^{209}Bi(^{13}C,3nγ) 1994Cr01,1986Dr07,1985Kh01

History

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

Includes ^{208}Pb(^{15}N,4nγ) from 1985Kh01.

1994Cr01: E=67 MeV. Measured Eγ, Iγ, $\gamma\gamma$-coin, $\gamma\gamma(\theta)$(DCO) using an array of 19 Compton-suppressed Ge and 50 NaI(Tl) detectors. Deduced high-spin levels, J^π, multipolarities, mixing ratios, B(E1)/B(E2) and B(M1)/B(E2) ratios, alternating parity bands typical of reflection asymmetry.

1986Dr07, 1985Dr02: E=60-73 MeV from Yale tandem accelerator. Measured Eγ, Iγ, $\gamma\gamma$- and $\gamma\alpha$-coin, $\gamma(\theta)$ for θ=0° to 90° in 15° increments using 67-MeV projectiles, γ-ray and α-particle excitation functions. Deduced high-spin levels, J^π, multipolarities and mixing ratios, alternating parity bands. Unsuccessful attempt to determine the electric or magnetic nature of γ-ray transitions by measuring γ-ray linear polarizations. Detectors: Ge(Li), HPGe, Si.

1985Kh01: ^{209}Bi(^{13}C,3nγ), ^{208}Pb(^{15}N,4nγ). E(^{13}C)=63-73 MeV. Measured Eγ, Iγ, $\gamma\gamma$-coin, $\gamma\gamma$(t), $\gamma(\theta)$. Deduced γ-ray multipolarities. Detectors: Ge(Li) and NaI multiplicity filter. The γ-ray energy uncertainties, intensities and coefficients A_2 and A_4 from $\gamma(\theta)$ are not provided by the authors.

^{219}Ac Levels

^{219}Ac appears to be in the transitional region between nuclei with mainly single-particle excitations, and those dominated by deformed collective excitations. The similarity between the level structure of ^{219}Ac and that of the N=130 isotones ^{218}Ra and ^{220}Th suggest that low-spin levels in ^{219}Ac may be interpreted in terms of a weak coupling of a proton in the $h_{9/2}$ shell to the ^{218}Ra core. The strongly enhanced E1 transitions observed in ^{219}Ac support this interpretation (1986Dr07). The parity-doublet structure that has been established at low energies surprisingly terminates at 2149 keV (J^π=31/2$^+$), breaking up into a new family of states of possibly particle-hole character (1994Cr01). Levels in ^{219}Ac are grouped into four rotational bands characterized by the *simplex* quantum number (s), and the parity (π), and based mainly on the proton configuration $h_{9/2}$. Other rotational bands are, most probably, based on single proton configurations (1994Cr01).

1985Kh01 assigned the 577 level as the first member of the (I,+) rotational band, and did not observe the 926, 1293, 1461 and 2129 levels.

In band labels, s=simplex quantum number with values of s=+i having 11/2$^-$, 13/2$^+$, 15/2$^-$,... and s=−i having 15/2$^+$, 17/2$^-$, 19/2$^+$, 21/2$^-$..., involved in reflection asymmetric or parity-doublet band structures.

E(level)[†]	J^{π}[#]	$T_{1/2}$[@]	Comments
0.0[f]	9/2$^-$	11.8 μs *15*	J^π,$T_{1/2}$: from Adopted Levels.
340.95[d] *8*	11/2$^-$		
355.29[f] *8*	13/2$^-$		
576.93[e] *9*	13/2$^+$		
631.31[h] *11*	(13/2$^+$)		
657.66[d] *9*	15/2$^-$		B(M1,302.5γ)/B(E2,316.6γ)=0.025 *10* (1994Cr01).
714.62[f] *11*	17/2$^-$		
866.62[e] *12*	17/2$^+$		
926.50[h] *11*	17/2$^+$		
965.31[g] *12*	19/2$^+$		
1017.64[d] *11*	19/2$^-$		
1116.08[f] *12*	21/2$^-$		B(E1,150.8γ)/B(E2,401.5γ) in W.u.=0.00011 *2* (1986Dr07).
1180.71[&] *14*	(19/2$^-$)		
1183.05[e] *13*	21/2$^+$		B(M1,217.8γ)/B(E2,316.5γ)=0.048 *17* (1994Cr01).
1292.65[h] *14*	21/2$^+$		
1301.01[g] *13*	23/2$^+$		B(E1,185.0γ)/B(E2,335.7γ) in W.u.=0.00011 *1* (1986Dr07).
1413.74[d] *13*	23/2$^-$		
1461.51?[‡] *19*			

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^{209}Bi(^{13}C,3nγ) 1994Cr01,1986Dr07,1985Kh01 (continued)

^{219}Ac Levels (continued)

E(level)[†]	Jπ[#]	Comments
1547.04[e] 13	25/2+	B(M1,246.0γ)/B(E2,364.0γ)=0.075 4 (1994Cr01). B(E1,133.3γ)/B(E2,364.0γ) in W.u.=0.000072 5 (1986Dr07).
1551.57[f] 14	25/2−	
1551.67[&] 16	(23/2−)	
1698.82[g] 14	27/2+	B(E1,147.3γ)/B(E2,397.7γ) in W.u.=0.000036 7 (1986Dr07).
1698.82+x[c]	J	
1699.90?[a] 17	(25/2+)	
1710.42[h] 16	25/2+	
1813.04[d] 14	27/2−	Stretched configuration=$\nu(g_{9/2},i_{11/2})\otimes\pi f_{7/2}$ (1994Cr01).
1959.32[e] 14	29/2+	B(M1,260.5γ)/B(E2,412.3γ)=0.116 12 (1994Cr01). B(E1,146.5γ)/B(E2,412.3γ) in W.u.=0.000065 15 (1986Dr07). Stretched configuration=$\nu g^2_{9/2}\otimes\pi i_{13/2}$ (1994Cr01).
2023.91[f] 15	29/2−	
2113.76?[a] 20	(29/2+)	
2129.5?[‡] 4	29/2−	
2149.32[g] 16	31/2+	
2178.0+x[c] 1	(J+2)	
2244.86[d] 15	31/2−	
2351.21[e] 18	33/2+	Stretched configuration=$\nu(g_{9/2},i_{11/2})\otimes\pi i_{13/2}$ (1994Cr01).
2401.30[i] 18	(33/2−)	
2427.62[b] 24	33/2+	
2444.55[b] 17	33/2+	
2734.1+x[c] 2	(J+4)	
2806.15[e] 19	37/2+	
2834.85[i] 22	(37/2−)	
2836.8[b] 3	37/2+	
3249.07[e] 22	41/2+	
3254.21[i] 24	(41/2−)	Stretched configuration=$\nu(g_{9/2},i_{11/2})\otimes\pi h_{9/2}$ (1994Cr01).
3720.5[i] 3	(45/2−)	

[†] Deduced by evaluators from a least-squares fit to γ-ray energies, by assuming a minimum uncertainty of 0.10 keV in Eγ value with the result that reduced χ^2 of the fit is 3.4 somewhat higher than critical χ^2 of 1.7 at 95% confidence level, but with no γ-ray energies deviating by more than 3σ values. Without this adjustment, least-squares fit is unacceptable, resulting in reduced χ^2 of 32 and many γ rays deviating in energy by more than 3 or 4 σ values. In the opinion of evaluators, quoted uncertainties in 1994Cr01 (several Eγ values with 0.01 keV uncertainty and many with below 0.1 keV) are atypical of general uncertainties in literature for gamma-ray spectroscopy in heavy-ion fusion reactions. Perhaps, the uncertainties given in 1994Cr01 are only from statistical fit of gamma-ray peaks, and do not include systematic uncertainties.

[‡] Level not confirmed by 1994Cr01 by γγ coincidence, although the authors observe a 535-668 γ cascade, and it is in coincidence with a 348.5γ but not in coincidence with 236γ and 269γ as would be expected if the placement of the cascade in 1986Dr07 were correct.

[#] As proposed by 1994Cr01 based on multipolarities deduced from γγ(θ)(DCO) data, band structures, decay pattern of yrast-type population of levels in heavy-ion fusion reactions, and previously suggested J^π values in 1986Dr07 and 1985Kh01.

[@] For excited states, no lifetime of ≥10 ns was observed (1985Kh01). The authors probably meant mean lifetimes.

[&] Group of two levels with J^π=(19/2−) and (21/2−); connected to members of side band based on (13/2+).

[a] Group of two tentative levels of J^π=(25/2+) and (29/2+).

[b] Group of three levels with J^π=33/2+, 33/2+ and 37/2+; two of which may be part of a band.

[c] γ cascade.

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^{209}Bi(^{13}C,3nγ) 1994Cr01,1986Dr07,1985Kh01 (continued)

^{219}Ac Levels (continued)

[d] Band(A): (s=+i,π=−) band. B(E1)/B(E2) values in fm^{-2} units range from 0.4×10^{-6} to 3.0×10^{-6} for 15/2 to 31/2 levels (1994Cr01).

[e] Band(a): (s=+i,π=+) band. B(E1)/B(E2) values in fm^{-2} units range from 0.4×10^{-6} to 3.0×10^{-6} for 15/2 to 31/2 levels (1994Cr01).

[f] Band(B): (s=−i,π=−) band. B(E1)/B(E2) values in fm^{-2} units range from 0.4×10^{-6} to 3.0×10^{-6} for 21/2 to 29/2 levels (1994Cr01).

[g] Band(b): (s=−i,π=+) band. B(E1)/B(E2) values in fm^{-2} units range from 0.4×10^{-6} to 3.0×10^{-6} for 21/2 to 29/2 levels, except for 31/2 level for which value is 5.0×10^{-6} (1994Cr01).

[h] Band(C): Side band based on ($13/2^+$). This band has interconnecting transitions to ($19/2^-$) and ($21/2^-$) levels.

[i] Band(D): Band based on ($33/2^-$).

γ(^{219}Ac)

A_2 and A_4 coefficients are from γ(θ) data of 1986Dr07, and DCO values are from 1994Cr01. The DCO values were measured at angles of (63°,117°) and (24°,156°) for any two gamma rays in a cascade. With gates on ΔJ=2, quadrupole (E2) transitions, expected DCO is ≈1 for stretched quadrupoles (assigned as E2 by 1994Cr01) and ≈0.67 for stretched pure dipoles (assigned as E1 by 1994Cr01). Values of DCO, other than the above two, are classified as ΔJ=1, M1+E2 below 300 keV and ΔJ=2, E2 above 400 keV.

E_γ[†]	I_γ[†]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[a]	α[c]	$I_{(\gamma+ce)}$	Comments
(x)		1698.82+x	J	1698.82	27/2+				
(x)		2178.0+x	(J+2)	2149.32	31/2+				
57.24 *3*		714.62	17/2−	657.66	15/2−	(M1+E2)	82 *65*	19.2 *6*	DCO=0.86 *9* α(L)=61 *48*; α(M)=16 *14* α(N)=4.3 *35*; α(O)=0.95 *76*; α(P)=0.15 *12*; α(Q)=0.0020 *13* $I_{(\gamma+ce)}$: evaluators assume that the quoted intensity of 19.2 *6* is the transition intensity, otherwise there is a large negative intensity balance at the 658 level, assuming, of course, that the placement of the 57.24γ in 1994Cr01 and 1985Kh01 is correct. Eγ=56.6 (1985Kh01).
(67)		1183.05	21/2+	1116.08	21/2−				
80.86 *2*	6.1 *3*	657.66	15/2−	576.93	13/2+	(E1)	0.200		DCO=0.74 *22* α(L)=0.1511 *22*; α(M)=0.0367 *6* α(N)=0.00957 *14*; α(O)=0.00212 *3*; α(P)=0.000349 *5*; α(Q)=1.783×10^{-5} *25* Eγ=80.8 (1985Kh01).
106.01 *2*		2351.21	33/2+	2244.86	31/2−	[E1]	0.0976		E_γ: this γ forms a doublet with Ac Kβ_2 x ray (1994Cr01), thus no intensity is given. Eγ=106.3 (1985Kh01).
111.67[‡] *11*	4.6 *5*	1292.65	21/2+	1180.71	(19/2−)	[E1]	0.371		α(K)=0.286 *4*; α(L)=0.0644 *10*; α(M)=0.01557 *23* α(N)=0.00407 *6*; α(O)=0.000910 *13*; α(P)=0.0001537 *22*; α(Q)=8.72×10^{-6} *13*
125.43 *3*	5.1 *2*	2149.32	31/2+	2023.91	29/2−	(E1)	0.282		DCO=0.73 *8* α(K)=0.219 *3*; α(L)=0.0475 *7*; α(M)=0.01147 *16* α(N)=0.00300 *5*; α(O)=0.000673 *10*; α(P)=0.0001145 *16*; α(Q)=6.73×10^{-6} *10* Eγ=125.3 (1985Kh01).
133.27 *1*	17.7 *2*	1547.04	25/2+	1413.74	23/2−	(E1)	0.244		DCO=0.68 *2*; A_2=−0.34 *7*; A_4=−0.02 *9* α(K)=0.190 *3*; α(L)=0.0406 *6*; α(M)=0.00979 *14* α(N)=0.00257 *4*; α(O)=0.000576 *8*; α(P)=9.83×10^{-5} *14*; α(Q)=5.87×10^{-6} *9* Eγ=133.39 *15*, Iγ=15 *1* (1986Dr07). Eγ=133.3 (1985Kh01).
146.53 *6*	15.4 *22*	1959.32	29/2+	1813.04	27/2−	(E1)	0.194		DCO=0.67 *2*; A_2=−0.07 *7*; A_4=−0.17 *9*

γ(^{219}Ac) (continued)

E_γ[†]	I_γ[†]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[a]	δ[b]	α[c]	Comments
									α(K)=0.1523 *22*; α(L)=0.0318 *5*; α(M)=0.00765 *11* α(N)=0.00201 *3*; α(O)=0.000451 *7*; α(P)=7.75×10^{-5} *11*; α(Q)=4.75×10^{-6} *7* DCO, A_2 and A_4 for 147.26+146.53 doublet. Note that A_4 is expected to be 0.0 for ΔJ=1, pure dipole. Eγ=146.90 *15*, Iγ=17 *1*, doublet (1986Dr07). Eγ=146.4 (1985Kh01).
147.26 *16*	5.4 *21*	1698.82	27/2$^+$	1551.57	25/2$^-$	(E1)		0.192	A_2=−0.07 *7*; A_4=−0.17 *9* α(K)=0.1505 *22*; α(L)=0.0314 *5*; α(M)=0.00755 *11* α(N)=0.00198 *3*; α(O)=0.000445 *7*; α(P)=7.65×10^{-5} *11*; α(Q)=4.70×10^{-6} *7* A_2 and A_4 for 147.26+146.3 doublet. Note that A_4 is expected to be 0.0 for ΔJ=1, pure dipole. Eγ=146.90 *15*, Iγ=17 *1*, doublet (1986Dr07). Eγ=147.5 (1985Kh01).
150.78 *5*	14.3 *24*	1116.08	21/2$^-$	965.31	19/2$^+$	(E1)		0.181	DCO=0.69 *2*; A_2=−0.10 *6*; A_4=−0.12 *9* α(K)=0.1424 *20*; α(L)=0.0295 *5*; α(M)=0.00711 *10* α(N)=0.00186 *3*; α(O)=0.000419 *6*; α(P)=7.21×10^{-5} *11*; α(Q)=4.46×10^{-6} *7* DCO, A_2 and A_4 for 150.99+150.78 doublet. Eγ=150.84 *15*, Iγ=41 *2* for doublet (1986Dr07). Eγ=150.6 (1985Kh01).
150.99[@] *2*	26.0 *25*	1017.64	19/2$^-$	866.62	17/2$^+$	(E1)		0.181	DCO=0.69 *2*; A_2=−0.10 *6*; A_4=−0.12 *9* α(K)=0.1419 *20*; α(L)=0.0294 *5*; α(M)=0.00708 *10* α(N)=0.00186 *3*; α(O)=0.000418 *6*; α(P)=7.19×10^{-5} *10*; α(Q)=4.44×10^{-6} *7* DCO, A_2 and A_4 for 150.99+150.78 doublet. Eγ=150.84 *15*, Iγ=41 *2*, doublet (1986Dr07). Eγ=150.9 (1985Kh01).
(153)		866.62	17/2$^+$	714.62	17/2$^-$				
156.44[‡] *6*	2.4 *3*	2401.30	(33/2$^-$)	2244.86	31/2$^-$	(M1+E2)		3.2 *16*	DCO=0.76 *12* α(K)=2.0 *18*; α(L)=0.85 *14*; α(M)=0.22 *5* α(N)=0.059 *13*; α(O)=0.013 *3*; α(P)=0.0022 *3*; α(Q)=9.7×10^{-5} *78*
158.74[‡] *8*	3.2 *3*	1710.42	25/2$^+$	1551.67	(23/2$^-$)	(E1)		0.1603	DCO=0.97 *35* α(K)=0.1261 *18*; α(L)=0.0259 *4*; α(M)=0.00622 *9* α(N)=0.001632 *23*; α(O)=0.000368 *6*; α(P)=6.35×10^{-5} *9*; α(Q)=3.97×10^{-6} *6*
165.29 *1*	34.2 *5*	1183.05	21/2$^+$	1017.64	19/2$^-$	(E1)		0.1454	DCO=0.67 *2*; A_2=−0.19 *7*; A_4=−0.09 *7* α(K)=0.1146 *16*; α(L)=0.0233 *4*; α(M)=0.00561 *8* α(N)=0.001471 *21*; α(O)=0.000332 *5*; α(P)=5.74×10^{-5} *8*; α(Q)=3.63×10^{-6} *5* Eγ=165.24 *15*, Iγ=34 *2* (1986Dr07). Eγ=165.3 (1985Kh01).
185.02 *1*	24.2 *5*	1301.01	23/2$^+$	1116.08	21/2$^-$	(E1)		0.1110	DCO=0.63 *14*; A_2=−0.19 *7*; A_4=−0.05 *7* Eγ=185.05 *15*, Iγ=24 *1* (1986Dr07). Eγ=185.0 (1985Kh01).
209.01 *1*	41.3 *3*	866.62	17/2$^+$	657.66	15/2$^-$	(E1)		0.0832	DCO=0.68 *2*; A_2=−0.18 *6*; A_4=−0.09 *7* Eγ=208.98 *15*, Iγ=40 *2* (1986Dr07). Eγ=209.1 (1985Kh01).

γ(^{219}Ac) (continued)

E_γ[†]	I_γ[†]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[a]	δ[b]	α[c]	Comments
217.87[‡] *23*	4.3 *15*	1183.05	21/2$^+$	965.31	19/2$^+$	(M1+E2)	−0.19 *9*	1.83 *6*	DCO=0.83 *7* α(K)=1.46 *6*; α(L)=0.280 *5*; α(M)=0.0673 *10* α(N)=0.0179 *3*; α(O)=0.00415 *7*; α(P)=0.000764 *13*; α(Q)=6.61×10^{-5} *25*
221.63 *7*	5.2 *4*	576.93	13/2$^+$	355.29	13/2$^-$	(E1)		0.0725	DCO=1.13 *16* Mult.: ΔJ=0 transition; DCO value for ΔJ=0, dipole is about the same as for ΔJ=2, quadrupole transitions. Eγ=221.5 (1985Kh01).
230.59 *2*	37.2 *9*	1413.74	23/2$^-$	1183.05	21/2$^+$	(E1)		0.0660	DCO=0.64 *2*; A_2=−0.23 *7*; A_4=+0.10 *10* Eγ=230.65 *15*, Iγ=29 *1* (1986Dr07). Eγ=230.7 (1985Kh01).
235.86 *3*	15.0 *7*	576.93	13/2$^+$	340.95	11/2$^-$	(E1)		0.0627	DCO=0.69 *4*; A_2=−0.15 *7*; A_4=−0.03 *7* Eγ=235.89 *15*, Iγ=20 *1* (1986Dr07). Eγ=235.9 (1985Kh01).
246.04[‡] *2*	4.9 *2*	1547.04	25/2$^+$	1301.01	23/2$^+$	M1+E2	−0.23 *5*	1.29 *3*	DCO=0.89 *7* α(K)=1.03 *3*; α(L)=0.197 *3*; α(M)=0.0475 *7* α(N)=0.01260 *19*; α(O)=0.00292 *5*; α(P)=0.000538 *9*; α(Q)=4.63×10^{-5} *12*
250.72[d] *1*	30.9[d@] *9*	965.31	19/2$^+$	714.62	17/2$^-$	(E1)		0.0544	DCO=0.66 *1*; A_2=−0.22 *6*; A_4=+0.01 *6* DCO, A_2, A_4 for 250.72 doublet, both ΔJ=1, dipole (E1). Eγ=250.70 *15*, Iγ=52 *2*, doublet (1986Dr07). Eγ=250.7 (1985Kh01).
250.72[d] *1*	18.6[d@] *8*	1551.57	25/2$^-$	1301.01	23/2$^+$	(E1)		0.0544	Mult.: see A_2, A_4 and DCO with the second placement from 965 level. Eγ=250.4 (1985Kh01).
253.98[‡] *1*	6.9 *2*	1180.71	(19/2$^-$)	926.50	17/2$^+$	(E1)		0.0528	DCO=0.74 *17*
259.01[‡] *6*	4.3 *3*	1551.67	(23/2$^-$)	1292.65	21/2$^+$	(E1)		0.0505	DCO=0.57 *23*
260.50 *5*	4.9 *3*	1959.32	29/2$^+$	1698.82	27/2$^+$	M1+E2	−0.50 *10*	0.96 *6*	DCO=1.21 *12* α(K)=0.75 *6*; α(L)=0.159 *5*; α(M)=0.0388 *9* α(N)=0.01029 *23*; α(O)=0.00237 *6*; α(P)=0.000431 *13*; α(Q)=3.41×10^{-5} *24* Eγ=260.5 (1985Kh01).
265.96 *1*	23.3 *3*	1813.04	27/2$^-$	1547.04	25/2$^+$	(E1)		0.0475	DCO=0.66 *2*; A_2=−0.13 *7*; A_4=−0.02 *7* Eγ=265.93 *15*, Iγ=17 *1* (1986Dr07). Eγ=266.0 (1985Kh01).
268.77 *3*	11.0 *3*	926.50	17/2$^+$	657.66	15/2$^-$	(E1)		0.0464	DCO=0.68 *3* Eγ=268.95 *15*, Iγ=7 *2*, isotropic γ(θ) (1986Dr07).
285.73 *2*	7.5 *3*	2244.86	31/2$^-$	1959.32	29/2$^+$	(E1)		0.0404	DCO=0.64 *3*; A_2=−0.34 *8*; A_4=+0.04 *10* Eγ=285.28 *15*, Iγ=4.8 *3* (1986Dr07). Eγ=285.6 (1985Kh01).
289.09 *13*	2.8 *3*	866.62	17/2$^+$	576.93	13/2$^+$	(E2)		0.179	DCO=0.93 *14* Eγ=290.0 (1985Kh01).
290.61[‡] *4*	7.7 *6*	631.31	(13/2$^+$)	340.95	11/2$^-$	(E1)		0.0388	DCO=0.74 *8* Initial level J^π=(13/2$^-$) in Table I of 1994Cr01 seems a misprint.

γ(^{219}Ac) (continued)

E_γ [†]	I_γ [†]	E_i(level)	J^π_i	E_f	J^π_f	Mult. [a]	δ [b]	α [c]	Comments
295.45[‡] *6*	2.9 *3*	926.50	17/2$^+$	631.31	(13/2$^+$)	(E2)		0.1677	DCO=0.99 *14* Final level J^π=(13/2$^-$) in Table I of 1994Cr01 seems a misprint.
302.53[@] *5*	25.0 *10*	657.66	15/2$^-$	355.29	13/2$^-$	M1+E2	−1.0 *4*	0.46 *15*	DCO=1.29 *3*; A_2=+0.43 *6*; A_4=+0.06 *7* α(K)=0.34 *13*; α(L)=0.088 *12*; α(M)=0.0219 *25* α(N)=0.0058 *7*; α(O)=0.00133 *16*; α(P)=0.00023 *4*; α(Q)=1.54×10^{-5} *56* Eγ=302.49 *15*, Iγ=32 *1* (1986Dr07). Eγ=302.4 (1985Kh01).
303.6[@] *5*	4.0 *10*	1017.64	19/2$^-$	714.62	17/2$^-$				Eγ=303.3 (1985Kh01).
316.5[@]	18.5[@] *16*	1183.05	21/2$^+$	866.62	17/2$^+$	E2		0.1363	DCO=1.07 *9*; A_2=+0.28 *5*; A_4=−0.18 *6* A_2 and A_4 for a doublet. Eγ=316.61 *15*, Iγ=50 *1*, doublet (1986Dr07). Eγ=316.4 (1985Kh01).
316.64 *1*	39.8[@] *17*	657.66	15/2$^-$	340.95	11/2$^-$	E2		0.1362	DCO=1.01 *4*; A_2=+0.28 *5*; A_4=−0.18 *6* A_2 and A_4 for a doublet. Eγ=316.61 *15*, Iγ=50 *1*, doublet (1986Dr07). Eγ=316.6 (1985Kh01).
325.04 *5*	5.3 *4*	2023.91	29/2$^-$	1698.82	27/2$^+$	(E1)			DCO=0.62 *5* Eγ=325.38 *15* (1986Dr07). Eγ=324.9 (1985Kh01).
335.68 *4*	4.8 *4*	1301.01	23/2$^+$	965.31	19/2$^+$	E2		0.1148	DCO=1.12 *12*; A_2=+0.36 *6*; A_4=−0.16 *17* Eγ=335.67 *15*, Iγ=3.8 *3* (1986Dr07). Eγ=335.8 (1985Kh01).
341.01 *1*	74.2 *7*	340.95	11/2$^-$	0.0	9/2$^-$	M1+E2	−0.26 *2*	0.516 *9*	DCO=0.88 *2*; A_2=+0.10 *5*; A_4=+0.06 *6* α(K)=0.413 *7*; α(L)=0.0784 *12*; α(M)=0.0188 *3* α(N)=0.00499 *8*; α(O)=0.001159 *17*; α(P)=0.000214 *4*; α(Q)=1.85×10^{-5} *3* δ: weighted average of −0.26 *2* from DCO (1994Cr01) and 0.25 *5* from γ(θ) (1986Dr07). Eγ=341.01 *15*, Iγ=82 *4* (1986Dr07). Eγ=340.8 (1985Kh01).
[x]348.5									This γ seen only in γγ-coin data (1994Cr01).
349.39 *4*	7.0 *5*	926.50	17/2$^+$	576.93	13/2$^+$	E2		0.1025	DCO=1.00 *8*; A_2=+0.13 *7*; A_4=−0.11 *9* Eγ=349.48 *15*, Iγ=11 *1* (1986Dr07).
355.23 *1*	100.0 *9*	355.29	13/2$^-$	0.0	9/2$^-$	E2		0.0978	DCO=1.01 *3*; A_2=+0.25 *5*; A_4=−0.07 *6* Eγ=355.19 *15*, Iγ=100 *4* (1986Dr07). Eγ=355.1 (1985Kh01).
359.11 *3*	57.2 *38*	714.62	17/2$^-$	355.29	13/2$^-$	E2		0.0949	DCO=1.00 *3*; A_2=+0.24 *6*; A_4=−0.12 *9* DCO for 359.11γ+359.96γ. Eγ=359.21 *15*, Iγ=78 *4* (1986Dr07); Iγ is probably for a doublet. Eγ=359.0 (1985Kh01).
359.96 *7*	23.5 *37*	1017.64	19/2$^-$	657.66	15/2$^-$	E2		0.0943	DCO=1.00 *3* DCO for 359.11γ+359.96γ. Eγ=360.0 *3*, part of 359.21 doublet (1986Dr07). Eγ=360.2 (1985Kh01).
364.01 *2*	18.4 *5*	1547.04	25/2$^+$	1183.05	21/2$^+$	E2		0.0914	DCO=0.99 *8*; A_2=+0.27 *6*; A_4=−0.10 *7* Eγ=363.99 *15*, Iγ=14 *1* (1986Dr07). Eγ=364.1 (1985Kh01).

γ(^{219}Ac) (continued)

E_γ[†]	I_γ[†]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[a]	α[c]	Comments
366.37 *4*	11.5 *5*	1292.65	21/2+	926.50	17/2+	E2	0.0898	DCO=1.05 *7*; A_2=+0.40 *6*; A_4=−0.23 *9* Eγ=366.44 *15*, Iγ=11 *1* (1986Dr07).
391.98 *2*	6.5 *2*	2351.21	33/2+	1959.32	29/2+	E2	0.0748	DCO=1.09 *11* Eγ=391.8 (1985Kh01).
396.19 *3*	8.9 *2*	1413.74	23/2−	1017.64	19/2−	E2	0.0727	DCO=1.07 *9* Eγ=396.0 *3*, part of 397.6 doublet (1986Dr07). Eγ=396.1 (1985Kh01).
397.74 *3*	12.8 *3*	1698.82	27/2+	1301.01	23/2+	E2	0.0720	DCO=0.98 *8*; A_2=+0.18 *7*; A_4=−0.05 *9* Eγ=397.61 *15*, Iγ=20 *1* (1986Dr07). Eγ=397.9 (1985Kh01).
399.31 *6*	3.9 *2*	1813.04	27/2−	1413.74	23/2−	(E2)	0.0712	DCO=0.93 *21* Eγ=399.5 (1985Kh01).
401.46 *1*	18.6 *3*	1116.08	21/2−	714.62	17/2−	E2	0.0702	DCO=0.99 *3*; A_2=+0.21 *6*; A_4=−0.06 *7* Eγ=401.54 *15*, Iγ=17 *1* (1986Dr07). Eγ=401.6 (1985Kh01).
407.25[‡e] *3*	4.0 *1*	1699.90?	(25/2+)	1292.65	21/2+	(E2)	0.0676	DCO=1.06 *20*
409.14[‡] *6*	1.9 *1*	2836.8	37/2+	2427.62	33/2+	(E2)	0.0668	DCO=0.96 *25*
412.30 *1*	15.5 *3*	1959.32	29/2+	1547.04	25/2+	E2	0.0655	DCO=0.95 *5*; A_2=+0.22 *9*; A_4=−0.03 *11* Eγ=412.27 *15*, Iγ=11 *1* (1986Dr07). Eγ=412.2 (1985Kh01).
413.86[‡e] *10*	2.2 *2*	2113.76?	(29/2+)	1699.90?	(25/2+)	(E2)	0.0649	DCO=1.40 *47*
417.78[‡] *2*	8.3 *3*	1710.42	25/2+	1292.65	21/2+	E2	0.0633	DCO=0.94 *8*
419.36[‡] *6*	2.5 *1*	3254.21	(41/2−)	2834.85	(37/2−)	(E2)	0.0627	DCO=1.19 *29*
431.53 *10*	3.3 *2*	2244.86	31/2−	1813.04	27/2−	[E2]	0.0583	DCO=0.71 *12* Mult.: E2 implied from ΔJ^π in 1994Cr01, but DCO is typical of ΔJ=1, dipole. Eγ=432.2 (1985Kh01).
433.55[‡] *12*	4.9 *3*	2834.85	(37/2−)	2401.30	(33/2−)	(E2)	0.0576	DCO=0.92 *15*
435.42 *5*	8.5 *5*	1551.57	25/2−	1116.08	21/2−	E2	0.0570	DCO=0.94 *8*; A_2=+0.38 *41*; A_4=+0.01 *90* Eγ=436.30 *15*, Iγ=2 *1* (1986Dr07). Eγ=435.2 (1985Kh01).
442.92[‡] *6*	2.6 *2*	3249.07	41/2+	2806.15	37/2+	(E2)	0.0546	DCO=0.95 *25*
450.47 *3*	7.5 *4*	2149.32	31/2+	1698.82	27/2+	E2	0.0523	DCO=0.90 *7*; A_2=+0.38 *12*; A_4=−0.25 *15* Eγ=450.1 *2*, Iγ=3.5 *2* (1986Dr07). Eγ=450.3 (1985Kh01).
454.94[‡] *3*	6.8 *3*	2806.15	37/2+	2351.21	33/2+	(E2)		DCO=0.88 *10*
466.27[‡] *8*	2.1 *2*	3720.5	(45/2−)	3254.21	(41/2−)	(E2)	0.0481	DCO=1.17 *42*
468.3[‡] *2*	6.1 *2*	2427.62	33/2+	1959.32	29/2+	(E2)	0.0475	DCO=0.89 *13*
472.57[‡] *18*	1.4 *3*	2023.91	29/2−	1551.57	25/2−			
479.17[‡] *3*	5.0 *2*	2178.0+x	(J+2)	1698.82+x	J	E2		DCO=0.93 *9*
485.23[‡] *8*	1.6 *1*	2444.55	33/2+	1959.32	29/2+	(E2)	0.0436	DCO=0.94 *19*
535.01[#&e] *15*	1.8[#] *1*	1461.51?		926.50	17/2+	D		A_2=−0.09 *6*; A_4=+0.02 *9* Iγ: value of 18 *1* given by 1986Dr07 seems erroneous in view of statement by the authors in the text that this γ ray was very weak. Also this γ was not seen in the coincidence spectrum with gate at 236γ. Evaluators assume that there is a misprint in the quoted Iγ value and that it is possibly 1.8.

γ(^{219}Ac) (continued)

E_γ[†]	I_γ[†]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[a]	Comments
556.07[‡] *2*	3.4 *1*	2734.1+x	(J+4)	2178.0+x	(J+2)	E2	DCO=1.07 *11*
668.0[#&e] *3*	[#]	2129.5?	29/2$^-$	1461.51?			

[†] From 1994Cr01, unless otherwise stated. Corresponding values from 1986Dr07 and 1985Kh01 are listed under comments. Note that some of the uncertainties for Eγ values are underestimated, as suggested by large reduced χ^2 in least-squares fit to obtain level energies.

[‡] This γ ray observed by 1994Cr01 only.

[#] This γ ray observed by 1986Dr07 only.

[@] From $\gamma\gamma$ coin data in 1994Cr01.

[&] Placement not confirmed by 1994Cr01 by $\gamma\gamma$ coincidence, although the authors observe a 535-668 γ cascade, and it is in coincidence with a 348.5γ but not in coincidence with 236γ and 269γ as would be expected if the placement of the cascade in 1986Dr07 were correct. 1994Cr01 mention that the 535 and 668 gamma rays may not belong to ^{219}Ac level scheme.

[a] From $\gamma(\theta)$, $\gamma\gamma(\theta)$(DCO), and γ-ray transition intensity balance at each level (1985Kh01). All observed γ rays decay with lifetimes ≤10 ns (1985Kh01), which from RUL implies that the measured stretched quadrupole transitions are E2, not M2.

[b] From $\gamma\gamma(\theta)$(DCO) data (1994Cr01).

[c] 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.

[d] Multiply placed with intensity suitably divided.

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

[x] γ ray not placed in level scheme.

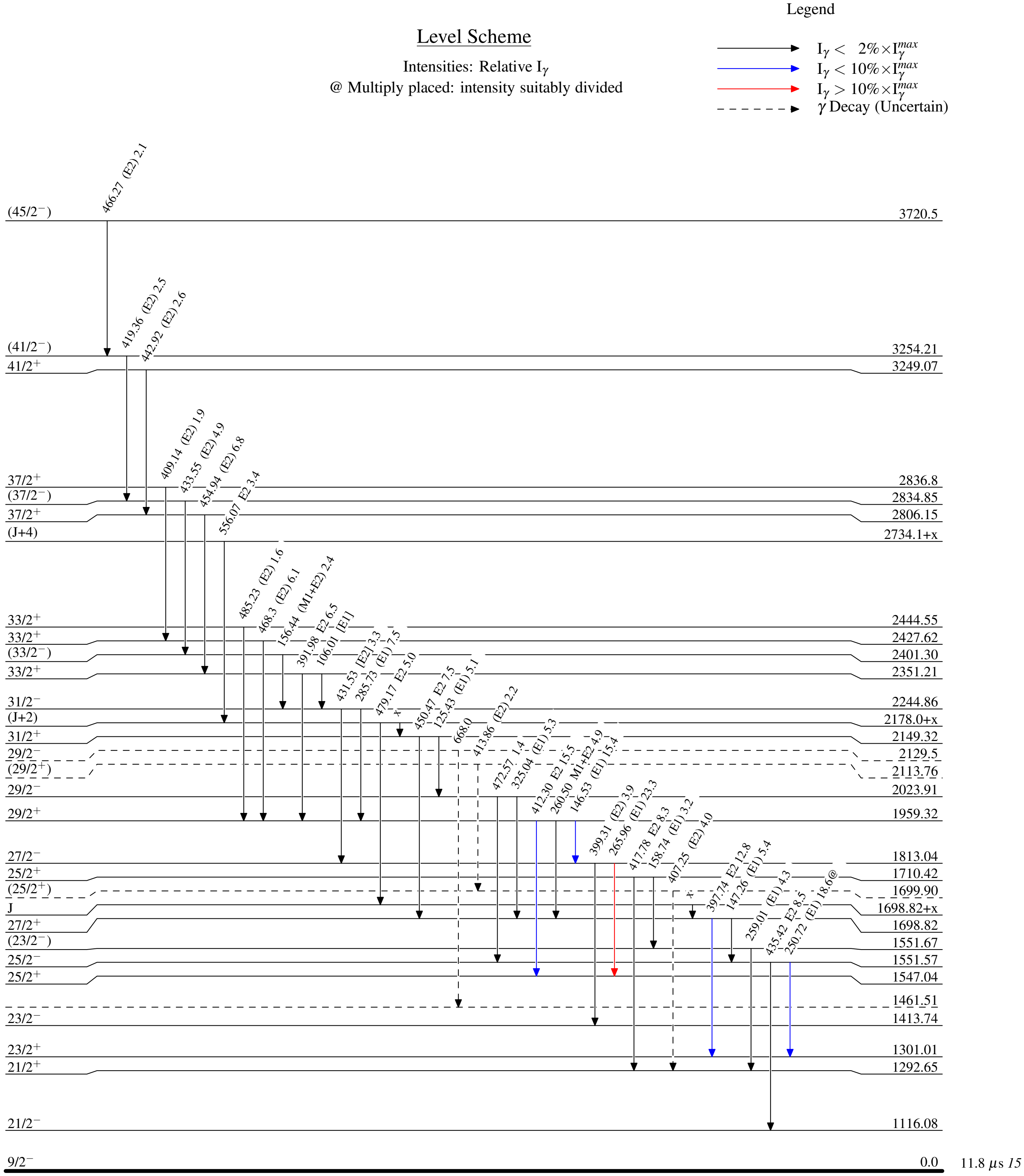
$^{219}_{89}$Ac$_{130}$-9

^{209}Bi(^{13}C,3nγ) 1994Cr01,1986Dr07,1985Kh01

Level Scheme

Intensities: Relative I_γ

@ Multiply placed: intensity suitably divided



$^{219}_{89}Ac_{130}$

^{209}Bi(^{13}C,3nγ) 1994Cr01,1986Dr07,1985Kh01

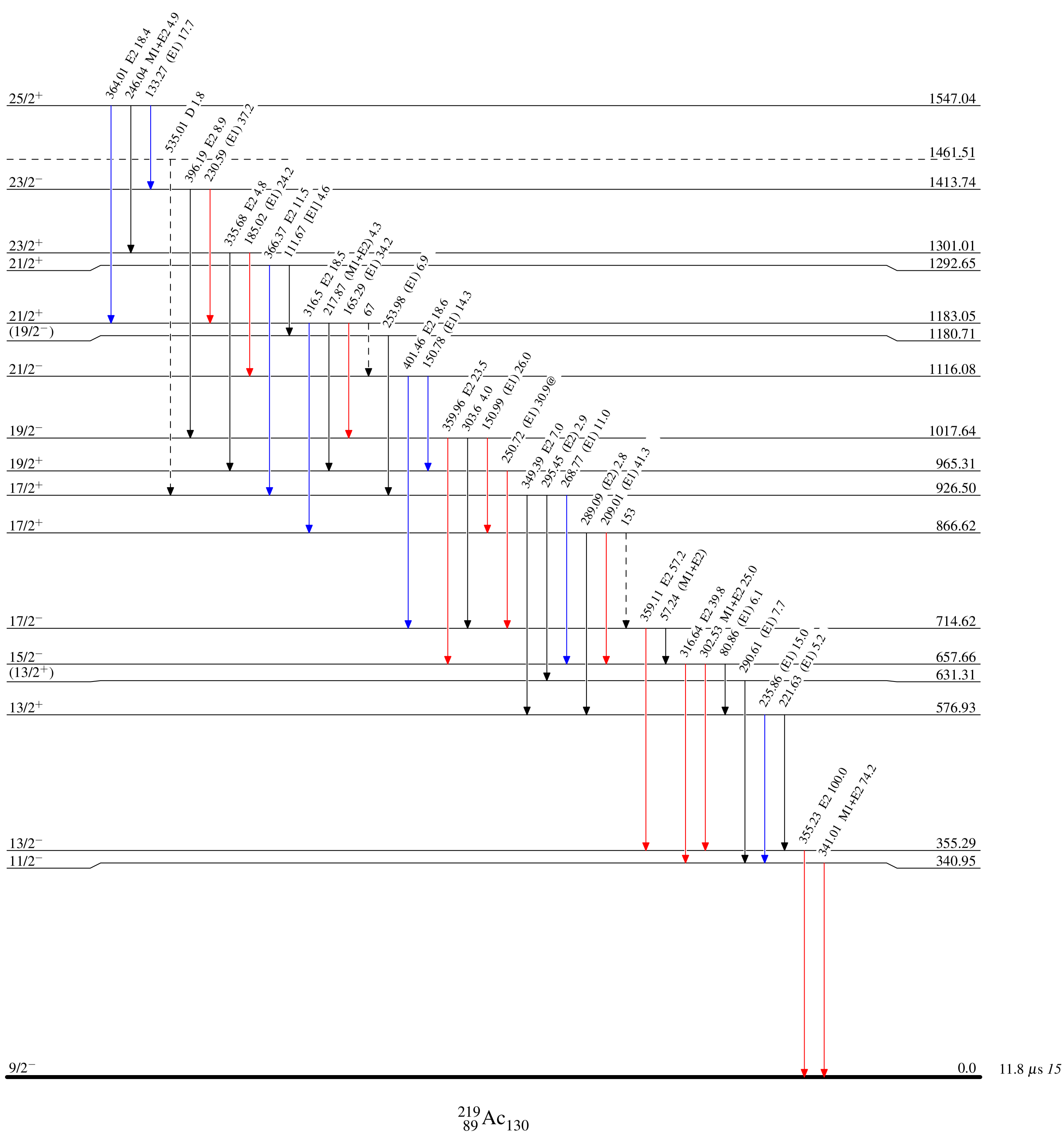
Level Scheme (continued)

Intensities: Relative I_γ

@ Multiply placed: intensity suitably divided

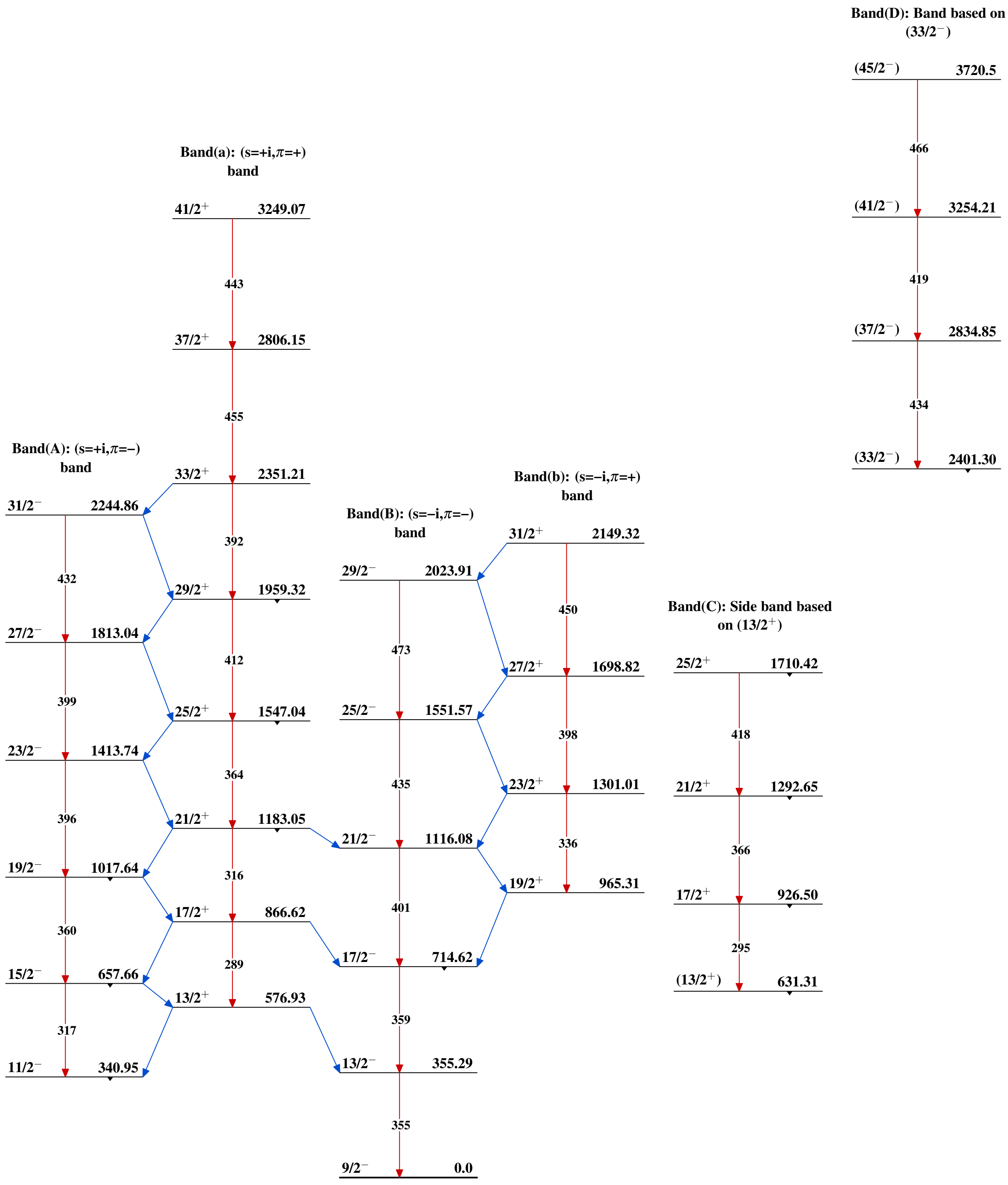
Legend

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



$^{219}_{89}Ac_{130}$

$^{209}Bi(^{13}C,3n\gamma)$ 1994Cr01,1986Dr07,1985Kh01



$^{219}_{89}Ac_{130}$