^{223}Ac α decay (2.10 min) 1991Li19,1969LeZW

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh et al. ,	NDS 175, 1 (2021)	19-May-2021

Parent: ^{223}Ac: E=0.0; J^π=(5/2$^-$); $T_{1/2}$=2.10 min *5*; Q(α)=6783.2 *10*; %α decay=99.0

^{223}Ac-J^π,$T_{1/2}$: From ^{223}Ac Adopted Levels in the ENSDF database (May 2001 update).

^{223}Ac-Q(α): From 2021Wa16.

^{223}Ac-%α decay: %α=99 for ^{223}Ac α decay (1951Me10).

1991Li19, 1990Li33: mass-separated ^{223}Ac source. Measured Eγ, Iγ, conversion electrons, Eα, Iα, $\alpha\gamma$-coin, (α)(ce)-coin using HPGe and Si(Li) detectors.

1969LeZW, 1968Ba73: measured Eγ, Iγ, Eα, Iα, $\alpha\gamma$-coin, magnetic spectrometer used.

1964Su04, 1963Su10: measured Eγ, Iγ, Eα, Iα, $\alpha\gamma$-coin.

1958Hi78: measured Eα, Iα.

1951Me10: measured Eα, Iα.

The ^{223}Ac decay scheme presented here is based on measurements by 1991Li19, and on the α-particle data of 1969LeZW, 1963Su10, and 1968Ba73. Some aspects of the level scheme, as proposed by 1991Li19 (and further discussed in 2002Sh19) should be considered as tentative, as the J^π values are mostly based on band assignments, and theoretical calculations, without a clear evidence of association of a level in a particular band, especially for closely spaced levels. 1991Li19 emphasized that the higher in energy in the level scheme and smaller the alpha population, the more tentative the level scheme. Evaluators also note a intensity imbalance of 1.9% at 191 and non-physical negative intensity imbalance of 0.5% at 305 levels.

The α feedings to levels deduced from γ-ray transition intensity balance at each level using the experimental absolute γ-ray intensities of 1991Li19 agree reasonably well with the measured α-particle abundances. The total Fr K-x ray intensity of 2.7% *2*, deduced by evaluators using the γ-ray data presented here, also agrees with the measured value of 2.90 *5*% (1991Li19). Both agreements confirm the correctness of the decay scheme.

^{219}Fr Levels

Configuration and band assignments are from 1991Li19. See also 2002Sh19.

E(level)[†]	J^π[#]	$T_{1/2}$	Comments
0.0[&]	9/2$^-$	24 ms *4*	$T_{1/2}$: from Adopted Levels.
15.0[&] *1*	(5/2$^-$)		
56.1[b] *1*	(3/2$^-$)		
73?[&] *1*	(13/2$^-$)		
81.0[&] *5*	(1/2$^-$)		
98.58[b] *5*	(7/2$^-$)		
134.4[b] *1*	(5/2$^-$)		
139.8[&] *1*	(3/2$^-$)		
191.29[a] *6*	(7/2$^+$)		
210.4[a] *2*	(3/2$^+$)		
216.0[a] *1*	(11/2$^+$)		
269.2[&] *1*	(7/2$^-$)		
305.5[b] *1*	(9/2$^-$)		
325?[‡@] *2*			J^π: possible 5/2$^-$.
333.5[&] *1*	(11/2$^-$)		
340.3[c] *1*	(5/2$^+$)		
369.5[c] *2*	(3/2$^+$)		J^π: 1991Li19 assign π=+ or -, band association favors positive parity.
372.4[c] *1*	(7/2$^+$)		
374.8[@] *2*	(7/2)		J^π: possible negative parity.
384.3[a] *1*	(5/2$^+$)		

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^{223}Ac α decay (2.10 min) 1991Li19,1969LeZW (continued)

^{219}Fr Levels (continued)

E(level)[†]	Jπ[#]	Comments
432.0[@] 2	(9/2)	Jπ: possible negative parity.
445?[‡] 4		
462.2[c] 5	(9/2+)	Jπ: 1991Li19 assign π=+ or -, band association favors positive parity.
490.3[d] 1	(5/2−)	
506.5[a] 3	(9/2+)	
530.0[c] 5	(11/2+)	
533.8[d] 4	(7/2−)	
589[d] 1	(9/2−)	
650[‡d] 3	(11/2−)	
705.5[e] 5	(5/2+)	
778[‡e] 1	(7/2+)	

† Deduced by evaluators from a least-squares fit to γ-ray energies.
‡ Weakly populated level by α branch, the gamma transition is either not confirmed or not observed.
# From Adopted Levels. ^{219}Fr lies in the transitional region between quadrupole deformation and spherical shape ($\epsilon_2=\epsilon_3=0.08$). For some reason, however, this nucleus presents a typical structure of parity doublet bands (1990Li33,1991Li19). Most of the assigned spins and parities are based mainly on rotational band structure, γ-ray multipolarities and decay patterns, favored α decay from ^{223}Ac and to ^{215}At, and on a comparison with similar band structures observed in ^{221}Fr. Assignments for the excited states should be considered as tentative.
@ Possible configuration=π5/2[523]+π5/2[512]+(π1/2[541]+Q_{30}).
& Band(A): $K^\pi=1/2^-$,π1/2[541], parity doublet band.
a Band(a): $K^\pi=1/2^+$, parity doublet band. Configuration=π1/2[411]+(π1/2[541]+Q_{30}).
b Band(B): $K^\pi=3/2^-$, parity doublet band. Configuration=π3/2[532]+(π3/2[402]+Q_{30}).
c Band(b): $K^\pi=3/2^+$, parity doublet band. Configuration=π3/2[402]+(π3/2[532]+Q_{30}).
d Band(C): $K^\pi=5/2^-$, parity doublet band. Configuration=π5/2[512]+π5/2[523]+(π1/2[660]+Q_{30}).
e Band(c): $K^\pi=5/2^+$, parity doublet band. Configuration=π5/2[402]+(π5/2[523]+Q_{30}).

α radiations

The coincidence evidence indicated here is taken from αγ-coin spectra Fig. 1 in 1991Li19.

Eα[†]	E(level)	Iα[†@]	HF[‡]	Comments
5892	778	0.01	14	Eα,Iα: from 1991Li19. Eα: 5897 from Qα and E(level).
5966.8 30	705.5	0.03	10	Iα: Iα<0.06 deduced by evaluators from γ-ray transition intensity balance.
6023.0 30	650	0.01	56	The 6023α seen in αγ-coin spectrum (1991Li19), but no γ transition is associated with this level at present.
6082.7 20	589	0.03	36	
6134.9 20	533.8	0.12 3	16 4	Iα: Iα=0.07 4 deduced by evaluators from γ-ray transition intensity balance.
6140.2 30	530.0	≈0.03	≈66	Iα: Iα=0.03 2 deduced by evaluators from γ-ray transition intensity balance.
6163.0 25	506.5	0.05	50	Iα: Iα=0.03 2 deduced by evaluators from γ-ray transition intensity balance.
6177.7 20	490.3	0.95 15	3.1 5	Iα: Iα=0.96 9 deduced by evaluators from γ-ray transition intensity balance.
6205.9 25	462.2	≈0.03	≈131	Iα: Iα=0.04 2 deduced by evaluators from γ-ray transition intensity balance.
6223.4 40	445?	≈0.006	≈781	
6235.8 20	432.0	0.09	59	Iα: Iα=0.12 6 deduced by evaluators from γ-ray transition intensity balance.
6281.3[&]	384.3	≈0.05	≈170	Iα: Iα=0.13 2 deduced by evaluators from γ-ray transition intensity balance.

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^{223}Ac α decay (2.10 min) 1991Li19,1969LeZW (continued)

α radiations (continued)

Eα[†]	E(level)	Iα[†@]	HF[‡]	Comments
				Eα: 6284.1 from Qα and E(level).
(6294)	374.8	0.071 *16*	130 *30*	Eα,Iα: from decay scheme. Existence of this α branch is uncertain.
6292.8 *15*	372.4	0.47 *6*	21 *3*	Eα: possible doublet to 372 and 375 levels. Iα: Iα=0.47 *5* deduced by evaluators from γ-ray transition intensity balance.
(6299)	369.5	0.074 *11*	135 *20*	Eα,Iα: from decay scheme. Existence of this α branch is uncertain.
6325.7 *15*	340.3	0.30 *5*	44 *8*	Iα: Iα=0.49 *5* deduced by evaluators from γ-ray transition intensity balance.
6332.5 *20*	333.5	0.14 *6*	100 *45*	Iα: Iα=0.16 *6* deduced by evaluators from γ-ray transition intensity balance.
6341.8 *20*	325?	0.05 *1*	310 *65*	
6360.5 *15*	305.5	0.22 *3*	85 *12*	Iα: Iα=0.67 *17* deduced by evaluators from γ-ray transition intensity balance. Note non-physical negative intensity imbalance of 0.5%.
6396.8 *15*	269.2	0.13 *2*	205 *30*	Iα: γ-transition intensity balance gives 0.30 *7* if the intensity of the 64.4-keV transition listed in Table I of 1991Li19 is interpreted as I(γ+ce).
6448.6 *15*	216.0	0.20 *3*	220 *35*	Iα: Iα=0.26 *7* deduced by evaluators from γ-ray transition intensity balance.
6454.7 *30*	210.4	0.06 *3*	7.8×10^2 *39*	Iα: Iα=0.10 *3* deduced by evaluators from γ-ray transition intensity balance.
6473.0 *15*	191.29	3.1 *3*	18 *2*	Iα: Iα=1.21 *6* deduced by evaluators from γ-ray transition intensity balance, with the assumed multipolarities. Note a large imbalance of 1.9% at this level. Other values: Eα=6476 *5*, Iα=3.2, Eα has been increased by 6 keV because of a change in the calibration energy of the ^{211}Bi standard (1963Su10,1977Ma31).
6523.2 *20*	139.8	0.6 *3*	150 *75*	Iα: Iα=0.70 *9* deduced by evaluators from γ-ray transition intensity balance.
6528.4 *15*	134.4	3.1 *3*	31 *3*	Iα: Iα=2.8 *3* deduced by evaluators from γ-ray transition intensity balance. Other values: Eα=6526 *5*, Iα=3.8, Eα has been increased by 6 keV because of a change in the calibration energy of the ^{211}Bi standard (1963Su10,1977Ma31).
6563.7[#] *10*	98.58	13.7[#] *10*	9.7 *8*	Iα: Iα=10.9 *17* deduced by evaluators from γ-ray transition intensity balance. Other values: Eα=6564, Iα=14.0 *7*, Eα has been increased by 3 keV because of a change in the calibration energy of the ^{211}Bi standard (1958Hi78,1977Ma31); Eα=6566 *5*, Iα=13.3, Eα has been increased by 6 keV because of a change in the calibration energy of the ^{211}Bi standard (1963Su10,1977Ma31).
6581.8 *30*	81.0	0.3 *2*	5.2×10^2 *35*	Iα: I(γ+ce) for 66.0-keV transition gives 0.7 *5*, but note that the placement of this γ ray is uncertain.
(6590)	73?	<0.01	$>164\times10^2$	Eα,Iα: from decay scheme. Existence of this α branch is uncertain.
6606[&]	56.1	<1	>190	Eα,Iα: from 1991Li19. Transition intensity balance giving 0 *3* is consistent with the upper limit of the measured Iα.
6646.7[#] *10*	15.0	44.6[#] *40*	6.4 *6*	Other values: Eα=6646, Iα=46.0 *23*, Eα has been increased by 3 keV because of a change in the calibration energy of the ^{211}Bi standard (1958Hi78,1977Ma31); Eα=6649 *5*, Iα=42.1, Eα has been increased by 6 keV because of a change in the calibration energy of the ^{211}Bi standard (1963Su10,1977Ma31).
6661.6[#] *10*	0.0	31.8[#] *30*	10 *1*	Iα: Iα=35 *5* deduced by evaluators from γ-ray transition intensity balance. Other values: Eα=6660, Iα=40 *2*, Eα has been increased by 3 keV because of a change in the calibration energy of the ^{211}Bi standard (1958Hi78,1977Ma31); Eα=6663 *5*, Iα=37.6, Eα has been increased

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^{223}Ac α decay (2.10 min) 1991Li19,1969LeZW (continued)

α radiations (continued)

Eα[†]	E(level)	Comments
		by 6 keV because of a change in the calibration energy of the ^{211}Bi standard (1964Su04,1977Ma31).

[†] From 1969LeZW and 1968Ba73 obtained with magnetic spectrometer, unless otherwise specified.
[‡] The nuclear radius parameter $r_0(^{219}Fr)$=1.5439 *23* is deduced from interpolation (or unweighted average) of radius parameters of the adjacent even-even nuclides from 2020Si16.
[#] From 1969LeZW, recommended by 1991Ry01. 1991Ry01 increased original Eα values by 0.7 keV to adjust for an energy change in the ^{211}Bi standard.
[@] For absolute intensity per 100 decays, multiply by 0.99.
[&] Existence of this branch is questionable.

$\gamma(^{219}Fr)$

Iγ normalization: Experimental γ-ray intensities per 100 α decays (1991Li19).
Measured I(K-x ray intensity)=2.90 *5* per 100 α decays.
The γ rays listed here were observed in coincidence with α particles with energies in the range 5892-6646 keV. Specific γ-ray coincidence evidence indicated here is gathered from $\alpha\gamma$-coin spectral Figs. 2 and 4, and comment column in Table I in 1991Li19.

E_γ[†]	I_γ[†a]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ	α[&]	$I_{(\gamma+ce)}$[a]	Comments
(15.0)	0.0025 *2*	15.0	(5/2$^-$)	0.0	9/2$^-$	[E2]		2.36×10^4	59.1 *47*	α(M)=1.786×10^4 *25*; α(N)=4.66×10^3 *7*; α(O)=959 *14*; α(P)=120.9 *17*; α(Q)=0.1125 *16* I$_{(\gamma+ce)}$: from Iα=44.6% *40* and γ-ray transition intensity balance of 14.5 *25* at 15.0 level. Iγ: deduced from I(γ+ce) and α(theory) for mult=E2 for 15.0-keV transition.
35.7 *1*	0.028 *4*	134.4	(5/2$^-$)	98.58	(7/2$^-$)	(M1)[#]		57.5 *10*		α(L)=43.6 *8*; α(M)=10.41 *17* α(N)=2.73 *5*; α(O)=0.611 *10*; α(P)=0.0979 *16*; α(Q)=0.00549 *9* Mult.: 1991Li19 list M1.
41.15 *10*	0.024 *4*	56.1	(3/2$^-$)	15.0	(5/2$^-$)	(M1+E2)	1.0 *2*	330 *70*		α(L)=240 *50*; α(M)=65 *13* α(N)=17 *4*; α(O)=3.5 *7*; α(P)=0.46 *9*; α(Q)=0.0024 *3* L1+L2, L3, M and N conversion lines seen in coincidence with 6563α. Mult.,δ: from γ-ray transition intensity balance at 56 level. 1991Li19 list M1+E2.
42.4 *1*	0.013 *3*	98.58	(7/2$^-$)	56.1	(3/2$^-$)	(E2)[#]		538 *10*		α(L)=397 *8*; α(M)=106.8 *20* α(N)=27.9 *5*; α(O)=5.76 *11*; α(P)=0.733 *14*; α(Q)=0.001019 *18* Mult.: 1991Li19 list E2. L2, L3, M and N conversion lines seen in coincidence with 6563α.
56.95 *20*	0.038 *6*	191.29	(7/2$^+$)	134.4	(5/2$^-$)	[E1]		0.481 *9*		α(L)=0.365 *7*; α(M)=0.0886 *15* α(N)=0.0227 *4*; α(O)=0.00473 *8*; α(P)=0.000634 *11*; α(Q)=1.93×10^{-5} *3* Mult.: 1991Li19 list (E1) from decay scheme.
64.4 *3*		333.5	(11/2$^-$)	269.2	(7/2$^-$)	[E2]		70.8 *19*	≈0.02	α(L)=52.2 *14*; α(M)=14.1 *4* α(N)=3.69 *10*; α(O)=0.764 *21*; α(P)=0.098 *3*; α(Q)=0.000164 *4* I$_{(\gamma+ce)}$: intensity listed in Table I of 1991Li19 is assumed by evaluators as transition intensity. If it were just the photon intensity, then it produces a large non-physical negative intensity balance at 269-keV level, as well as gives too large an Iα to the 333 level from γ-transition intensity balance.

$^{219}_{87}Fr_{132}$-5

^{223}Ac α decay (2.10 min) 1991Li19,1969LeZW (continued)

γ(^{219}Fr) (continued)

E_γ[†]	I_γ[†a]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	α[&]	$I_{(\gamma+ce)}$[a]	Comments
66.0[c] 5	0.011 7	81.0	(1/2⁻)	15.0	(5/2⁻)	[E2]	63 3		α(L)=46.4 19; α(M)=12.5 5 α(N)=3.28 13; α(O)=0.68 3; α(P)=0.087 4; α(Q)=0.000149 6
72.8[bc]	b	73?	(13/2⁻)	0.0	9/2⁻	[E2]	39.4	<0.01	α(L)=29.0 4; α(M)=7.84 11 α(N)=2.05 3; α(O)=0.425 6; α(P)=0.0544 8; α(Q)=0.0001003 14 Eγ=73 1, %Iγ=0.20 10, αγ coin, semi (1969LeZW).
72.8[bc]	b	778	(7/2⁺)	705.5	(5/2⁺)	[M1+E2]	23 17	<0.01	α(L)=17 12; α(M)=4.6 33 α(N)=1.20 86; α(O)=0.25 18; α(P)=0.033 22; α(Q)=3.9×10⁻⁴ 29 Eγ=73 1, %Iγ=0.20 10, αγ coin, semi (1969LeZW). I(γ+ce)=0.01 from intensity balance at 778 level.
78.25 10	0.055 7	134.4	(5/2⁻)	56.1	(3/2⁻)	[M1]	5.75		α(L)=4.36 7; α(M)=1.040 15 α(N)=0.273 4; α(O)=0.0610 9; α(P)=0.00978 15; α(Q)=0.000547 8 Mult.: 1991Li19 list (M1) from decay scheme.
82.4[c]	<0.01	589	(9/2⁻)	506.5	(9/2⁺)	[E1]	0.179		α(L)=0.1359 19; α(M)=0.0328 5 α(N)=0.00844 12; α(O)=0.00179 3; α(P)=0.000250 4; α(Q)=8.57×10⁻⁶ 12 The γ ray mixed with Tl, K-x rays.
83.55 10	0.58 4	98.58	(7/2⁻)	15.0	(5/2⁻)	(M1)	4.75		α(L)=3.60 6; α(M)=0.859 13 α(N)=0.225 4; α(O)=0.0504 8; α(P)=0.00808 12; α(Q)=0.000452 7 Mult.: from (L1+L2)/L3 ratio. L1+L2, L3, M and N conversion lines seen in coincidence with 6563α. Eγ=84 1, %Iγ=0.17 10, αγ coin, semi (1969LeZW); Eγ=82, %Iγ=0.23, αγ coin, scin (1963Su10).
89.6 2	0.05 1	305.5	(9/2⁻)	216.0	(11/2⁺)	[E1]	0.1433 22		α(L)=0.1087 17; α(M)=0.0262 4 α(N)=0.00675 11; α(O)=0.001433 22; α(P)=0.000202 3; α(Q)=7.11×10⁻⁶ 11
92.71 5	0.39 2	191.29	(7/2⁺)	98.58	(7/2⁻)	[E1]	0.1309		α(L)=0.0993 14; α(M)=0.0239 4 α(N)=0.00616 9; α(O)=0.001310 19; α(P)=0.000185 3; α(Q)=6.59×10⁻⁶ 10 Mult.: 1991Li19 list E1 from intensity balance.
98.58 5	0.90 2	98.58	(7/2⁻)	0.0	9/2⁻	(M1)	2.94		Eγ=93 1, %Iγ=0.17 10, αγ coin, semi (1969LeZW). α(L)=2.23 4; α(M)=0.532 8 α(N)=0.1395 20; α(O)=0.0312 5; α(P)=0.00500 7; α(Q)=0.000279 4 Mult.: from (L1+L2)/L3 ratio. 1991Li19 list M1 L1+L2, L3, M and N conversion lines seen in coincidence with 6563α. Eγ=99 1, %Iγ=0.20 10, αγ coin, semi (1969LeZW); Eγ=96, %Iγ=0.2, αγ coin, scin (1963Su10).
[x]101.1 2	0.04 1								
119.4 1	0.11 1	134.4	(5/2⁻)	15.0	(5/2⁻)	(M1)[#]	8.65		α(K)=6.96 10; α(L)=1.283 19; α(M)=0.306 5

$^{219}_{87}Fr_{132}$-6

^{223}Ac α decay (2.10 min) 1991Li19,1969LeZW (continued)

γ(^{219}Fr) (continued)

E_γ [†]	I_γ [†a]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	α[&]	Comments
								α(N)=0.0802 *12*; α(O)=0.0179 *3*; α(P)=0.00288 *4*; α(Q)=0.0001607 *23* Mult.: 1991Li19 list M1. Eγ=120 *2*, %Iγ≈0.03, αγ coin, semi (1969LeZW); Eγ=123, %Iγ<0.05, αγ coin, scin (1963Su10).
124.8 *1*	0.09 *1*	139.8	(3/2⁻)	15.0	(5/2⁻)	(M1)[#]	7.63	α(K)=6.14 *9*; α(L)=1.130 *16*; α(M)=0.269 *4* α(N)=0.0706 *10*; α(O)=0.01579 *23*; α(P)=0.00253 *4*; α(Q)=0.0001414 *20* Mult.: 1991Li19 list M1. Eγ=126 *2*, %Iγ≈0.04, αγ coin, semi (1969LeZW).
126.4 *2*	≈0.01	432.0	(9/2)	305.5	(9/2⁻)	[D,E2]	3.8 *35*	
[x]130.5[@]	0.02 *1*							γ observed in coin with α particles (Fig. 2 in 1991Li19).
134.6 *3*	≈0.01	269.2	(7/2⁻)	134.4	(5/2⁻)	[M1+E2]	4.3 *18*	α(K)=2.6 *24*; α(L)=1.28 *37*; α(M)=0.33 *12* α(N)=0.087 *30*; α(O)=0.0185 *58*; α(P)=0.0026 *6*; α(Q)=6.3×10^{-5} *51*
171.7 *3*	0.02 *1*	705.5	(5/2⁺)	533.8	(7/2⁻)	[E1]	0.1273	α(K)=0.1013 *15*; α(L)=0.0198 *3*; α(M)=0.00472 *7* α(N)=0.001225 *18*; α(O)=0.000265 *4*; α(P)=3.93×10^{-5} *6*; α(Q)=1.640×10^{-6} *24*
176.3 *2*	0.11 *2*	191.29	(7/2⁺)	15.0	(5/2⁻)	[E1]	0.1194	α(K)=0.0951 *14*; α(L)=0.0185 *3*; α(M)=0.00441 *7* α(N)=0.001145 *17*; α(O)=0.000248 *4*; α(P)=3.68×10^{-5} *6*; α(Q)=1.545×10^{-6} *22* Mult.: 1991Li19 list E1(+M2), with <5% M2 admixture from intensity balance. Eγ=176 *2*, %Iγ≈0.05, αγ coin, semi (1969LeZW). Eγ≈170, %Iγ<0.8, αγ coin, scin (1963Su10).
191.3 *1*	0.59 *4*	191.29	(7/2⁺)	0.0	9/2⁻	[E1]	0.098	α(K)=0.0783 *11*; α(L)=0.0150 *2*; α(M)=0.00358 *5* α(N)=0.000930 *13*; α(O)=0.000202 *3*; α(P)=3.01×10^{-5} *5*; α(Q)=1.287×10^{-6} *18* Mult.: 1991Li19 list E1(+M2), with <5% M2 admixture from intensity balance. Eγ=192 *1*, %Iγ=0.25 *15*, αγ coin, semi (1969LeZW).
195.4 *2*	0.12 *2*	210.4	(3/2⁺)	15.0	(5/2⁻)	(E1)[#]	0.0932	α(K)=0.0745 *11*; α(L)=0.01424 *21*; α(M)=0.00340 *5* α(N)=0.000881 *13*; α(O)=0.000191 *3*; α(P)=2.86×10^{-5} *4*; α(Q)=1.227×10^{-6} *18* Mult.: 1991Li19 list E1 from intensity balance.
199.3[c] *4*	0.03 *2*	705.5	(5/2⁺)	506.5	(9/2⁺)	[E2]	0.560 *9*	Tentative placement proposed by evaluators based on level-energy difference. This γ was unplaced in 1991Li19.
205.7 *3*	0.04 *2*	340.3	(5/2⁺)	134.4	(5/2⁻)	[E1]	0.0824	α(K)=0.0659 *10*; α(L)=0.01251 *19*; α(M)=0.00298 *5* α(N)=0.000774 *12*; α(O)=0.0001683 *25*; α(P)=2.52×10^{-5} *4*; α(Q)=1.095×10^{-6} *16*
207.0 *2*	0.19 *4*	305.5	(9/2⁻)	98.58	(7/2⁻)	[M1+E2]	1.2 *7*	α(K)=0.8 *7*; α(L)=0.258 *11*; α(M)=0.0652 *17* α(N)=0.0171 *5*; α(O)=0.00370 *7*; α(P)=0.00054 *6*; α(Q)=1.9×10^{-5} *15* Mult.: (M1) in 1991Li19 from decay scheme and γ-transition intensity balance. Eγ=207 *2*, %Iγ≈0.06, αγ coin, semi (1969LeZW).
216.0 *1*	0.37 *4*	216.0	(11/2⁺)	0.0	9/2⁻	[E1]	0.0734	α(K)=0.0588 *9*; α(L)=0.01107 *16*; α(M)=0.00264 *4* α(N)=0.000685 *10*; α(O)=0.0001491 *21*; α(P)=2.24×10^{-5} *4*; α(Q)=9.82×10^{-7} *14* Mult.: 1991Li19 list E1, possibly from decay scheme. Eγ=216 *1*, %Iγ=0.15 *10*, αγ coin, semi (1969LeZW).
216.1 *2*	0.04 *2*	432.0	(9/2)	216.0	(11/2⁺)	[D,E2]	0.84 *77*	
229.7 *2*	0.07 *1*	369.5	(3/2⁺)	139.8	(3/2⁻)	[E1]	0.0634	α(K)=0.0509 *8*; α(L)=0.00951 *14*; α(M)=0.00226 *4* α(N)=0.000588 *9*; α(O)=0.0001281 *19*; α(P)=1.93×10^{-5} *3*; α(Q)=8.57×10^{-7} *13*

$^{219}_{87}Fr_{132}$-7

^{223}Ac α decay (2.10 min) 1991Li19,1969LeZW (continued)

γ(^{219}Fr) (continued)

E_γ [†]	I_γ [†a]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	α[&]	Comments
238.1 *2*	0.07 *1*	372.4	(7/2$^+$)	134.4	(5/2$^-$)	[E1]	0.0583	α(K)=0.0468 *7*; α(L)=0.00870 *13*; α(M)=0.00207 *3* α(N)=0.000538 *8*; α(O)=0.0001173 *17*; α(P)=1.77×10^{-5} *3*; α(Q)=7.92×10^{-7} *12*
241.7 *2*	0.18 *2*	340.3	(5/2$^+$)	98.58	(7/2$^-$)	[E1]	0.0563	α(K)=0.0452 *7*; α(L)=0.00839 *12*; α(M)=0.00200 *3* α(N)=0.000519 *8*; α(O)=0.0001131 *16*; α(P)=1.709×10^{-5} *25*; α(Q)=7.67×10^{-7} *11* Mult.: 1991Li19 list (E1), possibly from decay scheme.
254.4 *3*	0.07 *2*	269.2	(7/2$^-$)	15.0	(5/2$^-$)	[M1+E2]	0.63 *40*	α(K)=0.46 *37*; α(L)=0.128 *23*; α(M)=0.032 *4* α(N)=0.0084 *10*; α(O)=0.0018 *3*; α(P)=0.00027 *7*; α(Q)=1.06×10^{-5} *82*
269.2 *1*	0.10 *2*	269.2	(7/2$^-$)	0.0	9/2$^-$	[M1+E2]	0.54 *34*	α(K)=0.40 *31*; α(L)=0.107 *22*; α(M)=0.027 *4* α(N)=0.0070 *11*; α(O)=0.0015 *3*; α(P)=2.28×10^{-4} *60*; α(Q)=9.1×10^{-6} *70* Eγ=268 *2*, %Iγ≈0.05, αγ coin, semi (1969LeZW).
274.0 *2*	0.05 *1*	372.4	(7/2$^+$)	98.58	(7/2$^-$)	[E1]	0.0421	α(K)=0.0339 *5*; α(L)=0.00618 *9*; α(M)=0.001470 *21* α(N)=0.000382 *6*; α(O)=8.35×10^{-5} *12*; α(P)=1.271×10^{-5} *18*; α(Q)=5.84×10^{-7} *9*
279.8 *3*	0.03 *1*	490.3	(5/2$^-$)	210.4	(3/2$^+$)	[E1]	0.0401	α(K)=0.0323 *5*; α(L)=0.00588 *9*; α(M)=0.001398 *20* α(N)=0.000363 *6*; α(O)=7.95×10^{-5} *12*; α(P)=1.210×10^{-5} *18*; α(Q)=5.58×10^{-7} *8*
284.2 *1*	0.20 *2*	340.3	(5/2$^+$)	56.1	(3/2$^-$)	[E1]	0.0387	α(K)=0.0312 *5*; α(L)=0.00567 *8*; α(M)=0.001346 *19* α(N)=0.000350 *5*; α(O)=7.66×10^{-5} *11*; α(P)=1.167×10^{-5} *17*; α(Q)=5.39×10^{-7} *8* Mult.: 1991Li19 list (E1) from decay scheme.
285.7 *1*	0.13 *2*	384.3	(5/2$^+$)	98.58	(7/2$^-$)	[E1]	0.0382	α(K)=0.0309 *5*; α(L)=0.00560 *8*; α(M)=0.001329 *19* α(N)=0.000346 *5*; α(O)=7.56×10^{-5} *11*; α(P)=1.152×10^{-5} *17*; α(Q)=5.33×10^{-7} *8*
299.1 *2*	0.03 *1*	490.3	(5/2$^-$)	191.29	(7/2$^+$)	[E1]	0.0344	α(K)=0.0278 *4*; α(L)=0.00502 *7*; α(M)=0.001191 *17* α(N)=0.000310 *5*; α(O)=6.78×10^{-5} *10*; α(P)=1.036×10^{-5} *15*; α(Q)=4.84×10^{-7} *7*
305.5 *1*	0.18 *2*	305.5	(9/2$^-$)	0.0	9/2$^-$	[M1+E2]	0.38 *25*	α(K)=0.28 *22*; α(L)=0.071 *20*; α(M)=0.018 *4* α(N)=0.0046 *11*; α(O)=1.01×10^{-3} *26*; α(P)=1.53×10^{-4} *50*; α(Q)=6.5×10^{-6} *49* Eγ=306 *2*, %Iγ≈0.08, αγ coin, semi (1969LeZW).
315.2 *3*	0.01	506.5	(9/2$^+$)	191.29	(7/2$^+$)	[M1+E2]	0.35 *23*	α(K)=0.26 *20*; α(L)=0.065 *19*; α(M)=0.016 *4* α(N)=0.0042 *10*; α(O)=9.1×10^{-4} *25*; α(P)=1.39×10^{-4} *47*; α(Q)=5.9×10^{-6} *45*
325.3 *1*	0.05 *2*	340.3	(5/2$^+$)	15.0	(5/2$^-$)	[E1]	0.0285	α(K)=0.0231 *4*; α(L)=0.00412 *6*; α(M)=0.000977 *14* α(N)=0.000254 *4*; α(O)=5.58×10^{-5} *8*; α(P)=8.55×10^{-6} *12*; α(Q)=4.05×10^{-7} *6*
333.5 *1*	0.11 *4*	333.5	(11/2$^-$)	0.0	9/2$^-$	[M1+E2]	0.30 *19*	α(K)=0.22 *17*; α(L)=0.054 *17*; α(M)=0.0133 *36* α(N)=0.00350 *94*; α(O)=7.7×10^{-4} *23*; α(P)=1.17×10^{-4} *42*; α(Q)=5.1×10^{-6} *38*
^{x}341.0[@]	0.05 *3*							
357.4 *1*	0.18 *3*	372.4	(7/2$^+$)	15.0	(5/2$^-$)	[E1]	0.0232	α(K)=0.0188 *3*; α(L)=0.00332 *5*; α(M)=0.000786 *11* α(N)=0.000204 *3*; α(O)=4.49×10^{-5} *7*; α(P)=6.91×10^{-6} *10*; α(Q)=3.33×10^{-7} *5* Eγ=359 *2*, %Iγ≈0.10, αγ coin, semi (1969LeZW).
372.4 *1*	0.16 *3*	372.4	(7/2$^+$)	0.0	9/2$^-$	[E1]	0.0212	α(K)=0.01720 *25*; α(L)=0.00302 *5*; α(M)=0.000715 *10* α(N)=0.000186 *3*; α(O)=4.09×10^{-5} *6*; α(P)=6.31×10^{-6} *9*; α(Q)=3.05×10^{-7} *5* Eγ=373 *2*, %Iγ≈0.05, αγ coin, semi (1969LeZW).
374.8 *2*	0.06 *1*	374.8	(7/2)	0.0	9/2$^-$	[D,E2]	0.19 *17*	
434.2 *1*	0.53 *5*	490.3	(5/2$^-$)	56.1	(3/2$^-$)	[M1+E2]	0.145 *93*	α(K)=0.112 *81*; α(L)=0.025 *10*; α(M)=0.0060 *23* α(N)=0.00158 *59*; α(O)=3.5×10^{-4} *14*; α(P)=5.4×10^{-5} *24*; α(Q)=2.5×10^{-6} *18* Eγ=433 *2*, %Iγ≈0.07, Eγ=435?, %Iγ≈0.07, αγ coin (1969LeZW).

$^{219}_{87}Fr_{132}$-8

^{223}Ac α decay (2.10 min) 1991Li19,1969LeZW (continued)

$\gamma(^{219}Fr)$ (continued)

E_γ [†]	I_γ [†a]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	α[&]	Comments
462.2 *5*	0.04 *2*	462.2	(9/2$^+$)	0.0	9/2$^-$	[E1]	0.01339	α(K)=0.01093 *16*; α(L)=0.00187 *3*; α(M)=0.000442 *7* α(N)=0.0001152 *17*; α(O)=2.54×10^{-5} *4*; α(P)=3.95×10^{-6} *6*; α(Q)=1.98×10^{-7} *3*
475.2 *1*	0.27 *4*	490.3	(5/2$^-$)	15.0	(5/2$^-$)	[M1+E2]	0.114 *73*	α(K)=0.089 *63*; α(L)=0.0190 *81*; α(M)=0.0046 *19* α(N)=0.00121 *48*; α(O)=2.7×10^{-4} *11*; α(P)=4.2×10^{-5} *19*; α(Q)=2.0×10^{-6} *14* Eγ=477 *2*, %Iγ≈0.14, $\alpha\gamma$ coin, semi (1969LeZW).
506.6 *5*	0.03 *2*	506.5	(9/2$^+$)	0.0	9/2$^-$	[E1]	0.0111	α(K)=0.00907 *13*; α(L)=0.001540 *22*; α(M)=0.000363 *6* α(N)=9.46×10^{-5} *14*; α(O)=2.09×10^{-5} *3*; α(P)=3.26×10^{-6} *5*; α(Q)=1.651×10^{-7} *24*
518.8 *4*	0.09 *3*	533.8	(7/2$^-$)	15.0	(5/2$^-$)	[M1+E2]	0.091 *57*	α(K)=0.071 *49*; α(L)=0.0148 *66*; α(M)=0.0036 *15* α(N)=9.4×10^{-4} *39*; α(O)=2.09×10^{-4} *90*; α(P)=3.3×10^{-5} *16*; α(Q)=1.6×10^{-6} *11*
530.0 *5*	0.03 *2*	530.0	(11/2$^+$)	0.0	9/2$^-$	[E1]	0.01013	α(K)=0.00829 *12*; α(L)=0.001401 *20*; α(M)=0.000330 *5* α(N)=8.60×10^{-5} *13*; α(O)=1.90×10^{-5} *3*; α(P)=2.97×10^{-6} *5*; α(Q)=1.513×10^{-7} *22*

† From 1991Li19. Others: 1969LeZW, 1963Su10.
‡ From γ-transition intensity balance or ce data, the latter from 1991Li19. Assignments listed in square brackets are implied from J^π values.
# From γ-transition intensity balance at the relevant level, with respect to the α feeding and intensity of any incoming γ rays.
@ Uncertain γ ray.
& Additional information 1.
a For absolute intensity per 100 decays, multiply by 0.99.
b Multiply placed with undivided intensity.
c Placement of transition in the level scheme is uncertain.
x γ ray not placed in level scheme.

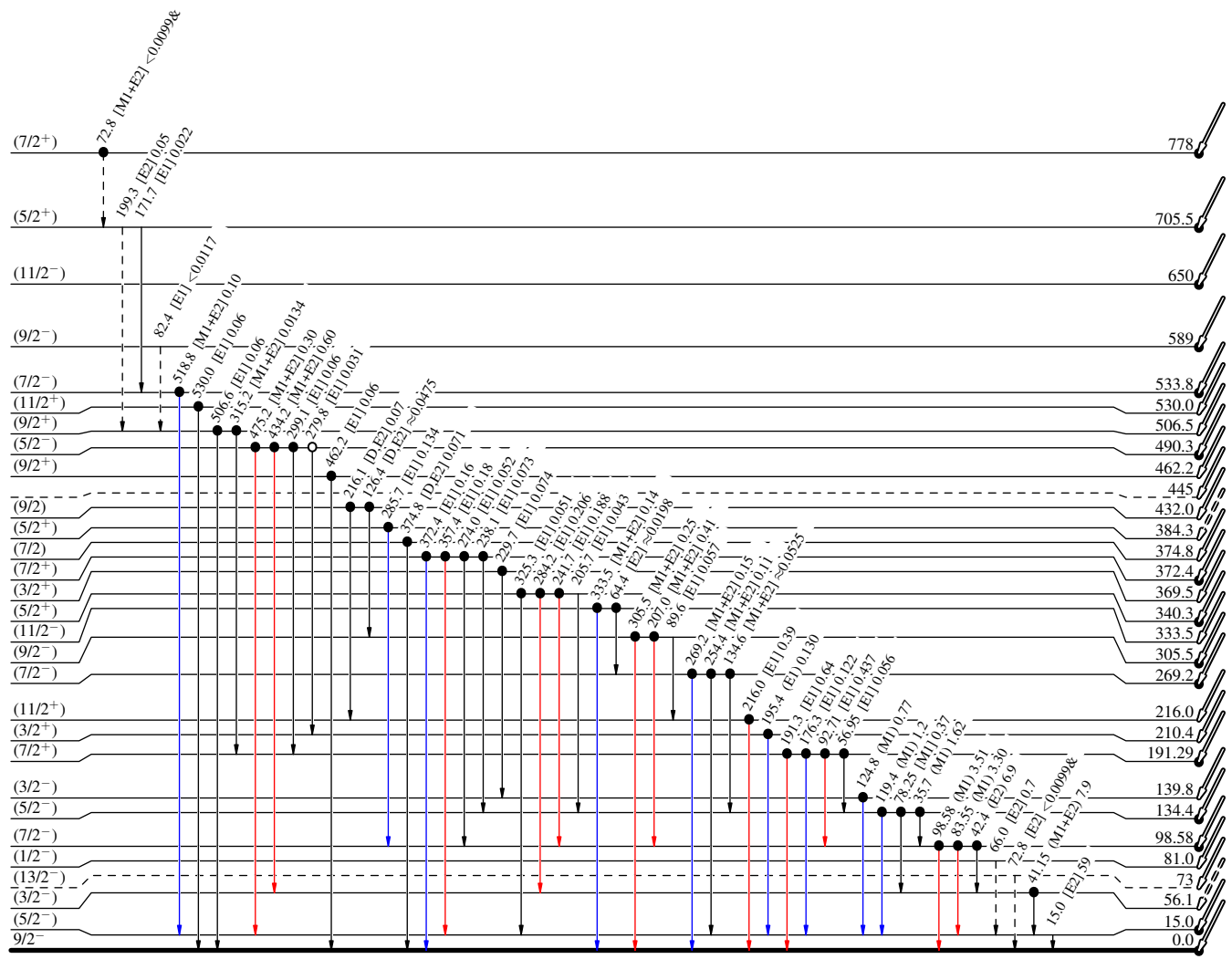
$^{219}_{87}Fr_{132}$-9

^{223}Ac α decay (2.10 min) 1991Li19,1969LeZW

Decay Scheme

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

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)
- Coincidence
- Coincidence (Uncertain)

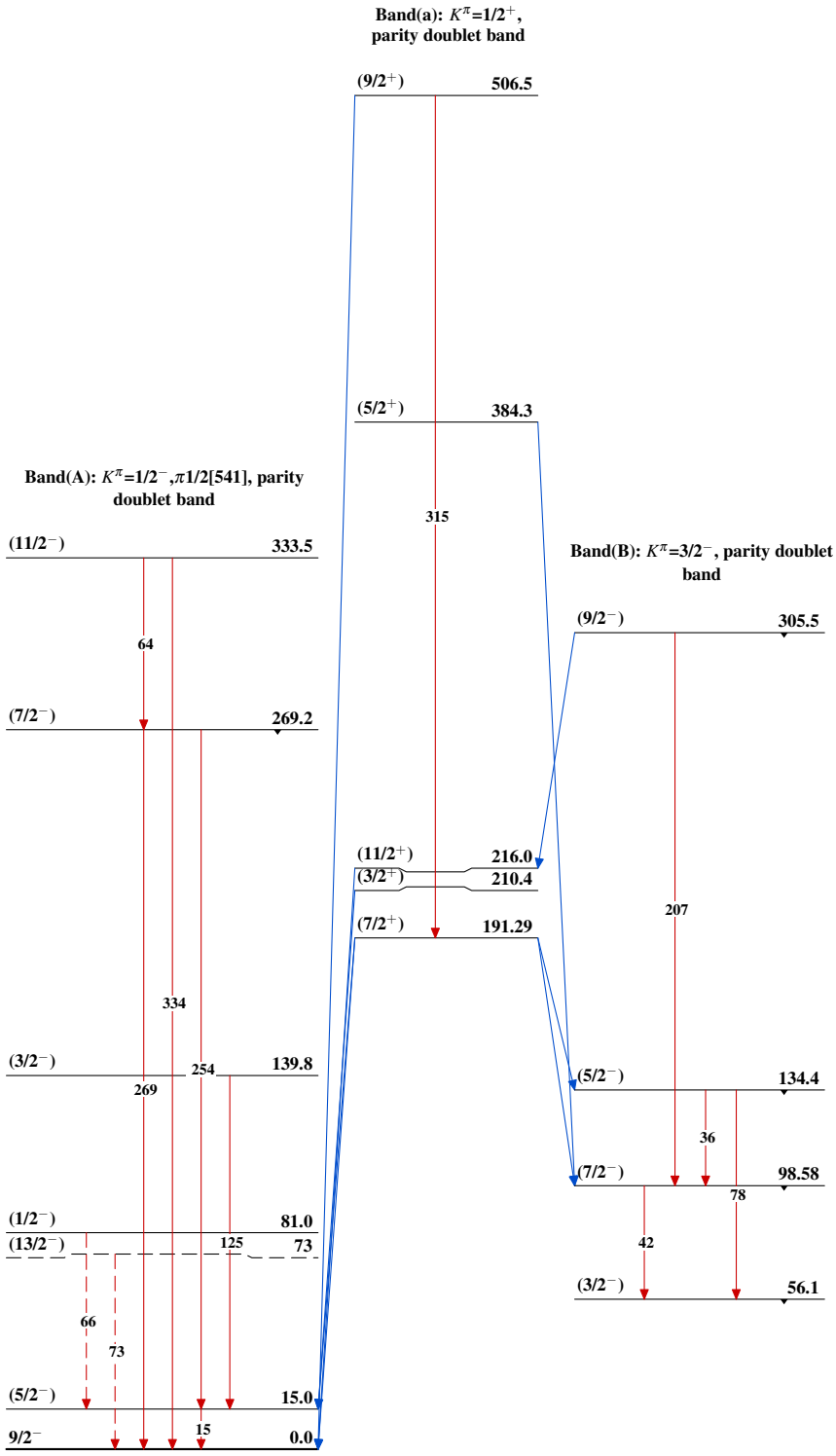


Eα	Iα	HF
5892	0.0099	14
5966.8	0.0297	10
6023.0	0.0099	56
6082.7	0.0297	36
6134.9	0.12	16
6140.2	≈0.0297	≈66
6163.0	0.0495	50
6177.7	0.94	3.1
6205.9	≈0.0297	≈131
6223.4	≈0.00594	≈781
6235.8	0.0891	59
6281.3	≈0.0495	≈170
6294	0.070	130
6292.8	0.47	21
6299	0.073	135
6325.7	0.30	44
6332.5	0.14	100
6360.5	0.22	85
6396.8	0.13	205
6448.6	0.20	220
6454.7	0.06	780
6473.0	3.1	18
6523.2	0.6	150
6528.4	3.1	31
6563.7	13.6	9.7
6581.8	0.4	520
6590	<0.0099	>16.4
6606	<0.99	>190
6646.7	44	6.4
6661.6	31	10

$^{219}_{87}Fr_{132}$

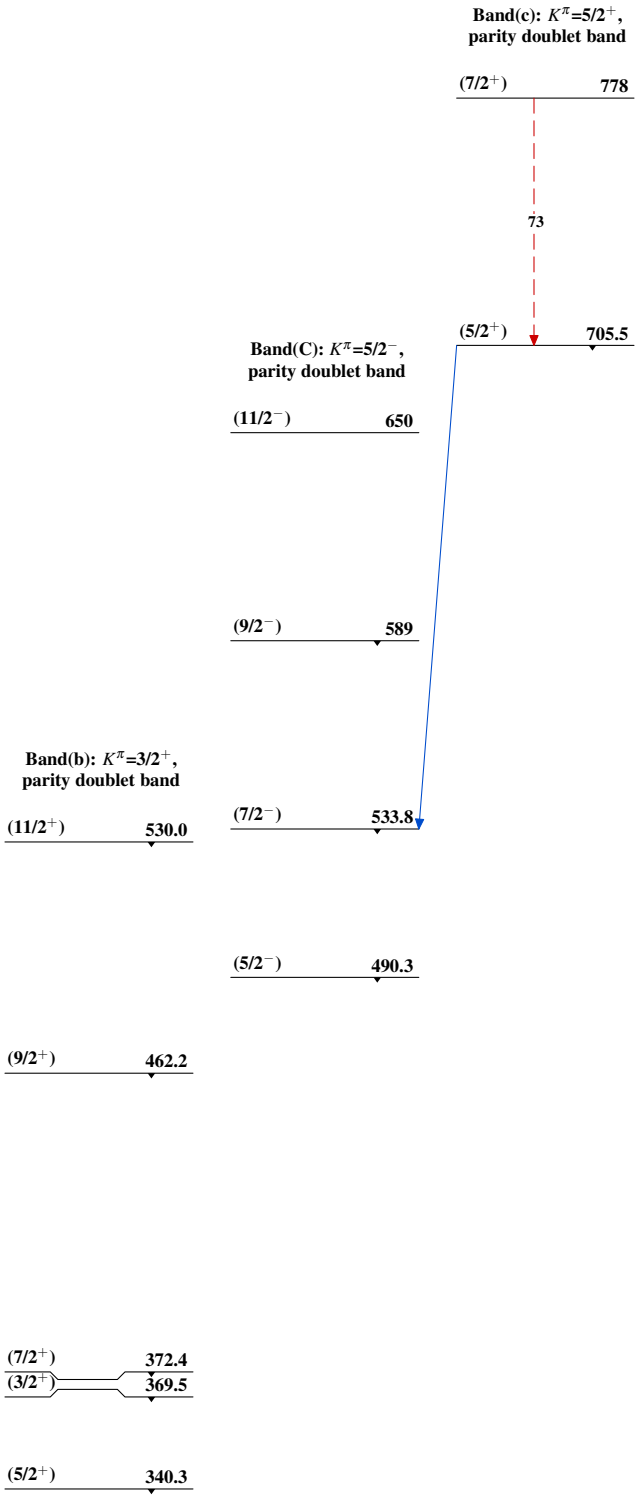
$^{219}_{87}Fr_{132}$-10

^{223}Ac α decay (2.10 min) 1991Li19,1969LeZW



$^{219}_{87}Fr_{132}$

^{223}Ac α decay (2.10 min) 1991Li19,1969LeZW (continued)



$^{219}_{87}Fr_{132}$