$^{17}O(\alpha,d)^{19}F$ to the $\frac{7}{2}^+$ and $\frac{11}{2}^+$ states*

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The pertinence of the observed features of the $^{17}O(\alpha, d)^{19}F$ transitions to the first two $\frac{7}{2}^+$ and first two $\frac{11}{2}^+$ states in ^{19}F to rotational-model and shell-model descriptions of this nucleus is outlined.

[NUCLEAR REACTIONS $^{17}O(\alpha, d)$, $E = 47.5$ MeV; measured $\sigma(E_d, \theta)$ for $\frac{7}{2}^+$ and $\frac{11}{2}^+$ states; DWBA analysis with $(sd)^3$ microscopic wave functions.]

The $\frac{1}{2}^+$, $\frac{3}{2}^+$, $\frac{5}{2}^+$, $\frac{9}{2}^+$, and $\frac{13}{2}^+$ states of ^{19}F at excitation energies of 0.0, 1.554, 0.197, 2.780, and 4.648 MeV, respectively, can be interpreted in terms of a decoupled $K^\pi = \frac{1}{2}^+$ rotational band. It has been realized for some time that a microscopic treatment in an $(sd)^3$ shell-model space can yield equivalent structural features for these states and that the most accurate description of these states is one obtained from a mixed-configuration shell-model calculation.[1] The $\frac{7}{2}^+$ and $\frac{11}{2}^+$ states that should lie within this same rotational scheme cannot be so clearly identified in the experimental spectrum. The lowest $\frac{7}{2}^+$ state, at 4.378 MeV, is apparently better characterized as $(d_{5/2})^3_{J=7/2}$ rather than as the $\frac{7}{2}^+$ member of the rotational sequence, while the state at 5.47 MeV appears[2] to better meet the criteria normally expected for the rotational $\frac{7}{2}^+$ state. The $(d_{5/2})^3$ character of the 4.378-MeV state is evident in the strong β decay[3] to it from the ground state of ^{19}O. The remaining band member to be identified is the state with $J^\pi = \frac{11}{2}^+$. We have attempted to study the character of the two $\frac{11}{2}^+$ states known[4] to occur at 6.499 and 7.935 MeV by populating them with the (α, d) reaction on ^{17}O. For np transfer on ^{17}O leading to an $\frac{11}{2}^+$ state in ^{19}F, the selection rules allow (in an

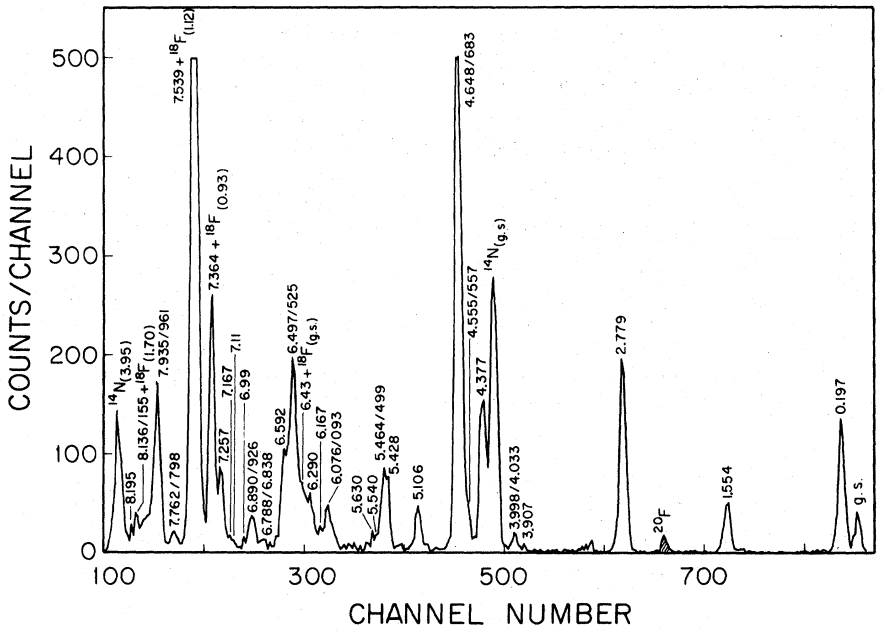

FIG. 1. Spectrum from the $^{17}O(\alpha, d)^{19}F$ reaction at 47.5 MeV and 10°.

TABLE I. Optical-model parameters used in analysis of $^{17}O(\alpha, d)^{19}F$.

Channel	V (MeV)	r_0 (fm)	a (fm)	W (MeV)	$W'=4W_D$ (MeV)	r_0' (fm)	a' (fm)	V_{so} (MeV)	Ref.
α	180	1.42	0.56	25	0	1.42	0.56	0	5
d	105	1.02	0.86	0	81	1.42	0.65	6.0	6
bd.s.	...	1.26	0.60	...	...	...	...	$\lambda=25$	

sd-shell space) $L=2$ (with $J=3$) and $L=4$ (with $J=3$, 4, or 5). The fact that the shell-model calculations predict a large $L=4$ component motivated our use of the (α, d) reaction which favors high-L transfers.

The experiment was performed with a 47.5-MeV α beam from the Michigan State University cyclotron. The target consisted of approximately 70 $\mu g/cm^2$ of WO_3 evaporated onto a gold backing. The WO_3 was prepared by oxidizing a heated W filament in O_2 gas enriched to 98.6% in ^{17}O. The actual target, as used, contained about 30% ^{16}O. The amount of ^{17}O present in the target was determined by measuring the elastic scattering and normalizing to calculations with standard optical-model parameters. Absolute cross sections thus obtained are believed to be accurate to within ±30%.

Outgoing deuterons from the (α, d) reaction were detected in the focal plane of a split-pole magnetic spectrograph with a combination of single-wire proportional counters plus backing plastic scintillators. The ΔE signal from the scintillator was used for particle identification. A silicon detector placed in the spectrograph scattering chamber allowed us to continuously monitor the condition of the target. No deterioration was observed for beam currents up to 400 nA.

A spectrum obtained at 10°(lab) is displayed in Fig. 1. The states under discussion are the $\frac{11}{2}^+$ states at excitation energies of 6.499 and 7.935 MeV. We have also extracted angular distributions for the first two $\frac{7}{2}^+$ states. Even though the states at 5.464, 6.499, and 7.935 are in regions of relatively high level density, the excitation energies extracted in the data analysis show that these states make up the dominant part of their respective peaks. Weak states on the shoulders of these peaks were separated with a peak-fitting routine. Additional uncertainties thus introduced into the cross sections for these three states are expected to be less than 10%. Angular distributions for these four states are displayed in Figs. 2 and 3 together with results of distorted-wave Born-approximation (DWBA) calculations. Optical-model parameters were standard[5,6] and are listed in Table I. The calculations were performed with the two-particle transfer option of the code DWUCK[7] using two-particle transfer amplitudes from a recent shell-model calculation.[8] For each state, the contribution for each allowed L, J is shown in Figs. 2 and 3 together with their sum. The various components are added together in the ratio required by the shell-model calculations. The summed curves are separately normalized to the data for the four states, and the normalization factors thus obtained are listed in Table II. The present wave functions predict reasonably well the relative magnitudes of the $^{17}O(\alpha, d)$ cross sections to the four states.

The difference in shapes for the two $\frac{7}{2}^+$ states is well accounted for by the calculations. The lower one is predicted to be dominated by $L=4$ and the

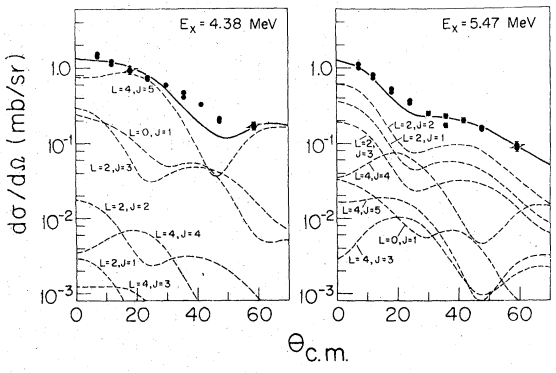

FIG. 2. Angular distributions for the $^{17}O(\alpha, d)^{19}F$ reaction for the first two $\frac{7}{2}^+$ states, together with results of DWBA calculations. $E_\alpha=47.5$ MeV.

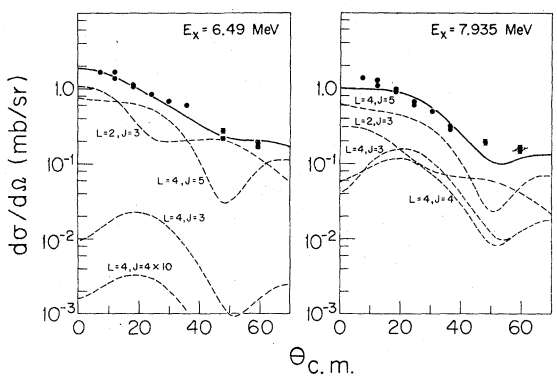

FIG. 3. Angular distributions for the $^{17}O(\alpha, d)^{19}F$ reaction for the first two $\frac{11}{2}^+$ states, together with results of DWBA calculations. $E_\alpha=47.5$ MeV.

TABLE II. Normalization factors for the $^{17}O(\alpha, d)^{19}F$ reaction to $\frac{7}{2}^+$ and $\frac{11}{2}^+$ states.

E_x (MeV)	J^π	$10^{-3}\frac{\sigma_{exp}}{\sigma_{th}}$
4.38	$\frac{7}{2}^+$	45
5.47	$\frac{7}{2}^+$	18
6.49	$\frac{11}{2}^+$	47
7.94	$\frac{11}{2}^+$	63

upper one by $L=2$, and this is borne out in the data. The situation regarding the $\frac{11}{2}^+$ shapes is less clear. The calculated angular distribution for the lower $\frac{11}{2}^+$ state contains roughly equal admixtures of $L=2$ and $L=4$, while that for the upper state is dominated by $L=4$. The experimentally observed shapes for the two states are more similar to each other and have characteristics that are intermediate between the two calculated curves. However, considering the usual uncertainties in DWBA analyses of (α, d) reactions the agreement in shape is not bad.

Taken together, these results for magnitude and shape strongly suggest that the present shell-model description for these states is essentially correct. Inspection of the shell-model wave functions[8] for the $\frac{7}{2}^+$ states shows that the lowest calculated state is mostly $(d_{5/2})^3_{J=7/2}$ and that the second state is more "deformed". Investigation of the $\frac{11}{2}^+$ shell-model wave functions in terms of the $B(E2)$ values between them and the $\frac{7}{2}^+$, $\frac{9}{2}^+$, and $\frac{13}{2}^+$ states indicates that the "deformed" component is split between them in approximately equal amounts and that hence there is no single $\frac{11}{2}^+$ "member" of the ground state rotational band.

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