^{224}Ac α decay (2.78 h) 1992Li31,1968Le17

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. Chen, M. S. Basunia P. Dimitriou, et al. ,	NDS 212,18 (2026)	31-Mar-2026

Parent: ^{224}Ac: E=0.0; J$^\pi$=0$^-$; T$_{1/2}$=2.78 h *20*; Q(α)=6326.9 *7*; %α decay=9.5 *17*

^{224}Ac-J$^\pi$: From ^{224}Ac Adopted Levels (ENSDF May 2022).

^{224}Ac-T$_{1/2}$: weighted average of 2.55 h *28* (1987Mi10) and 2.9 h *2* (1951Me10). Recommended uncertainty should generally be no smaller than the smallest measured uncertainty among the experimental half-lives.

^{224}Ac-Q(α): From 2021Wa16.

^{224}Ac-%α decay: 9.1% *+20−14* from Adopted Levels (ENSDF May 2022) was symmetrized to 9.5% *17* using NUBASE2020 method.

The previous ENSDF evaluation (2011Br05) served as a basis for this update.

1992Li31, 1968Le17, 1969Le07: Ac and other actinides Th, Pa, Ra, and Fr, were produced by bombarding 10 grams of Thorium-Cerium alloy with 1 μA of 200 MeV protons produced at the Orsay Synchrocyclotron with bombarding times from 30 to 48 hr. ^{224}AcF^{+-2} ions were separated using selective fluorination at the mass separator ISOCELER at Orsay. Measured γ, ce, α, $\alpha\gamma$, α(ce), $\gamma\gamma$, γ(ce) with alpha detector (energy resolution 17 keV FWHM), gamma detector (resolution of 600 eV at 100 keV) and a cooled 6 mm thick Si(Li) detector for the electrons.

1973ChZH: Irradiated natural Thorium targets 2 mm thick with 52 MeV protons produced at the Orsay Synchrocyclotron followed by chemical separation. Measured γ, $\alpha\gamma$, α(ce) with GeLi detectors (resolution 900 eV at 100 keV photons) combined with Si surface barrier detectors.

Others: 1970Br31, 1969Le07, 1967Br15.

The decay scheme is that of 1992Li31, based on γ and ce measurements, and on $\alpha\gamma$, α(ce) coincidence results of 1992Li31,and on α-particle measurements of 1968Le17.

^{220}Fr Levels

E(level)[†‡]	J$^\pi$[#]	Comments
0.0[@]	1$^+$	
6.92[a] *5*	(3)$^+$	
12.37[a] *5*	2$^+$	
19.89[a] *10*	(4)$^+$	
48.38[@] *4*	2$^+$	
55.83[a] *13*	(5$^+$)	
72.99[@] *5*	(3)$^+$	
127.31[@] *10*	(4$^+$)	
140.72[&] *5*	1$^-$	
156.82[&] *4*	2$^-$	
177.18[&] *8*	(3)$^-$	
200.21[@] *14*	(5$^+$)	
214.43[&] *8*	(4)$^-$	
246.8 *10*		E(level): 1968Le17, 1992Li31 give E(level)=237; this is a misprint, it should read 247 (priv. comm. from first author).
257.0 *15*		
273.64 *11*	1$^+$	
276.03[b] *19*		
290.81[&] *26*	(5$^-$)	
299.91 *15*	(1)$^+$	
306.9 *15*		
314.8[b] *4*		
340.25[c] *11*	(0)$^-$	
347.89 *32*		
355.14 *19*	(0$^-$,2$^-$)	

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^{224}Ac α decay (2.78 h) 1992Li31,1968Le17 (continued)

^{220}Fr Levels (continued)

E(level)[†‡]	J$^\pi$[#]	Comments
361.04 *32*		
364.15 *23*	3$^+$,4$^-$	
376.49[c] *19*	(2$^-$)	
380.1 *10*		
414.6 *20*		
442.2 *15*		
452.5[c] *4*		J$^\pi$: alternate assignment J^π=(5$^+$) (1992Li31).
479.6 *20*		
501.13 *31*		
511.1 *5*		
579.9 *20*		

† Additional information 1.
‡ From a least squares fit to Eγ data. Band assignments are from 1992Li31. They suggest that the bands with K^π=1± and K^π=2± form two sets of parity doublets.
# From Adopted Levels.
@ Band(A): K^π=1$^+$ g.s. rotational band.
& Band(B): K^π=1$^-$ band.
a Band(C): Possible K^π=2$^+$ band.
b Band(D): Possible K^π=2$^-$ band.
c Band(E): Possible K^π=0$^-$ band.

α radiations

Eα[#]	E(level)	Iα[#@]	HF[†‡]	Comments
5644.3 *25*	579.9	0.06	105	
5712.8 *20*	511.1	0.12	117	Iα: other: 0.4 *2*, from γ-ray transition-intensity balance.
5721.8 *20*	501.13	0.12	131	Iα: other: 0.12 *4*, from γ-ray transition-intensity balance.
5742.8 *25*	479.6	≈0.05	≈400	
5771.8 *20*	452.5	0.24	114	
5779.8 *20*	442.2	0.06	514	
5806.7 *25*	414.6	≈0.02	≈2100	
5840.6 *15*	380.1	0.26	238	
5844.5 *7*	376.49	0.55	117	Iα: other: 0.32 *7*, from γ-ray transition-intensity balance.
5854.6 *25*	364.15	≈0.07	≈1060	Iα: other: 0.15 *4*, from γ-ray transition-intensity balance.
5857.7 *20*	361.04	0.25	306	Iα: other: 0.13 *5*, γ-ray transition-intensity balance.
5864.0 *14*	355.14	0.75	109	Iα: other: 1.4 *8*, from γ-ray transition-intensity balance.
5871.0 *10*	347.89	0.1	884	Iα: other: 0.05 *5*, from γ-ray transition-intensity balance.
5880.3 *14*	340.25	1.7	57	Iα: other: 1.9 *3*, from γ-ray transition-intensity balance.
5905.4 *14*	314.8	0.15	848	Iα: other: 0.07 *3*, from γ-ray transition-intensity balance.
5912.5 *20*	306.9	0.15	925	
5919.6 *14*	299.91	0.94	159	Iα: other: 0.7 *2*, from γ-ray transition-intensity balance.
5945.6 *14*	273.64	4.4	45	Iα: other: 3.4 *4*, from γ-ray transition-intensity balance.
5961.5 *20*	257.0	≈0.04	≈5960	
5971.5 *14*	246.8	0.2	1330	
6003.6 *14*	214.43	6.7	56	Iα: other: 5.0 *6*, from γ-ray transition-intensity balance.
6017.6 *14*	200.21	1.4	313	Iα: other: 1.1 *3*, from γ-ray transition-intensity balance.
6059.8 *7*	156.82	21.9	32	Iα: other: 22 *1*, from γ-ray transition-intensity balance.
6141.7 *7*	72.99	25.6	65	Iα: other: 26 *2*, from γ-ray transition-intensity balance.
6158.9 *7*	55.83	1.03	1915	Iα: other: 0.9 *6*, from γ-ray transition-intensity balance.
6166[&]	48.38	<0.1	>1.7×10^4	Iα: Not seen. Upper limit given by 1969LeZW.
6202[&]	12.37	<0.4	>6205	Iα: Not seen. Upper limit given by 1969LeZW.

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^{224}Ac α decay (2.78 h) 1992Li31,1968Le17 (continued)

α radiations (continued)

Eα[#]	E(level)	Iα[#@]	HF[†‡]	Comments
6207.0 *7*	6.92	11.9	273	
6213.8 *7*	0.0	20.4	171	Iα: other: 25 *4* from 100−ΣIα(decay to excited levels) based on γ+ce intensity balance.

† Additional information 2.

‡ The nuclear radius parameter $r_0(^{220}Fr)$=1.5418 *13* is deduced from interpolation of radius parameters of the adjacent even-even nuclides in 2020Si16.

\# From 1968Le17, deduced based on measured α intensities. Iα values are for 100 α decays. These data are also given in 1969LeZW. Authors′ Eα values have been increased by 3.8 keV (see 1991Ry01) to adjust for newer energy calibration values. Where possible, alpha branches derived by evaluators from γ+ce intensity balances are given in comments.

@ For absolute intensity per 100 decays, multiply by 0.095 *17*.

& Existence of this branch is questionable.

γ(^{220}Fr)

E_γ[‡]	I_γ[#h]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[@]	α[†]	$I_{(\gamma+ce)}$[h]	Comments
(6.9)		6.92	(3)$^+$	0.0	1$^+$			212 *30*	$I_{(\gamma+ce)}$: from γ+ce intensity balance and Iα=11.9 *28* per 100 α decays from 1968Le17.
(12.4)		12.37	2$^+$	0.0	1$^+$			162[g] *13*	
(13.0)		19.89	(4)$^+$	6.92	(3)$^+$			33[g] *7*	
(16[&])	0.31 *12*	156.82	2$^-$	140.72	1$^-$	[M1][&]	159	50 *6*	α(M)=119 %Iγ=0.0030 *13* $I_{(\gamma+ce)}$: Deduced from transition-intensity balance at the 140.7-keV level; Iγ from I(γ+ce)=59 *5* and α[M1]=159 *59*.
(20.4[&])		177.18	(3)$^-$	156.82	2$^-$	[M1][&]	299 *4*		α(L)=226.0 *32*; α(M)=54.7 *8* α(N)=14.34 *20*; α(O)=3.21 *4*; α(P)=0.514 *7*; α(Q)=0.0288 *4*
24.6	1.0 *1*	72.99	(3)$^+$	48.38	2$^+$	[M1]	172.6 *24*	181 *11*	ce(L)/(γ+ce)=0.754 *7*; ce(M)/(γ+ce)=0.1807 *32* ce(N)/(γ+ce)=0.0474 *9*; ce(O)/(γ+ce)=0.01059 *21*; ce(P)/(γ+ce)=0.001699 *34*; ce(Q)/(γ+ce)=9.52$\times10^{-5}$ *19* α(L)=130.8 *18*; α(M)=31.4 *4* α(N)=8.23 *12*; α(O)=1.839 *26*; α(P)=0.295 *4*; α(Q)=0.01652 *23* %Iγ=0.0095 *20* ce(M) and ce(N) lines seen in ce spectrum. γ ray marked M1 in level scheme (1992Li31). $I_{(\gamma+ce)}$: from γ-ray transition-intensity balance at the 73.0 level. I_γ: from I(γ+ce)=181 *11* and α[M1]=172.6.
35.9[ja] *1*	0.3[j] *2*	48.38	2$^+$	12.37	2$^+$	[M1]	56.5 *9*		α(L)=42.9 *7*; α(M)=10.24 *17* α(N)=2.69 *4*; α(O)=0.601 *10*; α(P)=0.0963 *16*; α(Q)=0.00540 *9* %Iγ=0.0029 *20*
35.9[ja] *1*	0.2[j] *1*	55.83	(5$^+$)	19.89	(4)$^+$	[M1]	56.5 *9*		α(L)=42.9 *7*; α(M)=10.24 *17* α(N)=2.69 *4*; α(O)=0.601 *10*; α(P)=0.0963 *16*; α(Q)=0.00540 *9* %Iγ=0.0019 *10*
37.3 *1*	0.6 *1*	214.43	(4)$^-$	177.18	(3)$^-$	[M1]	50.5 *8*		α(L)=38.3 *6*; α(M)=9.15 *15* α(N)=2.40 *4*; α(O)=0.536 *9*; α(P)=0.0860 *14*; α(Q)=0.00482 *8* %Iγ=0.0057 *14* Mult.: E2 ruled out by intensity balance in the level scheme.
40.4 *3*	0.5[b] *2*	340.25	(0)$^-$	299.91	(1)$^+$	(E1)[e]	1.206 *30*		α(L)=0.912 *22*; α(M)=0.224 *6* α(N)=0.0571 *14*; α(O)=0.01167 *28*; α(P)=0.001487 *34*; α(Q)=3.99$\times10^{-5}$ *8* %Iγ=0.0048 *21*
41.5 *1*	0.4 *1*	48.38	2$^+$	6.92	(3)$^+$	[M1]	36.9 *6*		α(L)=28.0 *4*; α(M)=6.68 *10* α(N)=1.751 *28*; α(O)=0.392 *6*; α(P)=0.0628 *10*; α(Q)=0.00352 *6* %Iγ=0.0038 *12* γ ray unplaced in 1992Li31; placement suggested by evaluators based on γ-ray energy and intensity balance.
^{x}44.5 *2*	0.3 *1*								%Iγ=0.0029 *11*

γ(^{220}Fr) (continued)

E$_\gamma$[‡]	I$_\gamma$[#h]	E$_i$(level)	J$^\pi_i$	E$_f$	J$^\pi_f$	Mult.[@]	α[†]	Comments
[x]46.0 2	0.3 1							%Iγ=0.0029 11
48.40 5	6.5 5	48.38	2$^+$	0.0	1$^+$	M1[d]	23.45 34	α(L)=17.80 25; α(M)=4.24 6 α(N)=1.113 16; α(O)=0.249 4; α(P)=0.0399 6; α(Q)=0.002235 32 %Iγ=0.062 12
48.6[k]		501.13		452.5				γ shown only in level scheme of 1992Li31.
49.8 2	0.4 1	177.18	(3)$^-$	127.31	(4$^+$)	[E1]	0.689 12	α(L)=0.522 9; α(M)=0.1272 23 α(N)=0.0326 6; α(O)=0.00674 12; α(P)=0.000887 15; α(Q)=2.57×10^{-5} 4 %Iγ=0.0038 12
53.1 1	1.0 2	72.99	(3)$^+$	19.89	(4)$^+$	[M1]	17.86 27	α(L)=13.56 20; α(M)=3.23 5 α(N)=0.848 13; α(O)=0.1895 29; α(P)=0.0304 5; α(Q)=0.001702 26 %Iγ=0.0095 26
54.3 1	0.7 1	127.31	(4$^+$)	72.99	(3)$^+$	[M1]	16.72 25	α(L)=12.70 19; α(M)=3.03 5 α(N)=0.794 12; α(O)=0.1775 27; α(P)=0.0285 4; α(Q)=0.001594 24 %Iγ=0.0067 15
55.3 2	0.4 1	355.14	(0$^-$,2$^-$)	299.91	(1)$^+$	(E1)[e]	0.521 9	α(L)=0.394 7; α(M)=0.0959 16 α(N)=0.0246 4; α(O)=0.00511 9; α(P)=0.000683 11; α(Q)=2.053×10^{-5} 33 %Iγ=0.0038 12
60.67 5	4.6 2	72.99	(3)$^+$	12.37	2$^+$	M1[d]	12.08 17	α(L)=9.17 13; α(M)=2.187 31 α(N)=0.574 8; α(O)=0.1282 18; α(P)=0.02057 29; α(Q)=0.001151 16 %Iγ=0.044 8
66.0 1	2.3 4	72.99	(3)$^+$	6.92	(3)$^+$	[M1]	9.44 14	α(L)=7.17 11; α(M)=1.709 25 α(N)=0.448 7; α(O)=0.1002 15; α(P)=0.01608 24; α(Q)=0.000899 13 %Iγ=0.022 6
66.6 1	6.0 5	340.25	(0)$^-$	273.64	1$^+$	E1[c]	0.316 5	α(L)=0.2399 35; α(M)=0.0581 8 α(N)=0.01492 22; α(O)=0.00313 5; α(P)=0.000428 6; α(Q)=1.371×10^{-5} 20 %Iγ=0.057 11
[x]70.9 2	0.8 2							%Iγ=0.0076 24
72.9[j] 1	0.5[j] 2	72.99	(3)$^+$	0.0	1$^+$	(E2)	39.1 6	α(L)=28.8 4; α(M)=7.79 12 α(N)=2.041 32; α(O)=0.422 7; α(P)=0.0541 8; α(Q)=9.97×10^{-5} 15 %Iγ=0.0048 21 Mult.: Stated as E2 in 1973ChZH, based on αγ results, but no further details are given (1966BrZX).
72.9[j] 1	1.4[j] 3	200.21	(5$^+$)	127.31	(4$^+$)	[M1]	7.06 10	α(L)=5.36 8; α(M)=1.278 19 α(N)=0.335 5; α(O)=0.0749 11; α(P)=0.01202 18; α(Q)=0.000673 10 %Iγ=0.013 4
73.6 3	0.6 3	364.15	3$^+$,4$^-$	290.81	(5$^-$)			%Iγ=0.0057 30
79.10 5	2.8[b] 3	355.14	(0$^-$,2$^-$)	276.03		[M1,E1]	2.9 27	α(L)=2.2 20; α(M)=0.5 5 α(N)=0.14 13; α(O)=0.031 29; α(P)=0.005 5; α(Q)=2.7×10^{-4} 26 %Iγ=0.027 6
81.5 3	2.1[b] 2	355.14	(0$^-$,2$^-$)	273.64	1$^+$	(E1)[e]	0.1845 32	α(L)=0.1399 24; α(M)=0.0337 6

γ(^{220}Fr) (continued)

E_γ[‡]	I_γ[#h]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[@]	α[†]	Comments
								α(N)=0.00869 *15*; α(O)=0.001839 *31*; α(P)=0.000257 *4*; α(Q)=8.78×10^{-6} *14* %Iγ=0.020 *4*
83.9 *2*	18.0[b] *10*	156.82	2$^-$	72.99	(3)$^+$	E1[d]	0.1707 *26*	α(L)=0.1295 *20*; α(M)=0.0312 *5* α(N)=0.00804 *12*; α(O)=0.001703 *26*; α(P)=0.000239 *4*; α(Q)=8.23×10^{-6} *12* %Iγ=0.171 *32*
87.4 *3*	1.3 *5*	361.04		273.64	1$^+$			%Iγ=0.012 *5*
92.34 *5*	5.2 *5*	140.72	1$^-$	48.38	2$^+$	[E1]	0.1323 *19*	α(L)=0.1004 *14*; α(M)=0.02415 *34* α(N)=0.00623 *9*; α(O)=0.001324 *19*; α(P)=0.0001873 *26*; α(Q)=6.65×10^{-6} *9* %Iγ=0.049 *10*
97.3[k]		452.5		355.14	(0$^-$,2$^-$)			γ shown only in level scheme of 1992Li31.
103.1 *4*	≈0.4[b]	376.49	(2$^-$)	273.64	1$^+$	[E1]	0.433 *7*	α(K)=0.335 *5*; α(L)=0.0749 *13*; α(M)=0.01800 *31* α(N)=0.00465 *8*; α(O)=0.000991 *17*; α(P)=0.0001416 *24*; α(Q)=5.19×10^{-6} *9* %Iγ≈0.0038
104.4 *2*	1.3 *3*	177.18	(3)$^-$	72.99	(3)$^+$	[E1]	0.422 *6*	α(K)=0.327 *5*; α(L)=0.0725 *11*; α(M)=0.01741 *26* α(N)=0.00450 *7*; α(O)=0.000959 *14*; α(P)=0.0001372 *20*; α(Q)=5.04×10^{-6} *7* %Iγ=0.012 *4*
108.43 *5*	10.5 *10*	156.82	2$^-$	48.38	2$^+$	E1	0.387 *5*	α(K)=0.301 *4*; α(L)=0.0656 *9*; α(M)=0.01574 *22* α(N)=0.00407 *6*; α(O)=0.000869 *12*; α(P)=0.0001247 *18*; α(Q)=4.63×10^{-6} *7* %Iγ=0.100 *20* Mult.: α(L)exp<0.65 (1973ChZH); theory: α(L)(E1)=0.0663, α(L)(E2)=4.49, α(L)(M1)=1.78.
114.7 *5*	0.3 *2*	314.8		200.21	(5$^+$)	[E1]	0.339 *6*	α(K)=0.265 *5*; α(L)=0.0565 *10*; α(M)=0.01356 *25* α(N)=0.00350 *6*; α(O)=0.000750 *14*; α(P)=0.0001081 *19*; α(Q)=4.08×10^{-6} *7* %Iγ=0.0029 *20* Mult.: assumed by the evaluators for calculating intensity balance.
^{x}116.5 *5*	0.3 *2*							%Iγ=0.0029 *20*
^{x}122.3 *5*	0.4 *2*							%Iγ=0.0038 *20*
^{x}123.3 *5*	0.4 *2*							%Iγ=0.0038 *20*
^{x}126.7 *4*	0.5 *2*							%Iγ=0.0048 *21*
128.4 *3*	8.1 *20*	140.72	1$^-$	12.37	2$^+$	E1	0.258 *4*	α(K)=0.2027 *31*; α(L)=0.0420 *6*; α(M)=0.01007 *15* α(N)=0.00260 *4*; α(O)=0.000559 *9*; α(P)=8.13×10^{-5} *12*; α(Q)=3.16×10^{-6} *5* %Iγ=0.077 *24* Mult.: α(L)exp<0.14 (1973ChZH); theory: α(L)(E1)=0.0425, α(L)(E2)=2.06, α(L)(M1)=1.10.
128.9 *3*	3.6 *10*	177.18	(3)$^-$	48.38	2$^+$	[E1]	0.256 *4*	α(K)=0.2009 *30*; α(L)=0.0416 *6*; α(M)=0.00996 *15* α(N)=0.00258 *4*; α(O)=0.000554 *8*; α(P)=8.05×10^{-5} *12*; α(Q)=3.13×10^{-6} *5* %Iγ=0.034 *11*
140.7 *1*	35.6 *30*	140.72	1$^-$	0.0	1$^+$	E1[d]	0.2065 *29*	α(K)=0.1630 *23*; α(L)=0.0331 *5*; α(M)=0.00792 *11* α(N)=0.002050 *29*; α(O)=0.000441 *6*; α(P)=6.46×10^{-5} *9*; α(Q)=2.57×10^{-6} *4* %Iγ=0.34 *7*

γ(^{220}Fr) (continued)

E_γ[‡]	I_γ[#h]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[@]	α[†]	Comments
								Mult.: α(L)exp<0.15 (1973ChZH); theory: α(L)(E1)=0.0334, α(L)(E2)=1.36, α(L)(M1)=0.844.
141.4 *1*	10.6 *20*	214.43	(4)$^-$	72.99	(3)$^+$	[E1]	0.2041 *29*	α(K)=0.1611 *23*; α(L)=0.0327 *5*; α(M)=0.00782 *11* α(N)=0.002024 *29*; α(O)=0.000436 *6*; α(P)=6.38×10^{-5} *9*; α(Q)=2.54×10^{-6} *4* %Iγ=0.101 *26*
144.44 *5*	22.5 *20*	156.82	2$^-$	12.37	2$^+$	E1[d]	0.1938 *27*	α(K)=0.1531 *21*; α(L)=0.0309 *4*; α(M)=0.00739 *10* α(N)=0.001915 *27*; α(O)=0.000413 *6*; α(P)=6.05×10^{-5} *8*; α(Q)=2.422×10^{-6} *34* %Iγ=0.21 *4* Mult.: α(L)exp<0.42 (1973ChZH); theory: α(L)(E1)=0.0312, α(L)(E2)=1.21, α(L)(M1)=0.783.
149.90 *5*	12.5 *20*	156.82	2$^-$	6.92	(3)$^+$	E1	0.1770 *25*	α(K)=0.1401 *20*; α(L)=0.0281 *4*; α(M)=0.00671 *9* α(N)=0.001739 *24*; α(O)=0.000375 *5*; α(P)=5.51×10^{-5} *8*; α(Q)=2.228×10^{-6} *31* %Iγ=0.119 *29* Mult.: α(L)exp<0.061 (1973ChZH); theory: α(L)(E1)=0.0284, α(L)(E2)=1.03, α(L)(M1)=0.704.
156.82 *5*	81 *5*	156.82	2$^-$	0.0	1$^+$	E1[d]	0.1586 *22*	α(K)=0.1257 *18*; α(L)=0.02497 *35*; α(M)=0.00597 *8* α(N)=0.001547 *22*; α(O)=0.000334 *5*; α(P)=4.93×10^{-5} *7*; α(Q)=2.012×10^{-6} *28* %Iγ=0.77 *15* I_γ: other: Iγ/10×10^3 α's=53 (1969Le07). Mult.: α(L)exp<0.057 (1973ChZH); theory: α(L)(E1)=0.0252, α(L)(E2)=0.841, α(L)(M1)=0.619.
158.5 *2*	1.6 *4*	214.43	(4)$^-$	55.83	(5$^+$)	[E1]	0.1546 *22*	α(K)=0.1226 *18*; α(L)=0.02429 *35*; α(M)=0.00581 *8* α(N)=0.001505 *22*; α(O)=0.000325 *5*; α(P)=4.80×10^{-5} *7*; α(Q)=1.964×10^{-6} *28* %Iγ=0.015 *5*
163.3 *5*	≈0.5	290.81	(5$^-$)	127.31	(4$^+$)	[E1]	0.1438 *23*	α(K)=0.1141 *18*; α(L)=0.0225 *4*; α(M)=0.00538 *9* α(N)=0.001394 *22*; α(O)=0.000301 *5*; α(P)=4.45×10^{-5} *7*; α(Q)=1.836×10^{-6} *29* %Iγ≈0.0048
164.8 *1*	5.0 *10*	177.18	(3)$^-$	12.37	2$^+$	E1	0.1406 *20*	α(K)=0.1117 *16*; α(L)=0.02197 *31*; α(M)=0.00525 *7* α(N)=0.001361 *19*; α(O)=0.000294 *4*; α(P)=4.35×10^{-5} *6*; α(Q)=1.799×10^{-6} *25* %Iγ=0.048 *13* Mult.: α(L)exp<0.42 (1973ChZH); theory: α(L)(E1)=0.0222, α(L)(E2)=0.675, α(L)(M1)=0.538.
^{x}170.2 *5*	≈0.4							%Iγ≈0.0038
186.8 *3*	0.6 *2*	364.15	3$^+$,4$^-$	177.18	(3)$^-$			%Iγ=0.0057 *22*
194.5 *3*	0.7 *2*	214.43	(4)$^-$	19.89	(4)$^+$	E1	0.0942 *14*	α(K)=0.0753 *11*; α(L)=0.01441 *21*; α(M)=0.00344 *5* α(N)=0.000892 *13*; α(O)=0.0001936 *28*; α(P)=2.89×10^{-5} *4*; α(Q)=1.240×10^{-6} *18* %Iγ=0.0067 *23* Mult.: α(K)exp<2.9, α(L)exp<0.15 (1973ChZH); theory: E1: α(K)=0.0759, α(L)=0.0145; E2: α(K)=0.175, α(L)=0.329; M1: α(K)=1.84, α(L)=0.336.
199.5 *2*	3.0 *10*	340.25	(0)$^-$	140.72	1$^-$	M1[d]	2.021 *29*	α(K)=1.629 *23*; α(L)=0.297 *4*; α(M)=0.0708 *10*

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

E_γ[‡]	I_γ[#h]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[@]	α[†]	Comments
								α(N)=0.01857 *27*; α(O)=0.00415 *6*; α(P)=0.000666 *10*; α(Q)=3.72×10^{-5} *5* %Iγ=0.029 *11* Mult.: α(K)exp=2, α(L)exp<0.4 (1973ChZH); theory: E2: α(K)=0.167, α(L)=0.295; M1: α(K)=1.72, α(L)=0.313.
201.1 *4*	0.6 *3*	501.13		299.91	(1)$^+$			%Iγ=0.0057 *30*
207.6 *2*	3.6 *10*	214.43	(4)$^-$	6.92	(3)$^+$	E1	0.0806 *11*	α(K)=0.0645 *9*; α(L)=0.01223 *17*; α(M)=0.00291 *4* α(N)=0.000757 *11*; α(O)=0.0001645 *23*; α(P)=2.466×10^{-5} *35*; α(Q)=1.072×10^{-6} *15* %Iγ=0.034 *11* Mult.: α(K)exp<0.62, α(L)exp<0.03 (1973ChZH); theory: E1: α(K)=0.0650, α(L)=0.0123; E2: α(K)=0.154, α(L)=0.249; M1: α(K)=1.54, α(L)=0.280.
[x]210.0 *5*	≈0.2							%Iγ≈0.0019
[x]211.5 *5*	≈0.2							%Iγ≈0.0019
225.3 *2*	3.2 *10*	273.64	1$^+$	48.38	2$^+$	M1[d]	1.438 *20*	α(K)=1.160 *16*; α(L)=0.2113 *30*; α(M)=0.0503 *7* α(N)=0.01319 *19*; α(O)=0.00295 *4*; α(P)=0.000473 *7*; α(Q)=2.64×10^{-5} *4* %Iγ=0.030 *11* Mult.: α(K)exp=1.4, K/L=10 (1973ChZH); theory: E1: α(K)=0.0537, K/L=5.34; E2: α(K)=0.129, K/L=0.73; M1: α(K)=1.22, K/L=5.48.
227.7 *5*	0.6 *2*	501.13		273.64	1$^+$			%Iγ=0.0057 *22*
228[k]		355.14	(0$^-$,2$^-$)	127.31	(4$^+$)			γ ray shown only in level scheme of 1992Li31.
251.6 *3*	2.6 *7*	299.91	(1)$^+$	48.38	2$^+$	M1[d]	1.058 *15*	α(K)=0.853 *12*; α(L)=0.1552 *22*; α(M)=0.0369 *5* α(N)=0.00969 *14*; α(O)=0.002165 *31*; α(P)=0.000347 *5*; α(Q)=1.938×10^{-5} *28* %Iγ=0.025 *8* Mult.: α(K)exp=0.85, α(L)exp<0.24 (1973ChZH): theory: E2: α(K)=0.103, α(L)=0.113; M1: α(K)=0.90, α(L)=0.164.
258.8 *5*	≈0.3	314.8		55.83	(5$^+$)	[E1]	0.0480 *7*	α(K)=0.0386 *6*; α(L)=0.00710 *10*; α(M)=0.001688 *25* α(N)=0.000439 *6*; α(O)=9.58×10^{-5} *14*; α(P)=1.453×10^{-5} *21*; α(Q)=6.60×10^{-7} *10* %Iγ≈0.0029 Mult.: assumed by the evaluators for calculating intensity balance. γ seen only in $\alpha\gamma$ coin.
261.3 *2*	19.0 *15*	273.64	1$^+$	12.37	2$^+$	M1[d]	0.953 *13*	α(K)=0.769 *11*; α(L)=0.1397 *20*; α(M)=0.0332 *5* α(N)=0.00872 *12*; α(O)=0.001948 *28*; α(P)=0.000313 *4*; α(Q)=1.744×10^{-5} *25* %Iγ=0.18 *4* Mult.: α(K)exp=1.06 *25* from (K x ray)(α)/$\alpha\gamma$ (1966BrZX), K/L=4.9 (1973ChZH); theory: E1: α(K)=0.0380, K/L=5.45; E2: α(K)=0.095, K/L=0.98; M1: α(K)=0.808, K/L=5.48.
263.1[k] *5*	1.3 *4*	276.03		12.37	2$^+$			%Iγ=0.012 *5*
271.5 *4*	1.0 *3*	290.81	(5$^-$)	19.89	(4)$^+$	[E1][f]	0.0430 *6*	α(K)=0.0346 *5*; α(L)=0.00632 *9*; α(M)=0.001503 *22* α(N)=0.000391 *6*; α(O)=8.54×10^{-5} *12*; α(P)=1.298×10^{-5} *19*; α(Q)=5.95×10^{-7} *9* %Iγ=0.0095 *33*

γ(^{220}Fr) (continued)

E_γ[‡]	I_γ[#h]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[@]	α[†]	Comments
273.7 *4*	1.1 *3*	273.64	1^+	0.0	1^+	M1[df]	0.838 *12*	α(K)=0.676 *10*; α(L)=0.1228 *18*; α(M)=0.0292 *4* α(N)=0.00766 *11*; α(O)=0.001713 *25*; α(P)=0.000275 *4*; α(Q)=1.533×10^{-5} *22* %Iγ=0.0105 *34* Mult.: α(K)exp≤1.13 (1973ChZH); theory: α(K)(E2)=0.0859, α(K)(M1)=0.711.
287.6 *5*	0.7[b] *3*	299.91	$(1)^+$	12.37	2^+	[M1,E2]	0.45 *28*	α(K)=0.33 *26*; α(L)=0.086 *21*; α(M)=0.021 *4* α(N)=0.0056 *11*; α(O)=0.00122 *27*; α(P)=1.8×10^{-4} *5*; α(Q)=8 %Iγ=0.0067 *31*
^{x}291.2 *5*	0.3 *1*							%Iγ=0.0029 *11*
300.0 *3*	1.7 *4*	299.91	$(1)^+$	0.0	1^+	(M1)	0.651 *9*	α(K)=0.525 *7*; α(L)=0.0952 *14*; α(M)=0.02266 *32* α(N)=0.00594 *8*; α(O)=0.001328 *19*; α(P)=0.0002131 *30*; α(Q)=1.189×10^{-5} *17* %Iγ=0.016 *5* Mult.: α(K)exp≤1.65, α(L)exp=0.09 (1973ChZH); theory: E2: α(K)=0.0706, α(L)=0.0565; M1: α(K)=0.553, α(L)=0.100.
328.0[i] *3*	0.7[ib] *3*	347.89		19.89	$(4)^+$			%Iγ=0.0067 *31*
328.0[i] *3*	0.7[ib] *3*	376.49	(2^-)	48.38	2^+	[E1]	0.0280 *4*	α(K)=0.02268 *32*; α(L)=0.00404 *6*; α(M)=0.000959 *14* α(N)=0.0002494 *35*; α(O)=5.47×10^{-5} *8*; α(P)=8.39×10^{-6} *12*; α(Q)=3.98×10^{-7} *6* %Iγ=0.0067 *31*
340.3 *3*	0.5 *2*	340.25	$(0)^-$	0.0	1^+	[E1]	0.0258 *4*	α(K)=0.02092 *30*; α(L)=0.00371 *5*; α(M)=0.000880 *12* α(N)=0.0002289 *32*; α(O)=5.02×10^{-5} *7*; α(P)=7.72×10^{-6} *11*; α(Q)=3.68×10^{-7} *5* %Iγ=0.0048 *21*
357.0 *5*	≈0.3	364.15	$3^+,4^-$	6.92	$(3)^+$			%Iγ≈0.0029
364.1 *3*	2.1 *3*	376.49	(2^-)	12.37	2^+	[E1]	0.02224 *31*	α(K)=0.01806 *25*; α(L)=0.00318 *4*; α(M)=0.000753 *11* α(N)=0.0001960 *28*; α(O)=4.31×10^{-5} *6*; α(P)=6.63×10^{-6} *9*; α(Q)=3.20×10^{-7} *5* %Iγ=0.020 *5* Mult.: α(K)exp≤0.47 (1973ChZH); theory: α(K)(E1)=0.0181, α(K)(E2)=0.0469, α(K)(M1)=0.326.
^{x}376.5	0.3 *1*							%Iγ=0.0029 *11*
^{x}382.3	0.5 *2*							%Iγ=0.0048 *21*
^{x}409.8	≈0.3							%Iγ≈0.0029
^{x}415.8	≈0.3							%Iγ≈0.0029
^{x}424.4	≈0.3							%Iγ≈0.0029
491.2	≈0.4	511.1		19.89	$(4)^+$			%Iγ≈0.0038

† Additional information 3.
‡ From 1992Li31. Others: 1970Br31 (see also 1973ChZH), 1969Le07, 1969LeZW.
# From 1992Li31. Quoted values are for per 1000 α decays and have been converted to values for per 100 α decays by the evaluators. Others: 1973ChZH, 1969Le07, 1969LeZW.
@ From ce data in 1992Li31 and 1973ChZH. α(exp) values are from 1973ChZH. γ and the ce spectra were normalized through the 261γ (M1) with α(K)=0.83 and

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

α(L)=0.15.

[&] From 1992Li31. Not listed in the γ-ray table or shown in the γ-ray or ce spectra; however, γ ray is shown in the level scheme. Eγ and multipolarity probably have been deduced from the level scheme.

[a] γ ray placed from the 55.8-keV level in 1992Li31; however, the transition intensity indicates a slight imbalance at this level. The energy of the γ ray fits also from the 48.4-keV level, and this second placement would improve the intensity balance at both levels.

[b] Iγ deduced from $\alpha\gamma$ coin. In singles spectrum γ ray mixed or masked by K x rays or other γ rays of about the same energy from daughter nuclei.

[c] From transition-intensity balance in level scheme. With any other multipolarity, I(γ+ce) would be larger than total feeding from α decay to levels above this level.

[d] Deduced from internal conversion data (not given) (1992Li31). In some cases additional conversion data from other sources are given.

[e] From transition-intensity balance in level scheme. Based on the criterion that ΣI(γ+ce) de−exciting the level cannot exceed ΣIα populating levels with higher energy. From the level scheme the 55.3γ ray and 81.5γ ray from the 355.2-keV level must have the same mixing ratio $\Delta\pi$, therefore, from transition-intensity balance both must have E1 multipolarity.

[f] The M1(e-) multipolarity given in table 1 in 1992Li31 for the 271.5γ ray is a misprint, the multipolarity belongs to the next γ ray, the 273.7γ ray. (Priv. comm. from first author in 1992Li31).

[g] γ ray not seen; transition intensity estimated from transition-intensity balance, assuming no α-decay feeding to natural-parity levels from 0^- parent.

[h] For absolute intensity per 100 decays, multiply by 0.0095.

[i] Multiply placed with undivided intensity.

[j] Multiply placed with intensity suitably divided.

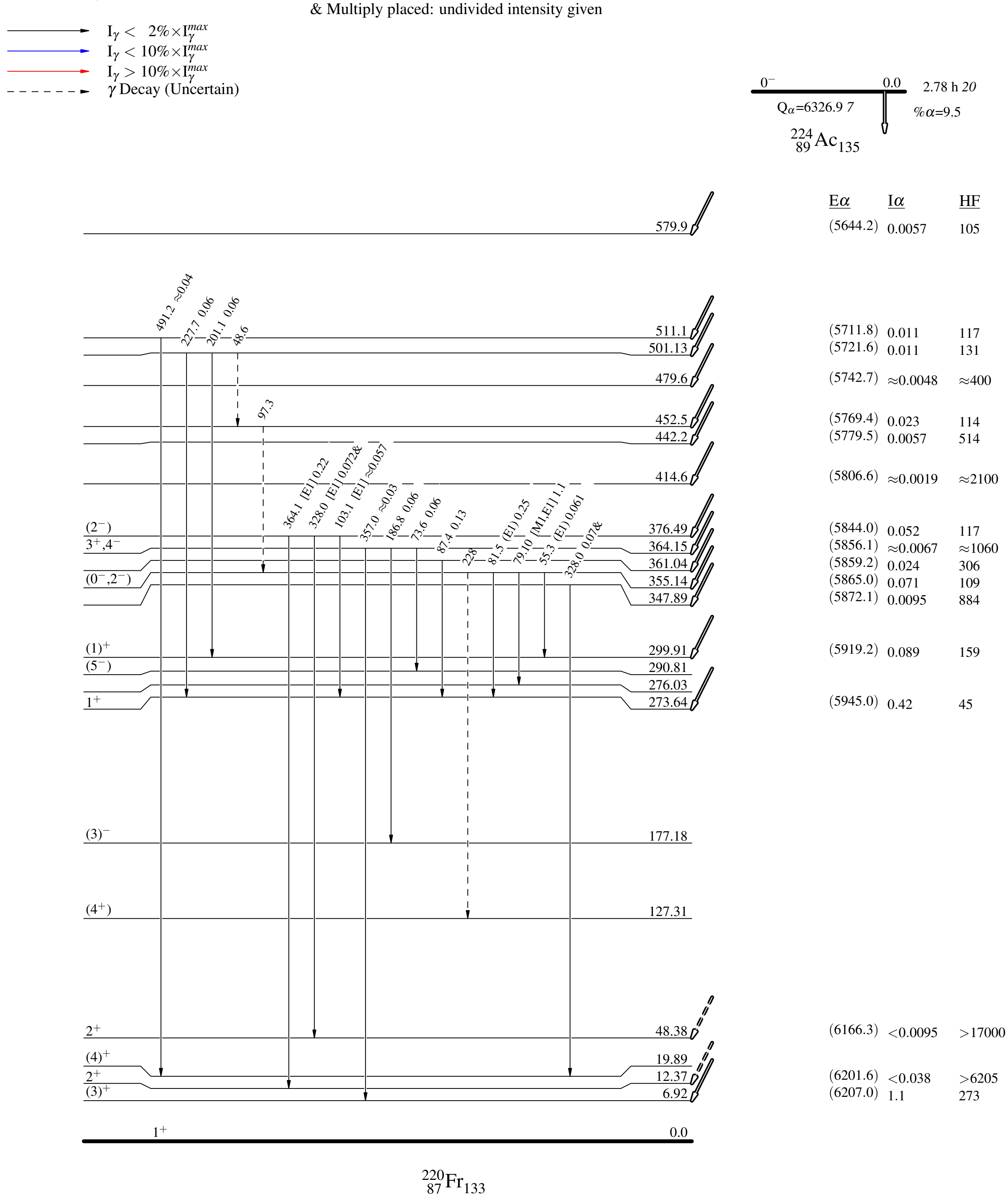
[k] Placement of transition in the level scheme is uncertain.

[x] γ ray not placed in level scheme.

^{224}Ac α decay (2.78 h) 1992Li31,1968Le17

Decay Scheme

Intensities: $I_{(\gamma+ce)}$ per 100 decays through this branch
& Multiply placed: undivided intensity given



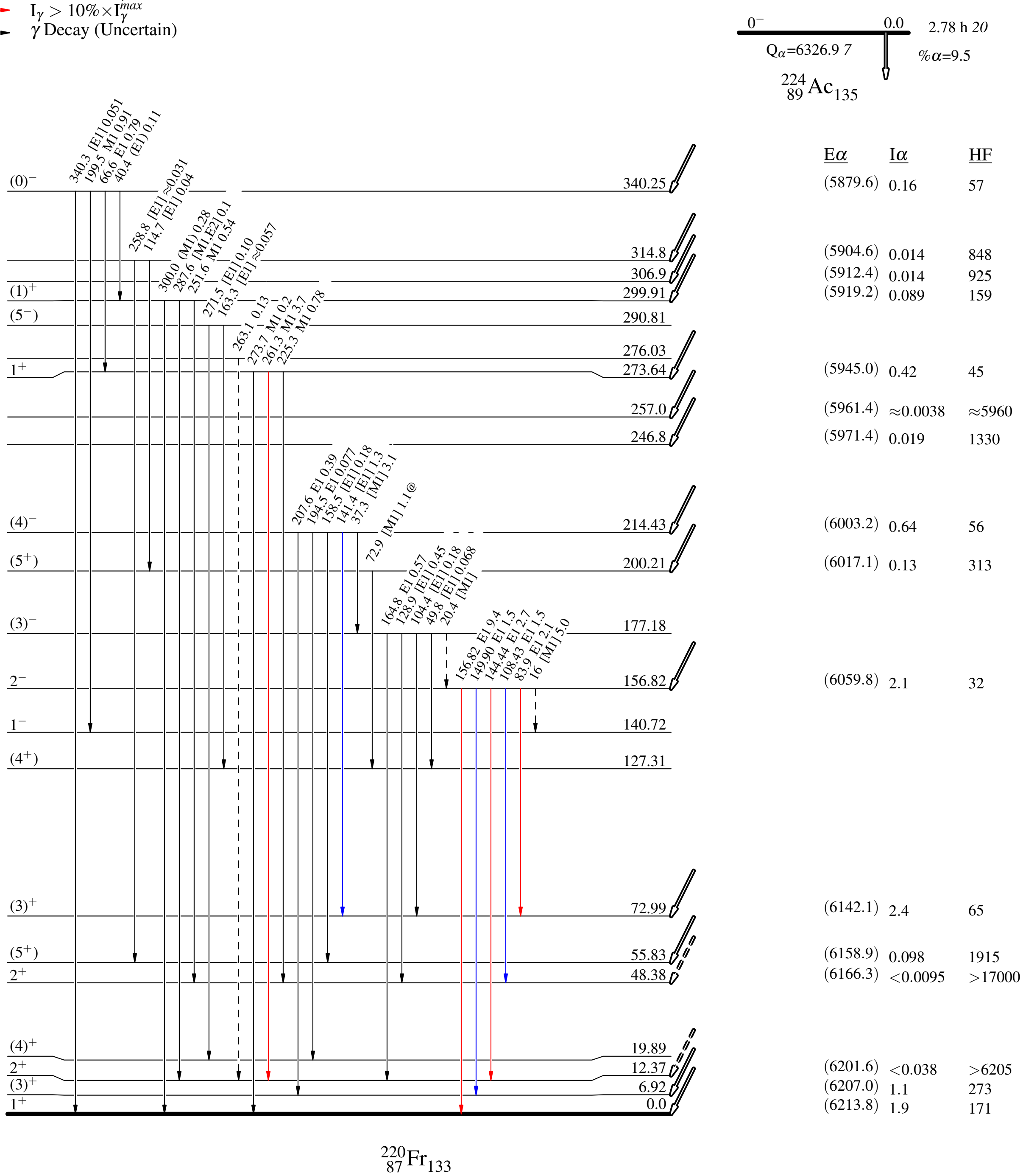
^{224}Ac α decay (2.78 h) 1992Li31,1968Le17

Decay Scheme (continued)

Intensities: $I_{(\gamma+ce)}$ per 100 decays through this branch
& Multiply placed: undivided intensity given
@ Multiply placed: intensity suitably divided

Legend

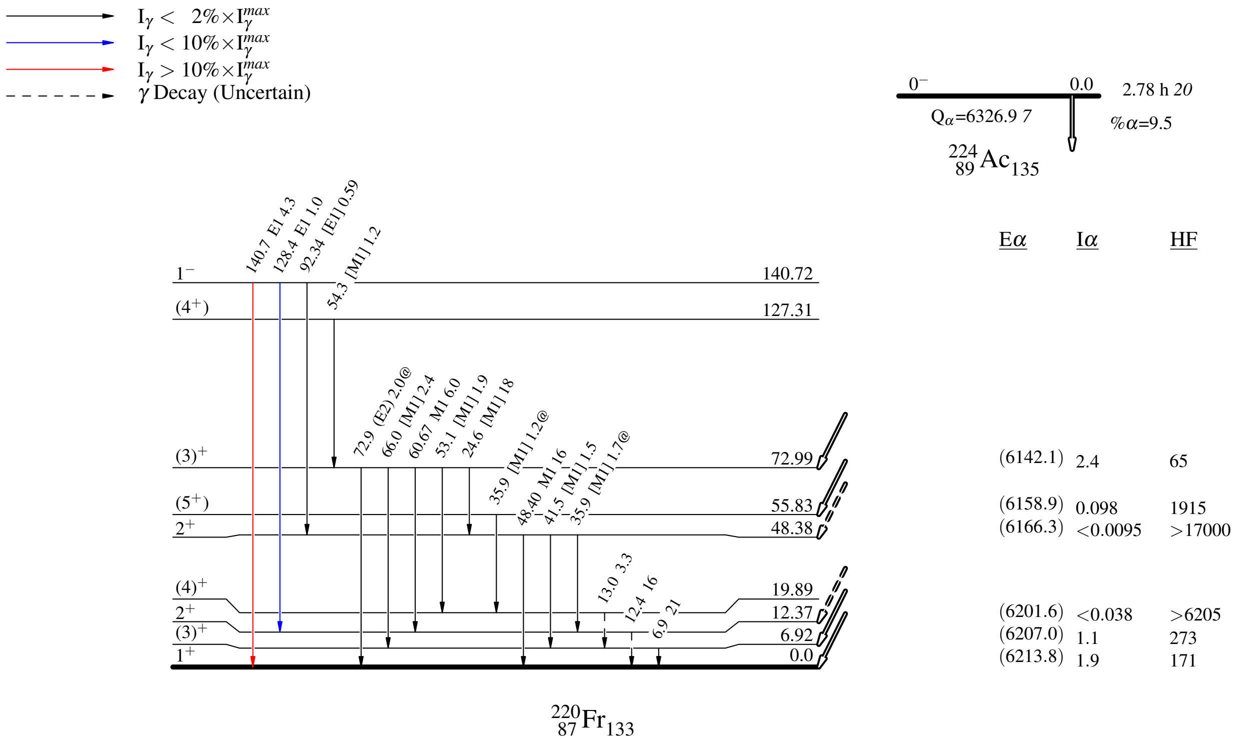
- $I_\gamma < 2\% \times I_\gamma^{max}$
- $I_\gamma < 10\% \times I_\gamma^{max}$
- $I_\gamma > 10\% \times I_\gamma^{max}$
- γ Decay (Uncertain)



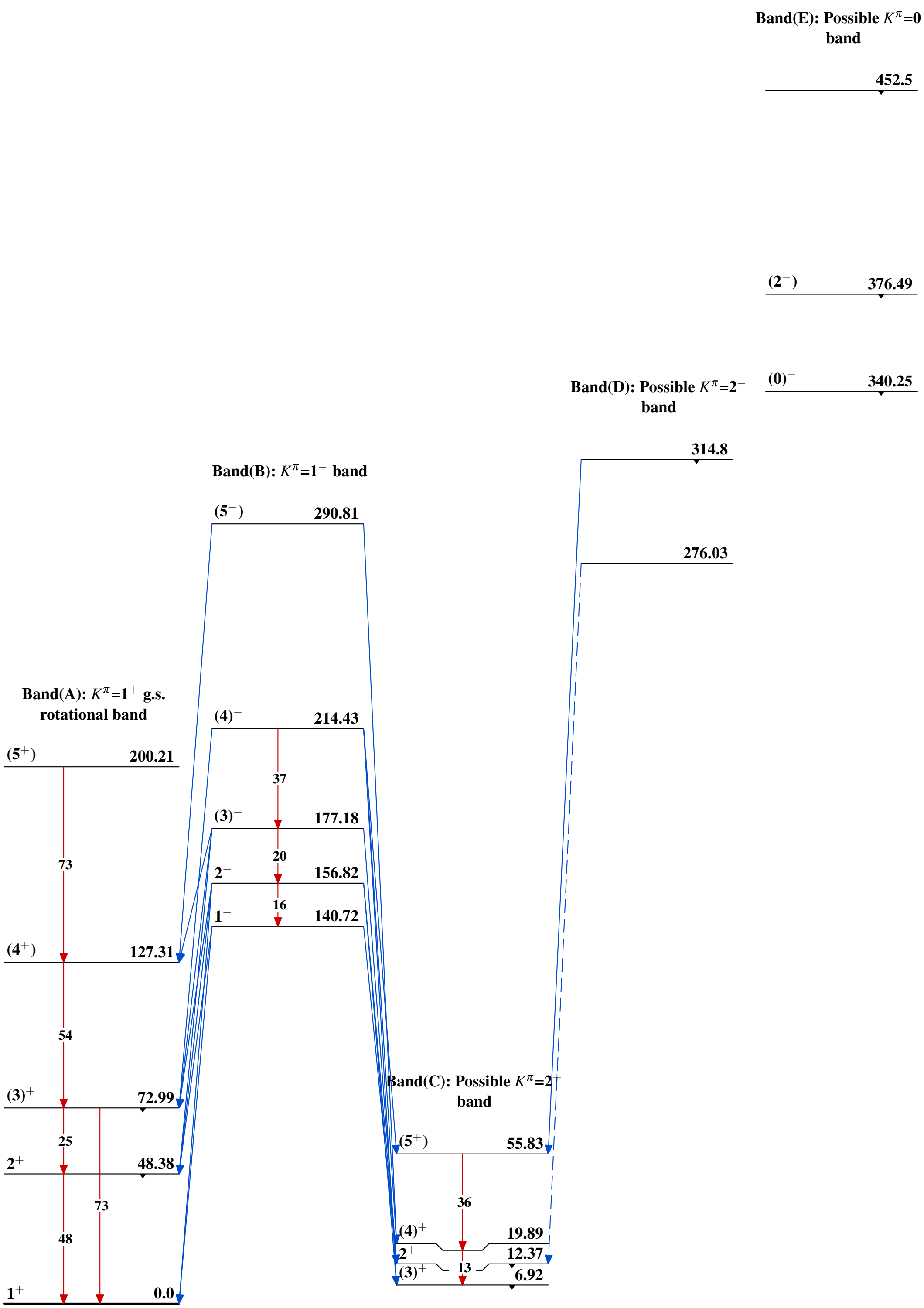
^{224}Ac α decay (2.78 h) 1992Li31,1968Le17

Decay Scheme (continued)

Intensities: $I_{(\gamma+ce)}$ per 100 decays through this branch
& Multiply placed: undivided intensity given
@ Multiply placed: intensity suitably divided



^{224}Ac α decay (2.78 h) 1992Li31,1968Le17



$^{220}_{87}Fr_{133}$