Adopted Levels, Gammas 1999Fr33,1992Bo05

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	E. Browne, J. K. Tuli	NDS 109,2657 (2008)	1-Jun-2008

Q(β^-)=1850 *18*; S(n)=4465 *15*; S(p)=8110 *20*; Q(α)=3589 *19* 2012Wa38
Note: Current evaluation has used the following Q record 1810 304450 198010 syst 2003Au03.
Atomic masses: Penning trap mass spectrometer (2005He26,2008We02).

Assignment: Th(600-MeV p,x) mass separation (1975Ra03), chem (1978Gi07); parent of ^{229}Ac;
^{228}Ra(pile n,x) chem, parent of ^{229}Ac (1952De01).
Daughter of ^{229}Fr β^- decay. ^{229}Fr activity produced by spallation of 1-GeV protons on uranium.

^{229}Ra Levels

Cross Reference (XREF) Flags

A ^{229}Fr β^- decay

E(level)[†]	J$^\pi$[‡]	$T_{1/2}$	XREF	Comments
0.0[b]	5/2$^+$	4.0 min *2*	A	%α=100 μ=0.5025 *27*; Q=2.96 *30* (1988Ah02) Other value: Q=+3.1 *2* (1989Ne03). Other: 1988Ne09. $T_{1/2}$: measured values: 4.0 min *2* (1975Ra03), 4.1 min *3* (1978Gi07). J$^\pi$: measured (hfs by LASER spectroscopy, 1983Ah03). Probably 5/2[633] state. See 1984Le04 for calculation of μ. Other calculations: 1985Dz04, 1985He03, 1988Le13. Deformation parameter was deduced as $<\beta^2>$ =0.229 by 1988Ah02 from their measured isotope shift.
41.25[b] *9*	(7/2)$^+$		A	J$^\pi$: 41γ M1(+E2) to 5/2$^+$.
107.04 *6*	(5/2)$^+$		A	J$^\pi$: 107γ M1 to 5/2$^+$, 36γ (E2) from 1/2$^+$.
137.45[c] *6*	5/2$^-$	0.66 ns *4*	A	J$^\pi$: 96γ E1 to (7/2)$^+$, 137γ E1 to 5/2$^+$, 342γ (E2) from 1/2$^-$.
142.67[@] *6*	1/2$^+$	17.23 ns *12*	A	J$^\pi$: 143γ E2 to 5/2$^+$, 337γ E1 from 1/2$^-$.
168.74[@] *6*	3/2$^+$	106 ps *18*	A	J$^\pi$: 169γ M1 to 5/2$^+$, 310γ E1 from 1/2$^-$.
212.91[&] *6*	3/2$^+$	18 ps *14*	A	J$^\pi$: 213γ M1(+E2) to 5/2$^+$, 266γ E1 from 1/2$^-$.
478.86[#] *7*	1/2$^-$	≤30 ps	A	J$^\pi$: log *ft*=5.8 from (1/2$^+$) is characteristic from a β^- transition between the 1/2[400] and 1/2[501] Nilsson states; 336γ E1 to 1/2$^+$.
501.37 *7*	(5/2$^+$)		A	
518.18[#] *9*	(3/2)$^-$		A	
541.46[#] *8*	5/2$^-$		A	
550.85 *9*	3/2$^-$,5/2$^-$,7/2$^-$		A	
563.07 *9*			A	
565.64[a] *8*	3/2$^-$		A	
598.26 *10*			A	
665.07 *11*			A	
752.91 *9*	(1/2,3/2)$^-$		A	
773.2 *3*			A	
813.88 *14*			A	
835.90 *19*			A	
870.88 *11*			A	
934.62 *18*			A	
1042.0 *3*			A	
1322.64 *22*			A	
1340.01 *14*			A	
1376.12 *20*			A	
1410.09 *11*			A	

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas 1999Fr33,1992Bo05 (continued)

^{229}Ra Levels (continued)

E(level)[†]	XREF
1424.87 *7*	A
1437.02 *14*	A
1461.30 *11*	A
1608.76 *15*	A
1696.84 *18*	A
1720.54 *19*	A

† Deduced by evaluators from least-squares fit to adopted γ-ray energies.

‡ Spin and parity assignments are based on γ-ray multipolarities and on rotational structure. Arguments for spin/parity assignments are given with some individual levels. Because of the high octupole components in the wave functions of low-energy states, rotational levels are seen with partners of the same K angular momentum projection and opposite parities ("parity doublets.") This interpretation has been confirmed by the enhanced E1 γ-ray transition probabilities between parity pair states.

Band(A): $K^{\pi}=1/2^{-}$ parity doublet band. 1/2[501].

@ Band(a): $K^{\pi}=1/2^{+}$ parity doublet band. 1/2[631].

& Band(B): $K^{\pi}=3/2^{+}$ parity doublet band. 3/2[631].

a Band(b): $K^{\pi}=3/2^{-}$ parity doublet band. 3/2[761].

b Band(C): $K^{\pi}=5/2^{+}$ parity doublet band. 5/2[633].

c Band(c): $K^{\pi}=5/2^{-}$ parity doublet band. 5/2[752].

Adopted Levels, Gammas 1999Fr33,1992Bo05 (continued)

$\gamma(^{229}Ra)$

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[‡]	δ[‡]	α[#]	Comments
41.25	$(7/2)^+$	41.3	100	0.0	$5/2^+$	M1(+E2)			
107.04	$(5/2)^+$	65.8 *1*	100 *7*	41.25	$(7/2)^+$	M1		10.51	α(L)=7.96 *12*; α(M)=1.91 *3*; α(N+..)=0.639 *10* α(N)=0.503 *8*; α(O)=0.1147 *17*; α(P)=0.0200 *3*; α(Q)=0.001572 *23* Mult.: From α(L1)exp + α(L2)exp=6.6 *9*, α(L3)exp≤0.26, α(M)exp=2.05 *14*.
		107.1 *1*	57 *4*	0.0	$5/2^+$	M1		12.77	α(K)=10.22 *15*; α(L)=1.93 *3*; α(M)=0.462 *7*; α(N+..)=0.1550 *23* α(N)=0.1219 *18*; α(O)=0.0278 *4*; α(P)=0.00485 *7*; α(Q)=0.000381 *6* Mult.: From α(L1)exp + α(L2)exp=1.53 *22*, α(L3)exp≤0.25, α(M)exp=0.77 *11*, α(N)exp=0.28 *9*.
137.45	$5/2^-$	96.2 *1*	100	41.25	$(7/2)^+$	E1		0.1223	α(L)=0.0927 *14*; α(M)=0.0224 *4*; α(N+..)=0.00728 *11* α(N)=0.00581 *9*; α(O)=0.001264 *18*; α(P)=0.000197 *3*; α(Q)=9.69×10^{-6} *14* B(E1)(W.u.)=0.000131 *8* Mult.: From α(L1)exp + α(L2)exp≤0.31.
		137.5 *1*	100	0.0	$5/2^+$	E1		0.222	α(K)=0.1746 *25*; α(L)=0.0363 *6*; α(M)=0.00871 *13*; α(N+..)=0.00285 *4* α(N)=0.00227 *4*; α(O)=0.000499 *7*; α(P)=7.99×10^{-5} *12*; α(Q)=4.35×10^{-6} *7* B(E1)(W.u.)=4.5×10^{-5} *3* Mult.: From α(K)exp≤0.94, α(L1)exp + α(L2)exp=0.017 *7*, α(L3)exp≤0.041.
142.67	$1/2^+$	35.6		107.04	$(5/2)^+$	(E2)			
		142.7 *1*	100	0.0	$5/2^+$	E2		2.14	α(K)=0.279 *4*; α(L)=1.369 *20*; α(M)=0.372 *6*; α(N+..)=0.1223 *18* α(N)=0.0982 *14*; α(O)=0.0209 *3*; α(P)=0.00306 *5*; α(Q)=1.83×10^{-5} *3* B(E2)(W.u.)=2.12 *4* Mult.: From α(K)exp≤0.48, α(L1)exp + α(L2)exp=0.72 *9*, α(L3)exp=0.35 *4*, α(M)exp=0.26 *3*, α(N)exp=0.080 *10*.
168.74	$3/2^+$	26.1		142.67	$1/2^+$				
		61.8 *1*	29 *2*	107.04	$(5/2)^+$	M1		12.62	α(L)=9.57 *15*; α(M)=2.29 *4*; α(N+..)=0.768 *12* α(N)=0.604 *9*; α(O)=0.1378 *21*; α(P)=0.0240 *4*; α(Q)=0.00189 *3* B(M1)(W.u.)=0.030 *6* Mult.: From α(L1)exp + α(L2)exp=5.2 *8*, α(M)exp=3.2 *5*.
		168.8 *1*	100 *4*	0.0	$5/2^+$	M1		3.53	α(K)=2.83 *4*; α(L)=0.525 *8*; α(M)=0.1255 *18*; α(N+..)=0.0421 *6* α(N)=0.0331 *5*; α(O)=0.00755 *11*; α(P)=0.001317 *19*; α(Q)=0.0001032 *15* B(M1)(W.u.)=0.0051 *10* Mult.: From α(K)exp=3.1 *4*, α(L1)exp + α(L2)exp=0.32 *5*, α(L3)exp=0.015 *8*, α(M)exp=0.07 *4*.
212.91	$3/2^+$	44.3 *2*	6.9 *8*	168.74	$3/2^+$	M1+E2	0.95 *33*	2.4×10^2 *9*	α(L)=1.8×10^2 *7*; α(M)=48 *18*; α(N+..)=16 *6* α(N)=13 *5*; α(O)=2.7 *10*; α(P)=0.39 *14*; α(Q)=0.0034 *7* B(M1)(W.u.)=0.03 *3*; B(E2)(W.u.)=4.E+3 *4* Mult.: From α(L1)exp+α(L2)exp=100 *30*. δ deduced by evaluators.

$^{229}_{88}Ra_{141}$-3

Adopted Levels, Gammas 1999Fr33,1992Bo05 (continued)

γ(^{229}Ra) (continued)

E_i(level)	J_i^π	E_γ †	I_γ †	E_f	J_f^π	Mult.‡	δ‡	α#	Comments
212.91	3/2+	70.3 *2*	4.4 *7*	142.67	1/2+				
		75.1@ *1*	5.2 *20*	137.45	5/2−				
		105.9 *1*	14.0 *12*	107.04	(5/2)+				
		212.9 *1*	100 *7*	0.0	5/2+	M1(+E2)		1.2 *7*	α(K)=0.8 *7*; α(L)=0.256 *18*; α(M)=0.0648 *10*; α(N+..)=0.0215 *5* α(N)=0.0171 *3*; α(O)=0.00378 *15*; α(P)=0.00061 *7*; α(Q)=3.0×10^{-5} *24* Mult.: From α(K)exp=1.05 *14*, α(L1)exp + α(L2)exp=0.27 *4*, α(M)exp=0.10 *3*.
478.86	1/2−	266.0 *1*	18.5 *6*	212.91	3/2+	E1		0.0462	α(K)=0.0372 *6*; α(L)=0.00690 *10*; α(M)=0.001645 *23*; α(N+..)=0.000543 *8* α(N)=0.000430 *6*; α(O)=9.60×10^{-5} *14*; α(P)=1.593×10^{-5} *23*; α(Q)=1.008×10^{-6} *15* Mult.: From α(K)exp=0.046 *10*.
		310.1 *1*	13.9 *6*	168.74	3/2+	E1		0.0327	α(K)=0.0263 *4*; α(L)=0.00479 *7*; α(M)=0.001141 *16*; α(N+..)=0.000377 *6* α(N)=0.000299 *5*; α(O)=6.68×10^{-5} *10*; α(P)=1.116×10^{-5} *16*; α(Q)=7.27×10^{-7} *11* Mult.: From α(K)exp=0.020 *3*, α(L1)exp + α(L2)exp=0.0058 *13*.
		336.2 *1*	100	142.67	1/2+	E1		0.0273	α(K)=0.0221 *3*; α(L)=0.00397 *6*; α(M)=0.000945 *14*; α(N+..)=0.000313 *5* α(N)=0.000247 *4*; α(O)=5.54×10^{-5} *8*; α(P)=9.29×10^{-6} *13*; α(Q)=6.14×10^{-7} *9* Mult.: From α(K)exp=0.0172 *22*, α(L1)exp + α(L2)exp=0.0039 *16*.
		341.4 *1*	1.96 *9*	137.45	5/2−	(E2)		0.1041	α(K)=0.0542 *8*; α(L)=0.0369 *6*; α(M)=0.00973 *14*; α(N+..)=0.00322 *5* α(N)=0.00257 *4*; α(O)=0.000558 *8*; α(P)=8.58×10^{-5} *12*; α(Q)=2.10×10^{-6} *3* Mult.: From α(K)exp=0.10 *7*.
501.37	(5/2+)	332.5 *1*	15.3 *20*	168.74	3/2+				
		358.7 *1*	100 *4*	142.67	1/2+	(E2)			From α(K)exp=0.051 *23*.
		363.9 *1*	4.5 *4*	137.45	5/2−				
518.18	(3/2)−	305.3 *3*	13.9 *12*	212.91	3/2+				
		349.5 *1*	100 *4*	168.74	3/2+	E1			From α(K)exp=0.024 *4*.
		375.5 *2*	49.7 *16*	142.67	1/2+				
		380.6 *4*	1.9 *5*	137.45	5/2−				
541.46	5/2−	372.8 *2*	23 *3*	168.74	3/2+				
		398.7 *1*	100 *8*	142.67	1/2+				
		404.1 *1*	49 *5*	137.45	5/2−	(M1)		0.315	α(K)=0.254 *4*; α(L)=0.0462 *7*; α(M)=0.01103 *16*; α(N+..)=0.00369 *6* α(N)=0.00291 *4*; α(O)=0.000663 *10*; α(P)=0.0001157 *17*; α(Q)=9.07×10^{-6} *13*

$^{229}_{88}Ra_{141}$-4

Adopted Levels, Gammas 1999Fr33,1992Bo05 (continued)

γ(^{229}Ra) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[‡]	δ[‡]	α[#]	Comments
550.85	3/2⁻,5/2⁻,7/2⁻	413.6 *2*	65 *12*	137.45	5/2⁻	M1(+E2)	0.2 *9*	0.29 *12*	α(K)=0.23 *11*; α(L)=0.042 *13*; α(M)=0.010 *3*; α(N+..)=0.0034 *10* α(N)=0.0027 *8*; α(O)=0.00061 *18*; α(P)=0.00011 *4*; α(Q)=8.E−6 *4* Mult.: From α(K)exp=0.23 *7*. δ deduced by evaluators.
		550.8 *1*	100 *10*	0.0	5/2⁺				
563.07		394.8 *2*	70 *11*	168.74	3/2⁺				
		562.9 *1*	100 *7*	0.0	5/2⁺				
565.64	3/2⁻	352.7 *1*	22 *1*	212.91	3/2⁺				
		428.1 *1*	100 *6*	137.45	5/2⁻	M1(+E2)	0.41 *35*	0.24 *5*	α(K)=0.19 *4*; α(L)=0.036 *6*; α(M)=0.0087 *12*; α(N+..)=0.0029 *4* α(N)=0.0023 *3*; α(O)=0.00052 *7*; α(P)=9.0×10^{-5} *14*; α(Q)=6.8×10^{-6} *15* Mult.: From α(K)exp=0.19 *4*. δ deduced by evaluators.
598.26		455.6 *1*	85 *6*	142.67	1/2⁺				
		598.2 *2*	100 *10*	0.0	5/2⁺				
665.07		522.4 *1*	82 *6*	142.67	1/2⁺				
		665.1 *3*	100 *13*	0.0	5/2⁺				
752.91	(1/2,3/2)⁻	211.5 *1*	25 *4*	541.46	5/2⁻				
		274.1 *1*	39 *3*	478.86	1/2⁻	M1(+E2)	0.3 *5*	0.85 *22*	α(K)=0.68 *20*; α(L)=0.130 *16*; α(M)=0.031 *3*; α(N+..)=0.0105 *11* α(N)=0.0083 *8*; α(O)=0.00188 *20*; α(P)=0.00033 *5*; α(Q)=2.5×10^{-5} *7* Mult.: From α(K)exp=0.66 *15*. δ deduced by evaluators.
		615.1 *2*	100 *10*	137.45	5/2⁻				
		645.4[@] *2*	94 *8*	107.04	(5/2)⁺				
773.2		560.3 *3*	100	212.91	3/2⁺				
813.88		149.4[@] *2*	31 *2*	665.07					
		601.0 *2*	17 *4*	212.91	3/2⁺				
		671.2 *2*	100 *10*	142.67	1/2⁺				
835.90		334.3 *5*	1.0×10^2 *3*	501.37	(5/2⁺)				
		667.7 *4*	93 *16*	168.74	3/2⁺				
		693.2 *3*	100 *13*	142.67	1/2⁺				
870.88		727.9 *2*	60 *6*	142.67	1/2⁺				
		763.6 *2*	41 *6*	107.04	(5/2)⁺				
		871.0 *2*	100 *9*	0.0	5/2⁺				
934.62		792.1 *3*	94 *24*	142.67	1/2⁺				
		827.5 *2*	100 *10*	107.04	(5/2)⁺				
1042.0		899.4 *3*	100 *17*	142.67	1/2⁺				
		1041.7 *6*	18 *9*	0.0	5/2⁺				
1322.64		757.0 *2*	100	565.64	3/2⁻				

$^{229}_{88}Ra_{141}$-5

Adopted Levels, Gammas 1999Fr33,1992Bo05 (continued)

γ(^{229}Ra) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π
1340.01		587.1 *1*	100	752.91	$(1/2,3/2)^-$
1376.12		441.5 *1*	100	934.62	
1410.09		844.3 *2*	30 *4*	565.64	$3/2^-$
		908.6 *2*	100 *11*	501.37	$(5/2^+)$
		1197.3 *2*	76 *8*	212.91	$3/2^+$
		1267.5 *4*	1.0×10^2 *3*	142.67	$1/2^+$
		1410.3 *3*	9 *2*	0.0	$5/2^+$
1424.87		611.1 *4*	13 *3*	813.88	
		858.9 *2*	8.3 *13*	565.64	$3/2^-$
		861.6 *2*	11.0 *13*	563.07	
		883.3 *2*	16 *2*	541.46	$5/2^-$
		923.1 *2*	8.1 *10*	501.37	$(5/2^+)$
		1256.2 *1*	100 *10*	168.74	$3/2^+$
		1282.3 *1*	36 *4*	142.67	$1/2^+$
		1288.0 *3*	3.8 *6*	137.45	$5/2^-$
1437.02		919.1 *2*	23 *5*	518.18	$(3/2)^-$
1437.02		1267.9 *2*	100 *20*	168.74	$3/2^+$
		1300.1 *4*	7.8 *17*	137.45	$5/2^-$
		1395.7 *3*	8.8 *17*	41.25	$(7/2)^+$
1461.30		525.6[@] *1*	26.0 *17*	934.62	
		590.0 *2*	34 *3*	870.88	
		625.6 *3*	18.7 *21*	835.90	
		943.1 *2*	17.3 *17*	518.18	$(3/2)^-$
		1248.4 *2*	10 *1*	212.91	$3/2^+$
		1292.8 *2*	100 *10*	168.74	$3/2^+$
		1324.0 *3*	6.9 *17*	137.45	$5/2^-$
1608.76		1440.0 *2*	100 *10*	168.74	$3/2^+$
		1466.1 *2*	72 *7*	142.67	$1/2^+$
1696.84		1178.6 *2*	100 *10*	518.18	$(3/2)^-$
		1554.3 *3*	61 *8*	142.67	$1/2^+$
1720.54		310.3 *4*	1.0×10^2 *4*	1410.09	
		1577.9 *2*	21 *6*	142.67	$1/2^+$

[†] From ^{229}Fr β^- decay.
[‡] From measured internal conversion coefficients in ^{229}Fr β^- 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.

$^{229}_{88}Ra_{141}$-6

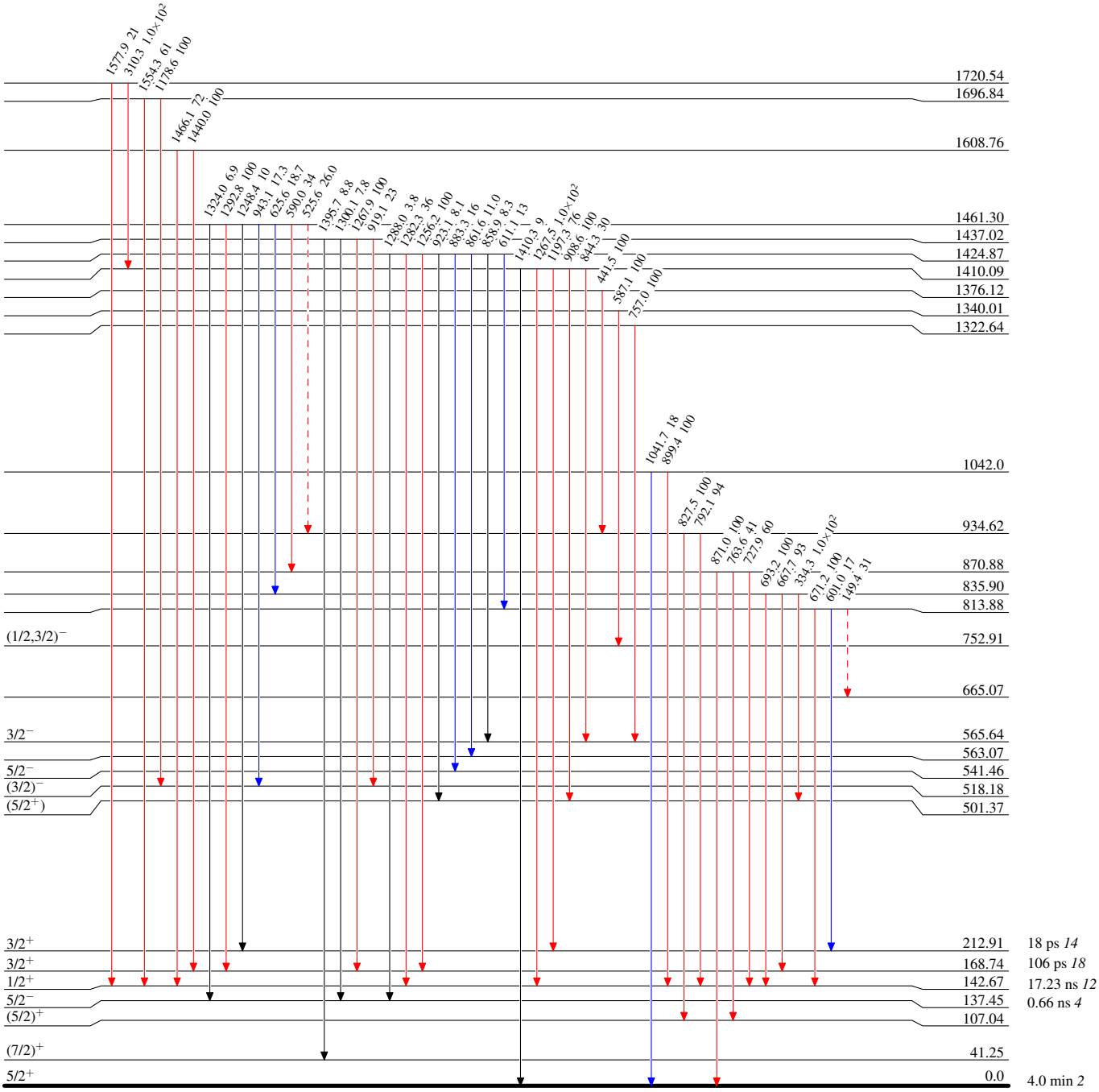
Adopted Levels, Gammas 1999Fr33,1992Bo05

Level Scheme

Intensities: Type not specified

Legend

$I_\gamma < 2\% \times I_\gamma^{max}$
$I_\gamma < 10\% \times I_\gamma^{max}$
$I_\gamma > 10\% \times I_\gamma^{max}$
γ Decay (Uncertain)

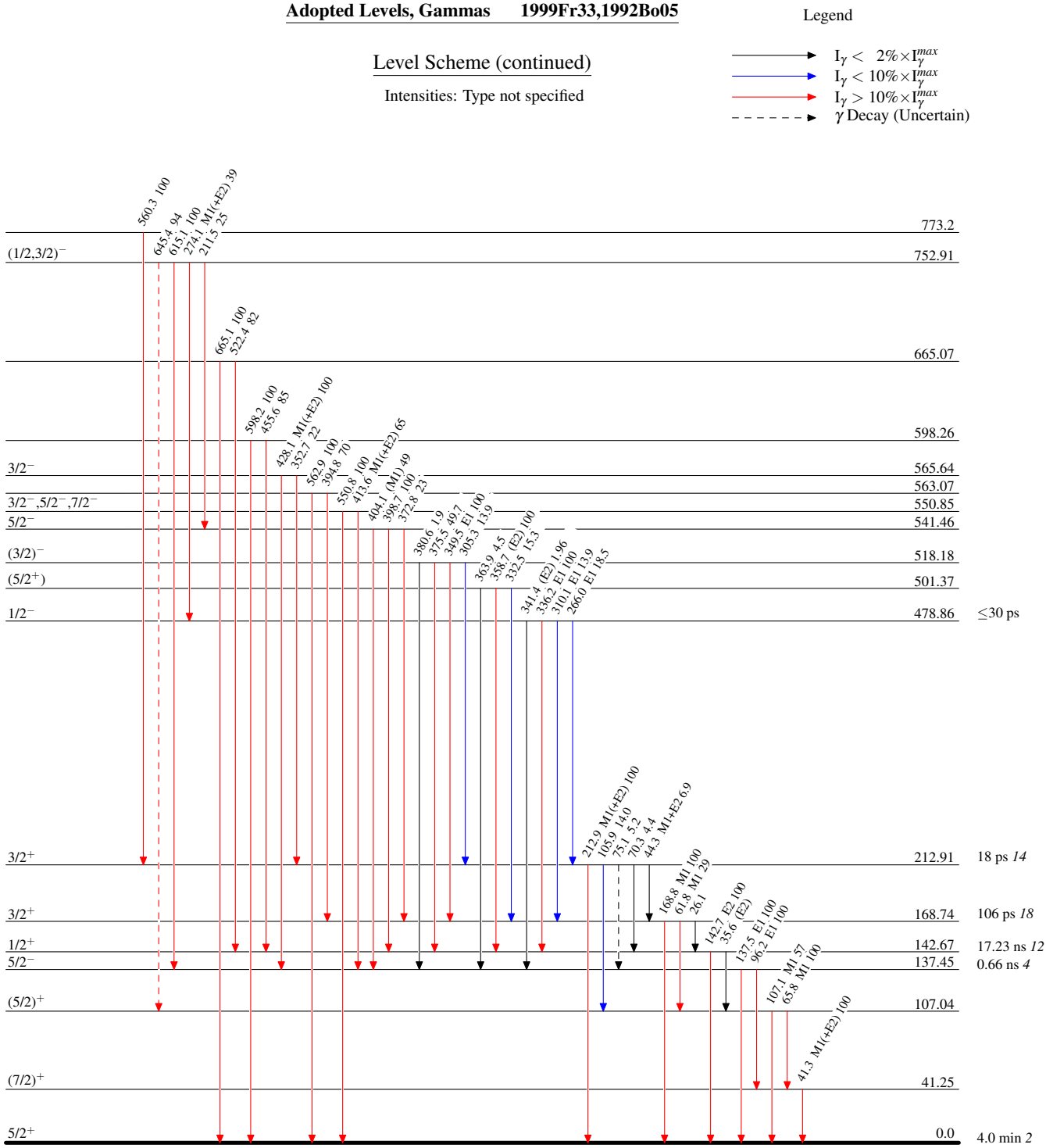


$^{229}_{88}Ra_{141}$

Adopted Levels, Gammas 1999Fr33,1992Bo05

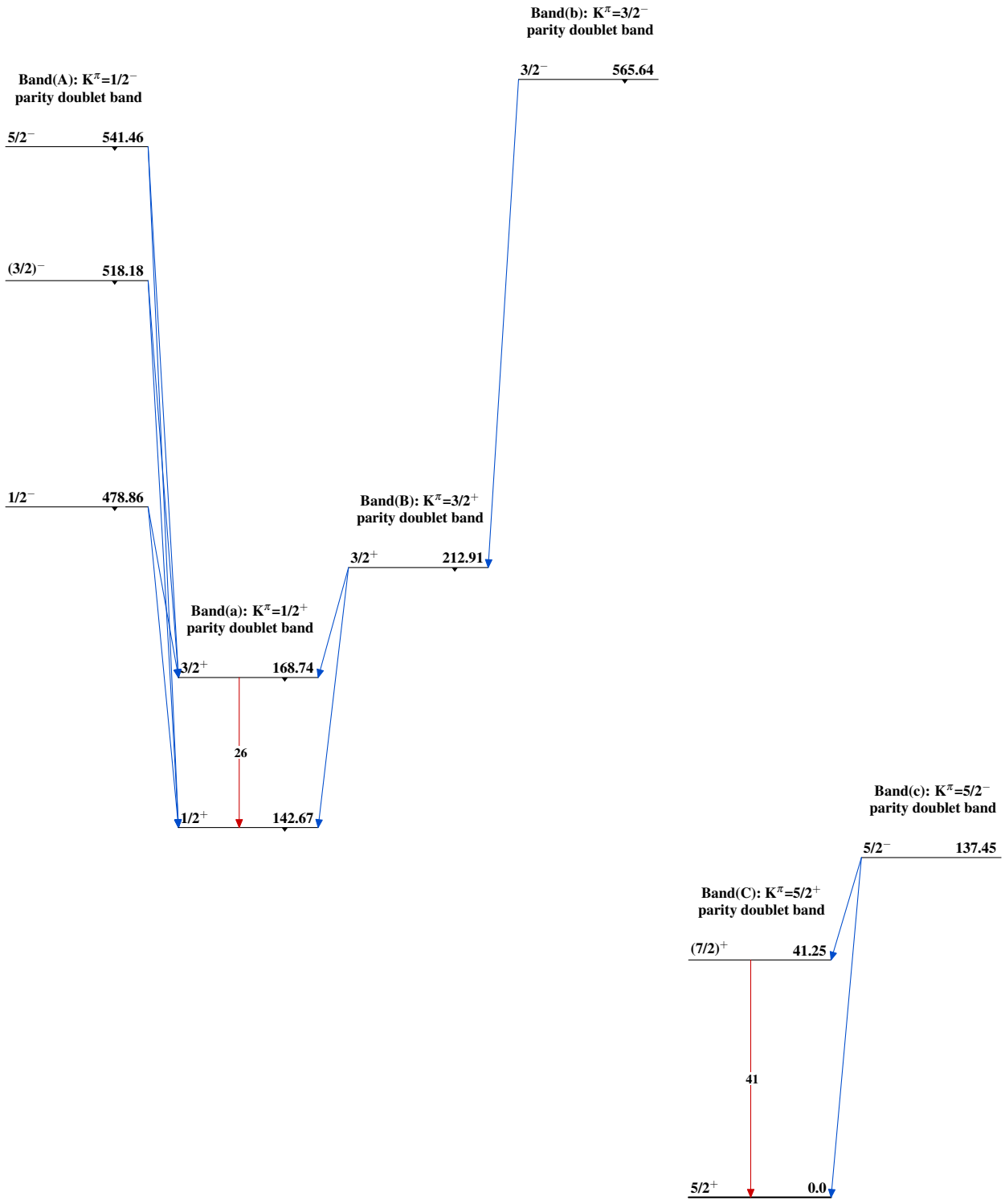
Level Scheme (continued)

Intensities: Type not specified



$^{229}_{88}Ra_{141}$

Adopted Levels, Gammas 1999Fr33,1992Bo05



$^{229}_{88}Ra_{141}$