PHYSICAL REVIEW VOLUME 152, NUMBER 3 16 DECEMBER 1966

Study of N^{16} by $N^{15}+n$ Total-Cross-Section Measurement*

D. B. Fossan,† R. A. Chalmers, S. R. Salisbury, and F. J. Vaughn
Lockheed Palo Alto Research Laboratories, Palo Alto, California

(Received 18 July 1966)

The total neutron cross section of N^{15} has been measured for neutron energies from 3.4 to 6.5 MeV corresponding to N^{16} excitation energies from 5.5 to 8.5 MeV. Neutrons with energy spreads between 15 and 50 keV were produced by the $D(d,n)He^3$ reaction with deuterons from a Van de Graaff accelerator. Resonance structure was observed in the cross section which corresponds to levels in N^{16}; the resonance amplitudes have been interpreted in terms of J values for these levels. The experimental results have been compared with theoretical calculations of Lemmer and Shakin, and the excitation energies of the observed resonances have been compared with those of known $T=1$ levels for the N^{16}-O^{16}-F^{16} isobaric triad.

I. INTRODUCTION

PRIOR to the present experiment, the N^{16} nucleus had been studied[1-3] up to an excitation energy of 5.8 MeV. A number of the established negative parity levels are understood on the basis of shell-model calculations[4]; in particular, four levels are associated with the coupling of a $(1p_{1/2})^{-1}$ proton hole to $(1d_{5/2})$ and $(2s_{1/2})$ neutron particles. Several other theoretically predicted levels have not been identified.[4-7] Lemmer and Shakin[8] have made calculations on N^{16} in terms of the total neutron cross section of N^{15}, using the unified theory of nuclear reactions of Feshbach. Their study was carried out for neutron energies up to 10 MeV.

Levels in N^{16} and F^{16} are of interest for an understanding of the $T=1$ levels of the N^{16}-O^{16}-F^{16} isobaric triad. The low-energy quartet of levels associated with the $(1p_{1/2})^{-1}(1d_{5/2})$ and $(1p_{1/2})^{-1}(2s_{1/2})$ configurations has recently been established[9] for F^{16} and compared with analogous quartets[1] in N^{16} and O^{16}. Griffith *et al.*[10] have observed higher F^{16} states at excitations of 4.20, 6.16, 7.3, 9.26, 11.1, 11.7, and 19.5 MeV, using the $O^{16}(p,n)F^{16}$ reaction. The direct determination of $T=1$ levels in O^{16} is made difficult by the presence of $T=0$ states and admixtures. Recently, Barnett[11] has observed eight narrow $T=1$ levels in O^{16} using the $N^{15}(p,n)O^{15}$ reaction; these levels are identifiable with analog N^{16} levels.

In order to investigate N^{16} at higher excitation energies, we have measured the N^{15} total neutron cross section in the neutron energy range from 3.4 to 6.5 MeV. Information regarding the spins of N^{16} excited states, as well as level widths and energies, can be obtained from the total-cross-section results. The region of excitation in N^{16} covered by these measurements is 5.5 to 8.5 MeV. Preliminary results of the experiment have been reported previously.[12] The excitation energy region corresponding to neutron energies up to 5.3 MeV has also been investigated by Donoghue *et al.*,[13] who measured angular distributions of neutrons elastically scattered from N^{15}.

Since the start of this experiment, results of a detailed study of N^{16} by Hewka *et al.*[14] have become available. This study included observations of levels in N^{16} excited by the $N^{14}(t,p)N^{16}$, $N^{15}(d,p)N^{16}$, and $O^{18}(d,\alpha)N^{16}$ reactions and angular-distribution measurements of the protons from the $N^{14}(t,p)N^{16}$ reaction. Excitation energies for 36 levels in N^{16} were measured, extending up to about 8.5 MeV in excitation. Spin and parity information was obtained from the angular distributions up to an excitation of about 5 MeV. The 1^- and 2^- states associated with the $(1p_{1/2})^{-1}(1d_{3/2})$ configuration were identified at 4.72 and 5.31 MeV, respectively. These identifications disagree with the suggested assignments for these states by Sikkema.[2] Hewka *et al.* also tentatively identified the 2^- and 3^- levels associated with the $(1p_{3/2})^{-1}(1d_{5/2})$ configuration.

Very recently, two further studies involving N^{16} have been performed. McGrath[15] has observed states in N^{16} with reactions induced by Li^6 and Li^7 on boron targets. Because the energy spreads employed were slightly greater than 100 keV, these reactions did not yield completely resolved spectra. Peaks were observed, however, at 8.83 and 9.47 MeV in N^{16} which are at

---

* This work was supported by the Lockheed Independent Research Program.

† Present address: State University of New York at Stony Brook, Stony Brook, New York.

[1] F. Ajzenberg-Selove and T. Lauritsen, Nucl. Phys. (to be published).

[2] C. P. Sikkema, Nucl. Phys. **32**, 470 (1962).

[3] D. B. Fossan, R. A. Chalmers, L. F. Chase, Jr., and S. R. Salisbury, Phys. Rev. **135**, B1347 (1964).

[4] J. P. Elliott and B. H. Flowers, Proc. Roy. Soc. (London) **242**, 57 (1957).

[5] G. E. Brown, L. Castillejo, and J. A. Evans, Nucl. Phys. **22**, 1 (1961).

[6] V. Gillet and N. Vinh Mau, Nucl. Phys. **54**, 321 (1964).

[7] J. M. Eisenberg, B. M. Spicer, and M. E. Rose, Nucl. Phys. **71**, 273 (1965).

[8] R. H. Lemmer and C. M. Shakin, Ann. Phys. (N. Y.) **27**, 13 (1964).

[9] C. D. Zafiratos, F. Ajzenberg-Selove, and F. S. Dietrich, Phys. Rev. **137**, B1479 (1965).

[10] J. A. R. Griffith, C. J. Batty, R. S. Gilmore, and G. H. Stafford, Nucl. Phys. **68**, 36 (1965).

[11] A. R. Barnett, in *Isobaric Spin in Nuclear Physics*, edited by J. D. Fox and D. Robson, (Academic Press Inc., New York, 1966), p. 774.

[12] D. B. Fossan, R. A. Chalmers, S. R. Salisbury, and F. J. Vaughn, Bull. Am. Phys. Soc. **10**, 497 (1965).

[13] T. R. Donoghue, R. A. Blue, J. E. Jackson, C. R. Soltesz, and K. J. Stout, Bull. Am. Phys. Soc. **9**, 628 (1964).

[14] P. V. Hewka, C. H. Holbrow, and R. Middleton (to be published).

[15] R. L. McGrath, Phys. Rev. **145**, 802 (1966).

excitation energies beyond the regions studied in other reported experiments. Gallmann *et al.*[16] have observed 13 levels in N^{16} up to an excitation of 5.3 MeV with the $C^{14}(He^3,p)N^{16}$ reaction. These N^{16} levels are in agreement with those observed by means of other reactions.

II. EXPERIMENTAL TECHNIQUES

Neutrons were produced using the $D(d,n)He^3$ reaction. Deuterons from a Van de Graaff accelerator bombarded a deuterium gas target, which was separated from the beam tube by either a 2.5×10^{-5}-in. or a 5×10^{-5}-in.-thick nickel foil. The deuteron beam was stopped in a 0.010-in.-thick gold backing foil at the end of the gas cell. The neutron energy spread ranged from 25 to 50 keV except in regions of rapidly varying cross section, where a thinner gas target producing a 15-keV energy spread was used.

The total neutron cross sections were measured by a transmission experiment, using a neutron-collimation technique that has been described previously.[3] Neutrons produced in the target were collimated in a beam less than 0.200 in. in diameter at the transmission sample. The same high-pressure N^{15} gas cell was used as in our earlier total cross section measurements. This cell had inside dimensions of 0.250 in. in diameter by 4 in. long and contained 1.5 liters (NTP) of gas enriched to 95% in N^{15}. The observed transmissions were of the order of 65%. Neutrons were detected with a stilbene scintillator 1 in. in diameter by 1.5 in. long. Gamma-ray discrimination was achieved by a space-charge technique involving the last dynode of the phototube.

Data were taken at intervals of the target thickness, except at resonances where more closely spaced points were taken. From shadow-cone measurements, contributions from background neutrons were determined. The gold backing, which became impregnated with deuterium as the measurements proceeded, was replaced at intervals to keep this contribution to the neutron background below about 10%. In-scattering corrections were calculated to be less than 0.2%.

III. EXPERIMENTAL RESULTS

Results for the total cross section as a function of neutron energy are shown in Fig. 1. The error bars show the statistical uncertainties; however, since the uncertainty in the number of N^{15} nuclei in the cell is considerably smaller than these statistical uncertainties, the error bars essentially indicate the absolute errors in the cross sections. Uncertainties in neutron energy are believed to be less than ±25 keV. In regions of narrow peaks, the results obtained with a thin target are shown. Some averaging of adjacent points at intervals of less than the target thickness has been performed. The curve in Fig. 1 is intended only as an aid to observing the data.

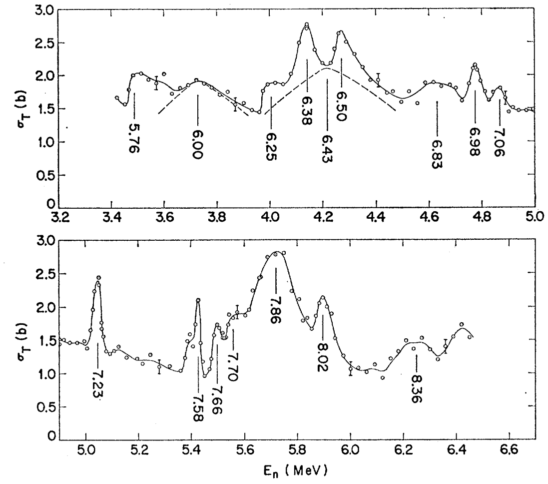

FIG. 1. The total neutron cross section of N^{15}. The neutron energy spread ranged from 25 to 50 keV except in regions of rapidly varying cross section where a 15-keV energy spread was used. Structure in the data has been labeled with N^{16} excitation energies. The dashed lines refer to two broad levels observed in the work of Hewka *et al.* (Ref. 14).

Good agreement is found between the absolute value of these total cross sections and those of Sikkema[2] in the region of overlap near 3.4-MeV neutron energy. The general shape of the total-cross-section curve also agrees with that obtained from integrating the angular-distribution results[13] of the Ohio State group; their absolute values, however, show a continuous increase with energy relative to ours which is probably associated with the difficulty of properly including the small-angle portions of the angular distributions. The angular-distribution measurements of the Ohio State group were made from 2.7- to 5.3-MeV neutron energy.

As shown in Fig. 1, a number of peaks are observed in the total cross section; these are related to energy levels in N^{16}. Analysis of the experimental data to obtain resonance parameters is made difficult by the considerable overlapping of levels evident in the results. However, some dominant peaks appear to stand out above interference and resolution effects; these occur at neutron energies of 4.14, 4.27, 4.78, 5.05, 5.42, 5.72, and 5.89 MeV. The energies of these peaks, their widths, and the corresponding excitation energies in N^{16} are listed in Table I. The parameters for several less prominent peaks are also included. Resonance parameters which are uncertain are shown in parentheses.

For comparison, the levels of N^{16} in this region of excitation observed by Hewka *et al.*[14] are also shown in Table I. All the resonances observed in the present $N^{15}+n$ experiment can be identified with levels from their work with the exception of the resonance at 7.06 MeV. Five very narrow levels seen by Hewka *et al.* were not observed in the present experiment because their widths are narrow compared with our energy

---

[16] A. Gallmann, P. Fintz, J. B. Nelson, and D. E. Alburger, Phys. Rev. 147, 753 (1966).

TABLE I. Levels in N^{16}.

Present $N^{15}+n$ work				Hewka, Holbrow, and Middleton[a]	
E_n (MeV)	E_{ex} (MeV)	Γ (keV)	J	E_{ex} (MeV)	Γ (keV)
(3.48)	(5.76)	...	...	5.74	$\leq 7\pm 4$
3.73	6.00	broad	(1,2)	6.01	270 ± 30
...	...	...	...	6.17	$\leq 7\pm 4$
(4.00)	(6.25)	...	...	(6.28)	...
4.14	6.38	50 ± 20	2	6.37	30 ± 6
(4.2)	(6.43)	broad	(3)	6.42	300 ± 30
4.27	6.50	60 ± 20	2	6.51	34 ± 6
...	...	...	...	6.61	$\leq 7\pm 4$
				(6.79)	...
(4.62)	(6.83)	...	...	6.85	$\leq 7\pm 4$
4.78	6.98	30 ± 10	1	7.01	22 ± 5
4.86	7.06	30 ± 20	(0)	...	...
...	...	...	...	7.14	$\leq 7\pm 4$
5.05	7.23	25 ± 10	3	7.25	17 ± 5
5.42	7.58	≤ 20	≥ 4	7.58	$\leq 7\pm 4$
5.50	7.66	≤ 25	≥ 1	7.64	$\leq 7\pm 4$
(5.55)	(7.70)	...	...	7.68	$\leq 7\pm 4$
5.72	7.86	150 ± 50	4,5[b]	7.86	100 ± 15
5.89	8.02	40 ± 20	≥ 2	8.04	85 ± 15
...	...	...	...	8.18	28 ± 8
...	...	...	...	8.28	24 ± 8
(6.25)	(8.36)	...	...	8.36	18 ± 8

[a] Reference 14.

[b] A larger J value would require a reduced width that is greater than the Wigner limit.

resolution; three of these levels had widths less than 7 keV. The experiments from which Hewka *et al.* obtained the level information given in Table I were performed with high-resolution magnetic spectrographs.

At excitations in N^{16} of 6.25 and 6.83 MeV both the $N^{15}+n$ experiment and the $N^{15}(d,p)N^{16}$ portion of the work of Hewka *et al.*[14] showed indications of level structure. The level positions near these energies are tentative and are shown in Table I with parentheses. No evidence of structure was seen at these energies from the $N^{14}(t,p)N^{16}$ or $O^{18}(d,\alpha)N^{16}$ reactions. These differences might be due to the fact that the $N^{15}+n$ and $N^{15}(d,p)N^{16}$ reactions would be expected to emphasize $1p$-$1h$ strengths while the other two reactions emphasize $2p$-$2h$ strengths.

IV. ANALYSIS AND DISCUSSION

For separated and noninterfering levels, peaks in the N^{15} total cross section can be interpreted in terms of parameters for levels of N^{16}. Up to a neutron energy of 5.6 MeV, the maximum variation in the cross section for a resolved isolated resonance is given by $\Delta\sigma=(0.74/E_{\rm lab})\times(2J+1)$, where $E_{\rm lab}$ is the energy in MeV of the incident neutron in the laboratory system, and J is the angular momentum of the compound state. For neutron energies above 5.6 MeV, where the inelastic channel is open, the above expression for $\Delta\sigma$ gives only a lower limit for J. In the present experiment, which covers a region of excitation in N^{16} from 5.5–8.5 MeV, the experimental results indicate that the assumption of separated and noninterfering levels is not always valid (see Fig. 1). However, calculations of J have been made for several of the peaks using the observed $\Delta\sigma$'s, and assuming that interference effects are small; the results of these computations are also given in Table I. Additional confidence in this assumption is gained from the fact that the high-resolution studies of Hewka *et al.* show essentially an identical level spectrum in this energy region.

Theoretical calculations of Lemmer and Shakin[8] and Gillet and Vinh Mau[6] predict that the states arising from the $(1p_{3/2})^{-1}(1d_{5/2})$ configuration will occur in the region of excitation covered by the present experiment. The 3^- and 2^- states are predicted to be broad levels at about 6-MeV excitation, while the 4^- state of this configuration is expected to be narrow and at a higher excitation energy. Hewka *et al.*[14] have tentatively concluded that the 6.01- and 6.42-MeV levels, which are about 300 keV wide, are the 3^- and 2^- members of this configuration, respectively.

States arising from the $(1p_{3/2})^{-1}(1d_{5/2})$ configuration mentioned above should be excited with the $N^{15}+n$ reaction; the incoming neutron excites the $(1p_{1/2})^{-1}$ target to a $(1p_{3/2})^{-1}$ hole while dropping into the $(1d_{5/2})$ particle state. The level observed in the present experiment at 6.00 MeV has a resonant amplitude which appears small for the spin of 3 assigned by Hewka *et al.* A value of $J=1$ gives a reasonable fit to the observed amplitude; however, this assignment is uncertain because of the inaccuracy of the background subtraction for broad levels. If a calculated potential background is used which is smaller than the apparent background, the resulting amplitude would be compatible with $J=2$. The 6.42-MeV resonance in the total-cross-section data is obscured by the two narrower peaks at 6.38 and 6.50 MeV; however, the large amplitude of this broad resonance is obvious from the data. From a calculation of the potential scattering background at this energy, the magnitude of cross-section variation is consistent with $J=3$. This suggested interchange of spins from the assignments of Hewka *et al.* also disagrees with the ordering given by theory for these two broad levels.

The only observed possibility in the total-cross-section results for the expected narrow 4^- state of the $(1p_{3/2})^{-1}$-$(1d_{5/2})$ configuration is the resonance at 7.58 MeV. The variation in the cross section over this resonance suggests a large spin. When corrections are made to the peak height for energy resolution, the resulting amplitude implies $J\geq 4$. In the work of Hewka *et al.*, this state is populated with considerably greater strength in the $N^{14}(t,p)N^{16}$ reaction than in the $N^{15}(d,p)N^{14}$ reaction. This difference is consistent with the fact that the latter reaction cannot easily populate pure $(1p_{3/2})^{-1}$-$(1d_{5/2})$ states because of the $(1p_{1/2})^{-1}$ character of the N^{15} ground state. Calculations of Lemmer and Shakin[8] place the 4^- level at about 6.5 MeV.

The large resonance at 7.86 MeV with a width of about 150 keV (see Fig. 1) is interesting in that the maximum variation in the cross section implies $J\geq 4$. The spin is also limited to $J\leq 5$ by the large width of the resonance, if the reduced width is to be less than the Wigner limit. These arguments allow $J=4$ or 5. The large width and this spin limitation suggest a contribution from the $(1p_{1/2})^{-1}(1f_{7/2})$ configuration. The expected position of levels with this configuration is not known because of the uncertainty about the $1f_{7/2}$ state in O^{17}. From the work of Hewka *et al.*, the 7.86-MeV level is strongly populated by the $N^{15}(d,p)N^{16}$ reaction as would be expected for a level with this configuration. Results of Eisenberg *et al.*[7] predict a 4^+ state with a relatively large $1p$-$1h$ component. They suggest a lower energy for this level; the position, of course, is dependent on their choice for the $(1f_{7/2})$ particle energy.

Lemmer and Shakin[8] have computed the $N^{15}+n$ cross section using the unified theory of nuclear reactions of Feshbach. Considering the N^{15} target as a $(1p_{1/2})^{-1}$ hole relative to the O^{16} core, they have calculated total elastic-scattering cross sections for neutron energies up to 10 MeV; the inelastic channel which opens at 5.6 MeV was neglected. Only states of negative parity having $J=0$, 1, 2, 3, and 4 were considered. These are the negative parity $1p$-$1h$ states discussed above. Results of the calculations of Lemmer and Shakin are shown in the upper part of Fig. 2; the J values for the various resonances are shown on the figure. For comparison, the experimental results[2,3,13] for the N^{15} total cross section, including those from the present experiment, are shown in the bottom part of Fig. 2. Because the experimental cross sections contain all types of resonances, including those of positive parity, a proper evaluation of the agreement is difficult. The arrows labeled 1^- and 2^- in the lower part of the figure indicate the level positions for the two $(1p_{1/2})^{-1}(1d_{3/2})$ states identified by Hewka *et al.*[14] These levels correspond to the first two labeled resonances of the theoretical curve. The next three resonances on the theoretical curve are predominantly of the $(1p_{3/2})^{-1}(1d_{5/2})$ configuration. The pair of arrows in parentheses on the experimental curve indicate the tentative positions for the first two of these levels. A change in their order is suggested by the present experiment, as described above. The narrow level indicated as 4^- on the experimental curve is tentatively identified with the third of these levels. Since definite information about the spin and parity of most levels in N^{16} is lacking, further correlations between levels on the theoretical and experimental curves could be only speculative and will not be attempted.

A way of studying the $T=1$ states for the N^{16}-O^{16}-F^{16} isobaric triad is to investigate the $T_3=\pm 1$ members, where no confusion is produced by the presence of $T=0$ states. The low-lying quartet of levels arising from the $(1p_{1/2})^{-1}(1d_{5/2})$ and $(1p_{1/2})^{-1}(2s_{1/2})$ configurations have been studied in both N^{16} and F^{16}. The corresponding levels have also been studied in O^{16}. Detailed comparisons of these levels as seen in the three members of the triad have recently been made.[9]

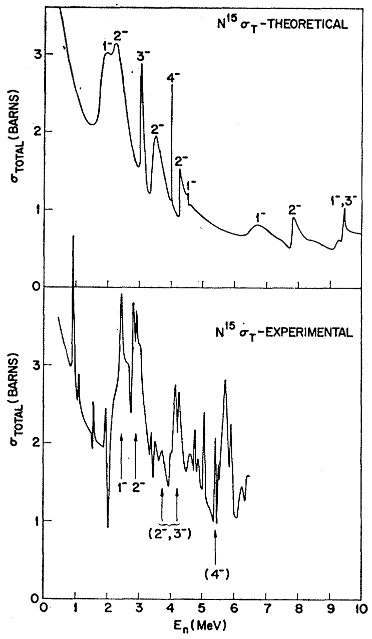

FIG. 2. Theoretical results of Lemmer and Shakin (Ref. 8) for the total elastic neutron cross section of N^{15} from the unified theory of Feshbach compared to the experimental total neutron cross sections (Refs. 2, 3, 13, and present experiment). Assignments shown are based on the work of Hewka *et al.* (Ref. 14) and the present experiment.

Griffith *et al.*[10] have made a study of F^{16} at higher excitations using the $O^{16}(p,n)F^{16}$ reaction with time-of-flight techniques. In the region of excitation covered in the present experiment, they observed two peaks, one with a high intensity at an excitation energy of 6.16 MeV and a weak one at 7.3 MeV. Considering the intrinsic resolution difficulties of a time-of-flight measurement, the large 6.16-MeV peak in F^{16} may be produced by levels that are analogous to the broad level at 6.42 MeV and the narrow levels at 6.38 and 6.50 MeV in N^{16}. At an excitation of 7.23 MeV in N^{16} there is an isolated level which, because of the similarity in excitation, may be the analog of the weak 7.3-MeV level of F^{16}; however, no definite identification can be made.

In O^{16}, positive identification of $T=1$ levels is difficult because of the lack of knowledge about spins and parities and also because of the presence of $T=0$ levels and the resulting admixtures. Barnett[11] has recently observed narrow peaks in the $N^{15}(p,n)O^{15}$ excitation curves, from which he identifies eight O^{16} $T=1$ levels with their N^{16} analogs. The isobaric mass difference N^{16}-O^{16} that he obtained from these results was 12.83 ±0.02 MeV. Only one of these levels falls into the region of excitation studied in the present experiment, namely, the 2^- level at 19.24-MeV excitation in O^{16}, which corresponds to the 6.50-MeV level in N^{16}. The results of the present experiment imply a spin of 2 for this level in N^{16}. Another state[1] in O^{16}, at an excitation energy of 19.15 MeV, has been tentatively assigned a 2^+ spin parity; it is in reasonable agreement in position and width with the 6.38-MeV N^{16} level. The J value of

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.

PHYSICAL REVIEW VOLUME 152, NUMBER 3 16 DECEMBER 1966

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

D. B. FOSSAN
State University of New York at Stony Brook, Stony Brook, New York
and
Brookhaven National Laboratory, Upton, New York
AND
A. R. POLETTI
Brookhaven National Laboratory, Upton, New York

(Received 29 July 1966)

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).