HIGH-EXCITATION HOLE STATES IN THE $^{24}Mg(p,d)$ REACTION

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Analyses of the data obtained for $^{24}Mg(p,d)$ reactions at E_p = 94.8 MeV[1,2] have been completed for 32 states or groups of states in ^{23}Mg up to 10.75-MeV excitation. Results were obtained at 28 angles between 6° lab and 88° lab for states up to 4.36 MeV, at 22 angles between 6° and 64° for states from 4.68 to 6.54 MeV, and at 11 angles between 8° and 48° for states from 7.8 to 10.75 MeV. For the low-lying states the data cover the momentum-transfer range from about 100 to 660 MeV/c.

Figures 1 - 3 show the angular distributions obtained for known ℓ = 0, 1 and 2 transitions to the low-lying states in ^{23}Mg; curves shown are guides to the eye. DWBA calculations using the distorted-wave code[3] DWUCK IV have been carried out in an attempt to extract spectroscopic information for these states. The proton potentials used were based on the work of Nadasen *et al.*[4], and a variety of deuteron potentials have been used (Kiss[5], Duhamel[6], and an adiabatic potential following Johnson and Soper[7]). Finite-range and non-locality effects were treated approximately in the calculations. Form factors were calculated using the separation-energy prescription with a Woods-Saxon radius of $1.25A^{1/3}$ fm and a diffuseness of 0.65 fm. For the ℓ = 2 calculations reasonably good fits are obtained, but there is approximately a factor of 3 variation in C^2S depending on the deuteron potential used. The ℓ = 1 prediction fits the slope of the data well at large angles, but at forward angles turns down sooner than the data which continue to rise to smaller angles.

The ℓ = 0 predictions do not provide a good fit to the shapes of the angular distributions. Predicted

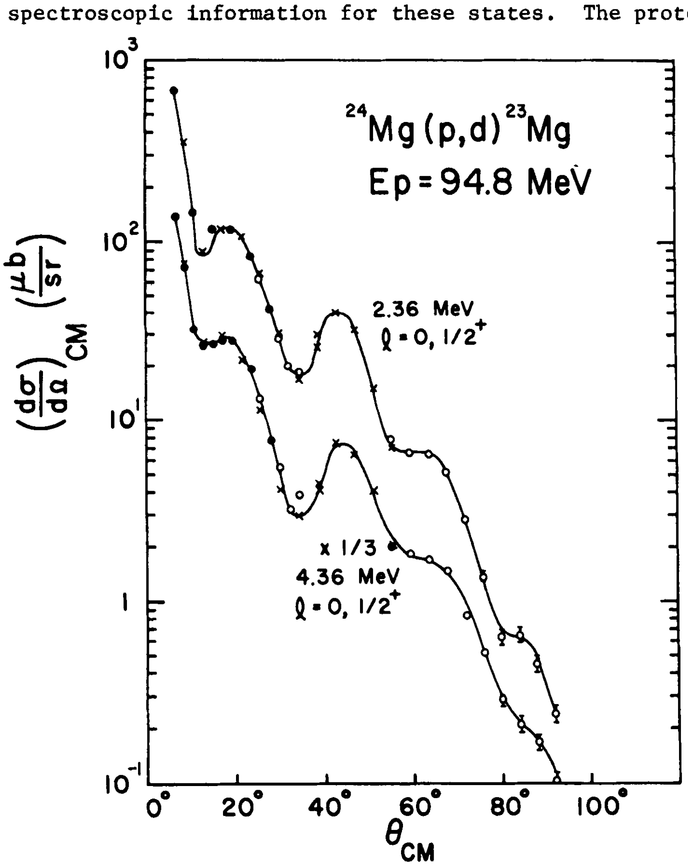

Figure 1.

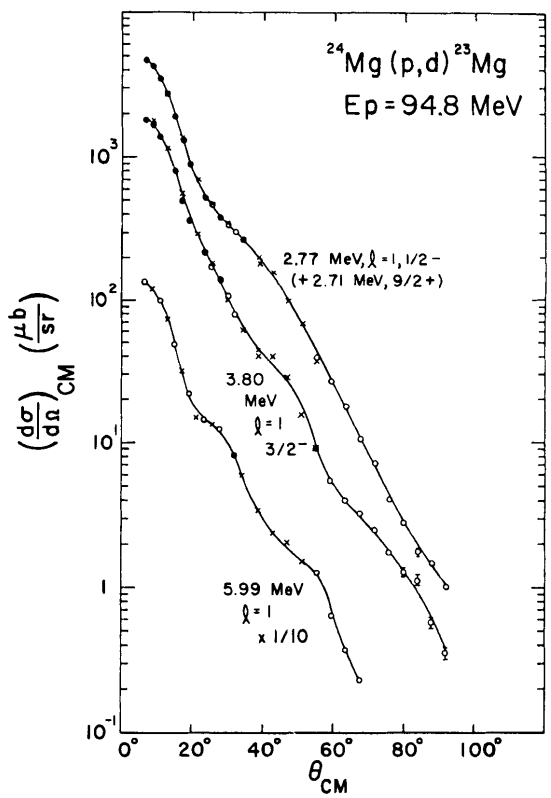

Figure 2.

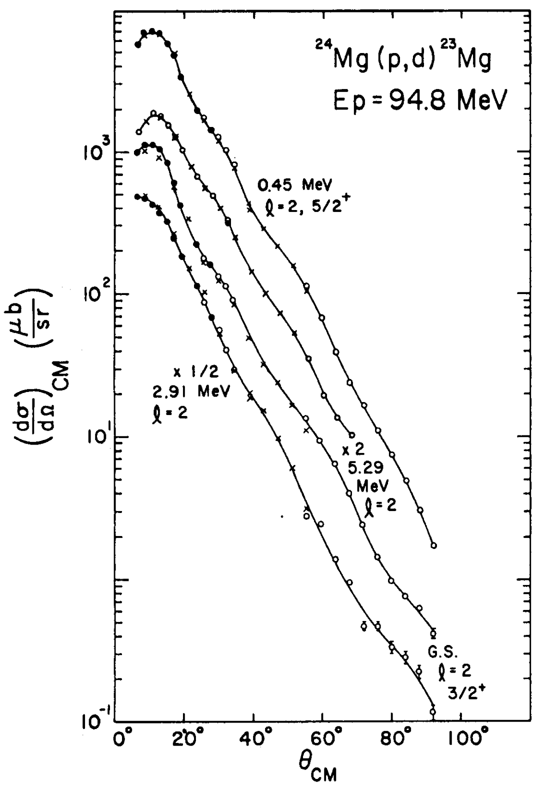

Figure 3.

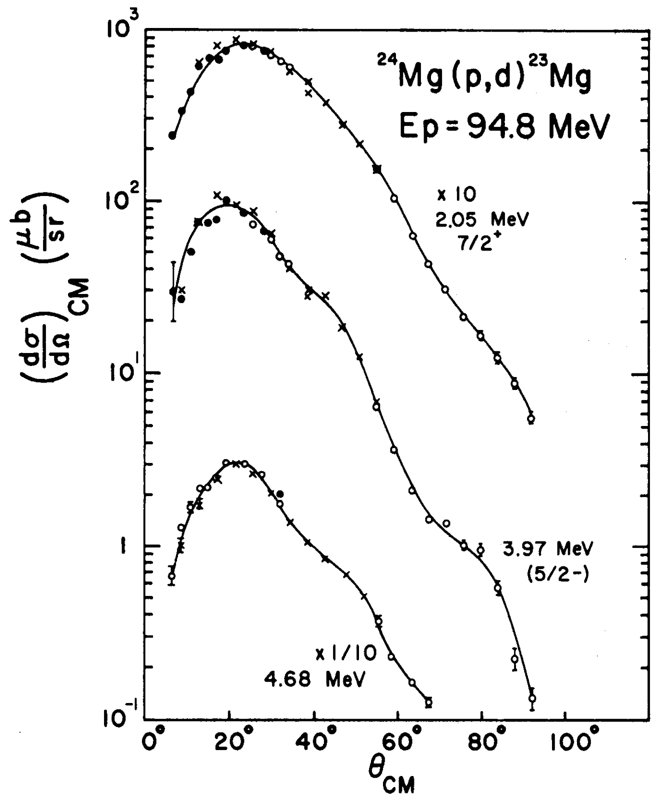

Figure 4.

oscillations have the correct angular spacing, but the average slope is not well reproduced and the predicted osciallations are shifted to larger angles than those exhibited by the data. Similar problems have been observed for $^{24}Mg(p,d)^{23}Mg$ investigated at 27.3 MeV[8] and $^{24}Mg(d,^{3}He)^{23}Na$ at 52 MeV[9], where different radius prescriptions were needed to obtain fits. In the present work the radius and diffuseness of the form factor for the $\ell = 0$ transitions were varied over the range $1.10A^{1/3}$ to $1.40A^{1/3}$ fm and 0.5 to 0.8 fm respectively. These adjustments did not make substantial improvements to the fits. The major difficulty to the one-step DWUCK fits may result from the fact that (p,d) processes which can occur in the nuclear interior at these energies are not well described using deuteron parameters derived from elastic scattering. No attempt has been made as yet to include possible two-step interference effects in the one-step allowed cases.

In contrast to Figs. 1-3, Fig. 4 shows the much broader angular distributions obtained for the known $7/2^+$ state at 2.05 MeV (top), and for states at 3.97 MeV and 4.68 MeV. The $7/2^+$ state at 2.05 MeV is generally believed to be excited by a two-step process, since 2p2h components of the ^{24}Mg ground-state are not expected to contain enough $(1g_{7/2})^2$ to allow one-step pickup with the observed cross section. A preliminary DWUCK prediction for an $\ell = 4$ one-step process to this state peaks at approximately the correct angle, but does not drop off appreciably at forward angles, and drops off more rapidly than the data in Fig. 4 at large angles. A rough spectroscopic factor estimated from this comparison _if_ the process were one-step is ≈ 0.02. A preliminary CCBA calculation assuming only a two-step process with inelastic excitation of the 2^+ state in ^{24}Mg followed by $\ell = 2$ pickup is not inconsistent with the observed experimental shape; further analysis along these lines is in progress.

Spin and parity assignments for the 3.97- and

4.68-MeV states are not certain[10]. The 3.86- and 3.97-MeV states in ^{23}Mg are believed[11] to be the (inverted) mirror states of the $5/2^+$ 3.91-MeV and $5/2^-$ 3.85-MeV states in ^{23}Na. An ℓ = 2 transition[11] to the 3.86 MeV state in ^{23}Mg provides a $(3/2,5/2)^+$ assignment. This state could not be resolved in the present work. However, the angular distribution shown in Fig. 4 for the 3.97-MeV state is certainly not consistent with an ℓ = 2 one-step transfer. On the other hand, the shape of the angular distribution may well suggest a two-step mechanism, which would be required for a $5/2^-$ assignment if a 2p2h component involving $(1f_{5/2})^2$ in the ^{24}Mg ground state is negligible. If the latter component is appreciable, then the angular distribution for the 3.97-MeV state may represent one-step ℓ = 3 pickup, or interference between this and the two-step mechanism. Either way, the shape of the angular distribution strongly favors the $5/2^-$ assignment for the 3.97-MeV state, in agreement with an inversion of the 3.86-3.97 MeV pair from the mirror nucleus ^{23}Na.

It has been proposed[12,13] that the 4.68-MeV state is $7/2^+$, based upon Nilsson-model arguments and experimental results. Although there are minor differences in detail, the similarity of the angular distributions in Fig. 4 would be consistent with a $7/2^+$ assignment for the 4.68-MeV state.

In order to make empirical assignments for the prominent deep-hole structures seen at about 8,9, 9.6 and 10.5-MeV excitation[1], cross sections for the low-lying states excited by known ℓ = 1 and ℓ = 2 transfers in Figs. 2 and 3 were replotted as a function of momentum transfer q (in MeV/c), after division by an exponentially decreasing average factor[14] exp(-q/66). On such plots the known ℓ = 1 transfers exhibit a forward peak at about 115 MeV/c and the ℓ = 2 transfers at about 155 MeV/c. Comparison with similar plots for the deep-hole states (with fewer angles available, however) indicates ℓ = 1 assignments for the 8.88, 8.99, 9.62 and 10.50-MeV peaks. A small peak at 9.80-MeV excitation is not consistent with ℓ = 1 behaviour. Weaker groups at high excitation do not allow definite conclusions to be drawn because of questions of reliability in extracting cross sections in the high-excitation region with the peak-fitting routine; some appear to show relatively broad angular distributions suggestive of multi-step processes or overlapping states.

The ℓ = 1 assignments to the deep-hole peaks cited above agree with recent ^{24}Mg(d,t) results[15] at this laboratory, and are consistent with shell-model expectations[16] for deep-hole structures in ^{28}Si(p,d). Other semi-empirical comparisons of the data to plane-wave cut-off and DWUCK calculations give similar conclusions.

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