^{35}Cl(p,p′γ) 1969Du08,1970Ta02,1972Br45

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Lijie Sun and Jun Chen	NDS 211,1 (2026)	30-Sep-2025

Also include (p,p′) measurements listed below.

^{35}Cl(p,p′γ) measurements:

1969Du08: E=4.6-6.2 MeV 0.05 μA proton beam. Thin targets of $CdCl_2$ (99% ^{35}Cl), 100 μg/cm^2. A 300 μm annular surface-barrier detector on the beam axis and a movable 390 μm surface-barrier detector rotated from 20° to 148° relative to beam direction for detecting protons, FWHM=24 keV; a 7.62 by 7.62-cm-diam NaI(Tl) crystal and 15- and 35-cc Ge(Li) for detecting γ-rays. Measured σ(E$_p$,θ), Eγ, Iγ, pγ(θ). Deduced levels, J^π, branchings, mixing ratios, half-lives using Doppler Shift Attenuation Method (DSAM).

1970Ta02: E=4.24, 4.82, 5.08 and 5.11 MeV proton beams produced from the Universite Montreal EN tandem accelerator. Targets of 16 μg/cm^2 AgCl evaporated onto 0.013 cm gold foils, 99% enriched in ^{35}Cl. A 12.70-cm-diam by 15.24-cm-long NaI(Tl) and a 30 cm^3 Ge(Li) detector for detecting γ-rays. Measured Eγ, Iγ, γ(θ), γ(lin pol). Deduced levels, J^π, branchings, mixing ratios.

1972Br45: E=3.45-6.00 MeV protons produced from the University of Auckland folded tandem accelerator. Natural chlorine targets of AgCl, $PbCl_2$ and solid Cl (75.77% ^{35}Cl, 24.33% ^{37}Cl). A 25 cm^3 Ge(Li) detector for detecting γ-rays, FWHM=2.3 keV for Eγ=1.332 MeV. Measured Eγ. Deduced levels, half-lives using DSAM. 1972Br45 reports a few mixing ratios in their TABLE V, but it is unclear where they are taken from. They are definitely not from 1972Br45 since this work is only focused on lifetime measurements.

1972Va06: E=5.47-5.61 MeV protons from the 5.5 MV Van de Graaff accelerator of the Southern Universities Nuclear Institute. Targets of $BaCl_2$ (99% ^{35}Cl) on gold backings. A 57 cm^3 Ge(Li) detector. Measured Eγ. Deduced half-lives using DSAM.

1961St09: E=2.3-3.25 MeV. NaI(Tl) detector. Targets of AgCl. Measured σ(E$_p$,θ), γ(θ). Deduced levels, J for the levels of 1.22 and 1.76 MeV.

1966Er06: E=0.733-2.595 MeV protons produced from the Utrecht 3 MV Van de Graaff accelerator. $BaCl_2$ target (99.5% ^{35}Cl) on a tantalum backing. Cylindrical NaI assemblies, 10-cm by 10-cm. Measured Eγ, γ(θ). Deduced levels, J^π, mixing ratios, mainly for ^{36}Ar and for the ^{35}Cl level at E$_x$=1760.

1970Ta09: E=5.11 MeV proton beam. NaI(Tl) detector. Measured Eγ. Developed an analytical method to interpret the linear polarization measurement of two unresolved γ-rays: 3.00 and 3.16 MeV. Same authors as 1970Ta02.

1971Ca40: E=4.15-6.15 MeV protons from the Oxford University Tandem accelerator. Targets of 20 μg/cm^2 natural $BaCl_2$ on gold, lead, and carbon backings. A 32 cm^3 Ge(Li) detector. Measured Eγ. Deduced half-lives for the levels of 2646 and 2695 keV using DSAM.

1974Hu09: E=5.65 MeV protons from the pulsed beam facility of the University of Alberta Van de Graaff accelerator. Targets of natural KCl on tantalum backing and $PbCl_2$ on gold backing. A 24 cm^3 coaxial Ge(Li) detector. Measured Eγ. Deduced half-life for the level of 3162 keV.

Other (p,p′γ) measurement: 1985Ki07 and 1975De16 (measured 1219γ yield).

(p,p′) measurements:

1969Ta13,1971Ta02: E=3.115 and 3.345 MeV protons produced from the Universite de Montreal Model EN tandem accelerator. AgCl target (99% ^{35}Cl) of 16 μg/cm^2 on gold backing. A 12.70-cm-diam by 15.24-cm-long NaI(Tl) for detecting γ-rays. Measured Eγ, Iγ, γ(θ). Deduced levels, J^π and mixing ratio for the level of 1763 keV. Same authors as 1970Ta02.

1969An35: E=6.03 MeV proton beams on a $CdCl_2$ target. Inelastic protons detected by a Si(Li) detector. Measured σ(E$_{p'}$,θ). Deduced J for a level at 3930.

Other (p,p′) measurement: 1993Bo40 (measured σ).

^{35}Cl Levels

E(level)[†‡]	J^π[#]	$T_{1/2}$	Comments
0	$3/2^+$		
1219.42 *10*	$1/2^+$	0.150 ps *+42−28*	J^π: pγ(θ) in 1969Du08 is consistent with spin=1/2. $T_{1/2}$: from τ=0.216 ps *+60−40*, weighted average of 0.215 ps *75* (1972Va06), 0.21 ps *+6−4* (1972Br45), 0.27 ps *+19−10* (1969Du08).
1763.26 *10*	$5/2^+$	0.43 ps *20*	J^π: $5/2^+$ from γ(θ) and γ(lin pol) in 1966Er06; spin=5/2 also from pγ(θ) in 1969Du08. $T_{1/2}$: from τ=0.62 ps *28*, unweighted average of 0.205 ps *75* (1972Va06), 0.49 ps *+9−6*

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^{35}Cl(p,p′γ) 1969Du08,1970Ta02,1972Br45 (continued)

^{35}Cl Levels (continued)

E(level)[†][‡]	J$^{\pi}$[#]	T$_{1/2}$	Comments
			(1972Br45), 1.15 ps *+45−63* (1969Du08).
2645.74 *17*	7/2$^+$	0.165 ps *35*	J$^{\pi}$: 5/2$^+$ from γ(θ) and γ(lin pol) in 1970Ta02; spin≥5/2 from pγ(θ) in 1969Du08. T$_{1/2}$: from τ=0.238 ps *50*, weighted average of 0.185 ps *50* (1972Va06) and 0.26 ps *6* (1972Br45), and 0.35 ps *+10−7* (1969Du08, using 2646γ). Other: τ=0.29 ps *+37−13* using 882γ also reported in 1969Du08, but is considered less reliable by authors; 0.083 ps *21* from 1971Ca40 is considered an outlier.
2694.50 *28*	3/2$^+$	43 fs *11*	J$^{\pi}$: 3/2$^+$ from γ(θ) and γ(lin pol) in 1970Ta02. T$_{1/2}$: from τ=63 fs *16*, weighted average of 65 fs *20* (1972Va06) and 62 fs *16* (1969Du08, using 2695γ). Other: τ=115 fs *+95−59* using 931γ also reported in 1969Du08, but is considered less reliable by authors; <120 fs (1972Br45); 11 fs *7* from 1971Ca40 is considered an outlier.
3002.6 *5*	5/2$^+$	19 fs *9*	J$^{\pi}$: 5/2$^+$ from γ(θ) and γ(lin pol) in 1970Ta02. T$_{1/2}$: from τ=27 fs *13*, weighted average of 18 fs *+26−15* (1972Va06) and 31 fs *13* (1969Du08). Other: <80 fs (1972Br45).
3162.75 *10*	7/2$^-$	32 ps *4*	J$^{\pi}$: spin=7/2 from γ(θ) and π=− from γ(lin pol) in 1970Ta02. T$_{1/2}$: from τ=46 ps *6* in 1974Hu09. Other: τ>17 ps (1972Va06), >10 ps (1972Br45).
3930 *30*	3/2		E(level),J$^{\pi}$: from 1969An35. Spin is determined based on J-dependence of measured proton inelastic scattering cross sections and known assignments of 3163 and 3000 levels.

[†] Additional information 1.
[‡] From a least-squares fit to γ-ray energies with uncertainties, unless otherwise noted.
[#] From Adopted Levels. Supporting arguments from this dataset are given under comments if available.

γ(^{35}Cl)

E$_i$(level)	J$_i^{\pi}$	E$_{\gamma}$[†]	I$_{\gamma}$[‡]	E$_f$	J$_f^{\pi}$	Mult.[#]	δ[#]	Comments
1219.42	1/2$^+$	1219.4 *1*	100	0	3/2$^+$			E$_{\gamma}$: weighted average of 1219.4 *1* (1972Br45) and 1219.3 *3* (1969Du08). Γ$_{\gamma}$=27.43×10^{-4} eV (1969Du08). Additional information 2. A$_2$=−0.025 *29* for E$_p$=3.115 MeV; +0.007 *8* for E$_p$=3.345 MeV (1969Ta13). A$_2$=+0.031 *16*, A$_4$=+0.014 *20*; A$_2$=−0.012 *22*, A$_4$=−0.003 *30*; A$_2$=−0.009 *14*, A$_4$=+0.014 *6*, for different beam energies (1961St09). A$_2$=+0.02 *6*, A$_4$=+0.05 *9* (1969Du08).
1763.26	5/2$^+$	1763.2 *1*	100	0	3/2$^+$	M1+E2	−2.66 *12*	E$_{\gamma}$: weighted average of 1763.2 *1* (1972Br45), 1763.3 *3* (1969Du08). δ: weighted average of −3.0 *5* from γ(θ,pol) in 1966Er06 and −2.64 *12* from γ(θ,pol) in 1969Ta13 and 1971Ta02. Others: δ<−0.4 or δ> +0.4 from pγ(θ) in 1969Du08. Additional information 3. A$_2$=−0.369 *9*, A$_4$=+0.213 *13*; A$_2$=−0.355 *14*, A$_4$=+0.200 *20*, for different beam energies (1969Ta13). A$_2$=−0.02 *2*, A$_4$=+0.07 *2* (1969Du08). A$_2$=−0.141 *13*, A$_4$=+0.107 *16*; A$_2$=−0.225 *29*, A$_4$=+0.083 *35*; A$_2$=−0.049 *12*, A$_4$=−0.036 *14*, for different beam energies (1961St09).
2645.74	7/2$^+$	882.3[@] *3*	13 *5*	1763.26	5/2$^+$	M1+E2	+0.17 *5*	I$_{\gamma}$: unweighted average of 8.7 *22* from 1970Ta02 and 17.6 *35* from 1969Du08. %Branching=8 *2* (1970Ta02), 15 *3* (1969Du08).

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^{35}Cl(p,p′γ) 1969Du08,1970Ta02,1972Br45 (continued)

γ(^{35}Cl) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[‡]	E_f	J_f^π	Mult.[#]	δ[#]	Comments
								Additional information 4. A_2=−0.372 *34*, A_4=+0.034 *38*; A_2=−0.533 *31*, A_4=+0.041 *34*, for different beam energies (1970Ta02).
2645.74	7/2+	1426[&a] 2645.7 *2*	<1[&] 100 *2*	1219.42 0	1/2+ 3/2+	 E2		%Branching<1 (1970Ta02). E_γ: weighted average of 2645.7 *2* (1972Br45) and 2645.6 *5* (1969Du08). δ: δ(O/Q)=0 from γ(θ,pol) in 1970Ta02 and pγ(θ) in 1969Du08. I_γ: from 1970Ta02. Other: 100 *4* from 1969Du08. %Branching=92 *2* (1970Ta02), 85 *3* (1969Du08). Additional information 5. A_2=+0.22 *5*, A_4=−0.13 *6* (1969Du08). A_2=+0.316 *22*, A_4=+0.024 *28*; A_2=+0.233 *11*, A_4=+0.044 *10*; A_2=+0.312 *32*, A_4=−0.117 *41*; A_2=+0.205 *18*, A_4=−0.044 *25*, for different beam energies (1970Ta02).
2694.50	3/2+	931.3[@] *3*	18.6 *25*	1763.26	5/2+	M1+E2	+0.09 *3*	I_γ: weighted average of 19.0 *25* (1970Ta02) and 17.7 *38* (1969Du08). %Branching=15 *2* (1970Ta02), 14 *3* (1969Du08). Additional information 6. A_2=+0.018 *46* (1970Ta02).
		1475[@] *2*	8.3 *25*	1219.42	1/2+	M1+E2	−0.63 *21*	I_γ: weighted average of 8.0 *25* (1970Ta02) and 8.9 *38* (1969Du08). %Branching=6 *2* (1970Ta02), 7 *3* (1969Du08). Additional information 7. A_2=−0.111 *45* (1970Ta02).
		2694.1 *6*	100 *3*	0	3/2+	M1+E2	+0.26 *2*	E_γ: unweighted average of 2693.5 *1* (1972Br45), 2694.6 *5* (1969Du08). I_γ: from 1970Ta02. Other: 100 *4* from 1969Du08. %Branching=79 *2* (1970Ta02), 79 *3* (1969Du08). Additional information 8.
3002.6	5/2+	1239[&]	2.2[&] *11*	1763.26	5/2+			I_γ: from 1970Ta02. %Branching=2 *1* (1970Ta02).
		1783	3.3 *11*	1219.42	1/2+			E_γ: from level-energy difference. I_γ: weighted average of 5.4 *32* (1970Ta02) and 3.1 *11* (1969Du08). %Branching=5 *3* (1970Ta02), 3 *1* (1969Du08).
		3002.5 *5*	100 *1*	0	3/2+	M1+E2	+0.07 *2*	Additional information 9. E_γ: weighted average of 3002.5 *5* (1972Br45) and 3002.4 *10* (1969Du08). I_γ: from 1969Du08. Other: 100 *2* from 1970Ta02. δ: others: −20<δ<−0.3 or +0.2<δ<+5 (1969Du08, pγ(θ)); −0.02<δ<0.09 (1970Ta09, γ(lin pol)).

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^{35}Cl(p,p′γ) 1969Du08,1970Ta02,1972Br45 (continued)

γ(^{35}Cl) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[‡]	E_f	J_f^π	Mult.[#]	δ[#]	Comments
								%Branching=93 *2* (1970Ta02), 97 *1* (1969Du08). Additional information 10. A_2=−0.30 *4*(1969Du08). A_2=−0.166 *7*, A_4=+0.004 *10*; A_2=−0.104 *23*, A_4=+0.050 *40*; A_2=−0.329 *13*, A_4=−0.001 *28*; A_2=+0.342 *24*, A_4=+0.022 *43*, for different beam energies (1970Ta02).
3162.75	7/2−	517.0[@] *8*	19 *8*	2645.74	7/2+			I_γ: unweighted average of 11.1 *22* (1970Ta02) and 26.6 *63* (1969Du08). %Branching=10 *2* (1970Ta02), 21 *5* (1969Du08). Additional information 11.
		1399[&a]	<1[&]	1763.26	5/2+			%Branching<1 (1970Ta02).
		1943[&a]	<1[&]	1219.42	1/2+			%Branching<1 (1970Ta02).
		3162.6 *1*	100 *2*	0	3/2+	M2+E3	−0.22 *5*	E_γ: weighed average of 3162.6 *1* (1972Br45) and 3162.5 *10* (1969Du08). I_γ: from 1970Ta02. Other: 100 *6* from 1969Du08. δ: weighted average of −0.14 *+8−6* (1969Du08, pγ(θ)) and −0.25 *4* (1970Ta02, γ(θ,pol)). Other: −0.31<δ<−0.21 from γ(lin pol) in 1970Ta09. %Branching=90 *2* (1970Ta02), 79 *5* (1969Du08). Additional information 12. A_2=+0.48 *21*, A_4=−0.13 *73* (1969Du08). A_2=+0.281 *68*, A_4=+0.241 *82*; A_2=+0.453 *44*, A_4=+0.136 *63*; A_2=+0.475 *24*, A_4=+0.096 *36*, for different beam energies (1970Ta02).

[†] Eγ values with uncertainties for the ground-state transitions are not explicitly listed in 1972Br45 and 1969Du08 and the evaluators have taken their listed E(level) values and uncertainties (which are deduced from Eγ values by authors) as Eγ values of the corresponding ground-state transitions, considering ground-state transitions are dominant in each level.

[‡] Relative photon branching ratios deduced by the evaluators based on percentage branching ratios reported in 1970Ta02 and 1969Du08, which are given under comments where available.

[#] From γ(θ) and γ(lin pol) in 1970Ta02, unless otherwise noted.

[@] From 1969Du08.

[&] γ reported in 1970Ta02. Energy is from level-energy difference and intensity is from 1970Ta02. The ones with Iγ reported as upper limit are considered questionable by the evaluators.

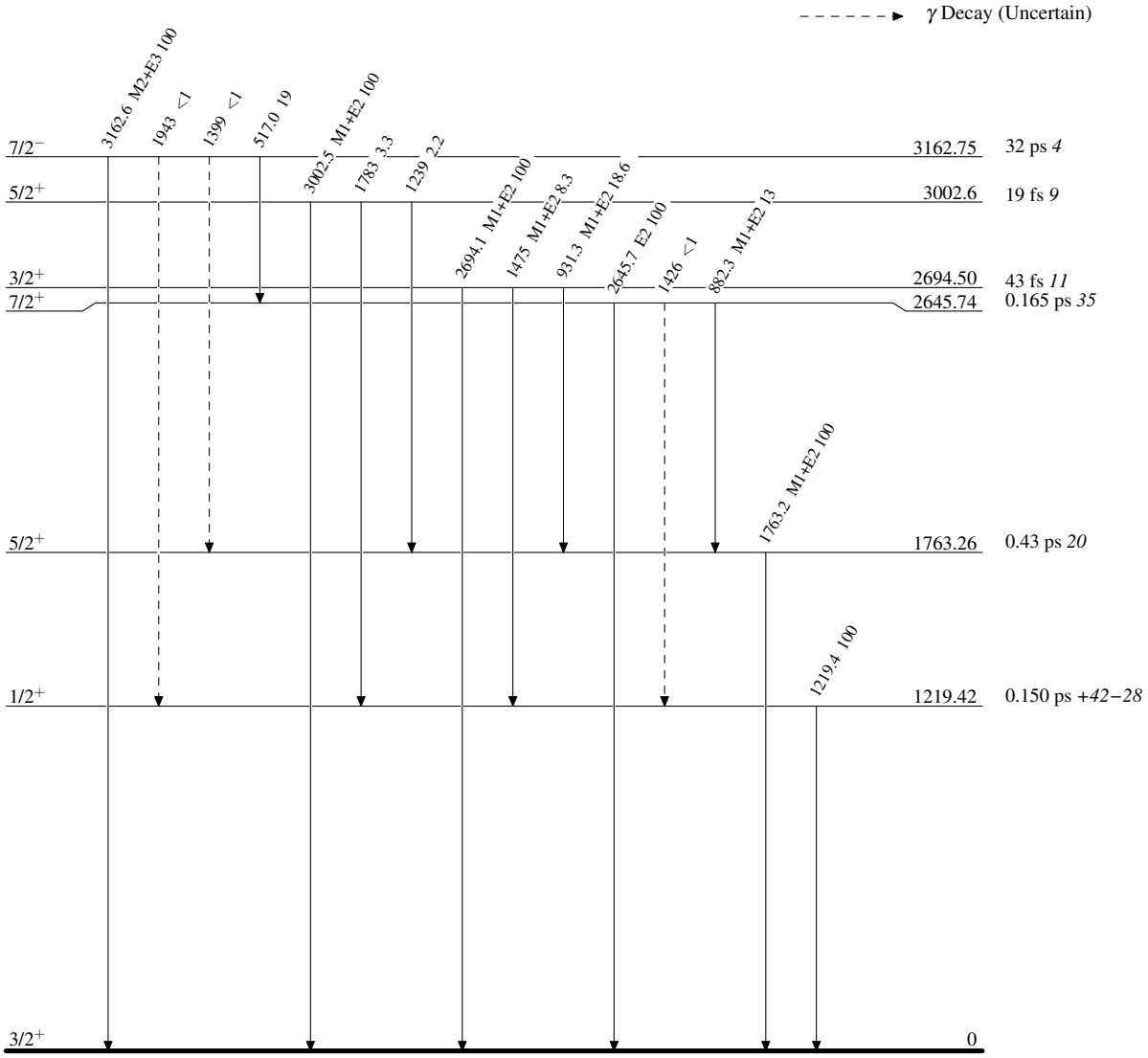
[a] Placement of transition in the level scheme is uncertain.

^{35}Cl(p,p′γ) 1969Du08,1970Ta02,1972Br45

Legend

Level Scheme

Intensities: Relative photon branching from each level



$^{35}_{17}Cl_{18}$