HIGH EXCITATION HOLE STATES IN THE (p,d) REACTION

D.W. Miller, D.W. Devins, R.E. Pollock, W.P. Jones, and V.C. Officer*

The (p,d) reaction seemed particularly well suited for early experiments at IUCF. From the theoretical standpoint, single-particle transfer reactions are relatively well understood at lower energies, and were a logical choice for good-resolution studies in the higher momentum-transfer region available at IUCF. From the experimental standpoint, the magnetic spectrograph system at IUCF is pushed to its rigidity limit for detection of deuterons at proton energies of 135 MeV, so this reaction could provide a good early test for resolution and calibration limitations at full spectrograph fields while the beam energy was still at a modest level.

The intent of the present experiment is to study higher excitation structure in ^{27}Si and ^{23}Mg. Earlier work on the ^{28}Si (p,d) reaction in the IUCF energy range had been reported by Bachelier et al.[1] at 156 MeV and by Källne and Fagerstrom[2] at 185 MeV. The lower part of Fig. 1 (left) shows the best results obtained at Uppsala[2], indicating prominent peaks up to about 18 MeV excitation with widths comparable to the Uppsala experimental resolution of about 300 keV. It was of interest in the present experiment to see the effect on these peaks of improved resolution, and to try to determine the character of the groups seen at high excitations which have not been accessible for study at lower energies because of the large negative Q value.

Results obtained with the QDDM spectrograph at 97 MeV gave an overall resolution of about 90 keV FWHM. An 8° composite spectrum is displayed in the upper part of Fig. 1 for comparison with the 185 MeV Uppsala data. As an example, the 2.65- and 2.86 MeV states are fully resolved. The peak shown at 10.01 MeV excitation is the highest excitation peak seen which is still as narrow as the experimental resolution. The 135 MeV results are quite similar; with an overall

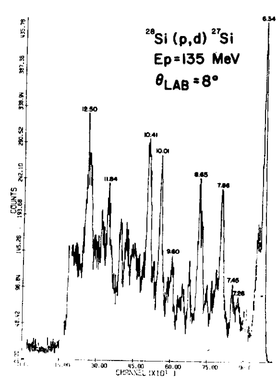

Figure 2.

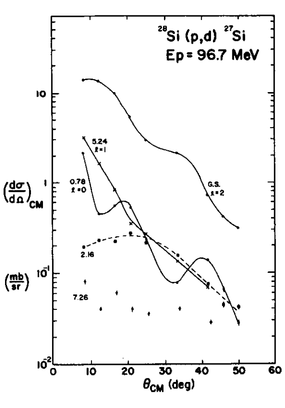

Figure 3.

FWHM resolution varying from 100-150 keV, the 2.65 and 2.86 MeV states are still fairly well resolved.

The excitation region from the break in the vertical scale at about 7 MeV excitation in Fig. 1 to the last prominent peak seen at 12.50 MeV is shown on a single spectrograph focal plane swath in Fig. 2. The excitation energies shown were assigned in this experiment by combining the 97- and 135 MeV results. It should be emphasized that the mirror nucleus ^{27}Al has about 50 known levels in the region between 6.34 and 8.65 MeV excitation, and at least 37 between 11.84 and 12.50 MeV. A major goal for this experiment is to determine the character of the six or seven rather dramatic peaks in Fig. 2 which are selectively excited by this reaction.

To provide comparisons of momentum-transfer dependence of the peaks at higher excitations, preliminary angular distributions for the known low-lying states in ^{27}Si have been extracted. Sample angular distributions at 97 MeV are shown in Fig. 3 for ℓ=0, 1, and 2 transfers. The curves are simply guides to the eye. The one known ℓ=0 transition shows a pronounced oscillation superimposed on a cross section dropping about a factor of 75 over the angular range covered (8^o to 48^o lab). A similar drop is shown for the ℓ=1 and ℓ=2 (ground state) cases, with a different oscillatory shape. The 2.16 MeV state has been assigned $7/2^+$ by other experiments, and is presumably reached by a two-step process. Shown for comparison at the bottom is an unusual angular distribution obtained for a group corresponding to an excitation energy of 7.26 MeV in ^{27}Si. The shape suggests that it corresponds to a higher ℓ transfer, or results from another mechanism.

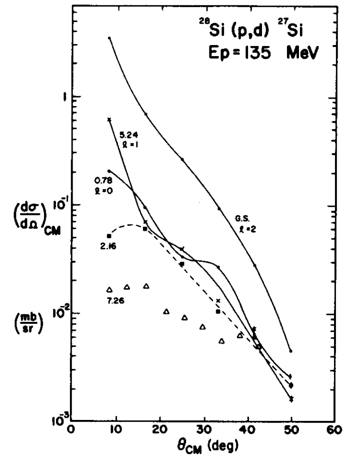

Figure 4.

Figure 4 shows a similar summary of angular distributions of known states obtained at fewer angles for 135 MeV bombarding energy. Additional shifts are scheduled to fill in additional points on these angular distributions. Absolute cross sections are a lower limit in Fig. 4 since dead-time corrections have not been applied. At this energy the momentum transfer range covered is 150 MeV/c to 500 MeV/c. The ℓ=2 transitions here drop by factors of about 100-500 over the observed angular range, and the oscillation is less pronounced. The ℓ=1 transitions still show a modest kink with a similar absolute drop. A fairly prominent ℓ=0 oscillation is also indicated. The maximum in the angular distribution for the 2.16 MeV state again occurs at a momentum transfer near 200 MeV/c. As at 97 MeV the group at 7.26 MeV excitation seems to show a much smaller slope than the others.

Angular distributions have also been obtained for the higher peaks (up to 7.86 MeV at 97 MeV, 12.50 MeV at 135 MeV), subject to considerable uncertainties in subtraction of the continuum. With a few exceptions, most of these angular distributions drop rapidly at 135 MeV, and it will likely be difficult to determine unique spin assignments at this energy. The situation is more promising for the 97 MeV results; further analysis is in progress.

Spectroscopic factors for transitions to states in ^{27}Si have been calculated by Sven Maripuu[3] in a large shell-model space. The prominent peaks in the region of 7-13 MeV excitation are consistent with large clumps of $1p_{3/2}$ pick-up strength predicted in his analysis. DWUCK calculations are now in progress to provide more quantitative comparisons with the angular distributions in Figs. 3 and 4.

Preliminary excitation spectra at 8^o lab have also been obtained for $^{24}Mg(p,d)$ at 97 MeV and 135 MeV. Additional shifts have been approved to obtain angular distributions for this reaction at 97 MeV.

*University of Melbourne; Melbourne, Australia

1) D. Bachelier, M. Bernas, I. Brissaud, C. Detraz, and P. Radvanyi, Nucl. Phys. A126, 60 (1969).

2) S. Fagerstrom and J. Kallne, Physica Scripta 8, 14 (1973).

3) S. Maripuu, Duke University, private communication.