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Neutron strength of the 5.08-MeV $\frac{3}{2}^+$ state of ^{17}O

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The data for the reaction ^{16}O$(d,p)^{17}$O to the unbound state at 5.08 MeV have been reanalyzed by using average sets of optical-model parameters and standard parameters for the transferred-particle well. Still, the neutron width extracted from the (d,p) data is only $\frac{2}{3}$ of the measured width.

[NUCLEAR STRUCTURE ^{16}O(d,p) (5.08 MeV), dependence of extracted spectroscopic factor on details of unbound DWBA calculation.]

The 5.08-MeV $\frac{3}{2}^+$ state of ^{17}O has been the object of much study. Since it is roughly a single-particle state[1] and also is unbound,[1] it has frequently been used[2-4] as a "test case" for methods of analyzing data on stripping leading to unbound final states. It is eminently suitable as a test case for such unbound stripping calculations because its neutron width is very accurately known from elastic scattering $\Gamma_n = 95 \pm 5$ keV.[1] In spite of the large amount of work[1] involving this state, however, its degree of single-particle character has never been accurately determined. The first analysis[3] of the ^{16}O$(d,p)^{17}$O reaction[4] that correctly accounted for the unbound nature of this state suggested[3] that its $d_{3/2}$ spectroscopic factor was near unity (after correcting[5] for the error in absolute cross section). However, a later distorted-wave Born-approximation (DWBA) calculation[4] using identical optical-model parameters but an improved integration technique yielded $S \approx 0.7$. At the time, the large difference between the two techniques was disturbing. However, it now appears that the second technique is more accurate and, in fact, the authors of Ref. 2 currently use it[6] in preference to their earlier method.[2] The use of the contour-integration technique in a large number of cases[6-9] has led to very good agreement between spectroscopic strengths obtained from analysis of stripping data and those obtained from resonant-scattering data. Even though disagreements of up to 30% were observed, they were always within the experimental uncertainties. Those encouraging results further increased the difficulty of understanding the situation for the 5.08-MeV state of ^{17}O.

Results of ^{16}O$(n,n)^{16}$O resonant scattering[10] data suggest[3,4] $S \approx 1$ for the 5.08-MeV state, where the (d,p) data[3,5] suggest[4] $S \approx 0.7$. It was therefore felt that the available data should be reanalyzed. Since the emphasis in Ref. 4 was on a comparison of the two methods of integration, all parameters of the calculation were identical to those of Ref. 3. In Ref. 3, the parameters of the potential describing the motion of the transferred neutron were chosen[3] to fit the observed neutron width. That is, those parameters were chosen in such a way that the single-particle width in that well was equal to the neutron width obtained from ^{16}O(n,n). Successful calculations[7-9] for other cases used a standard set of parameters for the transferred-particle well and did not attempt to force agreement between the single-particle width and the observed width.

We have now reanalyzed the ^{16}O(n,n) and ^{16}O(d,p)

TABLE I. Optical-model parameters used in DWBA analysis of the ^{16}O$(d,p)^{17}$O reaction to the 5.08-MeV state in ^{17}O.

Channel	Potential	V (MeV)	$r_0 = r_{so}$ (fm)	$a = a_{so}$ (fm)	W (MeV)	$W' = 4W_D$ (MeV)	r'_0 (fm)	a' (fm)	V_{so} (MeV)
^{16}O+d	2	119.1	0.90	0.90	0	23.68	1.513	0.81	6.0
	3	100	1.40	0.60	10	0	1.74	0.80	0
^{17}O+p	1	59.0	1.14	0.57	0	38.6	1.14	0.50	5.5
	1′	60.58	1.14	0.57	0	21.6	1.14	0.50	5.5
^{16}O+n		51.95	1.26	0.60	⋯	⋯	⋯	⋯	6.0

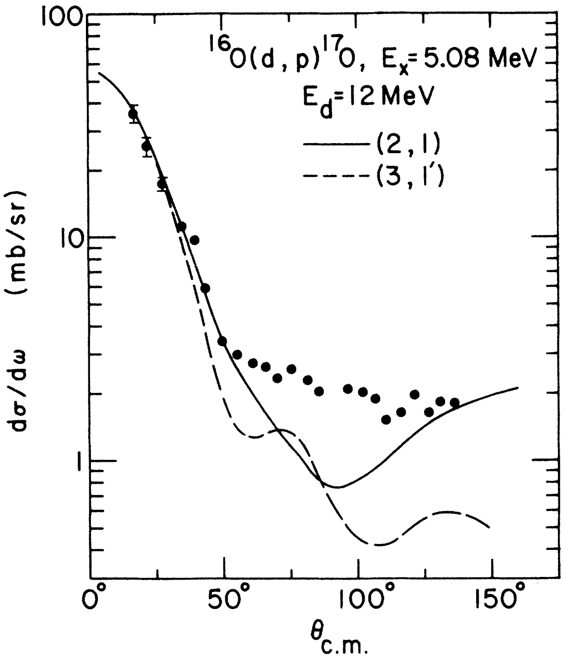

FIG. 1. Data (points) for the $^{16}O(d,p)^{17}O$ reaction leading to the unbound $\frac{3}{2}^+$ state at 5.08 MeV, together with results of DWBA calculations with optical-model parameters from Table I. In the calculations, the parameters used for the $^{16}O+d$ and $^{17}O+p$ channels were, respectively, those of potentials 2 and 1 (solid curve) or potentials 3 and 1′ (dashed curve).

data for the 5.08-MeV state by use of this standard set of parameters, which are listed in Table I. This potential yields a single-particle width Γ_n(s.p.) = 105 keV for the $^{16}O+n$ resonance at E_n(c.m.) = 940 keV. The latest experimental value for the width of the 5.08-MeV state is[1] Γ_n(exp.) = 95 ± 5 keV in c.m. The neutron scattering data thus suggest that the state is roughly 90% single particle.

In the earlier calculations[7-9] that gave good agreement between stripping and resonance data, the practice was to use average sets of optical-model parameters also in the DWBA calculations. We have followed that practice here. Two sets of potentials are listed in Table I. These potentials have previously been used[7] in a comparison of the type discussed here.

The results of the DWBA calculations are displayed in Fig. 1 and Table II. At forward angles, the fits to the shape of the angular distribution are quite acceptable and, in fact, are virtually identical with those of Ref. 4. The poorer fit at backward angles is normal, especially for reactions in light nuclei. As is conventional, the theoretical curves have been normalized to the data at forward angles.

Perhaps surprising is the fact that the neutron widths extracted from the present fits to the data are also virtually identical to the value $\Gamma_n = 68$ keV obtained in Ref. 4. The widths obtained in the present work are 64 keV for the potential combination (2, 1) and 66 keV for combination (3, 1′). Similar results for the width are obtained with several other combinations of potentials. Thus, the small width extracted from the earlier analysis[4] was not due to the particular choice of potentials used; the discrepancy is between the width extracted from analysis of (d, p) data and the measured width of the state. The source of this discrepancy is not known. The 5.08-MeV state of ^{17}O is not expected to have $S = 1$, since higher-lying $\frac{3}{2}^+$ states share some of the $d_{3/2}$ strength. However, the spectroscopic strengths for those states are not known well enough to allow a choice to be made between the two possibilities for the 5.08-MeV state.

A proper understanding of the present 30% discrepancy is crucial in assessing the validity of the DWBA. Recently, Schlessinger and Payne[11] used an entirely independent method to carry out the calculations of Ref. 4. They obtained results differing from ours by less than 10%. We may safely conclude that the errors of our numerical technique are far too small to explain the discrepancy. The errors in the measurement of Γ by $^{16}O+n$ total cross section measurements are also too small to explain the discrepancy. Two possibilities remain: Either the DWBA is inadequate to describe the reaction, or the measured (d, p) cross section is 30% too low. Friedman[12] has suggested that rescattering corrections to the DWBA might amount to as much as 80%. However, his analysis does not rule out the possibility that the rescattering corrections are much smaller. The measured (d, p) cross section would have been underestimated by about 30% by the seemingly reasonable procedure of taking the background cross section to be the cross sec-

TABLE II. Widths and reduced widths for the 5.08-MeV state of ^{17}O. All widths are in keV.

			Neutron width from (d,p)			
	Neutron width from (n,n)		Pots. (2, 1)		Pots. (3, 1′)	
Γ_n (s.p.)	Γ_n (exp.)	Γ_n (exp.)/Γ_n (s.p.)	Γ_n	Γ_n/Γ_n (s.p.)	Γ_n	Γ_n/Γ_n (s.p.)
105	95 ± 5	0.90	64	0.61	66	0.63

tion at $E = E_{\text{res}} \pm 2\Gamma$, and neglecting the contribution of the resonance wings ($|E - E_{\text{res}}| > 2\Gamma$). An unambiguous measurement of the (d, p) cross section for this state could therefore be of great value in deciding the applicability of DWBA.

Also, further work is desirable in other cases where such a comparison can be made. It is important to determine if the ^{17}O discrepancy is an isolated problem, or a more general one. In order for such comparisons to be meaningful, both the (d, p) cross sections and the measured neutron widths need to be known to about 5%.

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