0.00015
655.98	(5^-)	244.4 1	4.8 11	411.69	(6^+)	[E1]	0.0567	α(K)=0.0454; α(L)=0.00853; α(M)=0.00203; α(N+..)=0.00071
		451.20 6	100 5	204.702	4^+	[E1]	0.0147	α(K)=0.0119; α(L)=0.00207; α(M)=0.00049; α(N+..)=0.00017
674.29	(8^+)	262.6 1	100 13	411.69	(6^+)	(E2)	0.231	α(K)=0.0935 14; α(L)=0.1011 15; α(M)=0.0270 4; α(N+..)=0.00892 13 α(N)=0.00714 10; α(O)=0.001538 22; α(P)=0.000232 4; α(Q)=3.84×10^{-6} 6
721.19	0^+	247.01 8	44 5	474.18	1^-	[E1]	0.0549	α(K)=0.0440 7; α(L)=0.00825 12; α(M)=0.00197 3; α(N+..)=0.000650 10 α(N)=0.000515 8; α(O)=0.0001147 16; α(P)=1.90×10^{-5} 3; α(Q)=1.183×10^{-6} 17
		657.4 2	100 6	63.823	2^+	[E2]	0.0209	α(K)=0.01497 21; α(L)=0.00446 7; α(M)=0.001122 16; α(N+..)=0.000373 6 α(N)=0.000296 5; α(O)=6.56×10^{-5} 10; α(P)=1.071×10^{-5} 15; α(Q)=5.30×10^{-7} 8
		(721.2 5)		0	0^+	E0		E_γ: proposed by 1998Gu09 based on conversion electron spectrum. Mult.: α(K)exp>1.4 (1998Gu09);α(K)theory=0.0.0048 for E1, 0.057 for M1, and 0.013 for E2 (1998Gu09).
770.71	2^+	233.25 4	58 6	537.50	3^-	[E1]	0.0627	α(K)=0.0502 7; α(L)=0.00949 14; α(M)=0.00227 4; α(N+..)=0.000748 11 α(N)=0.000593 9; α(O)=0.0001319 19; α(P)=2.18×10^{-5} 3; α(Q)=1.341×10^{-6} 19
		296.53 5	63 7	474.18	1^-	[E1]	0.0363	α(K)=0.0293; α(L)=0.00536; α(M)=0.00128; α(N+..)=0.00044
		565.8 1	53 8	204.702	4^+	[E2]	0.0293	α(K)=0.0200; α(L)=0.00698
		706.9 1	76 5	63.823	2^+	E0+M1+E2	0.55 8	α(K)=0.037 24; α(L)=0.007 4 Mult.: α(K)exp=0.55 8;α(K)theory=0.0049 for E1, 0.061 for M1, and 0.013 for E2 (1998Gu09).
		770.7 1	100 5	0	0^+	[E2]	0.0152	α(K)=0.0113; α(L)=0.00296

Adopted Levels, Gammas (continued)

$\gamma(^{228}Ra)$ (continued)

E_i(level)	J^π_i	E_γ[‡]	I_γ[#]	E_f	J^π_f	Mult.[@]	α[†]	$I_{(\gamma+ce)}$	Comments
830.1	(7⁻)	418.4 *5*	100 *25*	411.69	(6⁺)	(E1)	0.0170		
846.15	2⁺	782.3 *1*	100 *5*	63.823	2⁺	M1+E2	0.036 *22*		α(K)=0.029 *18*; α(L)=0.006 *3* Mult.: α(K)exp=0.012 *5*;α(K)theory=0.0041 for E1, 0.046 for M1, and 0.010 for E2 (1998Gu09).
		846.2 *2*	72 *5*	0	0⁺	[E2]	0.0126		α(K)=0.0095; α(L)=0.00234
880.31	4⁺	224.35 *8*	48 *6*	655.98	(5⁻)	[E1]	0.0693		α(K)=0.0550 *8*; α(L)=0.01045 *15*; α(M)=0.00250 *4*; α(N+..)=0.000823 *12* α(N)=0.000652 *10*; α(O)=0.0001451 *21*; α(P)=2.39×10⁻⁵ *4*; α(Q)=1.460×10⁻⁶ *21*
		342.88 *6*	100 *8*	537.50	3⁻	[E1]	0.0263		α(K)=0.0211 *3*; α(L)=0.00380 *6*; α(M)=0.000903 *13*; α(N+..)=0.000299 *5* α(N)=0.000236 *4*; α(O)=5.30×10⁻⁵ *8*; α(P)=8.88×10⁻⁶ *13*; α(Q)=5.89×10⁻⁷ *9*
		468.4 *1*	1.0 *3*	411.69	(6⁺)	[E2]	0.0459		α(K)=0.01097 *16*; α(L)=0.00190 *3*; α(M)=0.000450 *7*; α(N+..)=0.0001493 *21* α(N)=0.0001179 *17*; α(O)=2.65×10⁻⁵ *4*; α(P)=4.50×10⁻⁶ *7*; α(Q)=3.14×10⁻⁷ *5*
		675.6 *5*	44 *7*	204.702	4⁺	E0+M1+E2	1.3	3	α(K)=0.04 *3*; α(L)=0.008 *4* Mult.: α(K)exp=1.3 *3*;α(K)theory=0.0054 for E1, 0.068 for M1, and 0.014 for E2 (1998Gu09).
898.86	(3⁺)	694.2 *1*	21.1 *11*	204.702	4⁺	[M1,E2]	0.05 *3*		α(K)=0.039 *25*; α(L)=0.008 *4*
		835.0 *2*	100 *6*	63.823	2⁺	[M1,E2]	0.029 *17*		α(K)=0.024 *15*; α(L)=0.0047 *24*
967.11	(2⁺,4⁺)	762.4 *2*	100	204.702	4⁺				
983.29	(10⁺)	309.0 *1*	100	674.29	(8⁺)	(E2)	0.1392		α(K)=0.0667 *10*; α(L)=0.0536 *8*; α(M)=0.01422 *20*; α(N+..)=0.00469 *7* α(N)=0.00376 *6*; α(O)=0.000812 *12*; α(P)=0.0001239 *18*; α(Q)=2.63×10⁻⁶ *4*
1013.24	2⁺	167.1 *3*		846.15	2⁺	E0		≈7.4	$I_{(\gamma+ce)}$: I(γ+ce)/Iγ(949)≈0.095 from I(K x ray) in $\gamma\gamma$.
		949.4 *2*	100 *5*	63.823	2⁺	[M1,E2]	0.021 *13*		α(K)=0.018 *10*; α(L)=0.0034 *16*
		1013.7[&] *10*	2.6[&] *7*	0	0⁺				
1042.01	(0⁺,1,2,3⁻)	567.8 *1*	100 *5*	474.18	1⁻				
1052.79	(2⁺,3,4⁺)	172.4 *2*	1.9 *3*	880.31	4⁺				
		515.2 *2*	10 *3*	537.50	3⁻				
		989.8 *3*	100 *5*	63.823	2⁺				
1055.0	(9⁻)	225.0[a] *5*		830.1	(7⁻)				
		380.8 *5*		674.29	(8⁺)				
1070.24	(3⁺)	171.4 *1*	10.0 *12*	898.86	(3⁺)	E0+M1+E2	16 *7*		Mult.: From α(L1+L2)(exp)=1.0 *3*; theory: 0.017 for E1, 0.41 for E2, and 0.53 for M1. These values reveal strong component of E0 (1998Gu09). α: from α(K)exp (value not given) from I(K x ray) in $\gamma\gamma$ and α/α(K) (theory, value not given).
		532.68 *8*	11.1 *12*	537.50	3⁻	[E1]	0.0105		α(K)=0.0085; α(L)=0.00146

$^{228}_{88}Ra_{140}$-5

Adopted Levels, Gammas (continued)

$\gamma(^{228}Ra)$ (continued)

E_i(level)	J^π_i	E_γ[‡]	I_γ[#]	E_f	J^π_f	Mult.[@]	α[†]	Comments
1070.24	(3^+)	865.8 2	100 5	204.702	4^+	[M1,E2]	0.028 16	α(K)=0.022 14; α(L)=0.0043 21
		1006.5 5	95 15	63.823	2^+			
1087.29	$(1^-,2,3^-)$	549.83 7	94 8	537.50	3^-			
		613.06 8	100 5	474.18	1^-			
1109.12	$(2^+,3)$	904.4 2	100 5	204.702	4^+			
1157.61	$(2^+,3,4^+)$	952.9 3	38 3	204.702	4^+			
		1092.8 5	100 5	63.823	2^+			
1182.28	(3^-)	526.22 8	30 3	655.98	(5^-)			
		644.9 1	100 6	537.50	3^-			
1219.98	(2^+)	498.8 1	36 4	721.19	0^+			
		1015.7 8	100 22	204.702	4^+			
1238.5	$(1,2,3^-)$	764.5 3	27.4 17	474.18	1^-			
		1174.2 5	100 5	63.823	2^+			
1327.0	(11^-)	272.0 5	100 38	1055.0	(9^-)	(E2)	0.206 4	α(K)=0.0869 13; α(L)=0.0880 14; α(M)=0.0235 4; α(N+..)=0.00774 13 α(N)=0.00620 10; α(O)=0.001337 22; α(P)=0.000202 4; α(Q)=3.54×10^{-6} 6
		343.6 5	100 46	983.29	(10^+)	(E1)	0.0260	α(K)=0.0210 3; α(L)=0.00378 6; α(M)=0.000898 13; α(N+..)=0.000297 5 α(N)=0.000235 4; α(O)=5.27×10^{-5} 8; α(P)=8.84×10^{-6} 13; α(Q)=5.87×10^{-7} 9
1331.1	(12^+)	347.8 3	100 47	983.29	(10^+)	(E2)	0.0988	α(K)=0.0522 8; α(L)=0.0345 5; α(M)=0.00908 13; α(N+..)=0.00300 5 α(N)=0.00240 4; α(O)=0.000521 8; α(P)=8.02×10^{-5} 12; α(Q)=2.02×10^{-6} 3
1349.5	(4^+)	937.6 5	42 6	411.69	(6^+)			
		1145.0 5	100 9	204.702	4^+			
1471.75	$(1^-,2,3,4^+)$	625.6 1	52 5	846.15	2^+			
		934.3 2	100 6	537.50	3^-			
		1406.4 15	48 10	63.823	2^+			
1495.35	$(1^+,2,3,4^+)$	425.1 1	23 5	1070.24	(3^+)			
		1432.9 15	100 17	63.823	2^+			
1507.14	$(2^+,3^-)$	493.9 1	30 3	1013.24	2^+			
		1033.0 10	100 19	474.18	1^-			
		1303.1 10	47 5	204.702	4^+			
1518.88?	$(0^+,1,2,3^-)$	551.9[a] 1	9.0 15	967.11	$(2^+,4^+)$			
		1043.2[a] 8	100 20	474.18	1^-			
		1454.7[a] 10	20 2	63.823	2^+			
1579.8	$(1^-,2,3^-)$	422.3 2	12.9 19	1157.61	$(2^+,3,4^+)$			
		1041.6 8	86 18	537.50	3^-			
		1105.6 8	100 6	474.18	1^-			
		1514.9 15	23 3	63.823	2^+			
1639.3	(13^-)	308.3 5	45 35	1331.1	(12^+)			

$\gamma(^{228}Ra)$ (continued)

E_i(level)	J^π_i	E_γ‡	I_γ#	E_f	J^π_f	Mult.@	α†	Comments
1639.3	(13^-)	312.3 *5*	100 *40*	1327.0	(11^-)			
1710.0	(14^+)	378.9 *5*	100	1331.1	(12^+)	(E2)	0.0780	α(K)=0.0438 *7*; α(L)=0.0253 *4*; α(M)=0.00664 *10*; α(N+..)=0.00220 *4* α(N)=0.00175 *3*; α(O)=0.000382 *6*; α(P)=5.92×10^{-5} *9*; α(Q)=1.670×10^{-6} *24*
1911.82	$1^+,2^+$	824.4 *5*	29.1 *24*	1087.29	$(1^-,2,3^-)$			
		869.7 *2*	40 *3*	1042.01	$(0^+,1,2,3^-)$			
		898.7 *2*	100 *5*	1013.24	2^+			
		1013.7& *10*	13& *3*	898.86	(3^+)			
		1190.8 *15*	27 *5*	721.19	0^+			
		1847.5 *10*	46 *7*	63.823	2^+			
		1911.5& *10*	≤34&	0	0^+			
1974.62	$1,2^+$	816.5 *3*	83 *7*	1157.61	$(2^+,3,4^+)$			
		922.3 *3*	100 *6*	1052.79	$(2^+,3,4^+)$			
		1501.6 *15*	36 *4*	474.18	1^-			
		1911.5& *10*	≤50&	63.823	2^+			
		1973.8 *10*	50 *5*	0	0^+			
1987.7	(15^-)	277.5 *5*	28 *18*	1710.0	(14^+)	(E1)	0.0420	α(K)=0.0338 *5*; α(L)=0.00623 *10*; α(M)=0.001486 *22*; α(N+..)=0.000491 *8* α(N)=0.000389 *6*; α(O)=8.68×10^{-5} *13*; α(P)=1.443×10^{-5} *21*; α(Q)=9.21×10^{-7} *14*
		348.3 *5*	100 *42*	1639.3	(13^-)	(E2)	0.0984	α(K)=0.0521 *8*; α(L)=0.0343 *6*; α(M)=0.00903 *14*; α(N+..)=0.00299 *5* α(N)=0.00239 *4*; α(O)=0.000518 *8*; α(P)=7.98×10^{-5} *12*; α(Q)=2.01×10^{-6} *3*
2041.1	(2^+)	821.7 *5*	29.2 *23*	1219.98	(2^+)			
		1027.2 *5*	38 *8*	1013.24	2^+			
		1162.0 *10*	50 *6*	880.31	4^+			
		1194.2& *15*	25& *5*	846.15	2^+			
		1318.8 *10*	29 *6*	721.19	0^+			
		1566.9 *10*	100 *6*	474.18	1^-			
2107.93	$(2^+,3)$	600.8 *1*	29 *2*	1507.14	$(2^+,3^-)$			
		1902.8 *10*	22.3 *24*	204.702	4^+			
		2043.5 *10*	100 *10*	63.823	2^+			
2110.8	$(2,3^-)$	1001.6 *5*	8.0 *15*	1109.12	$(2^+,3)$			
		1024.4 *10*	11.7 *27*	1087.29	$(1^-,2,3^-)$			
		1096.9 *8*	36.1 *20*	1013.24	2^+			
		1211.5 *15*	6.1 *14*	898.86	(3^+)			
		1340.2 *10*	12.2 *27*	770.71	2^+			
		1572.4 *10*	62 *7*	537.50	3^-			
		1637.7 *10*	10.7 *15*	474.18	1^-			
		2047.8 *10*	100 *10*	63.823	2^+			
2113.6	(16^+)	403.8 *5*	100 *23*	1710.0	(14^+)	(E2)	0.0659	α(K)=0.0385 *6*; α(L)=0.0203 *3*; α(M)=0.00529 *8*; α(N+..)=0.00175 *3* α(N)=0.001398 *21*; α(O)=0.000305 *5*; α(P)=4.76×10^{-5} *7*; α(Q)=1.454×10^{-6} *21*

From ENSDF

$^{228}_{88}Ra_{140}$-7

$\gamma(^{228}$Ra) (continued)

E_i(level)	J_i^π	E_γ[‡]	I_γ[#]	E_f	J_f^π	Mult.[@]	α[†]	Comments
2138.3	(2^+)	1171.0 *10*	100 *8*	967.11	$(2^+,4^+)$			
		1601.1 *15*	58 *12*	537.50	3^-			
		1663.7 *15*	53 *8*	474.18	1^-			
		1934.8 *15*	51 *6*	204.702	4^+			
		2137.8 *15*	46 *7*	0	0^+			
2161.3	(2^+)	1052.4 *10*	16.0 *22*	1109.12	$(2^+,3)$			
		1194.2[&] *15*	14[&] *3*	967.11	$(2^+,4^+)$			
		1390.8 *10*	17.3 *17*	770.71	2^+			
		1955.9 *10*	22.5 *17*	204.702	4^+			
		2097.4 *10*	100 *10*	63.823	2^+			
		2162.4 *15*	15.2 *22*	0	0^+			
2168.2	$(2^+,3)$	1631.0 *15*	28 *5*	537.50	3^-			
		1963.0 *10*	50 *7*	204.702	4^+			
		2104.7 *10*	100 *10*	63.823	2^+			
2368.0	(17^-)	254.6 *5*	30 *23*	2113.6	(16^+)	(E1)	0.0512	α(K)=0.0411 *6*; α(L)=0.00767 *12*; α(M)=0.00183 *3*; α(N+..)=0.000604 *9* α(N)=0.000478 *7*; α(O)=0.0001067 *16*; α(P)=1.77×10^{-5} *3*; α(Q)=1.108×10^{-6} *17*
		380.1 *5*	100 *40*	1987.7	(15^-)	(E2)	0.0773	α(K)=0.0435 *7*; α(L)=0.0251 *4*; α(M)=0.00656 *10*; α(N+..)=0.00217 *4* α(N)=0.00173 *3*; α(O)=0.000377 *6*; α(P)=5.86×10^{-5} *9*; α(Q)=1.659×10^{-6} *24*
2536.0	(18^+)	422.4 *5*	100	2113.6	(16^+)	(E2)	0.0586	α(K)=0.0352 *5*; α(L)=0.0174 *3*; α(M)=0.00452 *7*; α(N+..)=0.001497 *22* α(N)=0.001194 *18*; α(O)=0.000261 *4*; α(P)=4.09×10^{-5} *6*; α(Q)=1.320×10^{-6} *19*
2776.6	(19^-)	408.6 *5*	100	2368.0	(17^-)	(E2)	0.0639	α(K)=0.0376 *6*; α(L)=0.0195 *3*; α(M)=0.00508 *8*; α(N+..)=0.001680 *25* α(N)=0.001341 *20*; α(O)=0.000292 *5*; α(P)=4.57×10^{-5} *7*; α(Q)=1.417×10^{-6} *21*
2972.1	(20^+)	436.1 *5*	100	2536.0	(18^+)	(E2)	0.0540	α(K)=0.0330 *5*; α(L)=0.01563 *23*; α(M)=0.00405 *6*; α(N+..)=0.001342 *20* α(N)=0.001070 *16*; α(O)=0.000234 *4*; α(P)=3.68×10^{-5} *6*; α(Q)=1.233×10^{-6} *18*
3418.9	(22^+)	446.8 *5*	100	2972.1	(20^+)	(E2)		

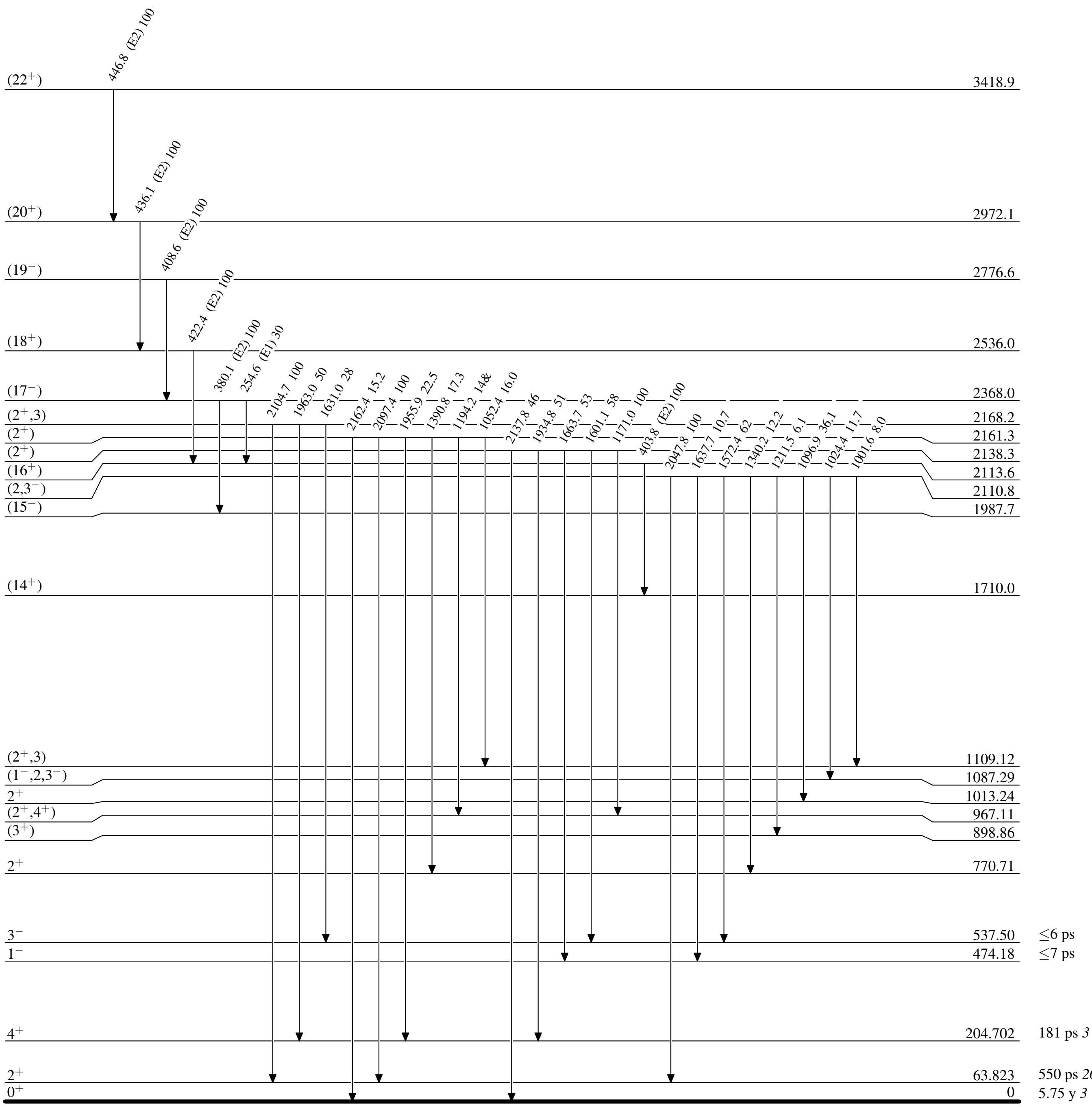
[†] Additional information 1.
[‡] Weighted average of available data, unless noted otherwise.
[#] Relative photon branching from each level in ^{228}Fr β^- decay.
[@] Extracted from the measured conversion electron intensity in ^{228}Fr β^- decay. These are in good agreement with the theoretical predictions (1998Gu09). Also ^{232}Th(^{136}Xe,Xγ) reaction assumes that γ-rays connecting thE in-band states of the g.s. and $K^\pi=0^-$ octupole-vibrational bands are E2; and the intraband γ's are E1.
[&] Multiply placed with undivided intensity.
[a] Placement of transition in the level scheme is uncertain.

$^{228}_{88}$Ra$_{140}$-8

Adopted Levels, Gammas

Level Scheme

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

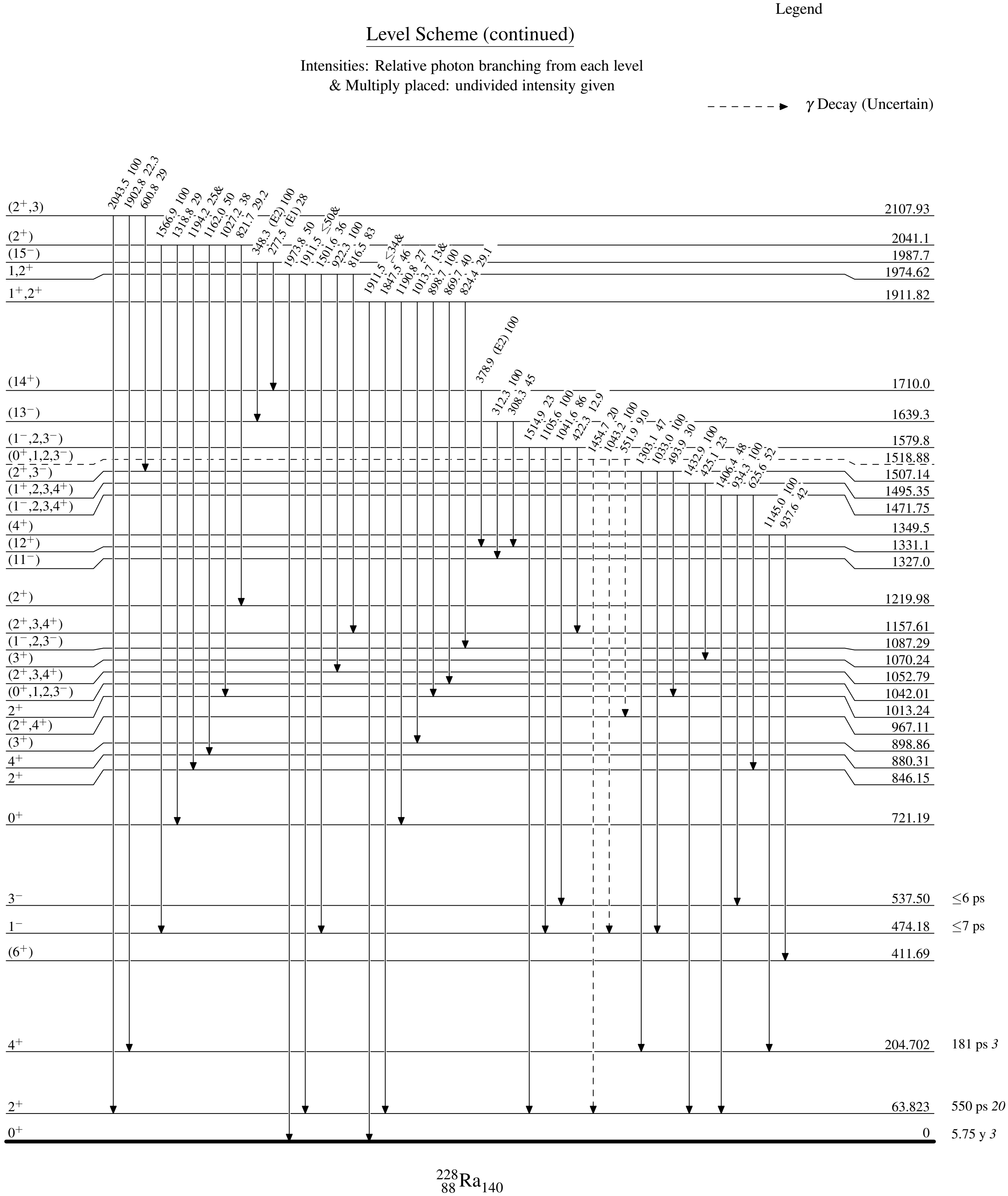


$^{228}_{88}Ra_{140}$

Adopted Levels, Gammas

Level Scheme (continued)

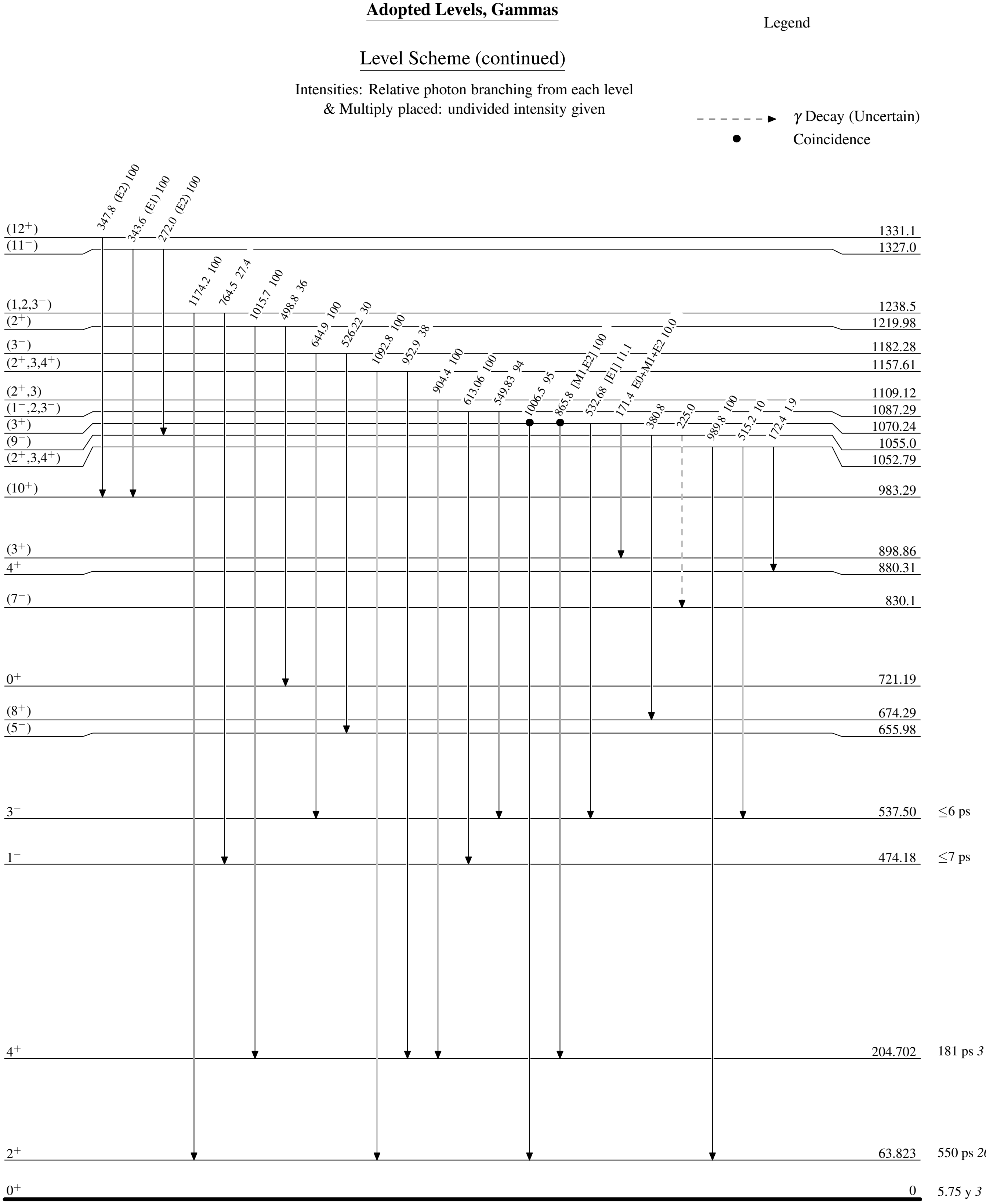
Intensities: Relative photon branching from each level
& Multiply placed: undivided intensity given



Adopted Levels, Gammas

Level Scheme (continued)

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



$^{228}_{88}Ra_{140}$

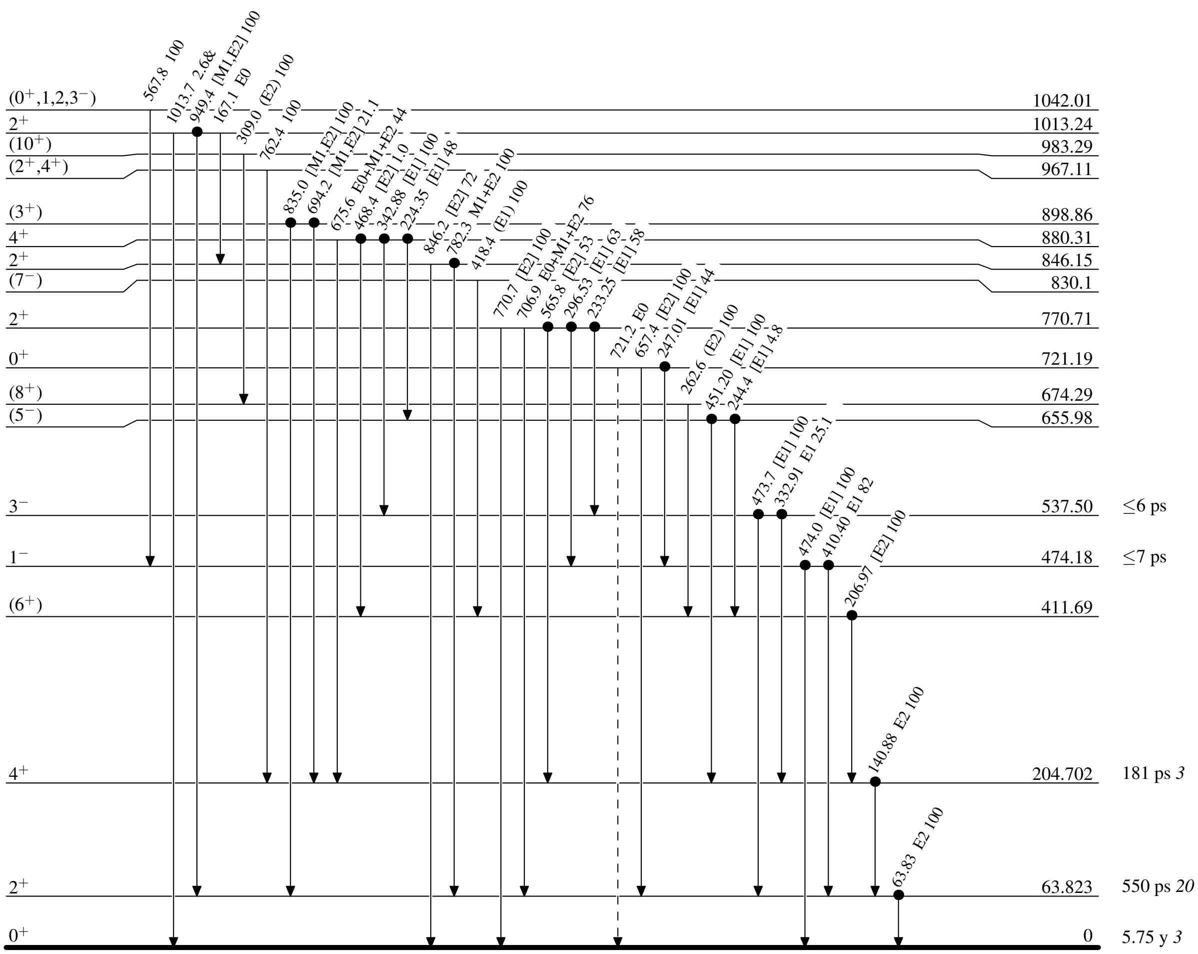
Adopted Levels, Gammas

Level Scheme (continued)

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

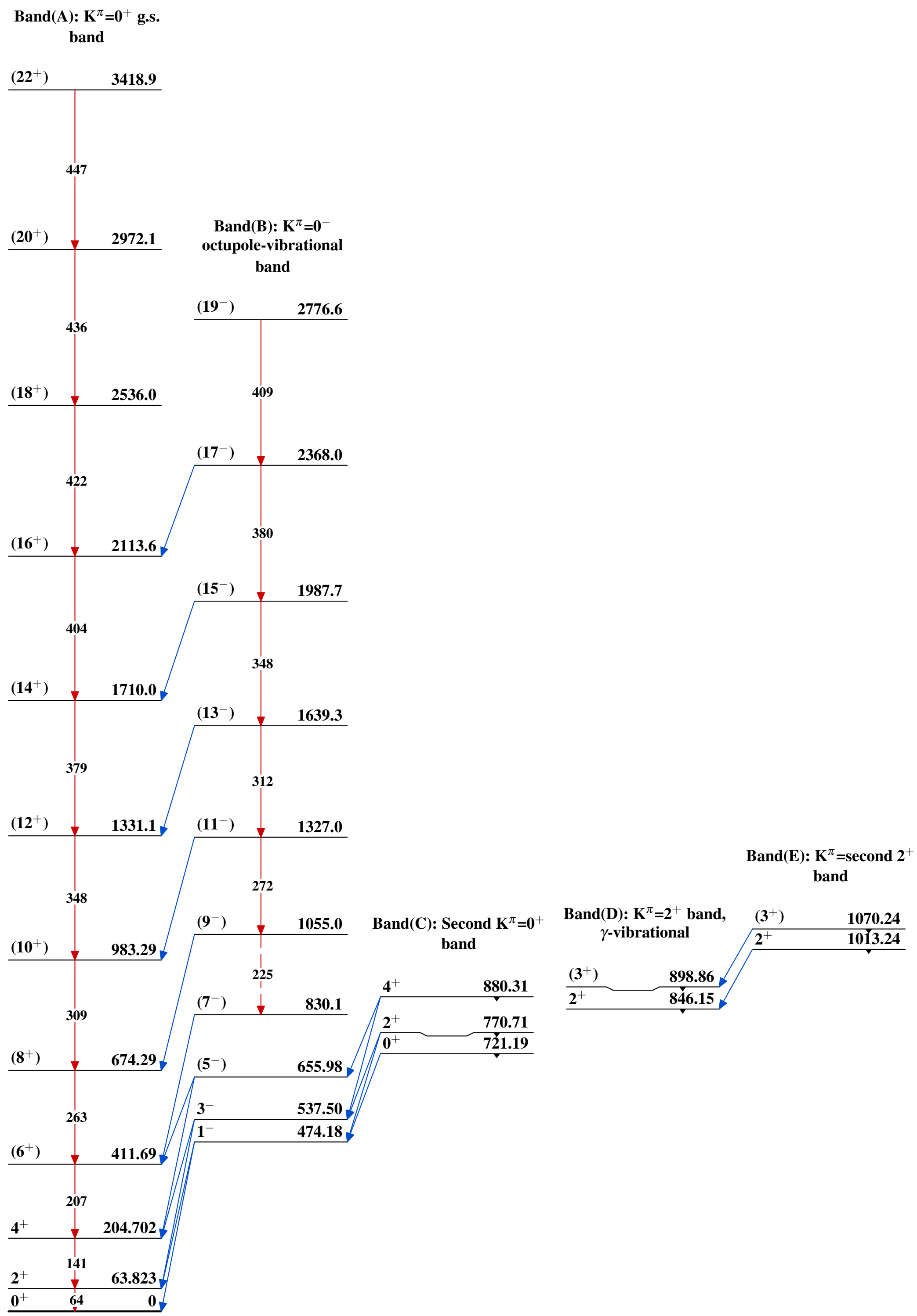
Legend

γ Decay (Uncertain)
Coincidence



$^{228}_{88}Ra_{140}$

Adopted Levels, Gammas



$^{228}_{88}Ra_{140}$

Adopted Levels, Gammas

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	E. Browne, J. K. Tuli	NDS 113,2113 (2012)	1-May-2012

Q(β^-)=678 *19*; S(n)=6104 *18*; S(p)=8447 *18*; Q(α)=3344 *15* 2012Wa38

Note: Current evaluation has used the following Q record 7.1E+2 30 *6110* 188589 403352 19 2011AuZZ.

Additional information 1.

Isotope shift (relative to ^{214}Ra)=−53634 *15* MHz (1988Ah02). The change in the nuclear mean square charge radius=1.67 *17*, was calculated in 1988Ah02 from the experimental value of the isotopic shift.

See 1988Ah02 for deformation parameter deduced from the measured isotope shift. See 1975Iv03, 1982Du16, 1982Le19, 1983Ro14, 1984Na22, for theoretical calculations of equilibrium deformations.

See 1975Iv03 and 1983Ro14 for theoretical quadrupole and hexadecapole moments.

See 1991Eg01 for calculation of K=0$^-$ octupole-vibrational level energy, and for B(E1) and B(E3) values. See 1988Ri07 for calculated values of B(E2; 2$^+$ to 0$^+$).

See 2010Ro08 and 2005Bo18 for calculation of octupole states and transition strengths.

Measured mass excess (Δm=34518 keV *12*) using a Penning trap mass spectrometer (2008We02).

Calculated excitation energy of first J^π=2$^+$ state (2008Bi03).

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Assignment: thorium(180-MeV d)     chem  (1952Je06);
            thorium(20-160 MeV n)  chem  (1978Gi07);
            parent of 230Ac                (1978Gi07).
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^{230}Ra Levels

Cross Reference (XREF) Flags

A ^{230}Fr β^- decay
B ^{232}Th(^{56}Fe,Xγ) E=362 MeV
C ^{232}Th(^{136}Xe,Xγ)

E(level)†	J$^\pi$	T$_{1/2}$	XREF	Comments
0.0#	0$^+$	93 min *2*	ABC	%β^-=100 No β-_fission (<3×10^{-4}%) (1990Me13,1993MeZW). T$_{1/2}$: from 1978Gi07. Other measured values: 60 min (1952Je06), 45.5 min *15* (tentative assignment to ^{230}Ra, 1975Ra03).
57.4# *1*	2$^+$		ABC	J$^\pi$: γ ray to the 0$^+$ g.s.; systematics of 2$^+$ states in even-even nuclei in the region.
186.64# *9*	(4$^+$)		ABC	J$^\pi$: γ ray to the 2$^+$ state; energy fit to the g.s. rotational band.
379.15# *13*	(6$^+$)		ABC	J$^\pi$: γ ray to the (4$^+$) state; no γ ray to lower-spin levels; energy fit to the g.s. rotational band.
626.4‡#	(8$^+$)		ABC	
710.93@ *8*	(1$^-$)		A C	J$^\pi$: γ rays to 0$^+$ and 2$^+$ states; systematics of 1$^-$ octupole-vibrational states.
734.87& *8*	(2$^+$)		A	J$^\pi$: γ rays to 0$^+$ and (4$^+$) levels.
768.54@ *10*	(3$^-$)		A	J$^\pi$: γ rays to the 2$^+$ and (4$^+$) states; level's energy spacing from the 1$^-$ octupole-vibrational state.
785.9& *1*	(3$^+$)		A C	J$^\pi$: γ rays to 2$^+$ and (4$^+$) states; energy difference from the 2$^+$ γ-vibrational state.
849.88& *12*	(4$^+$)		A	J$^\pi$: γ rays to the (2$^+$) and (4$^+$) states; energy fit to the band.
879.97@ *13*	(5$^-$)		A C	J$^\pi$: γ ray to the (4$^+$) state; no γ ray to 2$^+$, 0$^+$; energy fit to the band.
893.12 *13*			A	
920.0‡#	(10$^+$)		BC	
932.26& *20*	(5$^+$)		A	J$^\pi$: γ rays to the (4$^+$) and (6$^+$) levels; energy fit to the γ-vibrational band.
1033.94 *13*	(2$^+$)		A	J$^\pi$: γ rays to the 0$^+$ and (4$^+$) states.

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Adopted Levels, Gammas (continued)

^{230}Ra Levels (continued)

E(level)†	J^π	XREF	Comments
1144.57 *13*	(4+)	A	J^π: γ rays to the 2+ and (6+) states.
1158.57 *16*		A	
1189.07 *19*		A	
1211.89 *19*		A	
1252.2‡#	(12+)	BC	
1281.17 *23*		A	
1341.25 *22*		A	
1466.97 *24*		A	
1522.40 *20*		A	
1616.3‡#	(14+)	BC	
1897.30 *12*		A	
2005.05 *13*		A	
2006.3‡#	(16+)	BC	
2043.52 *18*		A	
2418.3?‡#	(18+)	BC	

† Excited state energies are from ^{230}Fr β^- decay, unless otherwise specified.
‡ From ^{232}Th(^{56}Fe,X), E=362 MeV.
# Band(A): K=0+ g.s. rotational band.
@ Band(B): K=0− octupole-vibrational band.
& Band(C): K=2+ γ-vibrational band.

γ(^{230}Ra)

E_i(level)	J^π_i	E_γ†	I_γ‡	E_f	J^π_f
57.4	2+	57.4 *1*	100	0.0	0+
186.64	(4+)	129.1 *1*	100	57.4	2+
379.15	(6+)	192.5 *1*	100	186.64	(4+)
626.4	(8+)	247.3#	100	379.15	(6+)
710.93	(1−)	653.4 *1*	96 *7*	57.4	2+
		711.0@ *1*	100@ *25*	0.0	0+
734.87	(2+)	548.0 *3*	4.9 *5*	186.64	(4+)
		677.4 *1*	100 *7*	57.4	2+
		734.9 *1*	89 *7*	0.0	0+
768.54	(3−)	57.1@ *1*	0.15@ *5*	710.93	(1−)
		581.9 *1*	13.4 *10*	186.64	(4+)
		711.0@ *1*	100@ *10*	57.4	2+
785.9	(3+)	599.3 *1*	26.2 *19*	186.64	(4+)
		728.4 *1*	100 *6*	57.4	2+
849.88	(4+)	663.2 *1*	100 *7*	186.64	(4+)
		792.4 *2*	62 *5*	57.4	2+
879.97	(5−)	693.3	100	186.64	(4+)
893.12		706.5 *1*	100 *7*	186.64	(4+)
		835.5 *3*	72 *8*	57.4	2+
920.0	(10+)	293.6#	100	626.4	(8+)
932.26	(5+)	553.2 *2*	30 *3*	379.15	(6+)
		745.4 *3*	100 *15*	186.64	(4+)
1033.94	(2+)	266.5 *2*	28 *4*	768.54	(3−)
		323.1 *2*	43 *4*	710.93	(1−)
		847.2 *3*	72 *9*	186.64	(4+)

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Adopted Levels, Gammas (continued)

γ(^{230}Ra) (continued)

E$_i$(level)	J$^\pi_i$	E$_\gamma$†	I$_\gamma$‡	E$_f$	J$^\pi_f$
1033.94	(2$^+$)	976.3 *3*	100 *10*	57.4	2$^+$
		1033.8 *5*	37 *6*	0.0	0$^+$
1144.57	(4$^+$)	264.5 *2*	55 *6*	879.97	(5$^-$)
		375.8 *2*	89 *9*	768.54	(3$^-$)
		765.5 *3*	63 *8*	379.15	(6$^+$)
		958.0 *2*	100 *11*	186.64	(4$^+$)
		1086.9 *5*	46 *8*	57.4	2$^+$
1158.57		971.8 *2*	100 *10*	186.64	(4$^+$)
		1101.2 *2*	93 *8*	57.4	2$^+$
1189.07		338.9 *3*	7.4 *15*	849.88	(4$^+$)
		1002.2 *3*	100 *10*	186.64	(4$^+$)
1211.89		832.4 *3*	51 *5*	379.15	(6$^+$)
		1025.4 *2*	100 *10*	186.64	(4$^+$)
1252.2	(12$^+$)	332.2#	100	920.0	(10$^+$)
1281.17		1094.8 *3*	100 *10*	186.64	(4$^+$)
		1223.4 *3*	78 *8*	57.4	2$^+$
1341.25		1154.6 *2*	100	186.64	(4$^+$)
1466.97		587.0 *2*	100	879.97	(5$^-$)
1522.40		333.1 *2*	40 *4*	1189.07	
		754.0 *3*	65 *16*	768.54	(3$^-$)
1522.40		811.9 *3*	100 *10*	710.93	(1$^-$)
		1465.0 *5*	18 *5*	57.4	2$^+$
1616.3	(14$^+$)	364.1#	100	1252.2	(12$^+$)
1897.30		863.5 *3*	11.0 *12*	1033.94	(2$^+$)
		1004.3 *3*	46 *5*	893.12	
		1111.8 *3*	27 *3*	785.9	(3$^+$)
		1128.8 *2*	87 *6*	768.54	(3$^-$)
		1162.6 *2*	100 *7*	734.87	(2$^+$)
		1710.2 *2*	63 *7*	186.64	(4$^+$)
		1839.3 *5*	13.0 *20*	57.4	2$^+$
2005.05		1219.0 *5*	32 *4*	785.9	(3$^+$)
		1236.6 *3*	74 *7*	768.54	(3$^-$)
		1270.2 *2*	74 *7*	734.87	(2$^+$)
		1294.0 *2*	86 *9*	710.93	(1$^-$)
		1947.7 *3*	100 *10*	57.4	2$^+$
2006.3	(16$^+$)	390#	100	1616.3	(14$^+$)
2043.52		898.7 *2*	100 *10*	1144.57	(4$^+$)
		1274.6 *3*	59 *9*	768.54	(3$^-$)
		1857.8 *3*	100 *10*	186.64	(4$^+$)
2418.3?	(18$^+$)	412#&	100	2006.3	(16$^+$)

† From ^{230}Fr β^- decay (1987Ku04), unless otherwise specified.

‡ Relative photon intensities deexciting each level, normalized to 100 for the strongest γ ray.

From ^{232}Th(^{56}Fe,X), E=362 MeV.

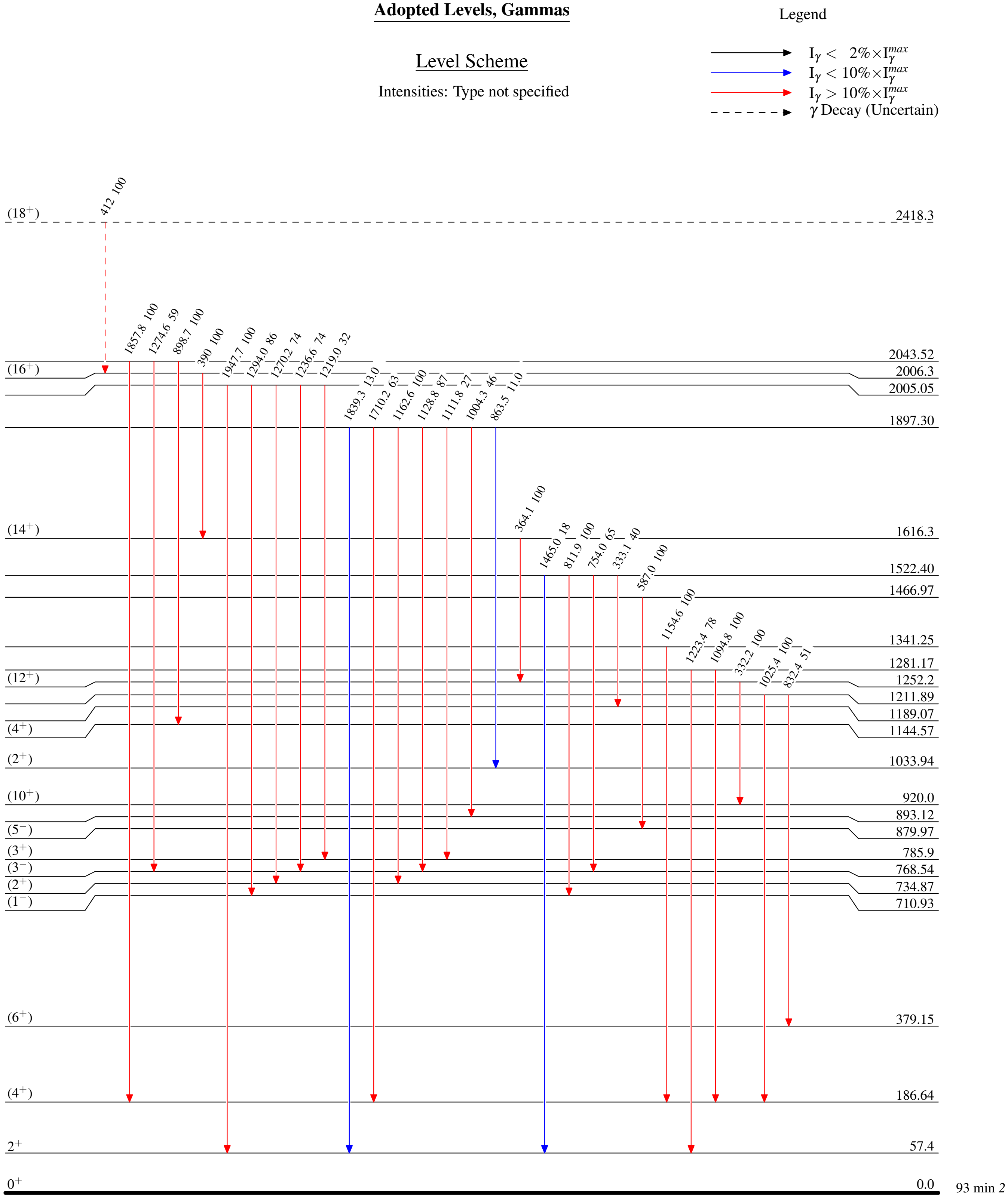
@ Multiply placed with intensity suitably divided.

& Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Level Scheme

Intensities: Type not specified

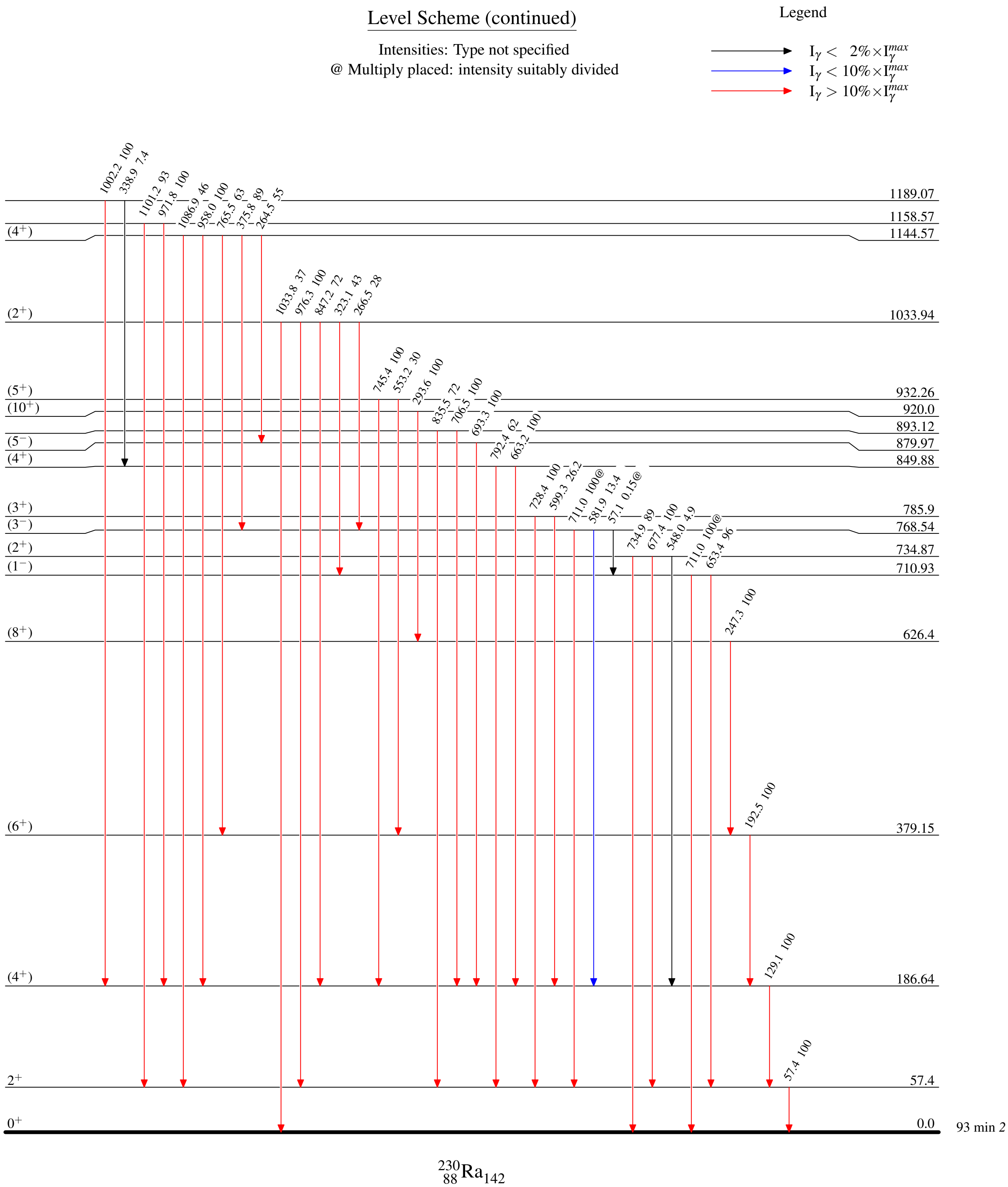


$^{230}_{88}Ra_{142}$

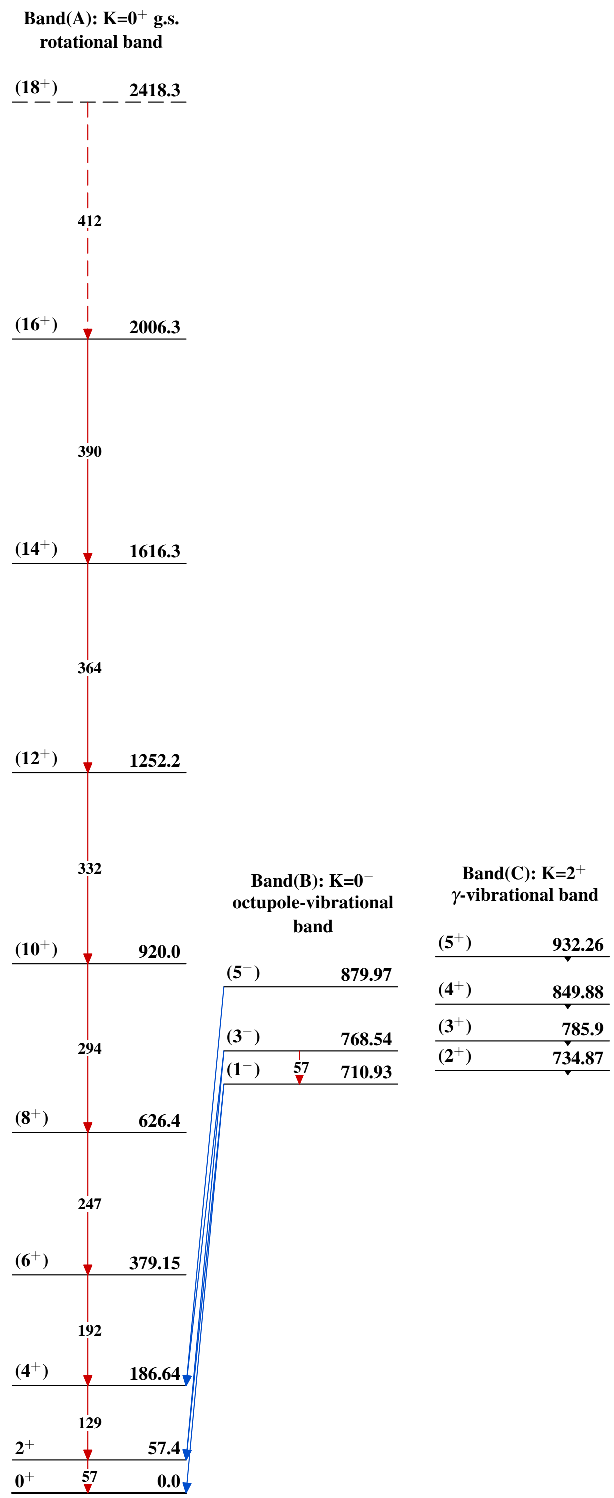
Adopted Levels, Gammas

Level Scheme (continued)

Intensities: Type not specified
@ Multiply placed: intensity suitably divided



Adopted Levels, Gammas



$^{230}_{88}Ra_{142}$