STUDIES OF THE (p,^{3}He) REACTION ON ^{24}Mg AND ^{28}Si INITIATED BY 90-MeV POLARIZED PROTONS

J.D. Brown, W.P. Jones, D.W. Miller, and H. Nann
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

P.M. Lister
University of Michigan, Ann Arbor, Michigan 48109

F. Khazaie
University of Maryland, College Park, Maryland 20742

J.R. Comfort
Arizona State University, Tempe, Arizona 85281

The resurgence of interest in two-nucleon transfer studies can be attributed in part to the recent observation of: strong population of high-spin states in the (d,α) reaction at 80 MeV,[1] signatures of (JLST) transfers seen in analysing power data for both the (d,α) and (^{3}He,p) reactions[1,2] and some controversy[3] about the relative roles of the sequential transfer reaction mechanism and D-state effects in (α,d) reactions. In comparison to other light-ion two-nucleon pick-up reactions there have been considerably fewer studies of the (p,^{3}He) reaction. This paucity of information can be attributed to the complexity of transferred (JLST) configurations, to highly negative Q values, and to small differential cross-sections.

One way to reduce the number of possible (JLST) values is to choose a 0^+, T=0 target nucleus. Frequent shortcomings of two-nucleon transfer analyses have been the lack of reliable spectroscopic amplitudes and uncertainties in optical model parameters for both entrance and exit channels. In order to lessen the complexities of the analysis it was decided to choose 0^+, T=0 sd-shell target nuclei which have been the subject of elastic scattering and transfer reaction studies. ^{24}Mg and ^{28}Si were chosen, because, apart from fulfilling the above conditions, the (p,^{3}He) reaction leads to final states with a wide range of spins and parities.

Data for both the ^{24}Mg(p,^{3}He)^{22}Na and ^{28}Si(p,^{3}He)^{26}Al reactions were taken using a polarized proton beam of 89.6 MeV, with detection of the ^{3}He particles being made in the focal plane of the QDDM spectrometer. The angular distribution of the data extends out to 40° lab for ^{24}Mg and 35° lab for ^{28}Si. Experimental energy spectra for both of these reactions are depicted in Fig. 1. From this diagram it can be

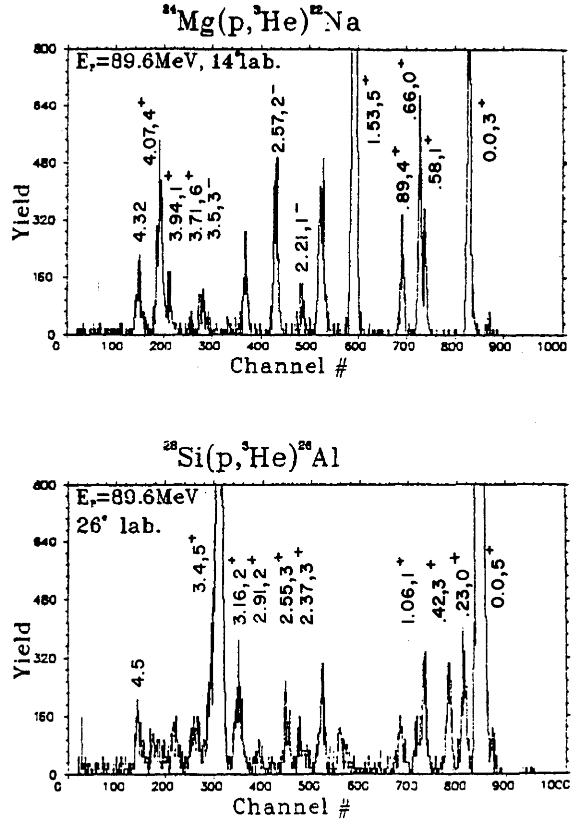

Figure 1. Experimental energy spectra for both the ^{28}Si(p,^{3}He)^{26}Al and ^{24}Mg(p,^{3}He)^{22}Na reactions.

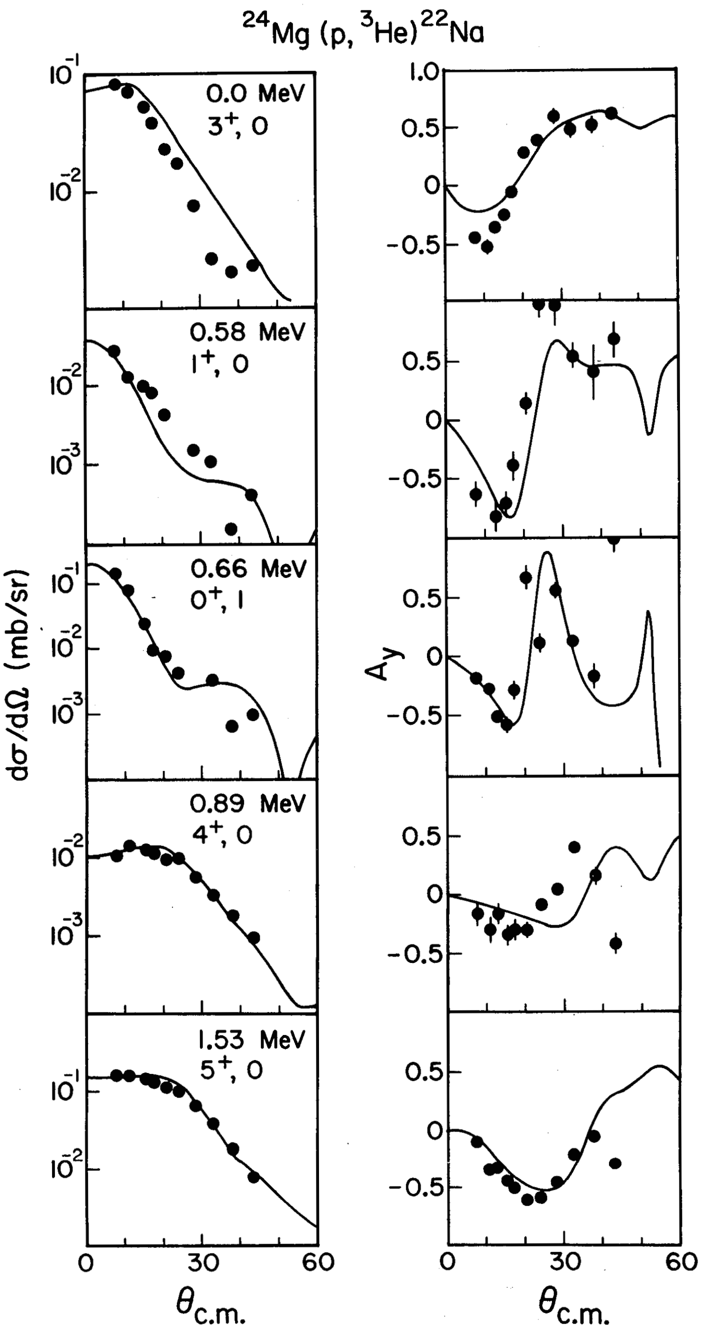

Figure 2. Data and DWBA predictions for selected positive parity final states in the $^{24}Mg(p,{}^{3}He)^{22}Na$ reaction.

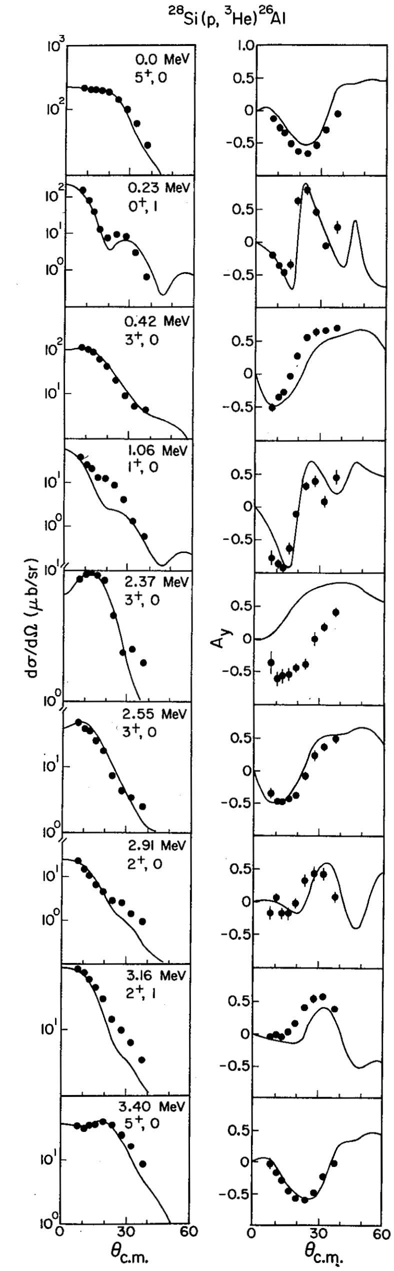

Figure 3. Data and DWBA predictions for selected positive parity final states in the $^{28}Si(p,{}^{3}He)^{26}Al$ reaction.

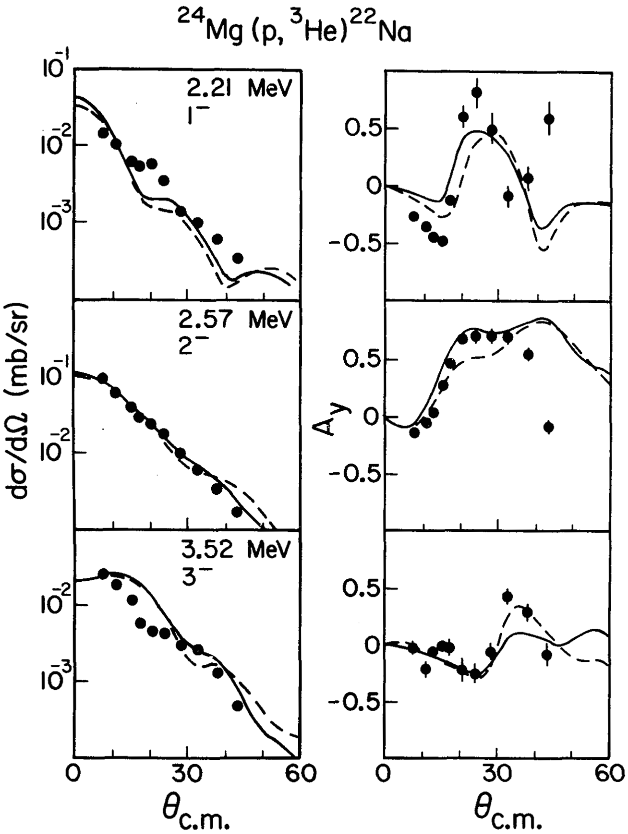

Figure 4. Data and DWBA predictions (dashed line = zero range, solid line = exact finite range) for selected negative parity states in the $^{24}Mg(p,^{3}He)^{22}Na$ reaction.

seen that there is a strong population of the 5^{+} $(d_{5/2})^{2}$ stretched states as observed in (d,α) studies, and in addition there is a strong population of a $(d_{5/2}\ d_{3/2})_{J=4,T=1}$ stretched state at 4.07 MeV in ^{22}Na.

Analyzing power and differential cross-section angular distributions extracted to date are shown in Figs. 2, 3, and 4. A comparison of states populated by the same (JLST) transfer reveals that the analyzing power distributions are indicative of the transferred J value while the differential

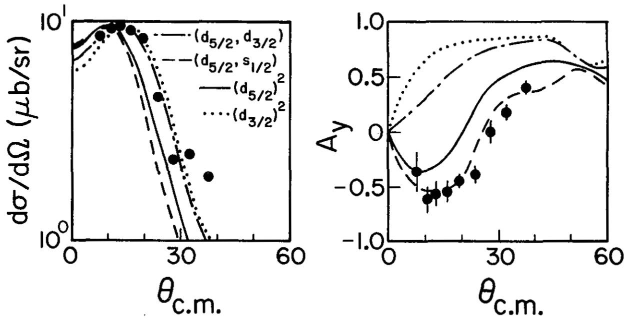

Figure 5. DWBA prediction for the 2.37 MeV state in ^{26}Al assuming a transfer of particles from specific orbitals as indicated.

cross-sections are indicative of the transferred L. Additionally, the striking resemblance of observables for final states in the two different residual nuclei populated by the same (JLST) transfer appears to suggest that the reaction mechanism is primarily a direct one. The negative analyzing power of the 5^{+} states is in accord with the distributions of (d,α) analyzing powers populating stretched states, and with a simple picture of the reaction. Differential cross-section ratios for the 2^{+}; T=0 state and 2^{+}; T=1 state at 2.91 MeV and 3.16 MeV, respectively, in ^{26}Al ield a value of 0.22 for R, where R is related to the fraction of Bartlett and Heisenberg exchange terms in the interaction potential.[4]

Results of microscopic zero range DWBA calculations, using spectroscopic amplitudes calculated from the Chung-Wildenthal wave functions[5] and a Bayman-Kallio prescription for the form factor,[6] are shown in Fig. 2. It was found that there was sensitivity to the choice of exit channel distorting potentials. This may be attributed to the fact that successful global proton parametrizations exist which are founded upon a very broad data base, while, to date, there exists no corresponding ^{3}He elastic scattering study. The reproduction of both the shape and magnitude of the experimental angular distributions is encouraging in the light of many possible complexities. The worst reproduction of the data is for the 2.37-MeV state in ^{26}Al. This 3^{+} state has analyzing power and differential cross-section angular distributions not unlike those of the 2.55 MeV state in ^{26}Al, also a 3^{+} state. Calculations, the results of which are shown in Fig. 5, show that the theoretical spectroscopic amplitudes for this state are to be questioned.

The negative-parity states in ^{22}Na are of particular interest since they are intruder states in shell model calculations which utilize a configuration space of an inert ^{16}O core and active $0d_{5/2}$, $1s_{1/2}$ and $0d_{3/2}$ shells. In addition to the normal zero-range calculations, exact finite-range predictions are shown for these states in Fig. 4.

It is hoped that future calculations will accentuate the role of two step processes as well as allow investigation of the two-nucleon transfer form factor.

1) H. Nann, private communication.

2) P.M. Lewis, O. Karban, J.M. Barnwell, J.D. Brown, P.V. Drumm, J.M. Nelson, and S. Roman Nucl. Phys. A404, 205 (1983).

3) W.W. Daehnick, M.J. Spisak, and J.R. Comfort, Phys. Rev. C 23, 1906 (1981); W.T. Pinkston and G.R. Satchler, Nucl. Phys. A383, 61 (1982); M.A. Nagarajan and G.R. Satchler, Phys. Rev. Lett. 49, 1899 (1982).

4) I.S. Towner and J.C. Hardy, Adv. Phys. 18, 401 (1969).

5) W. Chung and B.H. Wildenthal, unpublished.

6) B.F. Bayman and A. Kallio, Phys. Rev. 156 1121 (1967).