Mean lives in ^{38}Cl †

J. D. McCullen and L. C. McIntyre, Jr.
Department of Physics, University of Arizona, Tucson, Arizona 85721
(Received 20 May 1974)

Mean lives of eight states in ^{38}Cl have been measured using the ^{37}Cl($d,p\gamma$)^{38}Cl reaction at 3 MeV incident energy. The Doppler-shift attenuation method was used. Results are (levels in keV, and mean lives in fs): 755 (325 ± 35), 1309 (510 ± 45), 1617 (1110^{+190}_{-130}), 1692 (1330^{+240}_{-190}), 1745 (640^{+180}_{-110}), 1785 (100 ± 15), 1981 (330 ± 25), 2743 (≤30).

[NUCLEAR REACTIONS ^{37}Cl(d, $p\gamma$)^{38}Cl, E = 3.0 MeV; measured Doppler shifts, deduced $T_{1/2}$ for 8 levels.]

Recent Doppler-shift measurements of mean lives of states in ^{38}Cl have produced conflicting results. The measurements of Wedberg and Segel[1] are on the average a factor of 1.7 below those of Engelbertink and Olness.[2] Although the values for the mean life of any individual state agree within two standard deviations of the less precise of the two experiments, a comparison of all the results indicates a systematic difference. We have remeasured the mean lives of eight states in ^{38}Cl with the view of investigating this conflict.

An additional motive was to confirm the results of both the previous experiments concerning the 1617 → 1309-keV transition. In a simple weak-coupling shell model theory of ^{38}Cl these two levels belong to different multiplets formed by coupling in one case a $d_{3/2}$ proton or proton hole with an $f_{7/2}$ neutron and in the other case by coupling the $d_{3/2}$ proton or hole to a $2p_{3/2}$ neutron. If these configurations were pure, an $M1$ transition between multiplets would be forbidden.[1,3] The 1617-keV level has been proposed as the 3^- member of the $(\pi d_{3/2})(\nu f_{7/2})$ multiplet and the 1309-keV level as the 4^- member of the $(\pi d_{3/2})(\nu p_{3/2})$ multiplet.[3] The only major discrepancy between this theory and experiment is the observation, by both of the experiments mentioned above,[1,2] of a reasonably strong transition between the above two levels.

We have employed a coincidence version of the Doppler-shift attenuation method to measure the mean lives in ^{38}Cl. The ^{37}Cl($d, p\gamma$)^{38}Cl reaction was used with an incident deuteron energy of 3 MeV. The method and experimental arrangement have been described previously.[4,5] Two targets were used, each with an annular particle detector recording protons with reaction angles between 149 and 167°. γ rays were observed in coincidence with the protons, limiting the recorded events to those involving excited ^{38}Cl nuclei recoiling forward (in the beam direction). The Ge(Li) γ-ray detector was placed at an angle of 28° relative to the first target and 152° relative to the second. Data from both targets were collected simultaneously. Coincident events were stored on magnetic tape and were tagged as originating in the first or second target. This tape was subsequently searched to construct γ-ray spectra originating from particular ^{38}Cl excited states and recoiling either forward (28°) or away (152°) from the γ-ray detector. Mean lives were calculated from the observed Doppler shift of the peak centroids in the usual way.

Targets of $PbCl_2$ enriched to 90% ^{37}Cl were evaporated onto Au and Ta backings. Results are presented in Table I for a 120-μg/cm^2 target on a thick Au backing and a 260-μg/cm^2 target on a thick Ta backing. The calculation of the Doppler-shift attenuation factor F as a function of mean life τ was done using the method of Blaugrund[6] which uses the slowing down theory of Lindhard, Scharff, and Schiøtt.[7] Factors of 1.0 were used as the multipliers f_e and f_n for the electron and nuclear stopping terms.

This experimental arrangement used by us is very similar to each of the previous experiments. The differences lie primarily in choices of target thickness and detection geometry. There is no systematic trend with target thickness; Wedberg and Segel used targets of 50 μg/cm^2 and 1.0 and 1.7 mg/cm^2, while Engelbertink and Olness used targets comparable to ours. The targets were all backed with either Ta or Au, with no discernible systematic difference. The geometries of the three experiments are all somewhat different; of these, the present geometry should yield the largest Doppler shift with that of Engelbertink and Olness producing the smallest shift. This, along with the fact that in the work of Wedberg and Segel and in the present experiment the γ rays emitted in forward and backward directions were detected simultaneously, while in Ref. 2 they were detected separately, may account for the systematic dif-

TABLE I. Doppler-shift attenuation factors and mean lives in ^{38}Cl. Columns 3, 4, and 5 give results using a 120-μg/cm^2 $PbCl_2$ target on a thick Au backing. Columns 6, 7, and 8 are results using a 260-μg/cm^2 $PbCl_2$ target on a thick Ta backing. The column $\bar{F}$ gives the average shift factor taken over all observed transitions for a given state. The last three columns give final averaged results for this experiment as well as those given in Refs. 1 and 2.

State		120-μg/cm^2 $PbCl_2$ on Au			260-μg/cm^2 $PbCl_2$ on Ta			Adopted mean lives		
(keV)	Transition	F	$\bar{F}$	τ	F	$\bar{F}$	τ	This expt.	Ref. 1	Ref. 2
755	755 → g.s.	0.27 ± 0.04	0.27 ± 0.04	390 ± 60	0.39 ± 0.03	0.39 ± 0.03	300 ± 40	325 ± 35	290 ± 30	530 ± 180
1309	1309 → g.s.				0.26 ± 0.07					
	→ 671	0.22 ± 0.03			0.29 ± 0.04					
	→ 755	0.17 ± 0.04	0.20 ± 0.02	560 ± 70	0.27 ± 0.05	0.28 ± 0.03	470 ± 60	510 ± 45	560^{+150}_{-100}	1000^{+900}_{-400}
1617	1617 → g.s.	0.06 ± 0.06			0.19 ± 0.04					
	→ 755	0.07 ± 0.02			0.11 ± 0.03					
	→ 1309	0.10 ± 0.03	0.08 ± 0.02	1500^{+600}_{-300}	0.13 ± 0.05	0.14 ± 0.02	1050^{+200}_{-150}	1110^{+190}_{-130}	1500^{+1000}_{-500}	2300^{+2300}_{-900}
1692	1692 → g.s.	0.06 ± 0.02	0.06 ± 0.02	2100^{+1100}_{-600}	0.12 ± 0.02	0.12 ± 0.02	1250^{+350}_{-200}	1330^{+240}_{-190}	1200^{+300}_{-200}	1900 ± 700
1745	1745 → g.s.	0.19 ± 0.04	0.19 ± 0.04	590^{+190}_{-120}	0.16 ± 0.05	0.16 ± 0.05	900^{+450}_{-250}	640^{+180}_{-110}	1000 ± 300	2100^{+1400}_{-700}
1785	···	···	···	···	0.69 ± 0.04	0.69 ± 0.04	100 ± 15	100 ± 15	90 ± 60	90 ± 30
1981	1981 → g.s.	0.21 ± 0.04			0.37 ± 0.03					
	→ 755	0.25 ± 0.03			0.36 ± 0.04					
	→ 1617	0.34 ± 0.06			0.39 ± 0.04					
	→ 1692	···	0.26 ± 0.03	410 ± 60	···	0.37 ± 0.02	320 ± 25	330 ± 25	260 ± 80	430 ± 90
2743	2743 → g.s.	···			0.96 ± 0.04					
	→ 1309	0.95 ± 0.03			0.97 ± 0.03					
	→ 1617	0.83 ± 0.08			0.92 ± 0.04					
	→ 1785	0.90 ± 0.04	0.92 ± 0.03	≤30	1.03 ± 0.04	0.97 ± 0.02	≤30	≤30	40 ± 20	≤30

ference observed.

The analysis of the observed shifts to extract mean lives is also similar in the three investigations. The principal difference lies in the choice of f_e, the multiplier of the electronic stopping term. Our choice of $f_e = 1.0$ differs from that of Ref. 1 ($f_e = 1.16$) and Ref. 2 ($f_e = 1.25$). These alternate choices affect the results by less than 10% on the whole, the differences being negligible for the longer mean lives. If we were to use the value of f_e from either of the previous works, our quoted lifetimes would be even shorter, which would not help the discrepancy.

Table I provides a comparison of our results to both previous experiments. It is apparent that we tend to confirm the more precise measurements of Ref. 1. In addition, we confirm the results of both previous experiments concerning the mean life of the 1617-keV level. The strength of the "forbidden" transition from the 1617-keV state to the 1309-keV state also depends on the branching ratios given in Ref. 2. Although we cannot deduce these numbers from our data, since our γ-ray detector is symmetrically placed with respect to the proton recoil directions, the relative intensities we observe are for the most part quite consistent with the branching ratios given in Ref. 2.

†Work supported in part by the National Science Foundation.

[1]G. H. Wedberg and R. E. Segel, Phys. Rev. C 7, 1956 (1973).

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

[3]D. Kurath and R. D. Lawson, Phys. Rev. C 6, 901 (1972).

[4]R. L. Hershberger, M. J. Wozniak, Jr., and D. J. Donahue, Phys. Rev. 186, 1167 (1969).

[5]K. S. Burton and L. C. McIntyre, Jr., Nucl. Phys. A154, 551 (1970).

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

[7]J. Lindhard, M. Scharff, and J. E. Schiøtt, K. Dan. Vidensk. Selsk. Mat.-Fys. Medd. 33, No. 14 (1963).