PHYSICAL REVIEW C VOLUME 7, NUMBER 1 JANUARY 1973

Study of the Low-Lying States of ^{39}Cl via the Reaction ^{37}Cl($t, p\gamma$)^{39}Cl[†]

E. K. Warburton, J. W. Olness, and G. A. P. Engelbertink*
Brookhaven National Laboratory, Upton, New York 11973

(Received 11 October 1972)

A Ge(Li) detector was used to measure γ-ray transitions in ^{39}Cl via proton-γ coincidence studies in the ^{37}Cl $(t,p\gamma)$ ^{39}Cl reaction at $E_t = 3.4$ MeV. Measurements were carried out with the proton detector centered at 180° and the γ-ray detector at 90° and 0° to the beam. Excitation energies and γ-ray branching ratios were determined for the first 14 levels of ^{39}Cl. The mean lives of these ^{39}Cl states were deduced from the Doppler-shift attenuations observed in the primary transitions. The excitation energies (in keV) and mean lives (in psec) resulting from these measurements are as follows: 396 (> 2.0), 1301 (>3.0), 1695 ($1.1^{+1.4}_{-0.5}$), 1722 (0.44 ± 0.09), 1745 (1.3 ± 0.4), 1786 (>2.0), 2061 (<0.05), 2238 (0.08 ± 0.04), 2424 (>1.8), 2490 (0.10 ± 0.05), 2586 (<0.3), 2835 (>1.8), 3116 (0.21 ± 0.06), and 3534 (<0.2).

I. INTRODUCTION

The nucleus ^{39}Cl can be reached by three nuclear reactions which are convenient for spectroscopy studies; namely, ^{40}Ar(d, ^{3}He)^{39}Cl ($Q = -7.033$ MeV), ^{40}Ar(t, α)^{39}Cl ($Q = -7.287$ MeV), and ^{37}Cl(t, p)^{39}Cl ($Q = 5.696$ MeV). The first of these has recently been used[1] at $E_d = 52$ MeV and with an energy resolution of 250 keV full width at half maximum (FWHM) to study levels up to 6.3 MeV excitation. This has been the only spectroscopic study of ^{39}Cl to date other than a measurement[2] yielding the ^{37}Cl(t, p)^{39}Cl Q value and an excitation energy for the first excited state of 364 ± 30 keV.

The low-lying levels of ^{39}Cl should have dominant configurations of either 2p-3h or 3p-4h with respect to ^{40}Ca. These states are simple enough so that comparison of model predictions to experiment should prove rewarding. Thus, ^{39}Cl seemed a suitable nucleus for study via the ^{39}Cl($t, p\gamma$)^{39}Cl reaction using the triton beam available at the Brookhaven National Laboratory 3.5-MeV Van de Graaff accelerator. The main part of the study consisted of proton-γ coincidence measurements from which excitation energies, γ-ray branching ratios, and level lifetimes were extracted. The general procedure and apparatus have been described previously.[3]

II. EXPERIMENTAL PROCEDURE AND RESULTS

A. Coincidence Measurements

Proton-γ coincidence spectra from the reaction ^{37}Cl($t, p\gamma$)^{39}Cl were measured using a 13-cm-diam chamber, which permitted collinear detection of the reaction protons. The target consisted of Ba^{37}Cl$_2$, enriched to 96.1% in ^{37}Cl, of 520 ± 50μg/cm^2 evaporated onto a 42-mg/cm^2 Ta foil. Protons resulting from the triton bombardment were detected by 1-mm-thick annular surface-barrier detector, concentric with the triton beam and subtending an angle defined by $165° \leq \theta_p \leq 175°$. A 17-mg/cm^2 Al absorber on the front face of the detector stopped tritons elastically scattered from the target and Ta beam stop and α particles and deuterons formed in competing reactions. Figure 1 shows the proton spectrum measured at 3.4-MeV bombarding energy. The energy resolution of about 120 keV was due primarily to the target thickness, Al absorber, and close geometry.

γ rays were detected with a coaxial 40-cm^3 Ge(Li) detector which could be rotated between $\theta_\gamma = 0$ and 90° and which was located with its front face at a distance of 8.5 cm from the target. The chamber wall consisted of 0.25-mm brass in the quadrant used by the Ge(Li) detector. The front face of the Ge(Li) detector was shielded by 2 cm of Lucite and the detector sides were surrounded by a lead shield of about 3.5 cm. Beam currents were limited to less than 300 nA by the counting rate of this detector. The relative detection efficiency for γ rays of different energies was later determined by replacing the target with sources of ^{22}Na, ^{88}Y, and ^{208}Tl.

Signals from the Ge(Li) and silicon detector preamplifiers were used to generate a fast coincidence signal by feeding each through a fast-timing-filter amplifier and constant-fraction timing discriminator into a time-to-amplitude converter (TAC) set to start on proton and stop on γ-ray signals. ORTEC modular circuitry was used throughout. The resulting TAC spectrum had a peak of 10 nsec FWHM and a peak-to-random-events ratio of greater than 10 to 1. A time gate of 25 nsec was used throughout the measurements.

Coincidence spectra were accumulated in a TMC 16 384-channel analyzer operating in a spectrumsort mode which permitted spectra of 2048 channels from the γ-ray detector to be recorded in coincidence with up to eight digital voltage gates set on the proton detector. The digital voltage gates used are shown in Fig. 1. The gates were chosen to span resolved proton groups.

The main investigation was of the proton groups falling in gates 1 through 7 in Fig. 1. For this study the zero offset and dispersion of the γ-ray spectra were set to study the energy region $300 < E_\gamma < 2470$ keV with a dispersion of 1.16 keV/channel. Spectra were recorded at 0 and 90° to the triton beam.

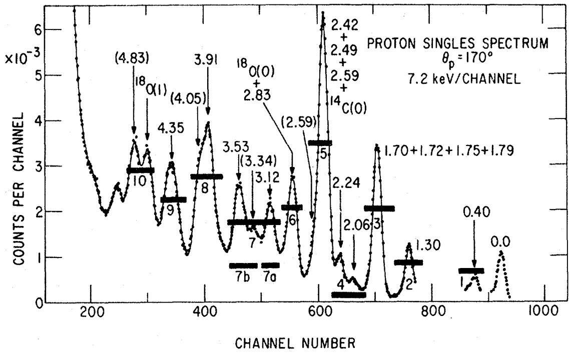

FIG. 1. Spectrum of protons resulting from 3.4-MeV triton bombardment of an enriched target of $Ba^{37}Cl_2$. These data were measured with an annular surface-barrier detector. Peaks due to $^{37}Cl(t,p)^{39}Cl$ are indicated by giving the excitation energies in MeV of the ^{39}Cl states to which the reaction leads. The background is due mainly to the (t,p) reactions on ^{16}O and ^{12}C. The broad horizontal bars labeled 1–10 define the proton gates set for the Ge(Li) coincidence measurements on the γ-ray decay of these states.

The runs at each angle required ~9 days at an average beam current of 250 nA, corresponding to a bombardment of 0.14 C. The net charge deposited during the bombardments was measured by a current integrator. Spectra were read out about every 8 h. During the course of these measurements (~3 weeks) the gain of the Ge(Li) detector system slowly changed by ~0.5%. The individual data were subsequently corrected for small shifts of this order. The energy resolution of the final coincidence spectra varied from 5.2 to 7.0 keV FWHM for 400- to 2000-keV γ rays, respectively. A second coincidence measurement was performed with the proton gates 3, 6, 7a, 7b, 8, 9, and 10 of Fig. 1, but with the Ge(Li) detector at 90° only; the offset and dispersion were such that the γ-ray energy region $300 < E_\gamma < 4500$ keV was displayed.

The energy calibration of the Ge(Li) spectra proceeded in three stages. First, the energies of

TABLE I. ^{39}Cl γ-ray energies from $^{37}Cl(t,p\gamma)^{39}Cl$.

γ-ray number	E_γ (MeV)	Assignment (initial level No. → final level No.)
	Singles measurements	
1	396.42 ± 0.07	1 → 0
2	410.65 ± 0.13	12 → 9
3	443.66 ± 0.10	5 → 2
4	484.61 ± 0.10	6 → 2
5	637.7 ± 0.3	9 → 6
6	1301.46 ± 0.10	2 → 0
	Coincidence measurements	
7	905.1 ± 0.3	2 → 1
8	1089.2 ± 0.4	12 → 5
9	1110.0 ± 0.5	14 → 9
10	1122.9 ± 0.4	9 → 2
11	1188.2 ± 0.3	10 → 2
12	1284.8 ± 2.0	11 → 2
13	1326.0 ± 0.4	4 → 1
14	1370.6 ± 0.5	13 → 5
15	1695.4 ± 0.6	3 → 0
16	1722.5 ± 0.7	4 → 0
17	1745.03 ± 0.15[a]	5 → 0
18	1841.4 ± 0.7	8 → 1
19	2060.3 ± 1.0	7 → 0

[a] Used for energy calibration, derived from the sum of the 5 → 2 and 2 → 0 energies.

the more prominent ^{39}Cl γ rays were determined from the second coincidence measurement as follows. As is indicated in Fig. 1, the proton group corresponding to the first excited state of ^{18}O, formed via the (t, p) reaction on oxygen contamination of the target, falls in gate 10. The ^{18}O $1 \rightarrow 0$ γ ray, with an energy of 1982 ± 0.20 keV,[4] was relatively quite intense and provided, together with annihilation radiation, an accurate and convenient calibration of the γ-ray spectra. By this means the energies of the more prominent ^{39}Cl γ rays were determined to $\sim \pm 0.5$ keV. It was then an easy matter to identify the more intense lines in singles spectra and to determine their energies more accurately. Finally, the energies of the rest of the ^{39}Cl γ rays observed in the first coincidence measurement were determined relative to those measured in singles. These last two steps are described in the next subsection (Sec. II B).

B. ^{39}Cl γ-Ray Energy Measurements

Lower-lying states. Ge(Li) singles spectra were also recorded for bombardments of the 520-μg/cm^2 Ba^{37}Cl$_2$ target with 3.4-MeV tritons. A 20-cm^3 Ge(Li) detector, with an energy resolution of 1.7 keV FWHM for 384-keV γ rays, was placed 4.5 cm from the target and at 90° to the triton beam. 4096-channel spectra were recorded using a 125-nA beam with various radioactive sources placed nearby to provide calibration peaks. Thus, the energy of the 1301-keV γ ray corresponding to the ^{39}Cl $2 \rightarrow 0$ transition was measured relative to the ^{60}Co γ rays of 1173 and 1333 keV and the 1267-keV γ ray from ^{39}Cl$(\beta^-)^{39}$Ar, while ^{192}Ir and ^{133}Ba sources provided the main energy standards for the energy region below the 511-keV line. ^{18}F γ rays from the ^{16}O$(t, n\gamma)^{18}$F reaction and γ rays from ^{37}Cl$(t, d)^{38}$Cl$(\beta^-)^{38}$Ar also were used in the energy calibration. The extraction of the positions of the γ-ray peaks followed previous practices,[5] as did the least-squares fitting to the peak positions of the calibration lines.

TABLE II. ^{39}Cl excitation energies from the γ-ray energies of Table I.

Level No.	E_x (MeV)	Source (γ-ray No. in Table I)
1	396.42 ± 0.07	1
2	1301.48 ± 0.10	6
3	1695.4 ± 0.6	15
4	1722.5 ± 0.7	16
5	1745.14 ± 0.15	3 + 6
6	1786.09 ± 0.15	4 + 6
7	2060.5 ± 1.0	19
8	2237.9 ± 0.8	1 + 18
9	2424.0 ± 0.4	5 + (4 + 6); 10 + 6
10	2489.6 ± 0.4	11 + 6
11	2585.8 ± 2.0	12 + 6
12	2834.5 ± 0.4	2 + (5 + 4 + 6); 8 + (3 + 6)
13	3115.7 ± 0.6	14 + (3 + 6)
14	3533.9 ± 0.6	9 + (5 + 4 + 6)

The γ rays observed in the singles spectra which were definitely assigned to ^{39}Cl are listed in the upper part of Table I together with their assignments to the ^{39}Cl decay scheme. These assignments are based on the γ-ray energies and, to a small extent, their relative intensities. That is, agreement with the energies obtained from the second set of proton-γ coincidence measurements was considered sufficient identification.

As stated, the γ rays whose energies were measured in singles provided the energy calibration for the first set of coincidence measurements. In addition the 1745-keV $5 \rightarrow 0$ γ ray, the energy of which is determined by summing the energies of the $5 \rightarrow 2$ and $2 \rightarrow 0$ transitions, also was used. The resulting γ-ray energies are listed in the lower part of Table I. The assignments are based mainly on energy but also on the intensities of the γ-ray peaks observed in the coincidence spectra taken at both 90 and 0° to the beam.

The ^{39}Cl excitation energies which result from the γ-ray energies of Table I are listed in Table II which also shows the source of the excitation energies. The correction for recoil has been applied in going from γ ray to excitation energies. For cases where excitation energies were derived from two different γ-ray branches, the two independent results yield good agreement.

The levels listed in Table II above the second excited state are newly observed since the previous ^{40}Ar$(d, {}^3$He$)^{39}$Cl data[1] were not obtained with adequate resolution to separate those states. In the present work the probability that a given ^{39}Cl level has been missed rises rapidly with excitation energy. On the other hand, all levels listed in Table II with the exception of the 12th are assigned with confidence. The 12th, at 2586 keV, is listed as uncertain because the evidence for it is one weak (but certain) γ ray and the proton group corresponding to it is obscured by the strong ^{12}C$(t, p)^{14}$C contaminant. As can be seen in Fig. 1, another possible ^{39}Cl level could be associated with an unidentified particle group in gate 7 which has an energy which would correspond to a ^{39}Cl level at 3.34 ± 0.07 MeV. However, no γ rays were observed which could be assigned to the decay of such a level.

Higher-lying states. In the proton-γ examination of the decay modes of possible higher-lying ^{39}Cl levels – those encompassed by gates 8, 9, and 10 of Fig. 1 – the Ge(Li) detector was set at 90° only and the statistics were poor so that only fragmentary information was obtained. The proton peak encompassed by gate 8 in Fig. 1 appears to be at least a doublet. In the Ge(Li) spectrum, γ rays with energies of 1483.4 ± 0.5 and 2606.7 ± 2.0 keV were observed. The proton and γ-ray spectra are consistent with the decay of a level at 3907.4 ± 0.5 keV to the 2424- and 1301-keV levels, respectively. There is also weak evidence for a level at 4.05 ± 0.03 MeV which decays to the first excited state and possibly the ground state.

The proton group included in gate 9 of Fig. 1 appears to be a singlet with an energy corresponding to an excitation energy in ^{39}Cl of 4.38 ± 0.07 MeV. In the γ-ray spectrum in coincidence with gate 9, two γ rays were observed which could originate from the decay of this level. These have energies of 2567.8 ± 2.0 and 3059 ± 6 keV and are possibly due to decay of a level at 4354 ± 2 keV to the 1786- and 1301-keV levels, respectively.

The higher-energy proton group in gate 10 is assigned to the ^{16}O$(t, p)^{18}$O reaction as discussed previously. The other proton peak, if due to ^{39}Cl, corresponds to an excitation energy of 4.83 ± 0.1 MeV. No γ rays were observed with any certainty which could be assigned to the decay of such a level.

C. Branching Ratios and Mean Lives

A portion of the first set of coincidence data is shown in Fig. 2, which represents the sum of most of the data obtained at both 0 and 90°. The plots show the Ge(Li) spectra measured in coincidence with gates 2, 3, and 6 of Fig. 1. Transitions in ^{39}Cl are labeled by giving the initial and final states (in keV) between which the transitions occur. The inset level schemes summarize the placement of these transitions within the ^{39}Cl level scheme.

The branching ratios resulting from the γ-ray spectra, such as those of Fig. 2, are given in Table III. The procedure used was to sum the peak intensities extracted from the 90 and 0° spectra, normalized to integrated charge, in the ratio 2 : 1. This corrects for terms in $P_2(\cos\theta_\gamma)$. Terms in $P_4(\cos\theta_\gamma)$, if present, were neglected.

For the coincidence geometry used, the ^{39}Cl ions were restricted to move in a forward cone of half-angle less than 7° with a z component of velocity of $v/c = 0.74$ to 0.66%, depending on excitation energy. Thus the full kinematical 0–90° Doppler shift, $E_k - E_0$, is, for example, 12.14 keV for a 1722-keV γ ray. Lifetimes were deter-

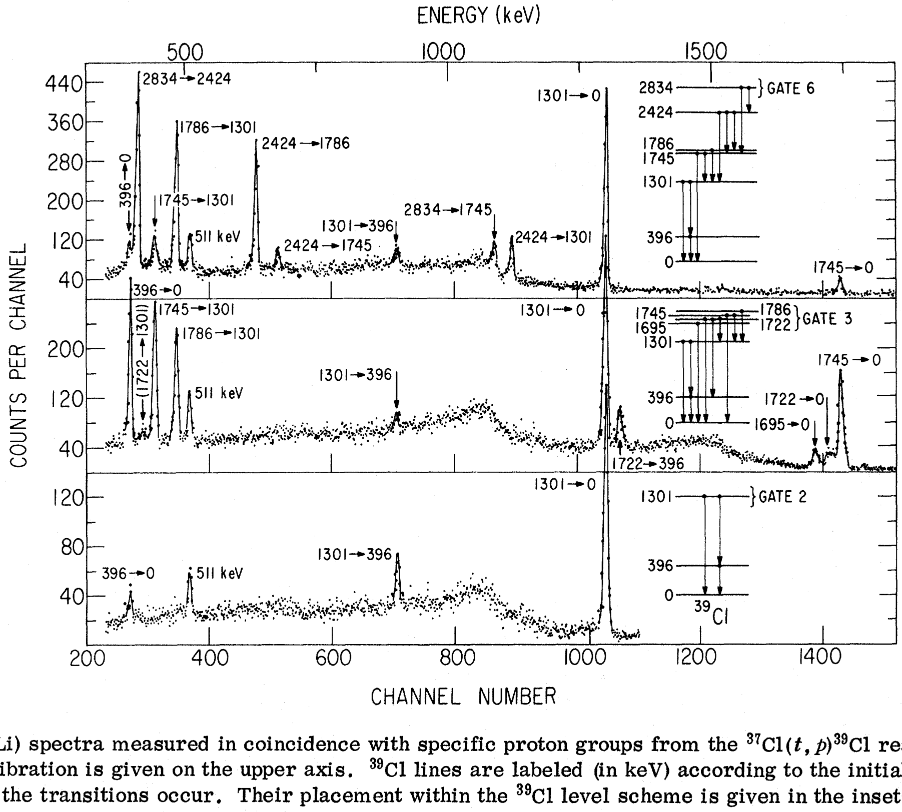

FIG. 2. Ge(Li) spectra measured in coincidence with specific proton groups from the ^{37}Cl$(t, p)^{39}$Cl reaction. The γ-ray energy calibration is given on the upper axis. ^{39}Cl lines are labeled (in keV) according to the initial and final states between which the transitions occur. Their placement within the ^{39}Cl level scheme is given in the inset level diagram, which also indicates the proton gate region (see Fig. 1). These data are the sum of data recorded at 0 and 90° and thus some Doppler effects are evident. For instance, the 1722 → 0-keV transition in coincidence with gate 3 is obviously broadened.

TABLE III. Summary of branching ratios for ^{39}Cl. The branching ratios are given (in percent) for transitions from the given initial to the indicated final state.

Final state (keV)	Initial state (keV) 396	1301	1695	1722	1745	1786	2061	2238	2424	2490	2834	3116	3534
0	100	94 ± 2	>50	44 ± 5	63 ± 4	<9	100	23 ± 6	<10	<8	<5	<25	<30
396		6 ± 2	<50	49 ± 5	<4	<14	<10	77 ± 6	<6	<7	<5	<25	<10
1301			<50	7 ± 5	37 ± 4	100	<11	<4	24 ± 3	100	<5	<22	10 ± 8
1695				...	...	...	<9	<5	<5	<5	<3	<27	<13
1722					...	...	<12	<8	<4	<6	<3	<22	<12
1745						...	<12	<5	9 ± 3	<4	13 ± 3	100	32 ± 10
1786							<16	<4	67 ± 3	<4	<5	<35	$\lesssim30$
2061								...	<5	<4	<3	<15	<10
2238									<4	<20	<2	<12	<10
2424										...	87 ± 3	<12	58 ± 10
2490											<2	<15	<5
2834												<15	<4
3116													<4

mined via the Doppler-shift attenuation method (DSAM) using the average attenuation factor $F(\tau)$ defined by $F(\tau)=(\Delta E_\gamma)_{\rm exp}/(\Delta E_\gamma)_{\tau=0}$. Here $(\Delta E_\gamma)_{\rm exp}$ denotes the experimentally measured shift determined from the difference between the centroids of the 0 and 90° data, and $(\Delta E_\gamma)_{\tau=0}$ is the shift which would have been observed for an infinitely short mean life. The latter was calculated from $E_k - E_0$ where E_0 is the γ-ray energy observed at 90° (and also for emission from nuclei at rest)

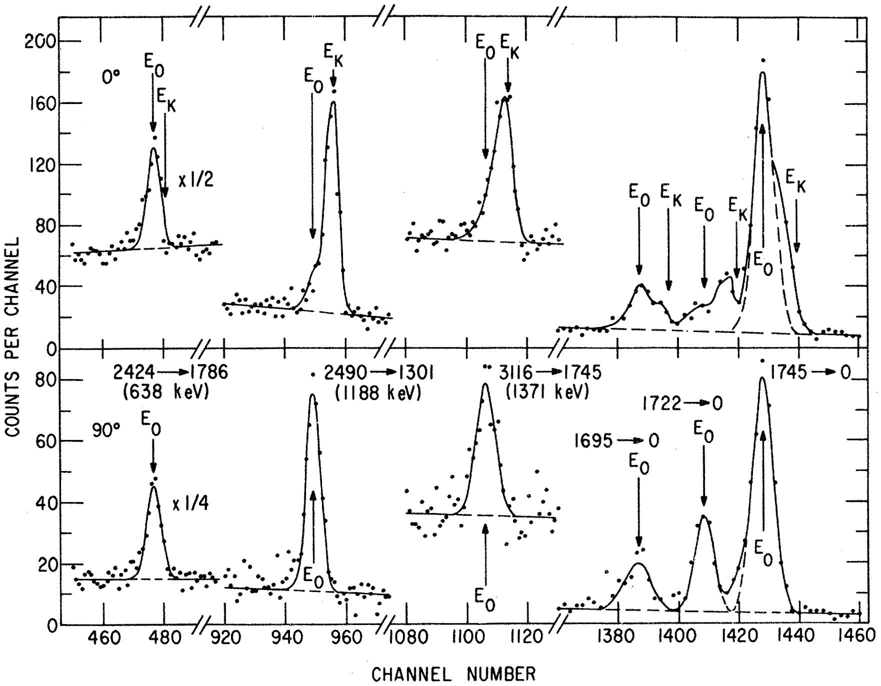

FIG. 3. Portions of the Ge(Li) coincidence spectra measured at $\theta_\gamma = 0$ and 90°, illustrating the Doppler shifts of primary transitions from low-lying states of ^{39}Cl. The transition energy E_0 and the full kinematic shifts E_k of the shifted lines at $\theta_\gamma = 0°$ are indicated. The data for the 1695-, 1722-, and 1745-keV γ rays have been summed in groups of two channels for clarity of display. For the 90° spectra the lines drawn through the points are Gaussian peaks on an exponential background and are least-squares fits. For the 1745-keV line the Gaussian is indicated by a dashed line as it is at 0°. For the remaining curves at 0° the background is a least-squares exponential fit, but the peak line shapes are drawn to approximate the line shapes expected for the mean lives deduced from the $F(\tau)$. The $F(\tau)$ values were obtained from centroids, and thus the deviation of the detector response from a Gaussian shape has no direct effect on the accuracy of the method.

and E_k, which is calculated from the kinematics, is the 0° γ-ray energy for $\tau = 0$. E_k includes small corrections due to carbon buildup on the target, the target thickness, and the solid angle of the Ge(Li) detector. Some representative data from which the $(\Delta E_\gamma)_{\rm exp}$ and $F(\tau)$ were obtained are illustrated in Fig. 3 and the DSAM results are given in Table IV. In the two cases where $F(\tau)$ was determined for two different transitions from the same level, the agreement is good, and an average value of $F(\tau)$ was used in the calculation of τ. The theoretical τ versus $F(\tau)$ relationship was calculated using a computer program[6] utilizing the Blaugrund treatment.[7] Details have been given in a report[3] of DSAM measurements of mean lives in ^{38}Cl using the ^{37}Cl$(d, p\gamma)^{38}$Cl reaction and the same target used in the present work.

III. DISCUSSION

In the ^{40}Ar$(d, {}^3$He$)^{39}$Cl angular distribution measurements of Wagner *et al.*[1] the ^{3}He groups corresponding to the ground state and first two excited states of ^{39}Cl were resolved: unambiguous $l = 2$ and $l = 0$ proton pickup distributions were obtained for the ground state and first excited state. The first of these is as expected, since the ^{39}Cl ground state is assigned $J^\pi = \frac{3}{2}^+$ from its β decay.[8] The $l = 0$ pattern observed for the first excited state leads to a $J^\pi = \frac{1}{2}^+$ assignment. The 1301-keV second excited state was very weakly excited in the $(d, {}^3$He) reaction and no angular distribution data were obtained. The results obtained by Wagner *et al.* for the states above 1.5 MeV excitation are quite difficult to interpret because of resolution problems. For instance, levels below 3 MeV were reported at 0.38, 1.25, 1.70, 1.96, 2.10, and 2.45 MeV, and thus it appears that the ^{3}He group corresponding to the "1.70"-MeV level actually has contributions from the 1695-, 1722-, 1745-, and 1786-keV levels. We conclude that better energy resolution is needed in order to obtain usable $(d, {}^3$He) angular distribution data for the ^{39}Cl levels above 1.5 MeV excitation.

TABLE IV. Summary of lifetimes determined for states of ^{39}Cl. For each initial state, we indicate the transitions studied, the observed 0–90° Doppler shifts, $(\Delta E_\gamma)_{\rm exp}$, the Doppler shift expected for $\tau=0$, $(\Delta E_\gamma)_{\tau=0}$, the experimental attenuation factors $F(\tau)$, and the corresponding mean lives τ.

$E_{\rm ex}$ (keV)	E_γ (keV)	$(\Delta E_\gamma)_{\rm exp}$ (keV)	$(\Delta E_\gamma)_{\tau=0}$ (keV)	$F(\tau)$ (%)	τ[a] (psec)
396	396	<0.28	2.85	<10	>2.0
1301	1301	<0.60	9.12	<7	>3.0
1695	1695	2.6 ± 1.3	11.71	22 ± 11	$1.1^{+1.4}_{-0.5}$
1722	1326	4.7 ± 0.8	9.16	52 ± 9	0.44 ± 0.09
	1722	5.2 ± 0.9	11.90	43 ± 7	
1745	444	0.6 ± 0.3	3.07	21 ± 8	1.3 ± 0.4
	1745	2.3 ± 0.4	12.05	19 ± 3	
1786	485	<0.33	3.35	<10	>2.0
2061	2060	13.7 ± 1.0	14.11	97 ± 7	<0.05
2238	1841	10.7 ± 0.8	12.54	85 ± 7	0.08 ± 0.04
2424	638	0.3 ± 0.3	4.23	7 ± 7	>1.8
2490	1188	6.3 ± 0.6	7.92	80 ± 8	0.10 ± 0.05
2586	1285	7.0 ± 2.3	8.57	81 ± 27	<0.3
2835	411	0.20 ± 0.20	2.70	7 ± 7	>1.8
	1089	<2.3	7.13	<33	
3116	1371	5.6 ± 0.6	8.86	63 ± 7	0.21 ± 0.06
3534	1110	6.3 ± 1.5	7.11	89 ± 20	<0.2

[a] The uncertainties include a 15% contribution from dE/dx.

The 0-90° intensity ratios obtained in the present work provide some spin information on these ^{39}Cl levels. For the levels at 1301, 1745, 1786, 2424, and 2834 keV this ratio deviated significantly from unity and $J = \frac{1}{2}$ can be excluded. For the remaining levels the intensity ratio was consistent with isotropy within the errors.

An upper limit of 4 nsec can be placed on the lifetimes of the 1301- and 1786-keV levels from a proton-γ timing measurement[9] performed in a

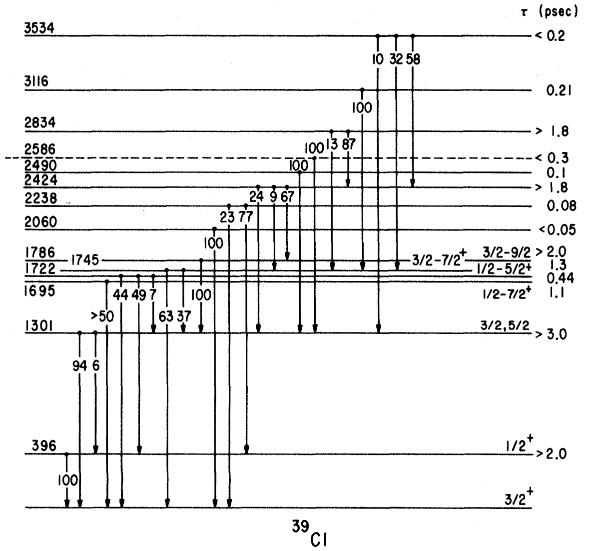

FIG. 4. Summary of excitation energies, γ-ray branching ratios, spin-parity assignments, and lifetimes for the energy levels of ^{39}Cl. The spin-parity assignments for the ground state and first-excited state are from Refs. 8 and 1, respectively. The rest of the information is from the present work. The 2586-MeV level is probable but not certain. Energies are in keV.

search for the lowest $\frac{7}{2}^-$ state of ^{39}Cl. The existence of the 6% branch to the $\frac{1}{2}^+$ 396-keV level, when combined with this limit, rules out $J > \frac{5}{2}$ for the 1301-keV level since, if this transition were $E3$, it would have a strength of 380 single-particle units for a 4-nsec mean life and a 4% branching ratio. Thus, the 1301-keV level has $J = \frac{3}{2}$ or $\frac{5}{2}$. Likewise the 1786 → 1301 transition must be dipole or quadrupole.

In a similar way, restrictions can be placed on the multipolarities of the γ rays emitted by the 1695-, 1722-, and 1745-keV levels using the branching ratios of Table III and the mean lives of Table IV. The resulting limitations on possible spin assignments are given in Fig. 4 which summarizes the results of the present study for levels below 3.6 MeV excitation.

The dominant configuration of the lowest-lying even-parity levels of ^{39}Cl should be $d_{3/2}{}^{-3}(\pi)f_{7/2}{}^{2}(\nu)$ and $d_{3/2}{}^{-2}(\pi)2s_{1/2}{}^{-1}(\pi)f_{7/2}{}^{2}(\nu)$, while the lowest odd-parity level should be $\frac{7}{2}^-$ from $d_{3/2}{}^{-4}f_{7/2}{}^{3}$. We should expect some similarity to ^{41}K then, since the dominant configurations there would be obtained by adding $d_{3/2}{}^{2}(\pi)$ to ^{39}Cl. Superficially, the ^{39}Cl and ^{41}K spectra are quite similar with the first two states being $\frac{3}{2}^+$ and $\frac{1}{2}^+$ and the second excited state in each being at 1.3 MeV followed by a group of levels at ~1.7 MeV.[10,11] However, the lowest $\frac{7}{2}^-$ level is at 1.3 MeV in ^{41}K; while, as summarized in Fig. 4, the ^{39}Cl 1.3-MeV level cannot be $\frac{7}{2}^-$ and, in fact, the lowest-lying candidate for a $\frac{7}{2}^-$ assignment is the 1786-keV level. Further speculation and quantitative comparison between theory and experiment is best left until more definitive spin assignments have been made for the low-lying levels of ^{39}Cl.

---

†Work performed under the auspices of the U. S. Atomic Energy Commission.

*Present address: Robert Van de Graaff Laboratories, Utrecht, The Netherlands.

[1] G. J. Wagner, G. Th. Kaschl, G. Mairle, U. Schmidt-Rohr, and P. Turek, Nucl. Phys. A129, 469 (1969).

[2] H. Jarmie and M. G. Silbert, Phys. Rev. 123, 909 (1961).

[3] G. A. P. Engelbertink and J. W. Olness, Phys. Rev. C 5, 431 (1972).

[4] J. W. Olness, J. A. Becker, and E. K. Warburton, to be published.

[5] See, e.g., K. A. Snover, J. M. McDonald, D. B. Fossan, and E. K. Warburton, Phys. Rev. C 4, 398 (1971).

[6] We wish to thank C. E. Ragan, III, for making this program available to us.

[7] A. E. Blaugrund, Nucl. Phys. 88, 501 (1966).

[8] G. A. P. Engelbertink, E. K. Warburton, and J. W. Olness, Phys. Rev. C 5, 128 (1972).

[9] A. R. Polleti, J. G. Pronko, and E. K. Warburton, unpublished.

[10] D. F. Beckstrand and E. B. Shera, Phys. Rev. C 3, 208 (1971).

[11] F. Jundt, E. Aslanides, A. Gallmann, and E. K. Warburton, Phys. Rev. C 4, 498 (1971).