Coulomb excitation 1985Oh03,1969Tv01

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh and Jun Chen	NDS 191,1 (2023)	22-Aug-2023

See also another Coulomb excitation dataset from 1997Ge07 using ^{167}Er(^{209}Bi,^{209}Bi′γ),E=5.4 MeV/nucleon, with no B(E2) values deduced in that work.

1985Oh03 (also 1983Oh03): E(^{35}Cl)=160 MeV from 20-UR Tandem Accelerator of the JAERI. Beam energy was chosen somewhat higher than the Coulomb barrier in order to populate high-spin levels. Targets were 91.5% enriched metallic ^{167}Er. Measured Eγ, Iγ, γγ-coin, γ(θ) at seven angles from 0° to 90° in 15° steps, γγ(θ)(DCO) for 0° and 90° geometry, and level lifetimes by Doppler-shift attenuation measurements (DSAM) using Ge(Li) detector with Compton-suppression for singles γ spectrum. Deduced levels, multipolarities, mixing ratios, B(M1) and B(E2) from lifetime data for levels and γ transitions in the ground-state rotational band (ν7/2[633]) in ^{167}Er up to 25/2$^+$. Comparison with Coriolis band-mixing calculations.

1978Wo02: ^{167}Er(α,α′),E(α)=12 MeV from the University of Frankfurt Van de Graaff generator. Thin (10-30 μg/cm^2) >91.2% enriched targets of ^{167}Er. Measured Eα, Iα for ten levels, 7/2$^+$ to 15/2$^+$ in g.s. (ν7/2[633]) band, 3/2$^+$ and 5/2$^+$ members of ν3/2[651] band, 5/2$^+$ and 7/2$^+$ members of ν5/2[642] band, and 11/2$^+$ member of 11/2$^+$ γ-vibrational band. FWHM=21 keV. Deduced seven E2 and one E4 matrix elements from α-particle yields, and intrinsic quadrupole and hexadecapole moments.

1969Tv01: E(^{16}O)=36-52 MeV from the Niels Bohr Institute tandem accelerator, with most spectra taken at 48 MeV. Enriched thin self-supporting metallic targets of 1-2 mg/cm^2 thickness. Measured Eγ, Iγ, excitation functions, σ(Eγ), (^{16}O)γ-coin using Ge(Li) detectors. A total of 18 γ rays reported placed among ten excited states up to 874 keV, with ground-state rotational band (ν7/2[633]) 3/2$^+$, K-2, and 11/2$^+$ K+2 γ-vibrational bands.

Others:

1978Br20: ^{167}Er(α,α′),E(α)=9.0-13.5 MeV from the University of Pittsburgh Van de Graaff accelerator. Target thickness was ≈30 μg/cm^2 evaporated on 10 μg/cm^2 carbon backing. Measured Eα, Iα using Enge split-pole spectrograph with a position sensitive detector located in the focal plane. Deduced B(E2) for two excited states in the g.s. rotational band.

1971Da17: (α,α′ ce),E(α)=4.0 MeV. Measured lifetime of the 70-keV level by α(ce)(t), a modified microwave method. Deduced magnitude of g_K-g_R value.

1970Ga19: (^{14}N,^{14}N′γ),E=59 MeV. Measured Eγ, Iγ using Ge(Li) detector. Deduced B(M1) for three ΔJ=1 transitions in g.s. band.

1969Wi17: (p,p′γ),E=3 MeV from Tulane University Tandem Van de Graaff accelerator. Target was 87.2% enriched ^{167}Er. Measured Mossbauer effect for 79.3-keV γ ray and deduced line width, from which half-life of the 79.3-keV level was determined as ≥103 ps *6*, using α(total)(theory)=5.2 for the 79.3-keV γ ray.

1967As03: (^{16}O,^{16}O′γ). Measured lifetime of the 79-keV level by decay curve of (^{16}O)γ-coin.

1966Bo16: (^{16}O,^{16}O′γ),E=42-47 MeV. Measured Eγ, Iγ for 79.3, 177.6, 293.6 and 432.4 levels in the g.s. band, and γ-ray branching ratios from the 178 and 294 levels. Deduced (g_K-g_R), g_R and g_K values.

1966As02: (p,p′) E=2.4 MeV. Measured Eγ, γγ-coin, Xγ-coin, pγγ(θ). Deduced mixing ratios, conversion coefficients.

1962Go23: (p,p′) E=3.1-3.4 MeV protons from the Saclay accelerator. Measured Eγ, Iγ, pγ-coin, γ(θ). Deduced transition strengths.

1960Ol02: (p,p′),(d,d′) E=4.5 MeV. Measured Eγ, γ yields. Deduced transition strengths.

1959De29: (p,p′) E=4 MeV. Measured Eγ, Iγ, γ(θ). Deduced γ-ray transition strengths, mixing ratios.

1958Ch36: (e,e′) electron beam from the A-48 accelerator at UCRL, Livermore. Measured Eγ, γ-ray yields using a high-precision bent quartz crystal spectrograph.

1955He64: (α,α′) E=6 MeV. Measured Eγ, Iγ with a NaI(Tl) detector. Deduced B(E2).

The level scheme for g.s. band members with J^π≥17/2$^+$ and most data are from 1985Oh03. The rest of the level scheme and considerable data are from 1969Tv01.

^{167}Er Levels

E(level)[†]	Jπ[#]	$T_{1/2}$[@]	Comments
0.0[&]	7/2$^+$		
79.338[&] *8*	9/2$^+$	119 ps *9*	B(E2)↑=2.51 *8* B(E2)↑: weighted average of 2.61 *8* (1963El06), 2.49 *10* (1978Br20), and 2.40 *9* (1978Wo02). E2 matrix element from 0, 7/2$^+$ to 79, 9/2+=+4.38 *8* (1978Wo02).

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Coulomb excitation 1985Oh03,1969Tv01 (continued)

^{167}Er Levels (continued)

E(level)[†]	J^{π}[#]	$T_{1/2}$[@]	Comments
			$T_{1/2}$: from (α)(ce)(t) (microwave method) for δ^2(79.3γ)=0.10 (1971Da17). Others: 118 ps *20* from B(E2) if δ(79.3)=0.32 (as in 1971Da17), but $T_{1/2}$=51 ps *20* if δ(79.3)=−0.20 *4* (as in 1966As02); 1971Da17 obtain 115 ps *9* if δ=0.20; 71 ps *21* (1967As03, impurity lines prevented accurate determination); ≥103 ps *6* from Mossbauer measurements in Coul. ex. and using α(total)(theory)=5.2 for the 79.3-keV γ ray (1969Wi17). Intrinsic quadrupole moment Q_0=7.68 *15* (1978Br20). Deduced magnitude of (g_K-g_R)=0.410 *16* (1971Da17).
177.973[&] *8*	11/2+	55 ps *6*	B(E2)↑=0.629 *6* B(E2)↑: weighted average of 0.648 *19* (1978Br20) and 0.627 *6* (1978Wo02). Other value: 0.61 *4* (1963El06). E2 matrix element from 0, 7/2+ to 178, 11/2+=+2.24 *1* (1978Wo02). $T_{1/2}$: from B(E2) and adopted properties for 178.0γ. Intrinsic quadrupole moment Q_0=7.73 *11* (1978Br20). Intrinsic quadrupole moment Q_{20}=7.60 *10* (1978Wo02) deduced from experimental E2 matrix elements for the 9/2+ and 11/2+ states of the 7/2[633] band.
294.961[&] *10*	13/2+	29 ps *6*	B(E4)↑=0.074 *+94−66* (1978Wo02) Intrinsic hexadecapole moment Q_{40}=1.35 *+69−90* (1978Wo02) deduced from experimental E4 matrix element. E4 matrix element from 0, 7/2+ to 178, 13/2+=+0.77 eb^2 *+39−51* (1978Wo02). $T_{1/2}$: from DSA for 215.6γ (1985Oh03).
434.452[&] *11*	15/2+	22 ps *6*	$T_{1/2}$: from DSA for 256.5γ (1985Oh03).
532.0[‡a] *5*	3/2+	19.3 ps *23*	B(E2)↑=0.034 *4* B(E2): weighted average of 0.0377 *38* (1969Tv01) and 0.030 *4* (1978Wo02). Other: 0.042 (1962Ga14). E2 matrix element from 0, 7/2+ to 532, 3/2+=+0.49 *3* (1978Wo02). $T_{1/2}$: from B(E2) and adopted properties for 532γ.
574.2[‡a] *2*	5/2+	36 ps *12*	B(E2)↑=0.0201 *30* B(E2): weighted average of 0.0221 *21* (1978Wo02) and 0.0155 *32* (1969Tv01). E2 matrix element from 0, 7/2+ to 574, 5/2+=+0.42 *2* (1978Wo02). B(E2)(79, 9/2+ to 574, 5/2+)=0.0093 *28* (1969Tv01). $T_{1/2}$: from B(E2)(495γ) and adopted 495γ properties.
587.382[&] *12*	17/2+	11.1 ps *21*	$T_{1/2}$: from DSA for 292.4γ in Fig. 6 of 1985Oh03, where mean lifetime τ=16 ps *3*. Uncertainty is 2 ps in authors′ Table 5.
641.2[‡] *2*	7/2+		B(E2)(79, 9/2+ to 641, 7/2+)=0.0052 *30*; B(E2)(0, 7/2+ to 641, 7/2+)=0.0051 *30* (1969Tv01).
711.3[‡] *2*	11/2+		B(E2)↑=0.056 *6* B(E2): weighted average of 0.061 *6* (1978Wo02) and 0.0479 *80* (1969Tv01). E2 matrix element from 0, 7/2+ to 711, 11/2+=+0.70 *2* (1978Wo02). B(E2)(79, 9/2+ to 711, (11/2+))=0.0170 *30* (1969Tv01).
772.693[&] *15*	19/2+	6.9 ps *14*	$T_{1/2}$: from DSA for 338.24γ (1985Oh03).
812.5[‡b] *5*	5/2+		B(E2)↑=0.033 *4* B(E2): weighted average of 0.035 *4* (1978Wo02) and 0.025 *8* (1969Tv01). E2 matrix element from 0, 7/2+ to 812, 5/2+=+0.53 *3* (1978Wo02).
873.8[‡b] *5*	7/2+		B(E2)↑=0.024 *5* (1978Wo02) E2 matrix element from 0, 7/2+ to 874, 7/2+=+0.44 *4* (1978Wo02). B(E2)(79, 9/2+ to 874, 7/2+)=0.018 *8* (1969Tv01).
955.00[&] *4*	21/2+	3.5 ps *7*	$T_{1/2}$: from DSA for 367.62γ (1985Oh03).
1194.20[&] *10*	23/2+	2.4 ps *5*	$T_{1/2}$: from DSA for 421.5γ (1985Oh03).
1394.0[&] *10*	25/2+		

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Coulomb excitation 1985Oh03,1969Tv01 (continued)

^{167}Er Levels (continued)

† From a least-squares adjustment of Eγ data, assuming 0.5 keV uncertainty when not stated as in 1969Tv01.
‡ Level from 1969Tv01, not studied in 1985Oh03.
# As given by 1985Oh03 and 1969Tv01 based on γ(θ) and γγ(θ)(DCO) data in 1985Oh03 and band assignments in 1969Tv01. Assignments in the Adopted Levels are the same, with the exception that J^π values for the 711 and 1394 levels are considered as tentative.
@ From Doppler-broadened γ-ray lineshapes (1985Oh03) for 294.9, 434.4, 587.4, 772.7, 955.0 and 1194.2 levels.
& Band(A): ν7/2[633].
a Band(B): ν3/2[651].
b Band(C): ν5/2[642].

γ(^{167}Er)

A_2, A_4, and DCO values are from 1985Oh03. Two type of γγ(θ) or DCO values were measured for ΔJ=1 transitions to obtain δ(Q/D) (or δ(E2/M1)): DCO(1) for J → J-1 → J−3 and DCO(2) for J+2 → J → J+1, where δ(Q/D) is for ΔJ=1 transitions in each case.

E_γ†	I_γ	E_i(level)	J^π_i	E_f	J^π_f	Mult.‡	δ#	α&	Comments
79.33 *1*	563 *56*	79.338	9/2+	0.0	7/2+	M1+E2	−0.32 *3*	5.70 *9*	α(K)exp=4.50 *21* (1966As02) α(K)=4.37 *8*; α(L)=1.03 *6*; α(M)=0.236 *15* α(N)=0.054 *4*; α(O)=0.0073 *4*; α(P)=0.000268 *5* Eγ=79.3 (1969Tv01). α(K)exp from (x ray)γ-coin (1966As02). δ: from δ^2=0.10 (1971Da17), with 20% uncertainty assumed by evaluators; sign from 1966As02. Magnitude disagrees with δ=−0.20 *4* from pγγ(θ) (1966As02); 1971Da17 suggest that γγ(θ) results in 1966As02 may have been affected by hyperfine interactions. δ=0.40 *11* from α(K)exp.
98.62 *1*	305 *31*	177.973	11/2+	79.338	9/2+	M1+E2	−0.28 *3*	2.97	α(K)exp=2.07 *14* (1966As02) DCO(2)=0.93 *8*; A_2=−0.038 *12*; A_4=+0.031 *54* (1985Oh03) B(M1)↓=0.21 *4* (1970Ga19) α(K)=2.38 *4*; α(L)=0.456 *19*; α(M)=0.104 *5* α(N)=0.0240 *11*; α(O)=0.00330 *12*; α(P)=0.000146 *3* Eγ=98.3 (1969Tv01). α(K)exp from (x ray)γ-coin (1966As02). δ: weighted average of −0.27 *3* (1966As02, pγγ(θ)) and −0.45 *15* (1985Oh03, −0.45 *15* from γ(θ) and −0.6 *10* from DCO ratio). Other δ: 0.71 *16* from α(K)exp (1966As02); 0.33 *+17−10* (1959De29); 0.302 *20* deduced from crossover-to-cascade branching ratio and using Eq. 2 (1969Tv01) is in agreement.

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Coulomb excitation 1985Oh03,1969Tv01 (continued)

$\gamma(^{167}Er)$ (continued)

E_γ †	I_γ	E_i(level)	J_i^π	E_f	J_f^π	Mult.‡	δ#	α&	Comments
116.99 *1*	88 *9*	294.961	13/2+	177.973	11/2+	M1+E2	−0.23 *11*	1.81	DCO(1)=1.29 *22*; DCO(2)=0.66 *8*; A_2=−0.195 *22*; A_4=+0.002 *30* B(M1)↓=0.208 *49*; B(E2)↓=1.2 *11* (1985Oh03); B(M1)↓=0.25 *6* (1970Ga19) α(K)=1.48 *5*; α(L)=0.25 *3*; α(M)=0.057 *7* α(N)=0.0131 *15*; α(O)=0.00185 *16*; α(P)=9.1×10^{-5} *4* Eγ=1116.1 (1969Tv01). δ: from 1985Oh03 (average of −0.33 *15* from γ(θ), −0.15 *15* and −0.24 *50* from DCO ratios). Evaluators obtain averaged δ=−0.24 *10*. Other δ: 0.296 *30*, deduced from crossover-to-cascade branching ratio and using Eq. 2 (1969Tv01) is in agreement.
139.50 *1*	37 *4*	434.452	15/2+	294.961	13/2+	M1+E2	−0.25 *9*	1.088 *19*	DCO(1)=1.63 *10*; DCO(2)=0.48 *7*; A_2=−0.245 *13*; A_4=+0.028 *18* B(M1)↓=0.158 *49*; B(E2)↓=0.73 *68* (1985Oh03); B(M1)↓=0.28 (1970Ga19) α(K)=0.897 *25*; α(L)=0.149 *9*; α(M)=0.0334 *22* α(N)=0.0077 *5*; α(O)=0.00110 *5*; α(P)=5.47×10^{-5} *19* Eγ=138.7 (1969Tv01). δ: from 1985Oh03 (average of −0.20 *10* from γ(θ), −1.0 *10* and −0.35 *15* from DCO ratios). Other δ: 0.304 *40*, deduced from crossover-to-cascade branching ratio and using Eq. 2 (1969Tv01) is in agreement.
152.93 *1*	13 *1*	587.382	17/2+	434.452	15/2+	M1+E2	−0.31 *8*	0.831 *16*	DCO(1)=1.72 *16*; DCO(2)=0.50 *15*; A_2=−0.303 *9*; A_4=−0.039 *12* B(M1)↓=0.190 *30*; B(E2)↓=1.13 *61* (1985Oh03) α(K)=0.682 *19*; α(L)=0.116 *5*; α(M)=0.0260 *13* α(N)=0.0060 *3*; α(O)=0.00085 *3*; α(P)=4.14×10^{-5} *14* δ: from 1985Oh03 (average of −0.30 *10* from γ(θ), −0.30 *15* and −0.9 *6* from DCO ratios). Evaluators note that negative A_4 is inconsistent with ΔJ=1, dipole + quadrupole transition.
177.98 *1*	100 *5*	177.973	11/2+	0.0	7/2+				A_2=+0.0176 *39*; A_4=−0.001 *6* Eγ=177.6 (1969Tv01). Measured Iγ(177.9γ)/Iγ(98.6γ)= 0.340 *7* (1966Bo16). Mult.: E2 in 1985Oh03.
182.3 *2*	1.3 *2*	955.00	21/2+	772.693	19/2+	M1(+E2)	−0.15 *45*	0.52 *5*	DCO(1)=1.48 *13* (1985Oh03)

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Coulomb excitation 1985Oh03,1969Tv01 (continued)

γ(^{167}Er) (continued)

E_γ †	I_γ	E_i(level)	J^π_i	E_f	J^π_f	Mult.‡	δ#	α&	Comments
									B(M1)↓=0.30 *9*; B(E2)↓=0.3 *18* (1985Oh03) α(K)=0.43 *6*; α(L)=0.066 *9*; α(M)=0.0146 *24* α(N)=0.0034 *6*; α(O)=0.00049 *5*; α(P)=2.6×10^{-5} *5* δ(E2/M1)=−0.15 *45* from DCO ratio in 1985Oh03, but this does not include uncertainty in alignment attenuation factors.
185.3 *2*	2.9 *5*	772.693	19/2$^+$	587.382	17/2$^+$	M1+E2	−0.35 *15*	0.478 *17*	DCO(1)=2.11 *14* (1985Oh03) B(M1)↓=0.103 *31*; B(E2)↓=0.53 *48* (1985Oh03) α(K)=0.394 *21*; α(L)=0.066 *3*; α(M)=0.0147 *9* α(N)=0.00342 *19*; α(O)=0.000482 *17*; α(P)=2.39×10^{-5} *16* δ: from DCO ratio (1985Oh03).
215.63 *1*	76 *4*	294.961	13/2$^+$	79.338	9/2$^+$	E2		0.196	A_2=+0.078 *4*; A_4=+0.012 *6* B(E2)↓=0.94 *20* (1985Oh03) α(K)=0.1303 *19*; α(L)=0.0508 *8*; α(M)=0.01207 *17* α(N)=0.00275 *4*; α(O)=0.000342 *5*; α(P)=6.25×10^{-6} *9* Eγ=214.8 (1969Tv01). Evaluators note that positive A_4 is inconsistent with ΔJ=2, quadrupole transition. Measured Iγ(215.6γ)/Iγ(116.9γ)= 0.80 *5* (1966Bo16).
239.4 *6*	0.56 *6*	1194.20	23/2$^+$	955.00	21/2$^+$	M1+E2	−0.20 *10*	0.241 *6*	A_2=−0.35 *10*; A_4=+0.010 *43* B(M1)↓=0.204 *51*; B(E2)↓=0.20 *21* (1985Oh03) α(K)=0.202 *6*; α(L)=0.0306 *5*; α(M)=0.00680 *12* α(N)=0.00159 *3*; α(O)=0.000228 *4*; α(P)=1.23×10^{-5} *4* δ(E2/M1)=−0.20 *10* from $\gamma(\theta)$ in 1985Oh03, but this does not include uncertainty in alignment attenuation factors.
256.47 *1*	60 *3*	434.452	15/2$^+$	177.973	11/2$^+$	E2		0.1122	DCO=0.96 *6*; A_2=+0.110 *4*; A_4=+0.015 *5* B(E2)↓=0.96 *28* (1985Oh03) α(K)=0.0789 *11*; α(L)=0.0257 *4*; α(M)=0.00606 *9* α(N)=0.001384 *20*; α(O)=0.0001750 *25*; α(P)=3.94×10^{-6} *6* Evaluators note that positive A_4 is inconsistent with ΔJ=2, quadrupole transition. Eγ=255.2 (1969Tv01).
292.42 *1*	36 *18*	587.382	17/2$^+$	294.961	13/2$^+$	E2		0.0747	DCO=1.05 *5*; A_2=+0.144 *4*; A_4=−0.017 *5* B(E2)↓=1.39 *20* (1985Oh03)

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Coulomb excitation 1985Oh03,1969Tv01 (continued)

$\gamma(^{167}Er)$ (continued)

E_γ[†]	I_γ	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	α[&]	Comments
								α(K)=0.0543 *8*; α(L)=0.01569 *22*; α(M)=0.00368 *6* α(N)=0.000841 *12*; α(O)=0.0001078 *15*; α(P)=2.78×10^{-6} *4*
338.24 *1*	17 *1*	772.693	19/2$^+$	434.452	15/2$^+$	E2	0.0483	DCO=0.98 *6*; A_2=+0.175 *4*; A_4=−0.007 *5* B(E2)↓=1.41 *32* (1985Oh03)
367.62 *4*	5.7 *6*	955.00	21/2$^+$	587.382	17/2$^+$	E2	0.0379	DCO=0.82 *13*; A_2=+0.121 *15*; A_4=−0.010 *20* B(E2)↓=1.76 *43* (1985Oh03)
421.5 *1*	2.3 *3*	1194.20	23/2$^+$	772.693	19/2$^+$	(E2)	0.0259	DCO=0.87 *31*; A_2=+0.298 *37*; A_4=−0.009 *45* B(E2)↓=1.29 *33* (1985Oh03) Mult.: E2 in 1985Oh03.
439 *1*		1394.0	25/2$^+$	955.00	21/2$^+$			Mult.: E2 in 1985Oh03.
463.0[@]		641.2	7/2$^+$	177.973	11/2$^+$			
494.5[@]		574.2	5/2$^+$	79.338	9/2$^+$	[E2]	0.01692	
532.0[@]		532.0	3/2$^+$	0.0	7/2$^+$			
533.5[@a]		711.3	11/2$^+$	177.973	11/2$^+$			
561.5[@]		641.2	7/2$^+$	79.338	9/2$^+$			
574.5[@]		574.2	5/2$^+$	0.0	7/2$^+$			Measured Iγ(574.5γ)/Iγ(494.5γ)=0.76 *15* (1969Tv01).
632.3[@]		711.3	11/2$^+$	79.338	9/2$^+$			
641.7[@]		641.2	7/2$^+$	0.0	7/2$^+$			Measured Iγ(641.7γ)/Iγ(561.5γ)=0.37 *17* (1969Tv01).
711.0[@]		711.3	11/2$^+$	0.0	7/2$^+$			Measured Iγ(711.0γ)/Iγ(632.3γ)=0.47 *7* (1969Tv01).
794.5[@]		873.8	7/2$^+$	79.338	9/2$^+$			
812.5[@]		812.5	5/2$^+$	0.0	7/2$^+$			

[†] From 1985Oh03, except as noted.
[‡] From γ(θ) except where noted, with mult=M1 and E2 assigned by comparison to RUL.
[#] Weighted average from γ(θ) and DCO ratio data of 1985Oh03, except where noted.
[@] From Fig. 4 of 1969Tv01, uncertainties not stated by authors.
[&] 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.
[a] Placement of transition in the level scheme is uncertain.

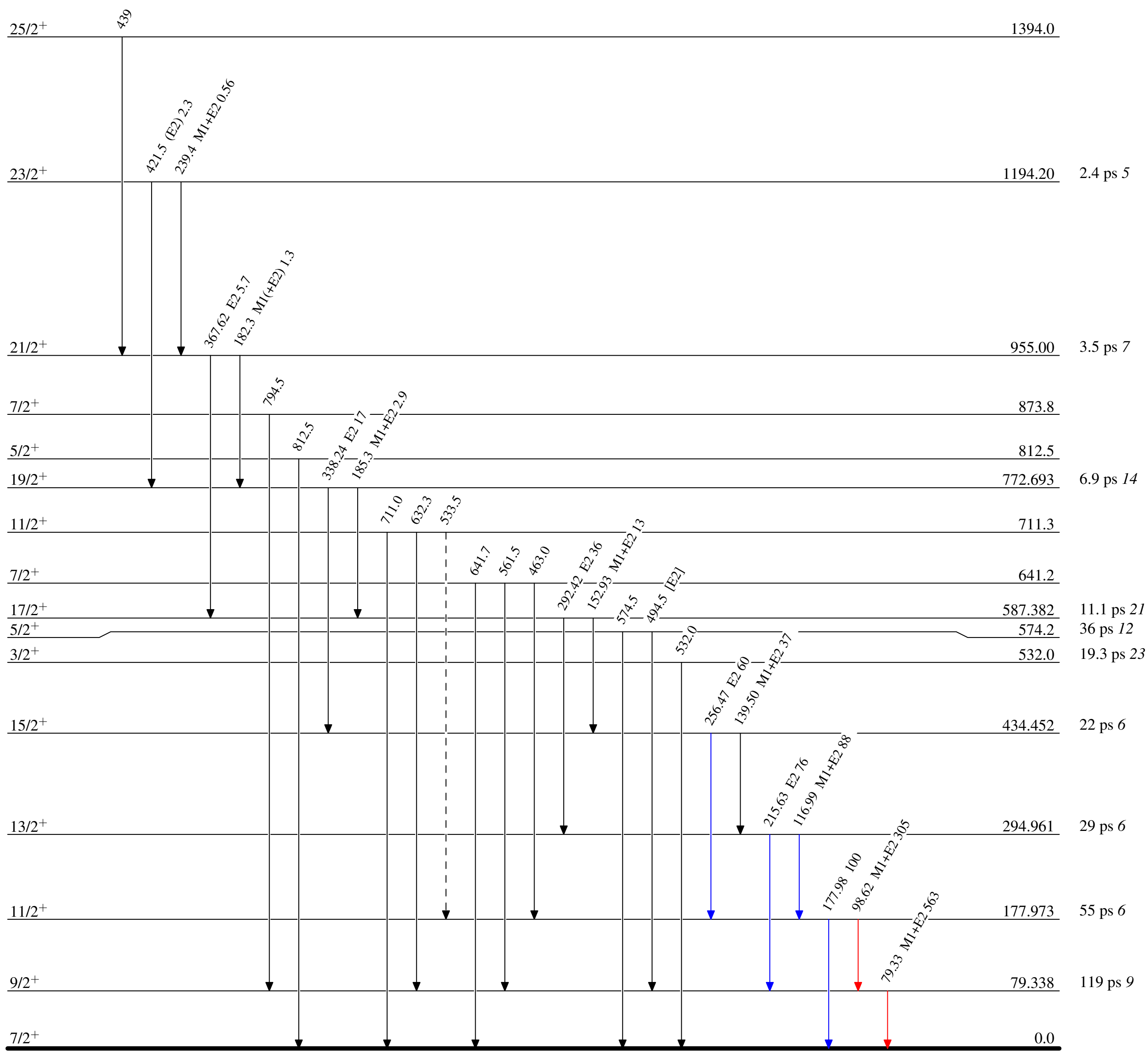
Coulomb excitation 1985Oh03,1969Tv01

Level Scheme

Intensities: Relative I_γ

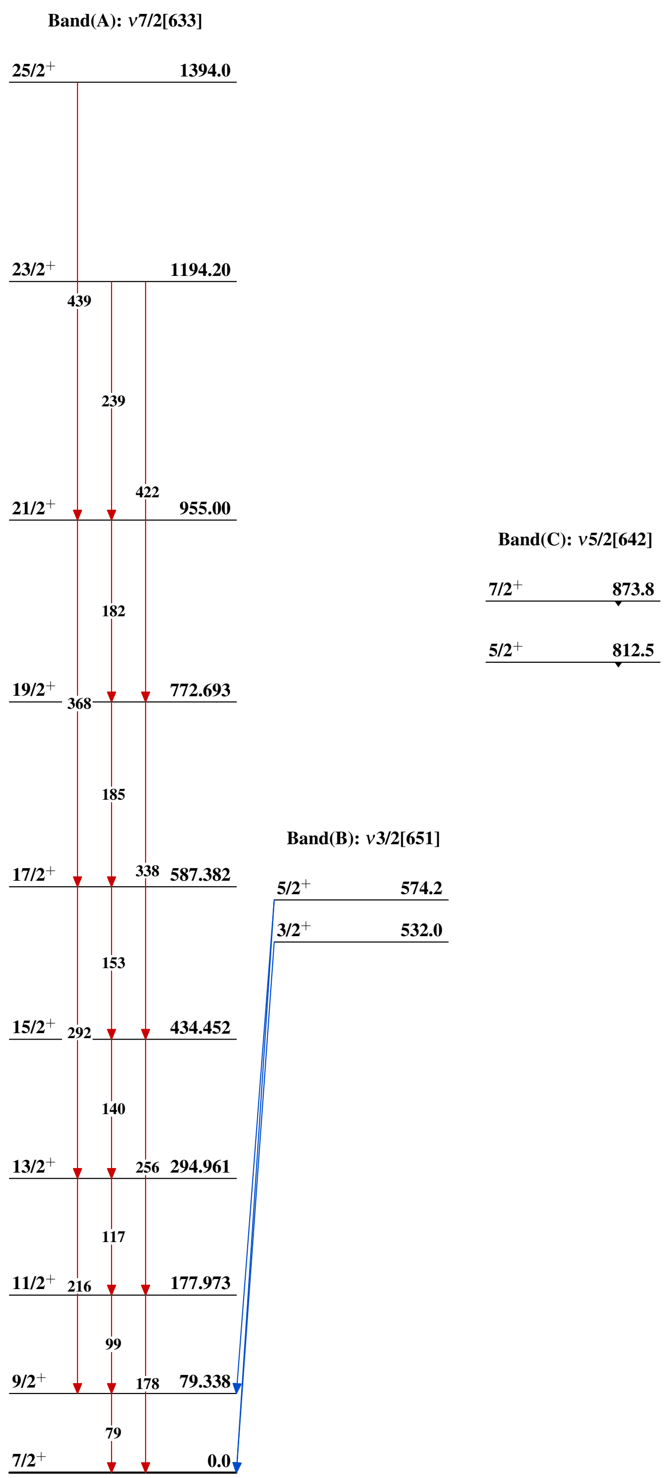
Legend

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



$^{167}_{68}Er_{99}$

Coulomb excitation 1985Oh03,1969Tv01



$^{167}_{68}Er_{99}$