

As reported previously¹⁾, the mirror reactions $^{24}\text{Mg}(d,t)^{23}\text{Mg}$ and $^{24}\text{Mg}(d,^3\text{He})^{23}\text{Na}$ have been studied at $E_d = 76$ MeV, with special emphasis on the region of excitation between 8 and 12 MeV. Earlier (p,d)²⁾ and (d,³He)³⁾ results suggested pronounced discrepancies in the spectrum of major 1p-shell neutron-hole vs. proton-hole fragments. It was hoped that a comparison of the (d,t) and (d,³He) results would allow us to distinguish whether the previous discrepancies reflect true differences in the structure of the mirror nuclei at high excitation, or arise instead from differences in reaction mechanism or misidentification of peaks.

Additional data for both (d,t) and (d,³He) reactions on ^{24}Mg have been obtained with the QDDM spectrograph at forward angles and excitation energy $E_x \lesssim 15$ MeV. Thus, a complete set of high resolution (~ 80 keV

FWHM) spectrograph data now exists for $6^\circ \leq \theta_L \leq 24^\circ$, supplanting previously obtained silicon-detector telescope data and some spectrograph data of poorer quality.

Representative angular distributions for several low-lying single-particle mirror-state fragments are shown in fig. 1. One notices at the outset the marked similarity in magnitude and shape for the corresponding mirror transitions at this bombarding energy. Relative magnitudes of the (d,t) and (d,³He) cross sections at lower bombarding energies reflect more strongly the detailed Coulomb-generated differences in the target bound-state wave functions⁴⁾. The similarity of the distributions observed here suggests that kinematic considerations may dominate the observed cross sections and that the reaction mechanism for the mirror pickup is simple. Further evidence for the direct pickup nature lies in the observed characteristic angular dependence of the cross section on l -transfer at these forward angles. Initial DWBA calculations correctly predict the relative (d,t) and (d,³He) cross sections and the forward-angle shapes for the different l -transfers, the agreement becoming worse in some cases for the largest angles measured.

Composite spectra for (d,t) and (d,³He) from the spectrograph are shown in fig. 2 for the higher excitation region. These spectra reveal a considerable fragmentation of strength in the region $\sim 8 - 12$ MeV. The largest sharp peaks in this region (corresponding to maximum cross sections between 0.1 and 1.0 mb/sr) appear to have mirror counterparts, but with substantially greater scatter (from state to state) in the Coulomb energy differences and relative strengths than one observes for states below 6 MeV excitation.

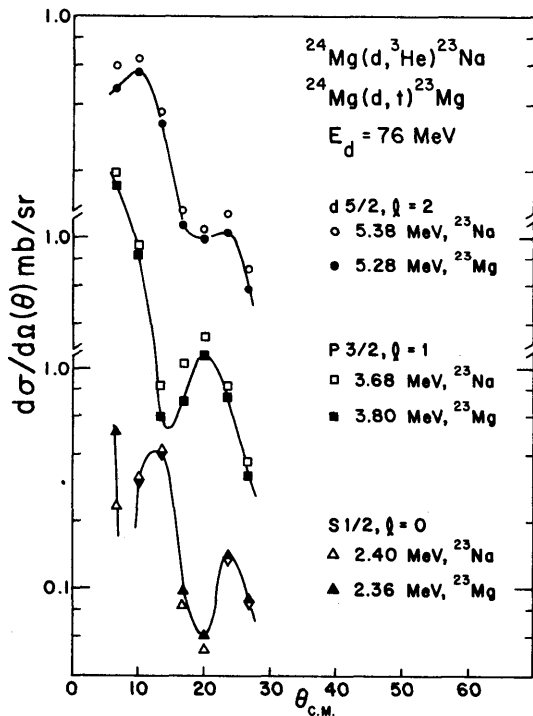


Fig. 1. Angular distributions for $^{24}\text{Mg}(d,^3\text{He})^{23}\text{Na}$ to low-lying residual states. The (d,³He) and (d,t) data are represented by open and closed symbols, respectively. The solid lines through the (d,t) results are guides to the eye.

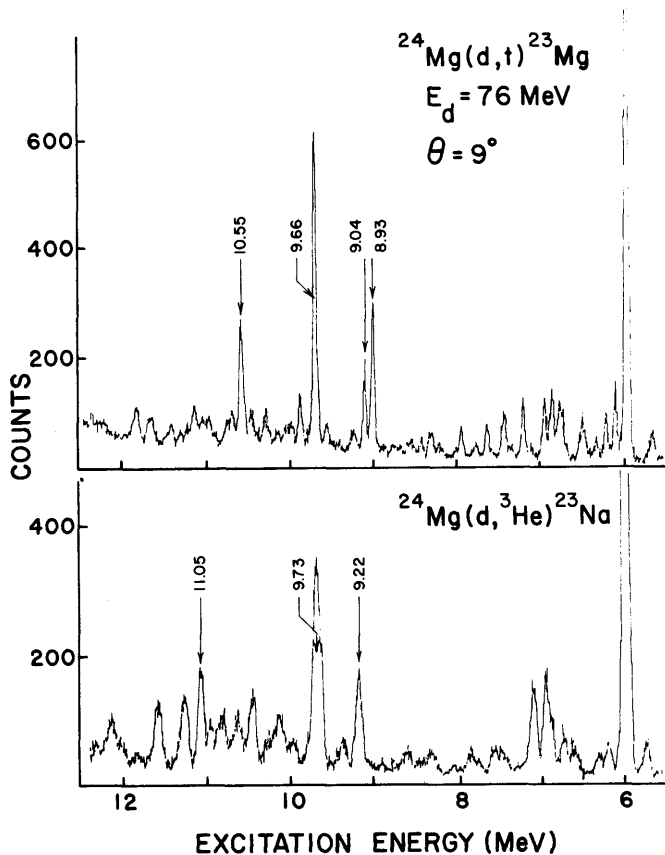


Fig. 2. Representative (d,t) and $(d,^3\text{He})$ spectra from ^{24}Mg at high excitation. The spectra are composites of several smaller energy bites taken with different spectrograph field settings.

Several states of $\ell=1$ character at high excitation (energies are labeled in fig. 2) have been identified by the similarity of their distributions to known low-lying $\ell=1$ state shapes. These angular distributions are shown in fig. 3. The $(d,^3\text{He})$ data is scaled by a factor of 0.824, which is the average relative experimental normalization for the $^{23}\text{Na}(3.68)$ and $^{23}\text{Mg}(3.80)$ $\ell=1$ states shown in fig. 1. The 8.93 and 9.66-MeV (d,t) states and the 9.22 and 9.73-MeV $(d,^3\text{He})$ states, respectively, appear as mirror-like $\ell=1$ fragments. If the $^{23}\text{Na}(11.05)$ state is the sole mirror of $^{23}\text{Mg}(10.55)$, it has only $\sim 70\%$ of the strength of $^{23}\text{Mg}(10.55)$ and has a large relative shift (1/2 MeV) in energy. The $^{23}\text{Mg}(9.04)$ state has no obvious identifiable mirror; the equality of the $^{23}\text{Mg}(8.93)$ and scaled $^{23}\text{Na}(9.22)$ cross sections, as indicated in fig.

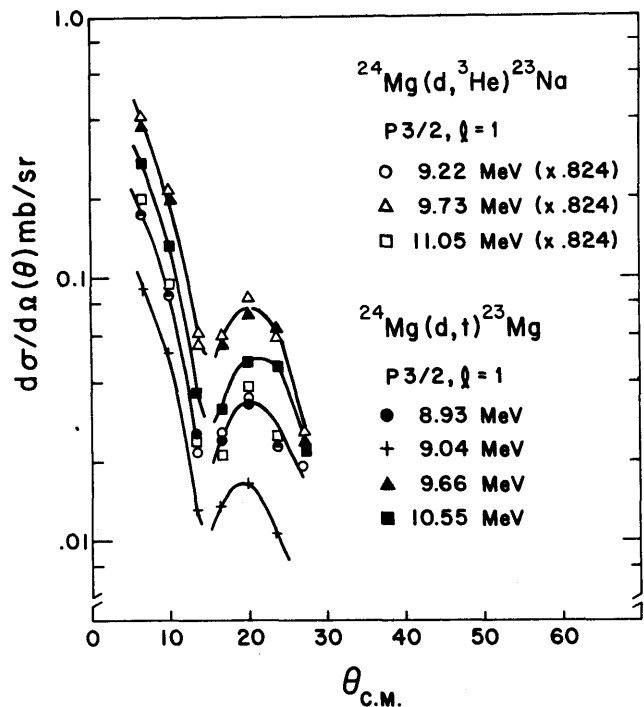


Fig. 3. Angular distributions for $^{24}\text{Mg}(d,t)^{23}\text{Mg}$ and $^{24}\text{Mg}(d,^3\text{He})^{23}\text{Na}$ to high-lying $\ell=1$ states. The $(d,^3\text{He})$ and (d,t) data are represented by open and closed symbols respectively. The $(d,^3\text{He})$ data points are normalized by 0.824 as discussed in the text. The solid lines are guides to the eye.

3, means that the $^{23}\text{Mg}(9.04)$ mirror is probably not an unresolved component of the $^{23}\text{Na}(9.22)$ state. Although preliminary shell-model calculations⁵⁾ predict a concentration of $1p_{3/2}$ -hole strength in this region, calculations to date do not include Coulomb effects in the residual interaction. Hence it is difficult to say whether the relatively large observed (state-to-state) scatter in Coulomb-energy differences and relative strengths for these high-lying mirror-like states (as compared to pairs below 6 MeV excitation) is anomalous or expected behavior for small high-lying fragments ($\sim 40\%$ of the total $1p_{3/2}$ single-particle $(d,^3\text{He})$ strength lies in two large states below 6 MeV; see Kramer et al., ref. 3). It seems, however, that the apparent discrepancies of the earlier (p,d) and $(d,^3\text{He})$ work are confirmed by the present data, and there are

real differences in these high-lying mirror spectra. The remaining large number of fragments seen in fig. 2. have angular distributions largely of $\ell=0$ or $\ell=2$ character. There are a few states, however in the (d, ^3He) spectra near 11 MeV excitation whose angular distributions are similar to $\ell=1$, suggesting perhaps admixtures of non-direct processes with weak $\ell=1$ components. Further careful data reduction and analysis of these weak states is continuing.

More recently, spectrograph data for $^{40}\text{Ca}(d,t)$ ^{39}Ca and $^{40}\text{Ca}(d,^3\text{He})$ have been obtained⁶⁾ for $E_d = 76$ MeV in the range $E_x \leq 12$ MeV and $6^\circ \leq \theta \leq 24^\circ$. Here it is found that the ratio of (d, ^3He) to (d,t) cross sections for some low-lying mirror states is as large as two at forward angles (decreasing rapidly to $\leq 20\%$ difference at the larger angles). Once again, considerable fragmentation of the strength (mainly $\ell=2$) appears in the high-lying region $E \approx 6-10$ MeV. More structure is apparent in the forward-angle $^{40}\text{Ca}(d,^3\text{He})$ vs. (d,t) spectra, possibly as a result of the larger (d, ^3He) mirror cross section. Analysis of this data is underway.

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- 1) IUCF Techn. and Scient. Report 1977, p. 48; W.W. Jacobs *et al.*, B.A.P.S. 23, 539 (1978).
- 2) IUCF Techn. and Scient. Report 1977, p. 58; D.W. Miller *et al.*, B.A.P.S., 23 527 (1978).
- 3) M. Arditì, L. Bimbot, H. Doubre, N. Frascaria, J. P. Garron, M. Riou, and D. Royer, Nucl. Phys. A165, 129 (1971); E. Kramer, G. Mairle, and G. Kaschl, Nucl. Phys. A165, 353 (1971).
- 4) R.E. Tribble and K.I. Kubo, Nucl. Phys. A282, 269 (1977).
- 5) S. Maripuu, private communication
- 6) Forward angle $^{40}\text{Ca}(d,^3\text{He})$ data taken in conjunction with D.W. Devins *et al.*, see p. 67 of this report.