2 also agrees with that obtained from the amplitude of the peak in the total-cross-section measurements. Although there are O^{16} levels with approximate analog energies of other N^{16} levels, further reliable comparisons are not possible without more knowledge of spins and parities.

As additional information is obtained from $N^{15}+n$ angular-distribution experiments,[13] a better understanding of the nature of the N^{16} levels can be achieved. If the l values of the neutrons exciting the various resonances can be extracted from these angular-distribution data, the resulting parities along with the J-value information given by the present experiment will aid their interpretation.

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Transition Probabilities within the $(f_{7/2})^3$ Configuration of Ar^{41}†

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The lifetimes of the 165- and 518-keV levels of Ar^{41} have been measured by fast timing techniques. Half-lives of 410±30 and 340±20 psec, respectively, were obtained from logarithmic slopes of the time-delay distributions. The time delays were marked by protons from the $Ar^{40}(d,p\gamma)Ar^{41}$ reaction detected in a solid-state counter and gamma rays detected with a plastic scintillator. The lower error limit for the half-life of the 165-keV level is somewhat uncertain because of difficulties in obtaining a true prompt resolution function for this measurement. $M1$ hindrances relative to Moszkowski estimates for the 165- and 353-keV gamma rays are approximately 100 and 3000, respectively. These hindrances are consistent with dominant $(f_{7/2})^3$ configurations predicted for the first three levels of Ar^{41} by Shadmi and Talmi plus a 2% $(f_{7/2})^2(f_{5/2})$ admixture into the 165-keV state. The 518-keV $E2$ transition to the ground state, which is enhanced by a factor of approximately 5 relative to single-particle estimates, requires an effective neutron charge of 2.3e for $(f_{7/2})^3$ configurations.

I. INTRODUCTION

PROPERTIES of the Ar^{41} nucleus are interesting with respect to the shell model since it has three $f_{7/2}$ neutrons outside a closed shell and two $d_{3/2}$ proton holes. Kashy *et al.*[1] have studied the level structure of Ar^{41} up to an excitation of about 6 MeV using the $Ar^{40}(d,p)Ar^{41}$ reaction. They obtained energies, reduced widths, and l_n values for a number of levels from their angular-distribution data. Mean energies for the various shell-model configurations were also extracted from the experimental results.

In an attempt to see whether the shell model could account for these experimental results on Ar^{41}, Shadmi and Talmi[2] have made calculations in j–j coupling considering the configurations which consisted of two $d_{3/2}$ proton holes together with $(f_{7/2})^3$, $(f_{7/2})^2(p_{3/2})$, and $(f_{7/2})^2(p_{1/2})$ neutron particles. The calculations are in fair agreement with low-lying levels and account for the large number of odd-parity $\frac{3}{2}$ and $\frac{1}{2}$ levels up to an excitation of 4.5 MeV.

The level energies of Ar^{41} have more recently been observed up to an excitation of 8.3 MeV by Holbrow *et al.*[3] using the same reaction. Their results for levels up to about 4.5 MeV are very similar to the excitation energies given by Kashy *et al.*[1] The spin and parity of the Ar^{41} ground state is inferred to be $\frac{7}{2}^{(-)}$ from beta-decay results of Schwarzschild *et al.*[4] Allen *et al.*[5] have made de-excitation and angular-correlation studies with the $Ar^{40}(d,p\gamma)Ar^{41}$ reaction for a deuteron energy of 3.30 MeV. This work of Allen *et al.*, together with the lifetimes measured in the present experiment and the stripping results of Kashy *et al.*[1] has enabled the assignment of spins and parities to be made to some Ar^{41} levels. In particular, the first excited state at 165 keV has a spin-parity assignment of $\frac{5}{2}^{(-)}$ or $\frac{7}{2}^{(-)}$ while the 0.518-

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

[1] E. Kashy, A. M. Hoogenboom, and W. W. Buechner, Phys. Rev. **124**, 1917 (1961).
[2] Y. Shadmi and I. Talmi, Phys. Rev. **129**, 1286 (1963).
[3] C. H. Holbrow, P. V. Hewka, J. Wiza, and R. Middleton, Nucl. Phys. **79**, 505 (1966).
[4] A. Schwarzschild, B. M. Rustad, and C. S. Wu, Phys. Rev. **103**, 1796 (1956).
[5] J. P. Allen, A. J. Howard, J. W. Olness, and E. K. Warburton, Phys. Rev. (to be published).

and 1.357-MeV levels are both $\frac{3}{2}^{(-)}$. The shell-model theory of Shadmi and Talmi[2] predicts a $(\frac{5}{2}^-)$ assignment for the 165-keV level. The other assignments mentioned also agree with the theory.

The interest of the present experiment is to study the gamma-ray transitions within the first group of three levels, that is, the ground state, the 165-keV level, and the 518-keV level of Ar^{41}. The calculations of Shadmi and Talmi discussed above predict these states to be predominantly of the $(f_{7/2})^3$ configuration. A result[6] of j–j coupling calculations shows that within a j^n configuration of identical particles, $M1$ transitions are forbidden in the long-wavelength approximation. From a measurement of the $M1$ transition probabilities within the group of three levels, the extent to which they are described by the $(f_{7/2})^3$ configuration should be apparent. If the theoretical calculations for these levels were reasonably accurate, large $M1$ hindrances would be observed.

In the present experiment, the lifetimes of the first two excited states of Ar^{41} at 165 and 518 keV are measured; from these lifetime measurements and a knowledge of the branching ratio for the 518-keV state, the $M1$ transition probabilities within the discussed group of three levels can be determined. With these $M1$ transition probabilities depending sensitively on deviations from the predicted $(f_{7/2})^3$ configuration, the lifetime meaurements serve as a close check on the wave functions of these states.

II. EXPERIMENTAL TECHNIQUE

The lifetime measurements in this experiment were obtained from logarithmic slopes of time-delay distributions. Experimental techniques were similar to those described previously.[7] The time of formation of the levels was determined by the detection of protons from the $Ar^{40}(d,p\gamma)Ar^{41}$ reaction in a solid-state detector, while the decay time was marked by the detection of gamma rays in a plastic scintillator. Time-delay pulses were produced in a fast time-to-height converter. The appropriate proton group and gamma-ray window were chosen in slow coincidence in order to isolate the level under consideration and to minimize time-delay jitter.

In this experiment, 2.8-MeV deuterons from the Brookhaven Van de Graaff accelerator bombarded a 0.6-cm long gas target equipped with beam entrance and exit foils of 1.2-μ nickel. The exit foil was slanted with respect to the entrance foil such that the outgoing protons could be detected at angles ranging from 15°–45°. An argon gas pressure of about 0.5 atm was used. The solid-state detector was positioned at 20° for most of the measurements, with appropriate collimation to minimize transit-time variations and kinematic energy spreads for the protons. Absorbers of aluminum foil were placed before the solid-state detector to stop the elastic-scattered deuterons. The plastic scintillator detected gamma rays that were emitted at right angles to the reaction plane defined by the deuteron beam and the proton detector; it was positioned approximately 1 cm from the center of the gas target and thus subtended a large solid angle.

The solid-state detector used was a 500-ohm cm silicon surface-barrier type of 100-μ thickness and 25-mm^2 area. To minimize the rise time, the solid-state detector was totally depleted. By means of an inductive pick-off,[8] fast pulses for timing purposes were obtained; the normal energy pulses used for the slow-coincidence conditions were not affected by the pick-off. The gamma rays were detected in a 4-cm-diam by 4-cm-long NE102 plastic scintillator mounted on an Amperex XP-1020 phototube. The fast timing pulses were taken from the anode while the energy pulses were taken from a dynode further up the phototube chain.

The time-delay spectra were obtained from a time-to-height converter gated by the coincidence requirements for the slow pulses; these were recorded in a pulse-height analyzer. This system was capable of achieving time resolutions of about 400 psec full width at half-maximum (FWHM) for 1-MeV gamma rays with a corresponding slope that dropped a factor of 2 in less than 75 psec. The time resolution becomes worse as the accepted gamma-ray window decreases in energy. Time calibration of the time-to-height converter was made with two air-dielectric trombones.

III. EXPERIMENTAL MEASUREMENTS

The decay scheme for the low-lying levels in Ar^{41} from the work of Allen *et al.*[5] is shown in Fig. 1. The two states to be measured, the 165- and 518-keV states, are only weakly populated in the $Ar^{40}(d,p)Ar^{41}$ reaction as observed by Kashy *et al.*[1] A proton-gamma coincidence measurement for these two levels directly is difficult because of low coincidence rates. This difficulty was circumvented by making use of the fact that the 1.357-MeV state which decays to both the 165- and 518-keV

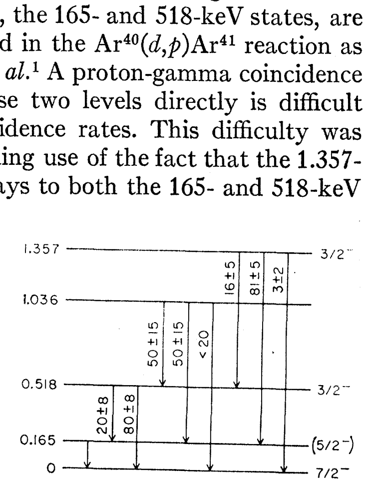

FIG. 1. Decay scheme for the low-lying levels of Ar^{41} from the work of Allen *et al.* (Ref. 5).

[6] A. de-Shalit and I. Talmi, *Nuclear Shell Theory* (Academic Press Inc., New York, 1962), p. 409.

[7] R. E. McDonald, D. B. Fossan, L. F. Chase, Jr., and J. A. Becker, Phys. Rev. **140**, B1198 (1965).

[8] Oak Ridge Technical Enterprises Corporation, Oak Ridge, Tennessee, similar to that described by C. W. Williams and J. A. Biggerstaff, Nucl. Instr. Methods **25**, 370 (1964).

levels is strongly populated by the $Ar^{40}(d,p)Ar^{41}$ reaction. If the lifetime of the 1.357-MeV state is very short compared to those being measured, the gamma branching to the 165- and 518-keV levels can be used as a means of populating them in a prompt manner relative to the protons feeding the 1.357-MeV state.

To check this lifetime assumption for the 1.357-MeV state, a time measurement was made between the protons feeding this state and the 1.2-MeV gamma rays de-exciting it. This measurement showed that the half-life of the 1.357-MeV state is less than 100 psec, a result which is expected because of the large energy available for the gamma decay. Thus, the lifetimes of the 165- and 518-keV levels can be measured by observing time-delay distributions between protons feeding the 1.357-MeV state and the ground-state gamma rays of 165 and 518 keV. For both lifetime measurements, then, the slow-coincidence condition for the solid-state detector was adjusted to accept the group of protons from the $Ar^{40}(d,p\gamma)Ar^{41}$ reaction feeding the 1.357-MeV state.

For the lifetime measurement of the 518-keV level, the gamma-ray coincidence requirement was set to accept a 20% channel at the Compton edge of the 518-keV gamma ray. For the 165-keV level, the gamma-ray channel was lowered to include a 20% window at about 60 keV, which is the Compton edge for the 165-keV gamma ray.

For both of these measurements, a fraction of the pulses associated with the direct high-energy gamma rays from the 1.357-MeV level will fall into the gamma-ray windows. For the measurement of the 165-keV level, the number of these high-energy gamma rays accepted is less than 1% of the desired 165-keV gamma rays because of the large energy difference in the respective Compton edges.

For the 518-keV level measurement, the situation is different. Here just 16% of the gamma decays from the 1.357-MeV level are to the 518-keV level. With the appropriate gamma-ray window for this measurement, only about 25% of the proton-gamma time coincidences will result from 518-keV gamma rays. Those time coincidences resulting from the direct gamma rays leaving the 1.357-MeV state will, of course, fall in a prompt time peak since the 1.357-MeV level has a half-life of less than 100 psec. For a lifetime of the 518-keV level which is significantly greater than that corresponding to the slope of the prompt resolution function, this expected prompt portion of the time spectrum will not interfere with the lifetime measurement.

The observed time-delay distribution representing the decay curve for the 165-keV level is shown as solid data points in Fig. 2. The logarithmic slope shown and those for several other runs not shown imply a half-life of $t_{1/2}=410\pm30$ psec. In order to determine whether this result is significant, the prompt-resolution function had to be measured under similar experimental conditions. To do this, the argon in the gas target was replaced by oxygen. Also, the deuteron energy was adjusted so that the $O^{16}(d,p)O^{17}$ proton group populating the 871-keV level in O^{17} fell into the same proton window, and the unchanged gamma-ray window observed a portion of the Compton spectrum from the 871-keV gamma ray. The half-life of the 871-keV state of O^{17} is $t_{1/2}=182\pm5$ psec;[7] this half-life is less than that corresponding to the slope of the prompt resolution function for these conditions, namely, a gamma-ray window as low as 60 keV. Thus, the resulting time spectrum shown with open data points in Fig. 2 represents the prompt resolution function for the 165-keV level measurement. The decay curve in comparison appears to have a lifetime slope greater than that of the prompt resolution function, although the difference is not great. Even though the slope of the prompt resolution function is not a straight line, a rough fit to it corresponds to a half-life of 250–300 psec; this could be slightly larger than under the actual measuring conditions, since there were considerably more coincident gamma rays that were not accepted in the gamma-ray window compared to the case when argon was in the gas target. The measured slope of the decay curve, $t_{1/2}=410\pm30$ psec, gives a good upper limit to the lifetime of the 165-keV level; however, because of the difficulty in producing identical background conditions for the measurement of the prompt resolution function, the lower limit may be more uncertain.

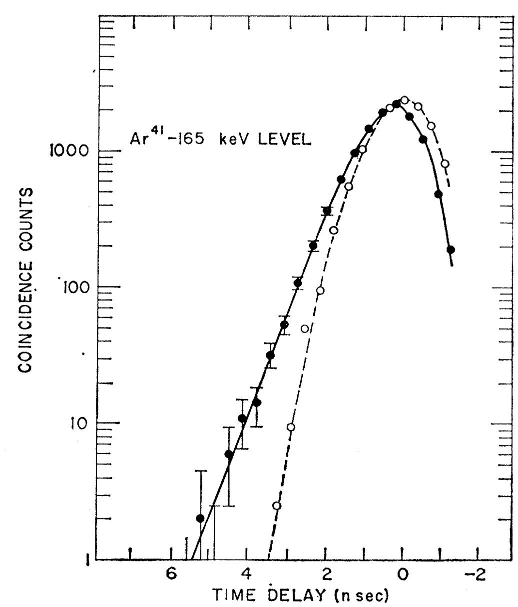

FIG. 2. The experimental decay curve for the 165-keV level of Ar^{41} as shown with solid data points. The logarithmic slope corresponds to a half-life of $t_{1/2}=410\pm30$ psec. Open data points represent the prompt resolution which was measured from the 871-keV level of O^{17} by the $O^{16}(d,p\gamma)O^{17}$ reaction. The lower error limit for the lifetime measurement is somewhat uncertain because of the difficulties in obtaining a true prompt resolution function for gamma rays of this small energy. An arbitrary zero time is used.

The time spectrum in Fig. 3, which is the result obtained for the 518-keV level, has the expected amount of a prompt peak in addition to the decay slope for the 518-keV state; the two parts of the spectrum are easily discernible. A least-squares fit to the logarithmic decay slope implies a half-life of $t_{1/2}=340\pm20$ psec for the 518-keV state. The error limits allow for statistical and time-calibration uncertainties.

To make certain that the prompt peak is not associated with the 518-keV level, a measurement was made with the window of the solid-state detector accepting the weaker proton group leading to the 518-keV level. These slow-coincidence conditions completely isolated this level from any prompt contributions; however, the coincidence rate was smaller. The decay curve for a 20-h run with these conditions is shown in Fig. 4 by solid data points. No prompt peak was observed and the slope is consistent with the lifetime result of Fig. 3, although the statistical uncertainties are larger. A prompt resolution function was measured as discussed above, but with conditions appropriate to the 518-keV level measurement. Because of the higher gamma-ray window, the prompt resolution function was improved to the point where the left slope observed with oxygen in the gas target represents the lifetime of the 871-keV level in O^{17}. This time spectrum is shown with open data points in Fig. 4; the left slope which is approximately 200 psec shows the validity of the lifetime measurement for the 518-keV level. The actual prompt resolution function under these experimental conditions would have a left slope that drops off significantly faster.

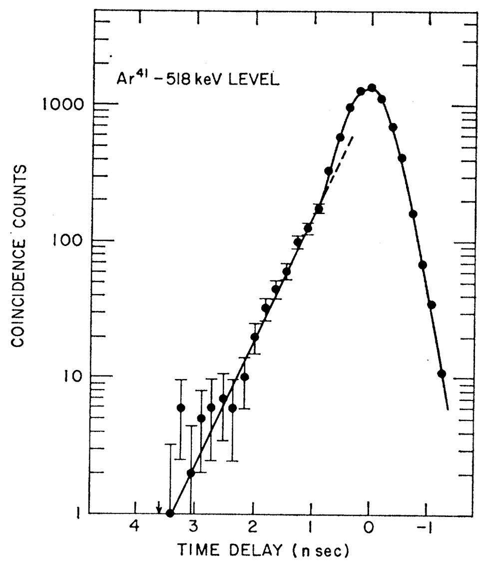

FIG. 3. The experimental decay curve for the 518-keV level of Ar^{41} plus a prompt contribution that resulted from gamma rays de-exciting the 1.357-MeV level. This time spectrum was obtained relative to protons that populated the level at 1.357 MeV from the $Ar^{40}(d,p\gamma)Ar^{41}$ reaction. The logarithmic slope of the decay curve corresponds to a half-life of $t_{1/2}=340\pm20$ psec. An arbitrary zero time is used.

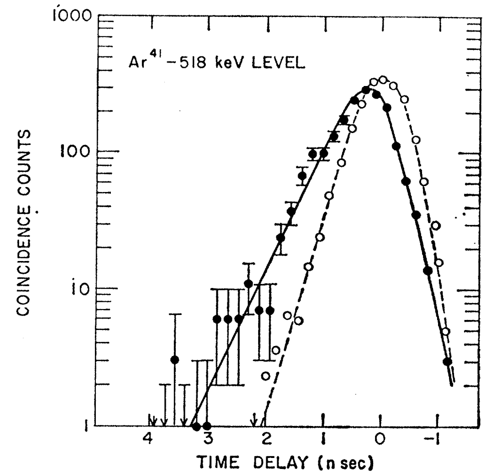

FIG. 4. The experimental decay curve for the 518-keV level of Ar^{41} as shown with solid data points. This time spectrum was obtained relative to protons that populated the 518-keV level directly from the $Ar^{40}(d,p\gamma)Ar^{41}$ reaction. The logarithmic slope is consistent with the lifetime measurement shown in Fig. 3, $t_{1/2}=340\pm20$ psec. The time spectrum shown with open data points is a decay curve for the 871-keV level in O^{17} which has a half-life of $t_{1/2}=182\pm5$ psec (Ref. 7). The measurement was made under experimental conditions identical to those for the measurement of the 518-keV state in Ar^{41} except that the $O^{16}(d,p\gamma)O^{17}$ reaction was used. The left slope, which represents this lifetime, falls off more slowly than that expected for the actual prompt resolution function. An arbitrary zero time is used.

With protons detected at about 20° in this experiment, the Ar^{41} nuclei are aligned to some extent by the $Ar^{40}(d,p)Ar^{41}$ reaction. The attenuation in the resulting gamma-ray angular correlation should not affect the measured decay curves of this experiment, first, because of the large solid angle for detecting gamma rays and, second, because the attenuation for recoiling nuclei in gas is expected to be considerably faster than the measured lifetimes.

IV. DISCUSSION

A summary of the present lifetime measurements for states in Ar^{41} is shown in Table I; no previous lifetime results are known for these states. For the 165-keV level, the lower error limit for the lifetime results is somewhat uncertain because of the difficulties in obtaining a proper prompt resolution function.

TABLE I. Experimental results for excited states of Ar^{41} from the present work.

E_{ex} (MeV)	$t_{1/2}$ (psec)	$B(M1)$ (10^{-43} MeV cm^3)	Hindrance[a]
0.165	410 ± 30[b]	$2.9(\frac{5}{2}^- \rightarrow \frac{7}{2}^-)$	100
0.518	340 ± 20	$0.087(\frac{3}{2}^- \rightarrow \frac{5}{2}^-)$	3000
1.357	<100		

[a] Relative to the Moszkowski single-particle estimates. S. A. Moszkowski, in *Alpha-, Beta-, and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (North-Holland Publishing Company, Amsterdam, 1965), p. 883.
[b] The lower error limit is somewhat uncertain because of the difficulties in obtaining a true prompt resolution function for gamma rays of this small energy.

TABLE II. Theoretical results[a] for low-lying levels in Ar^{41}.

E_{ex} (MeV)	(J^{π})	Dominant neutron configuration[b]	Calculated E (MeV)
0	$\frac{7}{2}^-$	$(f_{7/2})^3$	0
0.165	$\frac{5}{2}^-$	$(f_{7/2})^3$	0.17
0.518	$\frac{3}{2}^-$	$(f_{7/2})^3$	1.3
1.036	...	...	...
1.357	$\frac{3}{2}^-$	$(f_{7/2})^2(p_{3/2})$	1.1

[a] Y. Shadmi and I. Talmi, Phys. Rev. **129**, 1286 (1963).
[b] The $(d_{3/2})^{-2}$ protons are coupled to spin 0.

The theoretical results of Shadmi and Talmi[2] for the levels in Ar^{41} of concern in this experiment are summarized in Table II. Their shell model calculations were made in j-j coupling using the $(d_{3/2})^{-2}$ proton configuration together with $(f_{7/2})^3$, $(f_{7/2})^2(p_{3/2})$, and $(f_{7/2})^2(p_{1/2})$ neutron configurations. The neutron configurations listed in Table I for the various levels are only meant as dominant ones. In this discussion the first excited state is assumed to be $\frac{5}{2}^{(-)}$ in agreement with theory, although the various experiments do not eliminate the $\frac{7}{2}$ spin possibility or make a definite parity assignment.

The calculated energies of Shadmi and Talmi for these levels agree well with experiment except for the 518-keV level for which they are too high. Kashy *et al.*[1] observed a small $l_n=1$ stripping width for the 518-keV level which implies an admixture of $(f_{7/2})^2(p_{3/2})$ into the dominant $(f_{7/2})^3$ configuration. This admixture which is repelled by the $(f_{7/2})^2(p_{3/2})$ level at 1.357 MeV would lower the calculated energy into closer agreement with the experimental value of 518 keV.

If the three lowest states are described well by the $(f_{7/2})^3$ configuration as Shadmi and Talmi predict, $M1$ transitions within these states should be strongly hindered. For like particles of a configuration j^n, the $M1$ operator is simply gJ and thus the $M1$ matrix elements within the configuration are zero.[6] Any $M1$ strength between such levels would then result only by admixtures in the wave functions.

From the lifetime measurements of the present experiment, the $M1$ transition probabilities for the various gamma rays can be deduced. These results are tabulated in Table I. The $M1$-$E2$ mixing ratio for the $(\frac{5}{2}^{(-)}\rightarrow\frac{7}{2}^{(-)})$ transition of 165 keV is undetermined by the angular-correlation studies.[5] Because of the low transition energy, a 100% $M1$ is assumed; any reasonable amount of $E2$ with its $1/E^5$ dependence has a negligible effect on the deduced $M1$ transition probability. In comparison to single particle estimates, this $M1$ is hindered by a factor of approximately 100.

The gamma-ray branching for the 518-keV state was measured by Allen *et al.*,[5] as shown in Fig. 1. The 80% $(\frac{3}{2}^{(-)}\rightarrow\frac{7}{2}^{(-)})$ branch to the ground state has to be $E2$, while the $M1$-$E2$ mixing ratio for the 20% $(\frac{3}{2}^{(-)}\rightarrow\frac{5}{2}^{(-)})$ branch is undetermined. Again, because of the small gamma-ray energy for this 20% branch, a normal $E2$ strength would yield only a small percentage contribution to the transition probability even for a fairly large $M1$ hindrance. Assuming no $E2$ contribution for this 20% branch, an $M1$ hindrance of 3000 is deduced for the $(\frac{3}{2}^{(-)}\rightarrow\frac{5}{2}^{(-)})$ transition. An unusually enhanced $E2$ for this branch would only increase the $M1$ hindrance.

The observed $M1$ hindrances are consistent with the theoretical prediction of $(f_{7/2})^3$ for these three states; however, the difference in the amount of hindrance is unexpected. An $M1$ hindrance of 100 is rather normal, while a hindrance of 3000 is large but perhaps more reasonable for fairly pure $(f_{7/2})^3$ states. Shell-model configurations which might mix into these states are $(f_{7/2})^2(p_{3/2})$, $(f_{7/2})^2(p_{1/2})$, and $(f_{7/2})^2(f_{5/2})$; from the work of Kashy *et al.*,[1] their mean energies relative to the $(f_{7/2})^3$ ground state are 1.5, 3.5, and 5.5 MeV, respectively. Kashy *et al.*, have identified an admixture of the $(f_{7/2})^2(p_{3/2})$ configuration in the 518-keV state from the observation of a weak $l_n=1$ stripping pattern as discussed above. An $M1$ transition between this admixture and the $(f_{7/2})^3$ configuration is also forbidden, however, since the $M1$ operator cannot change the orbital angular momentum l. Similar arguments would also apply to $(f_{7/2})^2(p_{1/2})$ admixtures.

A possible way of explaining the smaller $M1$ hindrance for the $(\frac{5}{2}^{(-)}\rightarrow\frac{7}{2}^{(-)})$ transition is to invoke an admixture of the $(f_{7/2})^2(f_{5/2})$ configuration into the $\frac{5}{2}^-$ state at 165 keV. An $M1$ transition between this admixture and the $(f_{7/2})^3$ ground state would not be forbidden and therefore could contribute to the $M1$ transition probability. The amount of this admixture in the 165-keV state is not expected, however, to be large; it was not identified in the (d,p) stripping analysis of Kashy *et al.*[1] Assuming that this $(f_{7/2})^2(f_{5/2})$ admixture is responsible for all of the observed $M1$ transition probability, the amount of the admixture can be deduced from a calculation of the $M1$ matrix element between $|f_{7/2}{}^2 0) f_{5/2}\frac{5}{2}\frac{5}{2}\rangle_a$ and $|f_{7/2}{}^3\frac{7}{2}\rangle_a$. This calculation shows that an admixure of approximately 2% in intensity of the $(f_{7/2})^2(f_{5/2})$ configuration (lowest seniority) can account for the observed transition probability. Such an admixture is rather small to be seen in (d,p) angular distributions and is thus consistent with the results of Kashy *et al.* This admixture for the $\frac{5}{2}^{(-)}$ state does not yield any $M1$ strength for the $(\frac{3}{2}^{(-)}\rightarrow\frac{5}{2}^{(-)})$ transition because $|f_{7/2}{}^3\frac{3}{2}\rangle_a$ is entirely of a higher seniority.

In addition to transitions between an admixture and the $(f_{7/2})^3$ configuration, some $M1$ strength can also be obtained from matrix elements between an admixture of the initial state and another admixture in the final state; this contribution should be rather small since it involves the product of two small amplitudes. Admixtures with the $(d_{3/2})^{-2}$ protons coupled to spin 2 rather than 0 have no $M1$ contributions. The participation of proton-hole configurations different from $(d_{3/2})^{-2}$ is unlikely for negative parity levels at these low excitation energies. Hindrances for similar $M1$ transitions within the dominant $(f_{7/2})^3$ proton configuration of V^{51} have been analyzed and discussed by Vervier.[9]

The decay of the $\frac{3}{2}^{(-)}$ level at 1.357 MeV to the 165- and 518-keV levels by $M1$ transitions should be hindered since the 1.357-MeV state is of the $(f_{7/2})^2(p_{3/2})$ configuration. The 100-psec lifetime limit for this state does not allow any interpretation of the states involved in terms of transition probabilities. The gamma branching from the 1.357-MeV level can be understood roughly on the basis of energy considerations.

The 80% $E2$ branch from the 518-keV state to the ground state is interesting in that the measured lifetime implies an $E2$ transition probability that is enhanced by a factor of about 5 relative to single-particle estimates. The reduced transiton probability for this $(\frac{3}{2}^{(-)}\rightarrow\frac{7}{2}^{(-)})$ transition is $B(E2)=3.7\times10^{-51}\,e^2\text{cm}^4$. This $E2$ strength is consistent with $(f_{7/2})^3$ configurations provided an effective neutron charge of $2.3e$ is assumed. $E2$ enhancements such as this add to the evidence which favors a collective aspect of the $f_{7/2}$ shell.

[9] J. Vervier, Phys. Letters, 5, 79 (1963).

To summarize the discussion for the low-lying levels in Ar^{41}, the $M1$ hindrances of 100 and 3000 implied by the present lifetime measurements for the $(\frac{5}{2}^{(-)}\rightarrow\frac{7}{2}^{(-)})$ and $(\frac{3}{2}^{(-)}\rightarrow\frac{5}{2}^{(-)})$ transitions, respectively, are consistent with dominant $(f_{7/2})^3$ configurations within which $M1$ transitions are forbidden. A 2% $(f_{7/2})^2(f_{5/2})$ admixture into the $\frac{5}{2}^-$ first excited state can explain the smaller $M1$ hindrance for the $(\frac{5}{2}^{(-)}\rightarrow\frac{7}{2}^{(-)})$ transition. The $(\frac{3}{2}^{(-)}\rightarrow\frac{7}{2}^{(-)})$ $E2$ transition is enhanced over single-particle estimates by a factor of 5. For pure $(f_{7/2})^3$ configurations, this $E2$ strength requires an effective neutron charge of $2.3e$.

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Study of the Reaction $Al^{27}(d,\alpha)Mg^{25}$ at 20.9 MeV

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The differential cross sections corresponding to the excitation of seven states of the residual nucleus in the reaction $Al^{27}(d,\alpha)Mg^{25}$ have been measured from 20° to 170° for a deuteron energy of 20.9 MeV (lab). The states resolved correspond to the first three members (ground, third, and eighth states) of the $K=\frac{5}{2}$ rotational band, the first three members (first, second, and fourth states) of the $K=\frac{1}{2}$ rotational band, and a state at 5.47±0.03 MeV. The angular distributions are all peaked in the forward direction with very little enhancement of the differential cross sections at large angles. The integrated differential cross sections for the first three $K=\frac{5}{2}$ states are 459, 475, and 417 μb, respectively, as compared to 38, 38, and 95 μb for the first three $K=\frac{1}{2}$ states. The angular distributions corresponding to a given rotational band in Mg^{25} are strikingly similar both in magnitude and shape. Analysis of the energy level structure in terms of the rotational model indicates that the state in Mg^{25} at 5.47±0.03 MeV is the 11/2 member of the $K=\frac{5}{2}$ rotational band.

INTRODUCTION

RECENTLY, Yanabu *et al.*[1] studied the $Al^{27}(d,\alpha)$-Mg^{25} reaction using 14.7-MeV deuterons. Data were obtained for the first three states of both the $K=\frac{1}{2}$ and $K=\frac{5}{2}$ rotational bands of Mg^{25}. They found that the transitions to the $K=\frac{5}{2}$ states are greatly enhanced over the transitions to the $K=\frac{1}{2}$ states. The integrated differential cross sections for the $K=\frac{5}{2}$ transitions are nearly identical (1.02±0.06 mb), while those for the $K=\frac{1}{2}$ transitions are 0.14, 0.22, and 0.61 mb for the first three states, respectively. They interpret the enhancement of the $K=\frac{5}{2}$ transitions to be a consequence of a large overlap between the initial Al^{27} state and the final $K=\frac{5}{2}$ states of Mg^{25}. Cosper *et al.*[2,3] and Hinds *et al.*,[4] who investigated this reaction for deuteron energies of 9.2 and 10.1 MeV, did not observe these pronounced effects. For these energies the integrated cross sections are approximately proportional to $2I+1$ (I is the spin of the final state) irrespective of the rotational band in question. Cosper *et al.*[3] observed a

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