SPECTROSCOPY WITH THE (d,n) REACTION AT 80 MeV

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In an initial exploratory study which was intended to establish the feasibility and usefulness of the (d,n) reaction at IUCF energies as a spectroscopic tool, cross-section angular distributions for $^{11}B(d,n)^{12}C$, $^{27}Al(d,n)^{28}Si$ and $^{48}Ca(d,n)^{49}Sc$ were measured at E_d = 80 MeV in $0° < \theta < 50°$. Figure 1 shows counts versus excitation energy at zero degrees for each of these cases. Energy resolution of about 300 keV was achieved. Time resolutions attained appear to be poorer than expected. Additional work is planned to improve time resolution.

DWBA analysis with DWUCK4[1] is being performed to extract spectroscopic factors for selected states excited in each of these reactions. The factors obtained are being compared with those from previous (^{3}He,d), (α,t) and (d,n) measurements. It is found that good fits to the angular distributions out to about 40 degrees are attainable with reasonable parameters in DWUCK4 and that zero and near-zero degree data, which is easily obtained in (d,n), is important for determining low ℓ transfer strengths (especially for ℓ=0).

As examples of this work, results of the analysis of the $^{11}B(d,n)$ reaction to the ^{12}C ground state and the ^{27}Al (d,n) reaction to the ^{28}Si ground and first excited state at 1.78 MeV is presented. Figure 2 shows the measured $^{11}B(d,n)^{12}C$ ground state angular distribution compared to the results of a DWUCK calculation. Deuteron optical model parameters were obtained from Daehnick, Childs and Vrcelj,[2] neutron

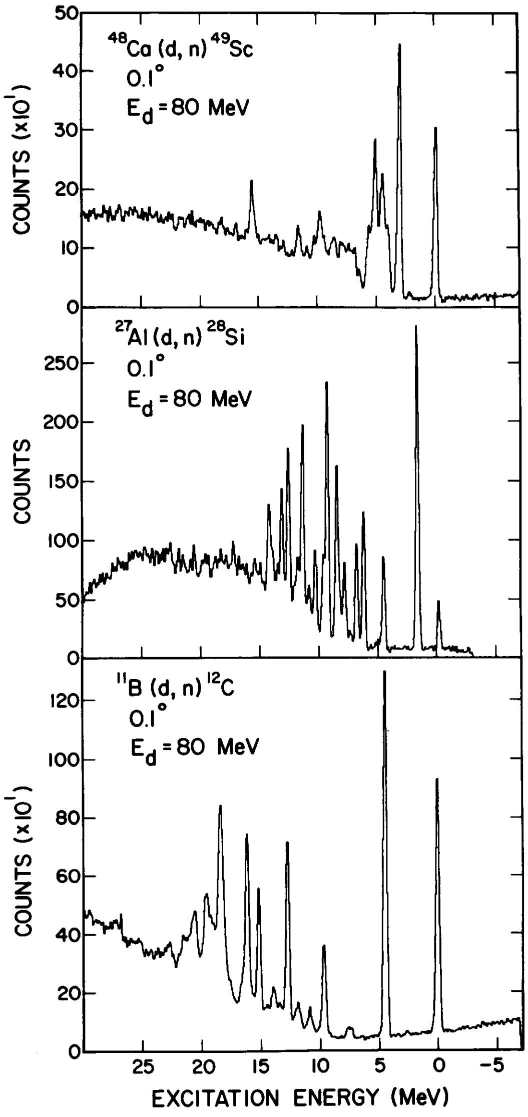

Figure 1. Excitation energy spectra at 0.1° for the reactions $^{48}Ca(d,n)^{49}Sc$, $^{27}Al(d,n)^{28}Si$, and $^{11}B(d,n)^{12}C$ at 80 MeV incident energy.

optical model parameters from Comfort and Karp,[3] and the wavefunctions are from Cohen and Kurath.[4] A spectroscopic strength [$(2J+1)S_p$] of 5.9±0.6 for this

ℓ=1 transfer is obtained. Table 1 compares the present result with previous measurements and a theoretical prediction.

Figures 3 and 4 show measured angular distributions in $^{27}Al(d,n)^{28}Si$ reactions at 80 MeV to the ground and 1.78 MeV states compared to the appropriate DWUCK calculations (deuteron OMP from Daehnick,[2] neutron OMP from Olmer,[5] and wavefunctions from Wildenthal and McGrory[6]). The silicon ground state is a 0^+ state populated by an ℓ=2 proton transfer into the $1d_{5/2}$ shell. The calculated ℓ=2 shape is seen to agree with the shape of the measured angular distribution. Excitation of the 1.78 MeV state occurs by both ℓ=0 and ℓ=2 proton transfers as is seen in Fig. 4. Notice how difficult it would be to determine the relative ℓ=0 to ℓ=2 contributions if the two points near zero degrees were unavailable as they are in most other studies.

Table 2 compares the spectroscopic factors from one $^{27}Al(d,n)^{28}Si$ measurements for these states with those from previous studies and a shell model calculation. Nearly all the shell model strength is observed for the ground state in contrast to the recent result of A. Djaloeis et al.,[7] who report seeing only 40% of the ground state strength in their $^{27}Al(^3He,d)^{28}Si$ studies at 130 MeV.

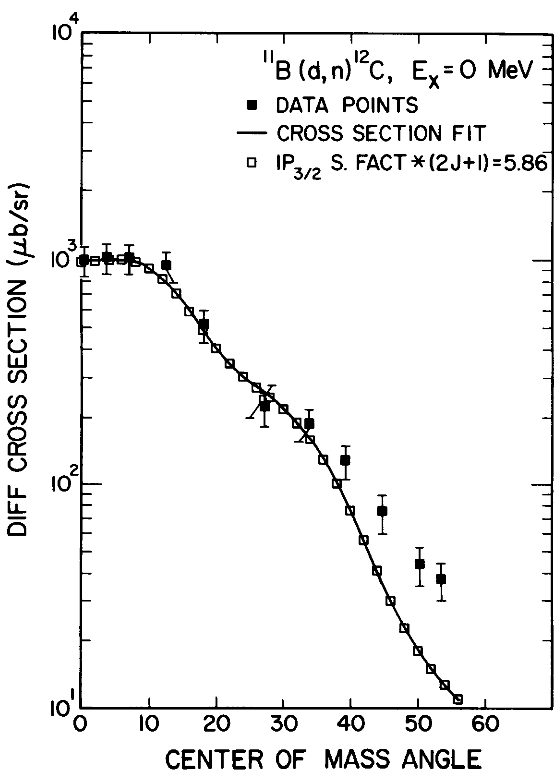

Figure 2. Ground state angular distribution for the reaction $^{11}B(d,n)^{12}C$.

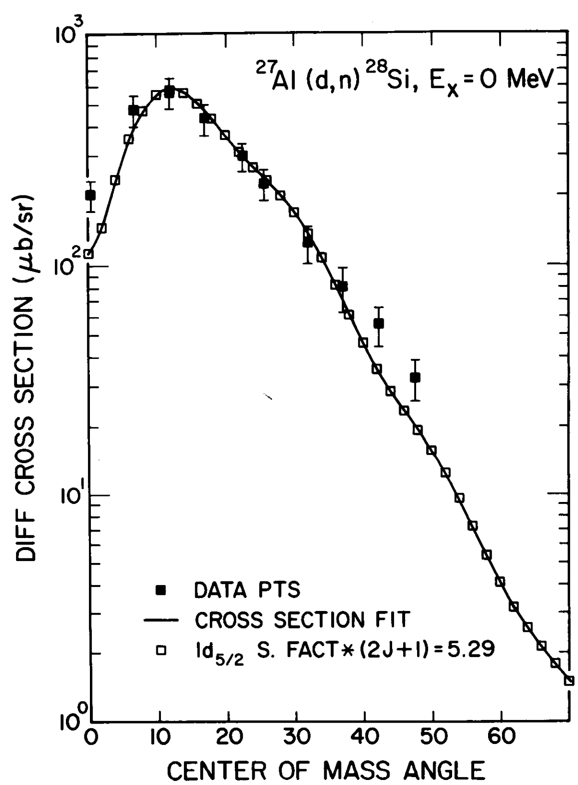

Figure 3. Ground state angular distribution for the reaction $^{27}Al(d,n)^{28}Si$.

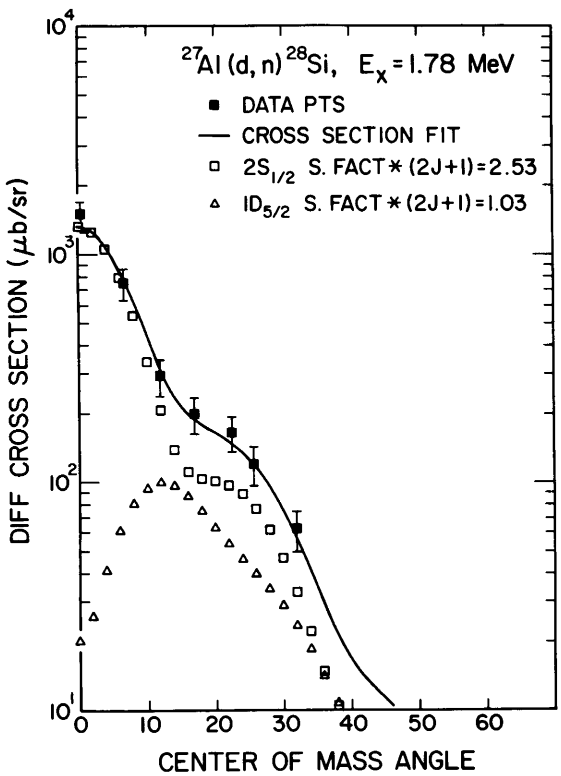

Figure 4. Angular distribtuion of the 1.78 MeV state in ^{28}Si from the reaction ^{27}Al(d,n)^{28}Si.

Analysis is proceeding for other states of interest. It is clear, however, that (d,n) reaction studies at IUCF are feasible and yield interesting spectroscopic results.

Table I. Spectroscopic strengths $G(n\ell j) = (2J_f + 1)S_p$ for proton stripping to the ground state of ^{12}C.

Reaction	Einc (MeV)	$G(n\ell j)$ ℓ=1	Reference
(d,n)	11.8	4.18	G.S. Mutchler et al., Nucl. Phys. A172 469 (1971).
	78.9	5.9	present experiment
(^{3}He,d)	10,12	3.2-6.56	P.D. Miller et al., Nucl Phys. A136 229 (1969).
	44.0	4.25	G.M. Reynolds et al., Phys. Rev. C 3 442 (1971).
Theory	----	5.7	S. Cohen and D. Kurath, Nucl. Phys. A101 1 (1967).

Table II. Spectroscopic strengths $G(n\ell j) = (2J_f + 1)S_p$ for proton stripping to states in ^{28}Si.

Reaction	E_{inc} (MeV)	G(nℓj)			Reference
		g.s.	1.78 MeV		
		ℓ=2	ℓ=0	ℓ=2	
(d,n)	3	---	0.84	---	B. Lawergren et al., Nucl. Phys. A106, 455 (1968).
	6	3.0	1.86	0.84	W. Bohne et al., Nucl. Phys. A131, 273 (1969).
	78.9	5.29	2.53	1.03	present experiment
(^{3}He,d)	8	5.88	4.32 1.92	0 9.12	J. Kalifa et al., J. Phys. (Paris) 34, 139 (1973).
	15	6.39	3.68	---	S. Martin, Ph.D. thesis, Univ. of Heidelberg, W. Germany, 1968, unpublished.
	37.7	5.28	4.56	0.84	R.W. Barnard and G.D. Jones, Nucl. Phys. A108, 641 (1968).
	130	2.64	---	---	A. Djaloeis et al., Phys. Rev. C 26, 797 (1982).
(α,t)	25.2	6.96	1.2	2.4	V.M. Lebedev et al., Nucl. Phys. A298, 206 (1978).
	27.2	5.28	2.52	2.04	O.F. Nemets et al., Ukr. Fiz. Zh. 22, 246 (1977).
	64.5	9.2	3.4	2.4	M. Yasue et al., Nucl. Phys. A391, 377 (1982).
	104	12.1	10.7	---	G. Hauser et al., Nucl. Phys. A182, 1 (1972).
Theory	---	6.36	4.56	0.66	B.H. Wildenthal and J.B. McGrory, Phys. Rev. C 7, 714 (1973).
"Best Values"	---	6.4	2.65	2.05	P.M. Endt, At. Data and Nucl. Data Tables 19, 23 (1977).

1) DWUCK4, P.D. Kunz (unpublished); Extended Version, J.R. Comfort (unpublished).

2) W.W. Daehnick, J.D. Childs, and Z. Vrcelj, Phys. Rev. C 21, 2253 (1980).

3) J.R. Comfort and B.C. Karp, Phys. Rev. C 21, 2162 (1980).

4) S. Chen and D. Kurath, Nucl. Phys. A101, 1 (1967).

5) C. Olmer, private communication.

6) B.H. Wildenthal and J.B. McGrory, Phys. Rev. C 7, 714 (1973).

7) A. Djaloeis et al., Phys. Rev. C 26, 797 (1982).