doublet of 2^+ states separated by about 2 keV.[3]) This is in good agreement with the Argonne results.[1] The large uncertainty arises primarily from an uncertainty about the shape of the low-energy tail of the standard peak shape, an uncertainty which does not significantly affect the results for the 0^+ states.

Our spectra also gave clear indication of the presence of a state near 1055-keV excitation. This is in excellent agreement with the position of two known 4^+ states,[3] separated by about 7 keV, one of which probably belongs to a rotational band built on the excited 0^+ state. This level was not identified in the previous (p, t) experiments.[1] Such a rotational band is expected to have a 6^+ state near 1200-keV excitation. While our spectra show some indication of the presence of a state below the 1240-keV state, no positive identification of a 1200-keV state is given here.

Although we cannot speculate on their character, we note that the existence of excited 0^+ states of a new collective mode has been predicted by Belyaev.[4,5] The properties of these states, such as strong $E0$ decays to the ground state and unusually large population strengths in two-neutron-transfer reactions, agree well with the properties noted in Ref. 1. While effects due to other higher-order processes[6,7] in the reaction mechanism are not excluded, our data appear to confirm the view in Ref. 1 that the strong yields of the excited 0^+ states indeed reflect a property of the states.

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Nondirect ^{26}Mg(^{4}He, ^{6}He)^{24}Mg Reaction at 35 MeV*

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The differential cross sections for the two-neutron pickup reaction ^{26}Mg(^{4}He, ^{6}He)^{24}Mg have been found to exhibit a strong dependence on bombarding energy, evidence of some process other than a direct reaction. Angular distributions at a fixed energy for several low-lying states of ^{24}Mg are found to exhibit structure reminiscent of known direct reactions, and we conclude that this signature cannot be considered proof of a direct reaction.

The study by Rickey, Wegner, and Jones[1] of the ^{26}Mg(^{4}He, ^{6}He)^{24}Mg reaction suggests that this reaction might be a useful complement to the (p, t) two-neutron transfer reaction. The strong absorption in the ^{4}He and ^{6}He channels would seem to avoid the sensitivity to the details of the nuclear interior found in recent (p, t) studies.[2] The utility of (^{4}He, ^{6}He) studies is predicated, however, on the direct nature of the reaction.

α-particle channels on $N = Z$ targets have been observed to exhibit nondirect properties at the bombarding energies to be considered here,[3-5] but the mechanism seems to become more direct as even a few neutrons are added to the target.[3,5] At a beam energy of 40 MeV, the earlier study of the ^{26}Mg(^{4}He, ^{6}He)^{24}Mg reaction[1] found structured, seemingly direct angular distributions for several levels of ^{24}Mg. Our attempt to study this reaction at 35 MeV was, however, frustrated by strong dependences of the yields on the bombarding energy. We present our results as a caveat to those interested in the study of direct nuclear reactions.

We have measured the angular distributions for populating several low-lying states of ^{24}Mg at beam energies of 35.5 and 33.3 MeV, and an excitation function at 40° (lab) for beam energies from 33.3 to 36.0 MeV. α particles from the University of Colorado 1.3-m cyclotron were incident upon an enriched (99.22%) target of ^{26}Mg. A conventional ΔE-E-Veto counter system was used with fast pileup rejection. As is shown in Fig. 1, the energy resolution was not sufficient to separate the 4.12–4.24-MeV doublet in ^{24}Mg, but the extra width of this peak indicated that both members of the doublet are nearly equally populated. The energy spread inherent in the beam and target thickness is ~110 keV, so energy dependence within this interval is averaged.

The angular distributions for populating the ground state and 1.37-MeV (2^+) state of ^{24}Mg are shown in Fig. 2. The structure is reminiscent of that observed in direct reactions; we emphasize this by including distorted-wave Born-approximation (DWBA) predictions in the figure. The observed and predicted curves exhibit the same general shape, with a shift in phase. The DWBA prediction is too simplistic to be valid. The zero-range, s-wave $(1d_{5/2})^2$ pickup of a dineutron was assumed, with ^{4}He optical potentials obtained at 42 MeV,[6] and ^{6}He parameters taken to be those for ^{6}Li on ^{24}Mg.[7]

Difficulties in reproducing cross sections led to the measurement of the excitation functions shown in Fig. 3. The relative changes in peak differential cross sections (near 30°) predicted by the DWBA calculations as a function of beam energy are also shown. The observed change is clearly not that predicted by kinetics alone; even for the

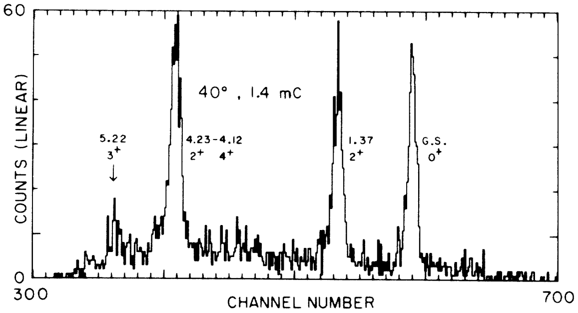

FIG. 1. The spectrum of ^{6}He observed when a ^{26}Mg target is bombarded with 35.6-MeV α particles.

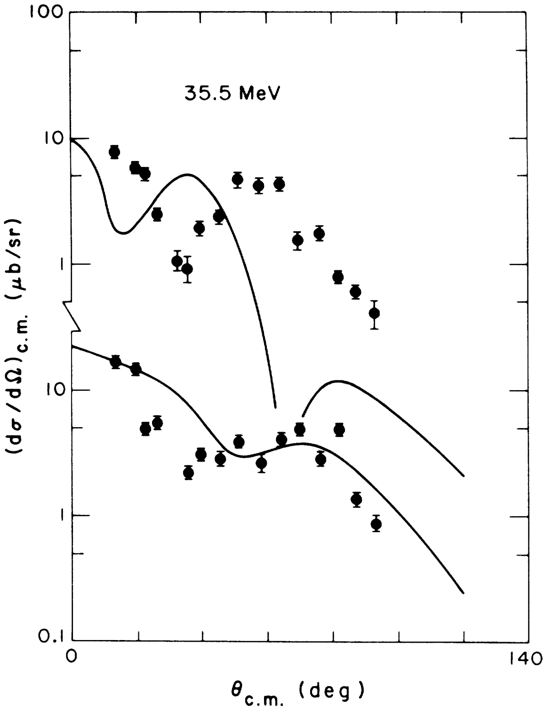

FIG. 2. The angular distributions for populating the ground state (0^+) and 1.37-MeV state (2^+) of ^{24}Mg. The curves show the DWBA predictions for an assumed s-wave pickup.

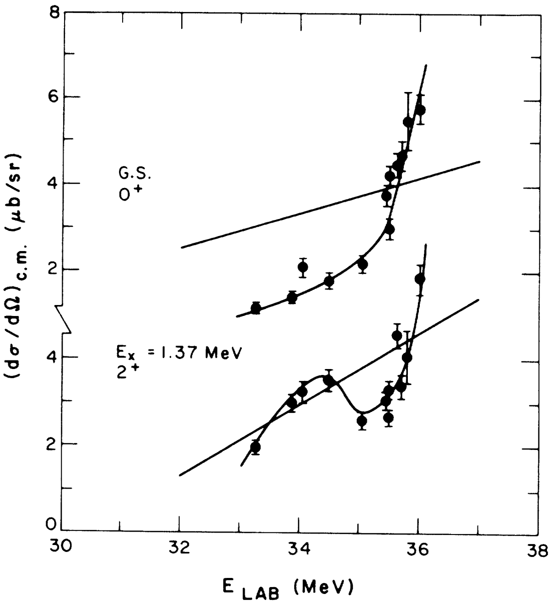

FIG. 3. The excitation functions for populating the ground state and 1.37-MeV state of ^{24}Mg at a lab angle of 40°. The heavy curves serve to guide the eye, and the lighter lines give the relative shifts in magnitude predicted by the DWBA.

6.44-MeV state of ^{24}Mg, the ^{6}He we identify are still at least 6 MeV above the Coulomb barrier over our angular range. A comparison of angular distributions measured at 35.5 and 33.3 MeV showed striking differences in shape. These evidences of a nondirect-reaction mechanism may be due to Ericson fluctuations or to an actual resonance near 41 MeV in ^{30}Si. We have not studied other reaction channels.

The following general features were observed in the data for the higher-lying states. The angular distribution for populating the 2^+-4^+ doublet shows structure similar to that for the 1.37-MeV state, and the 40° cross section decreases strongly with decreasing beam energy. The excitation of the 5.22-MeV 3^+ state is forbidden by direct-reaction selection rules but is observed by us at small angles with about $\frac{1}{10}$ the strength of the allowed transitions. At our lower beam energies, this transition is relatively stronger compared to the allowed transitions than was observed at 40 MeV.[1] At the smallest angles, we observe the 6.44-MeV 0^+ state to be nearly as strongly excited as the ground state of ^{24}Mg. Only at these small angles did the ^{6}He corresponding to the 6.44-MeV excitation have sufficient energy to penetrate the 43-μ ΔE counter. The 6.00-MeV 4^+ state is very weakly populated, but exhibits a forward-peaked angular distribution.

Our intuition concerning the influence of strong absorption on the two-nucleon-transfer cross section was further investigated by a computer experiment, comparing DWBA calculations with a range of lower cutoffs on the radial integrals. The shape of the angular distribution, but not its magnitude, is strongly influenced by contributions from the interior, and we take this as evidence that even a direct (^{4}He, ^{6}He) cross section is not purely a surface reaction.

In summary, we find the ^{26}Mg(^{4}He, ^{6}He)^{24}Mg reaction to be of a primarily nondirect nature near 35 MeV, in spite of a seemingly direct angular distribution at a fixed beam energy. This latter signature is not sufficient to guarantee a valid direct-reaction analysis, as is sometimes assumed.[1,8]

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