# Multistep Processes in the $^{26,24}Mg(p,t)^{24,22}Mg$ Reactions

C. H. King, H. Nann, M.A.M. Shahabuddin and B. H. Wildenthal

The nuclear shell model has been quite successful in describing the properties of nuclei in the 2s-1d shell.[1] However, certain anomalous results have been observed in various nuclear reactions in this region, which have thus far appeared to be inexplicable assuming shell-model wavefunctions for the nuclear states. Examples of these anomalies have been observed in the $^{26}Mg(p,t)$ and $^{24}Mg(p,t)$ reactions.[2] In the $^{24}Mg(p,t)$ reaction, for instance, the ratio of the strength of the ground-to-first-$2^+$ transition to that of the ground-to-ground transition was found to be two orders of magnitude larger than what was predicted using shell model wave functions. Similarly, in the $^{26}Mg(p,t)$ reaction the strength of the transition to the second $2^+$ state was also found to be anomalously large.

However, the predictions for the reaction strengths which lead to these discrepancies do not depend on the shell model wave function alone but also on assumptions about the reaction mechanism. Specifically, it is assumed that the transitions can be described by a first-order reaction model, that is, the distorted-wave Born approximation (DWBA). Because of the highly collective nature of the magnesium nuclei, it is questionable that this is a reasonable assumption. In particular, multistep processes involving inelastic scattering in the initial and final nuclei ("inelastic-plus-transfer" processes) could be significant. Such processes, have been shown[3,4] to explain the excitation of unnatural parity states in $^{22}Ne(p,t)$. The observation[2] of considerable strength in the $^{26}Mg(p,t)$ transition to the unnatural parity $3^+$ state at 5.22 MeV in $^{24}Mg$ is a good indication that multistep inelastic-plus-transfer processes are important in the reactions on magnesium as well.

To discover whether inclusion of the inelastic-plus-transfer processes can resolve the anomalies observed in the magnitudes of the $^{26,24}Mg(p,t)$ transitions, we have begun a series of calculations of these reactions using the coupled-channel Born approximation[5] (CCBA), which includes multistep inelastic-plus-transfer processes explicitly to all orders. As a first example, we have considered the $^{24}Mg(p,t)$ transitions to the members of the ground state rotational band of $^{22}Mg$, where the $2^+$ member is observed to be populated with anomalously large strength. In these calculations we have included all possible transitions between each member of the ground bands of $^{24}Mg$ and $^{22}Mg$. The form factors for these transitions were based on shell model wavefunctions calculated with the Oak Ridge-Rochester shell model code.[6] The inelastic matrix elements were determined from the Bohr-Mottelson rotational model with deformation parameters based on the analysis of Rebel, et al.[7] The calculations were performed using the coupled-channel code LISA of R. J. Ascuitto, which we now have working on the Sigma-7 computer at this laboratory.

In the figure are shown the results of such a calculation with the $0^+$, $2^+$, and $4^+$ states included in the reaction space. The overall normalization of the calculation was adjusted so as to reproduce the strength of the $0^+$ transition. It is evident that the inclusion of the inelastic-plus-transfer processes virtually eliminates the discrepancy in the strength of the $2^+$ transition. As is shown in this figure, the strength of the $2^+$ transition including the inelastic-plus-transfer processes (solid line) is more than two orders of magnitude larger than that resulting from the direct one-step $0^+$ to $2^+$ transition alone (dashed line). A number of refinements in the calculations can still be made, such as reasonable changes in the optical and deformation parameters, which are somewhat uncertain. Preliminary indications are than such variations can change the shapes of the angular distributions without affecting the overall improvement in relative strengths already observed.

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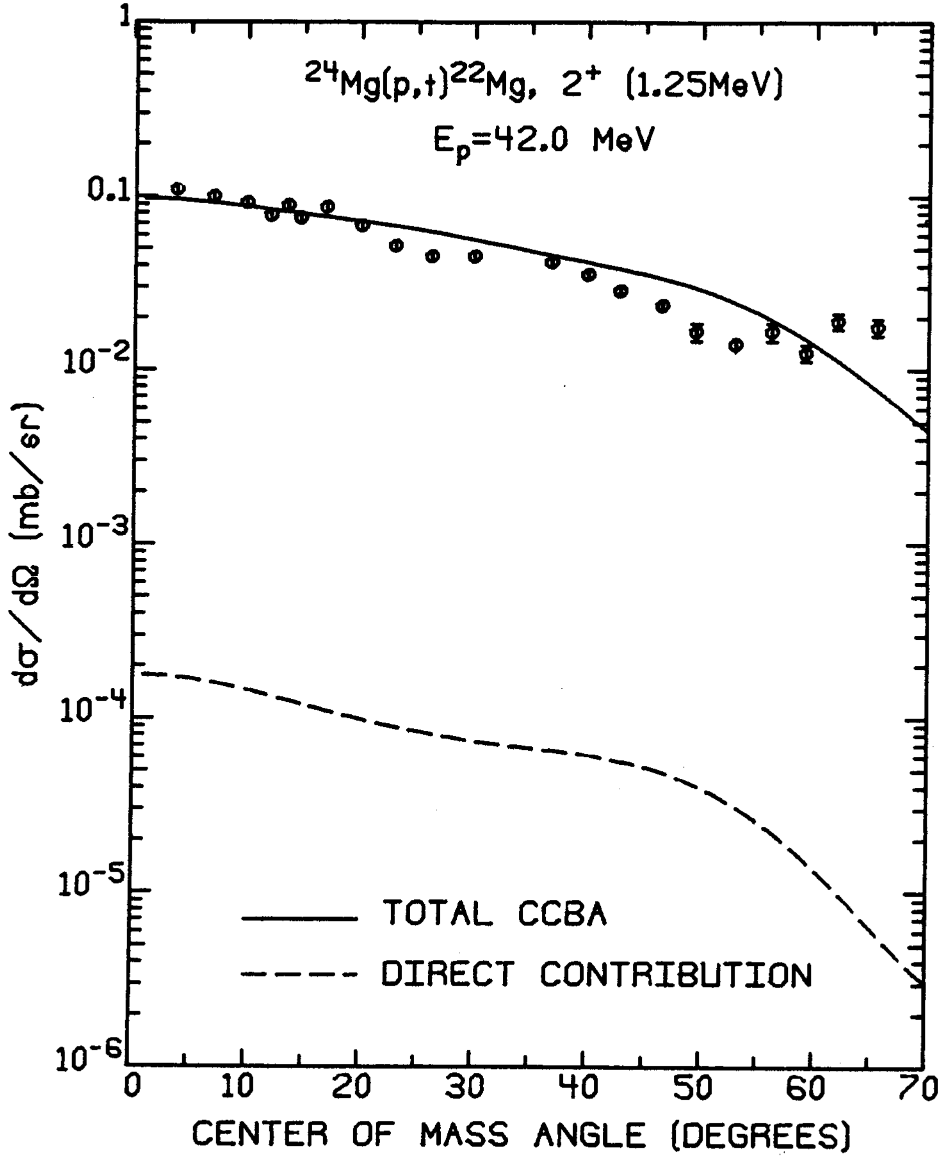
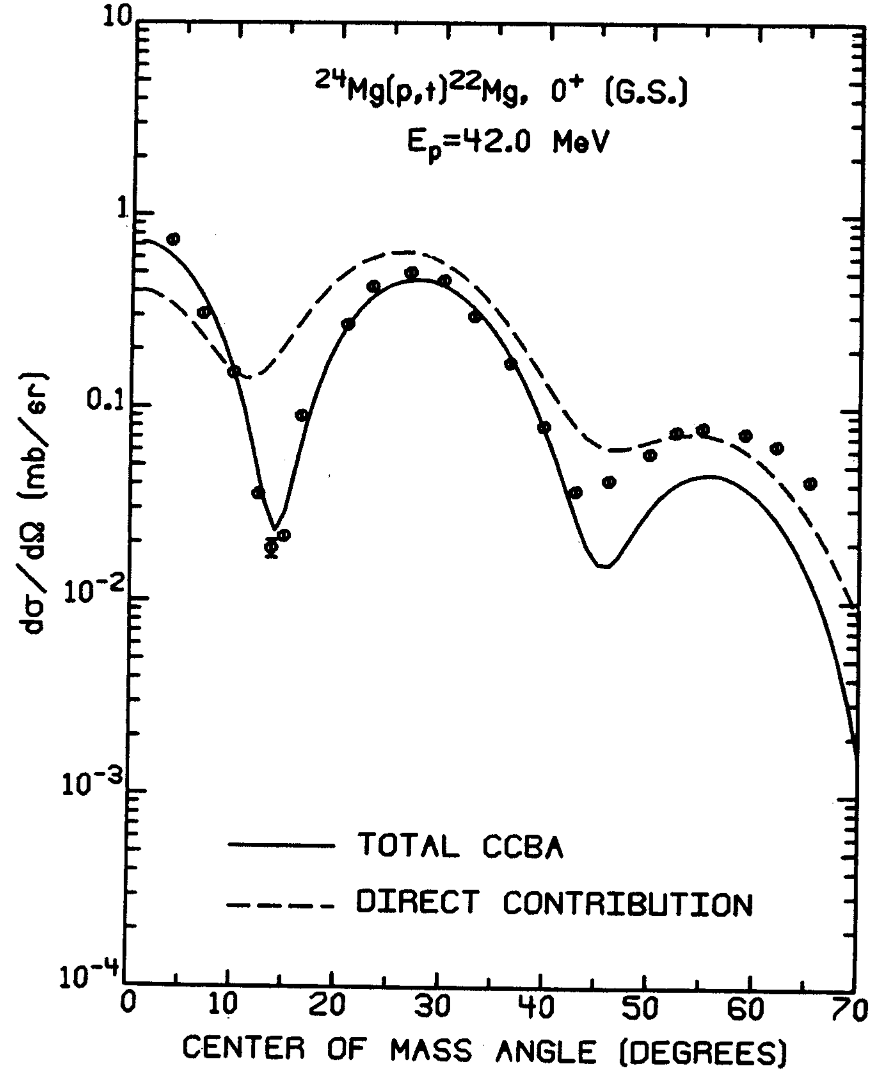

$^{24}Mg(p,t)^{22}Mg$, $2^+$ (1.25MeV)
$E_p$=42.0 MeV
dσ/dΩ (mb/sr)
CENTER OF MASS ANGLE (DEGREES)
TOTAL CCBA
DIRECT CONTRIBUTION


$^{24}Mg(p,t)^{22}Mg$, $0^+$ (G.S.)
$E_p$=42.0 MeV
dσ/dΩ (mb/sr)
CENTER OF MASS ANGLE (DEGREES)
TOTAL CCBA
DIRECT CONTRIBUTION

## Higher-Order Processes in $^{22}$Ne(p,t)

W. S. Chien, C. H. King, H. Shahabuddin, and J. A. Nolen

Transitions to unnatural parity states in (p,t) reactions on $0^+$ targets provide excellent examples for studying the mechanism of higher-order processes in nuclear reactions, since the competing single-step path is essentially eliminated.[1,2] There are two multistep mechanisms which can contribute to such unnatural parity transitions: those involving inelastic excitations in the target and residual nuclei ("inelastic-plus-transfer"), and those involving successive single-nucleon transfer (g.g., p-d-t). Multistep inelastic-plus-transfer processes are reasonably well-understood in terms of the coupled-channel Born approximation (CCBA) formalism.[3] However, the role of successive single-nucleon transfer is not as well understood, and, in particular, the magnitude of such processes is in doubt.[4] It can be shown[5] that multistep processes involving transferred spin S=0 have reduced transition amplitudes which vanish at zero degrees. Since spin-orbit parts of the optical-model potential are usually negligible in determining (p,t) transitions (as has been demonstrated by the weak polarization measured in such reactions[6]), the inelastic-plus-transfer mechanism will tend to result in a cross section which decreases rapidly at very forward angles. On the other hand, the (p-d-t) mechanism to unnatural parity final states is mainly in S=1 process, and thus the cross section in general will not decrease at forward angles. Therefore, the very forward angle data could provide a sensitive test of these two distinctive higher-order transition mechanisms.

We have measured the angular distribution for the $^{22}$Ne(p,t)$^{20}$Ne($2^-$) reaction from laboratory angles of 4° to 25° at a bombarding energy of 40 MeV using protons from the MSU Cyclotron. The target gas used was 99.9% purity $^{22}$Ne contained in a 3 mm thick sandwich-type gas cell with 1 mil Kapton windows. The gas pressure was constantly monitored with a Wallace and Tieran pressure gauge. The gas temperature was assumed to be room temperature. The measurement has been repeated at a given angle to monitor the variations in target thickness. The tritons were detected in a resistive-wire proportional counter placed in the focal plane of an Enge split-pole magnetic spectrograph. The proportional counter was backed by a plastic scintillator which was used to identify the tritons by time of flight measurement. Our data, as well as the Minnesota data[1] taken at larger angles is shown in Figure 1. The dashed curve is a CCBA calculation,[1] and the solid curve is that for a (p-d-t) type transition using the coupled-reaction-channel (CRC) formalism.[5] Our forward angle data demonstrate that the cross section continues to drop at very forward angles. Hence these data seem to indicate that the inelastic-plus-transfer process is the most important higher-order mechanism contributing to the $^{22}$Ne(p,t) $^{20}$Ne($2^-$) reaction.

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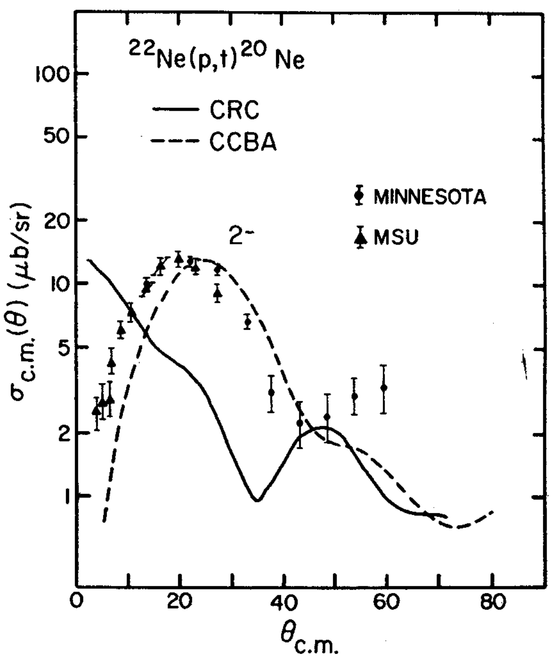


Figure 1.

Search of Weak-Coupling Structure in (p,t) Results

H. Nann, B. H. Wildenthal, W. Benenson, K. K. Seth+ and A. Saha+

Recent (p,t) experiments[1,2] on a number of odd-A and on adjoining even-A targets in the 1f-2p shell have shown that the results can be explained by a weak-coupling core-excitation model. It has been found that for the odd-A nuclei the g.s.($J_i$)→g.s($J_f$=$J_i$) transitions show highly enhanced L=0 transfers although the selection rules allow other L-values. In addition, a second enhanced L=0 transition to an excited state with $J_f$=$J_i$ was always found. This state lies at an excitation energy within a few hundred keV of that of the first excited $0^+$ state in the adjoining even-A nucleus. The explanation of this phenomenon must arise from specific nuclear-structure properties of the states involved, since there exist no selection rules which restrict the angular momentum transfer in such cases to only L=0. It is suggested that the L=0 enhancement, the closeness of the excitation energies and moreover the relative magnitude of the observed cross section indicate that these excited states in the odd-A nuclei are formed by weak coupling of a particle or hole to the first excited $0^+$ state of the even-even core, just as the odd-A ground state is based on the $0^+$ ground state of the core.

We have extended the search for this sort of weak-coupling structures in (p,t) results to the 2s-1d shell. The specific cases we have studied so far are the correlated $^{31}$P, $^{30}$Si(p,t) $^{29}$P, $^{28}$Si and $^{35}$Cl, $^{34}$S(p,t) $^{33}$Cl, $^{32}$S reactions. The experiments were done using the 40 MeV proton beam of the MSU Cyclotron and the Enge split-pole spectrograph equipped with a single-wire proportional-counter plastic-scintillator combination. This detector setup provides excellent particle discrimination and an energy resolution of about 25 keV.

## $^{31}$P(p,t)$^{29}$P and $^{30}$Si(p,t) $^{28}$Si Reactions

Figure 1a shows the measured angular distributions for the transitions to the $1/2^+$ g.s. and the $1/2^+$ state at 4.764 MeV in $^{29}$P and to the $0^+$ g.s. and first excited $0^+$ state at 4.979 MeV in $^{28}$Si. Comparing the magnitudes of the observed differential cross sections--the L=0 purity of the odd-odd (p,t) distributions is not significant, since $1/2^+$→$1/2^+$ transitions require L=0 rigorously--the $1/2^+$ state at 4.764 MeV in $^{29}$P can be described as a weakly coupled $2s_{1/2}$ particle to the first excited $0^+$ state at 4.979 MeV in $^{28}$Si just as the ground states are associated.

## $^{35}$Cl(p,t) $^{33}$Cl and $^{34}$S(p,t) Reactions

In Figure 1b the measured angular distributions for the transitions to the first three $3/2^+$ states in $^{33}$Cl and first two $0^+$ states in $^{32}$S are shown. Here only the transitions to the g.s. and 3.979 MeV states in $^{33}$Cl show characteristic L=0 shapes. The transition to the 2.351 MeV state in $^{33}$Cl was found to have only a small L=0 component in it. We, therefore, believe that the 3.979 MeV state is the core-excited $3/2^+$ state which is associated with the first excited $0^+$ state at 3.779 MeV in $^{32}$S.

The above drawn empirical conclusions are verified by mixed-configuration shell-model wave functions[3,4] predicting the observed phenomena.[5]

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+Visitors from: Northwestern University, Evanston, Illinois 60201

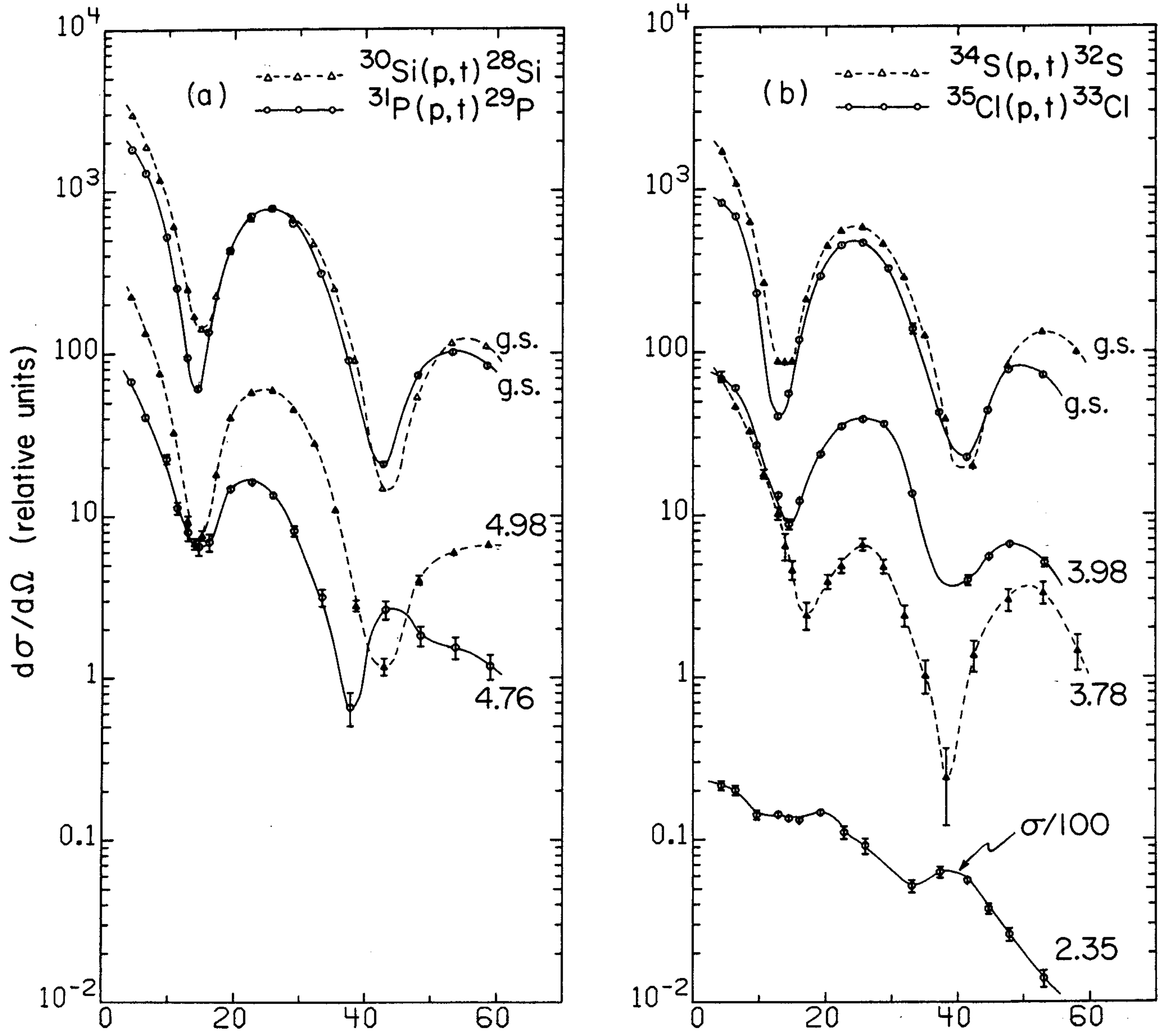


Figure 1a

Figure 1b

# ($^3He,^7Be$) Studies from A=12 to 206

W. F. Steele and G. M. Crawley

The systematic investigation of the ($^3He,^7Be$) reaction with 70 MeV $^3He$ particles has continued. The nuclei studied now include $^{12}C$, $^{13}C$, $^{16}O$, $^{24}Mg$, $^{26}Mg$, $^{40}Ca$, $^{48}Ca$, $^{58}Ni$, $^{60}Ni$, $^{62}Ni$, $^{64}Ni$, $^{90}Zr$, $^{120}Sn$, $^{124}Sn$, and $^{206}Pb$. The $^7Be$ particles are detected with a proportional counter and scintillation counter in the focal plane of the Enge split pole spectrograph. Time of flight measurements using the scintillation counter assist in particle identification.

Two typical spectra from $^{58}Ni(^3He,^7Be)^{54}Fe$ and $^{60}Ni(^3He,^7Be)^{56}Fe$ are shown in Fig. 1. The doublet structure of the spectrum, which arises because both the $3/2^-$ ground state and $1/2^-$, 0.429 keV state are particle stable, is clearly visible. The experimental resolution is predominantly due to target thickness effects and in this case is about 150 keV. A number of excited states in both $^{54}Fe$ and $^{56}Fe$ can be resolved. Angular distributions for some of the states observed in the $^{58}Ni(^3He,^7Be)^{54}Fe$ reaction are shown in Fig. 2. The ratio of cross sections for transitions which leave the $^7Be$ nucleus in the $1/2^-$ (0.429 MeV) and $3/2^-$ ground state are plotted below the angular distributions. For a simple direct model of the reaction, this ratio should equal 0.5. While the ratio is approximately 0.5 especially for the ground state transition, the ratio varies with angle, implying a more complex reaction mechanism. All the angular distributions are strongly forward peaked with fairly sharp diffraction structure even though the magnitude of the cross sections is very small. Even the strongest state observed (4.85 MeV) has a peak cross section of less than 10 μb/st and the ground state transition has a cross section of only 0.2 μb/st at 30°.

Spectra from the reactions $^{120}Sn(^3He,^7Be)^{116}Cd$ and $^{124}Sn(^3He,^7Be)^{120}Cd$ are shown in Figure 3. The resolution is again limited by the target thickness and because of the greater level density fewer states can be resolved. The mass of $^{120}Cd$ and a number of energy levels previously unknown, could be determined from this reaction and the results are presented in Table I. The experimentally observed mass excess is within 60 keV of the Garvey-Kelson prediction which is reasonably satisfactory agreement but differs by about 840 keV from the Meyers-Swiatecki prediction.

Since the $^3He$ and $^4He$ are bound in a relative $\ell=1$ state in $^7Be$, zero range calculations are invalid for describing the ($^3He,^7Be$) reaction. Fortunately the finite range code LOLA is available which allows the calculation of recoil effects exactly. These calculations have been carried out for a number of the reactions studied and some examples for the $^{12}C(^3He,^7Be)^8Be$ reaction are shown in Figure 4. The optical potentials used are given in Table II. Unfortunately it is not possible to directly obtain $^7Be$ optical parameters so $^7Li$ parameters are used as a guide. The fits to the angular distributions are satisfactory for the ground state and the first $2^+$ state but much poorer for the $4^+$ state near 11.4 MeV.

TABLE I.--Mass and Energy Levels of $^{120}Cd$.

| Level | Mass excess (MeV) | $E_x$(MeV) |
|---|---|---|
| 1 | -83.98±0.03 | 0.00 |
| 2 | -83.48±0.05 | 0.50 |
| 3 | -82.68±0.04 | 1.30 |

Garvey-Kelson, ground state mass excess=-83.92 MeV
Meyers-Swiatecki, ground state mass excess =-84.82 MeV.

TABLE II.--Optical Parameters for $^{12}C(^3He,^7Be)^8Be$.

| | $V_R$ (MeV) | $R_R$ (fm) | $A_R$ (fm) | W (MeV) | $V_I$ (fm) | $A_F$ (fm) |
|---|---|---|---|---|---|---|
| $^3He$ | 120 | 1.16 | .933 | 10.6 | 1.28 | .819 |
| $^7Be$ | 213.5 | 1.21 | .88 | 14.54 | 2.09 | .78 |

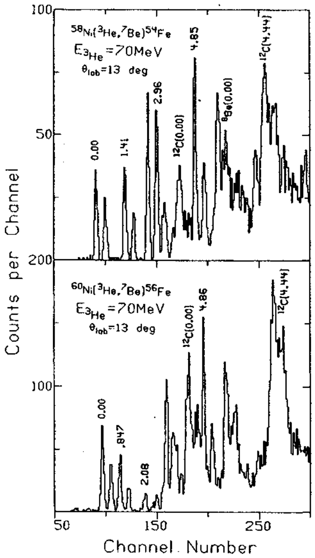


Fig. 1

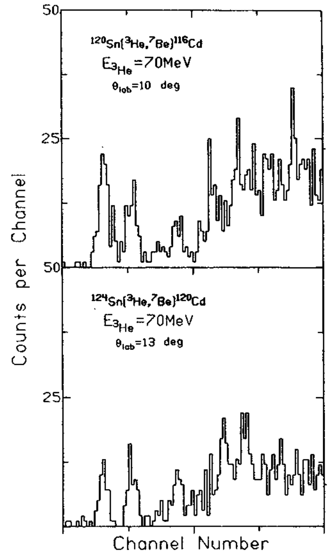


Fig. 3

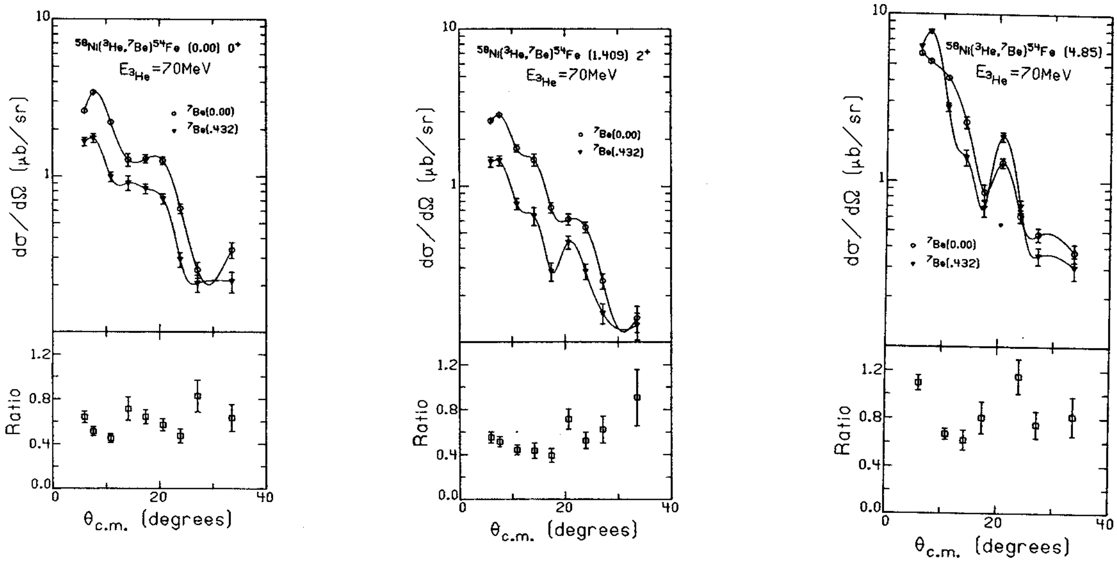


Fig. 2.

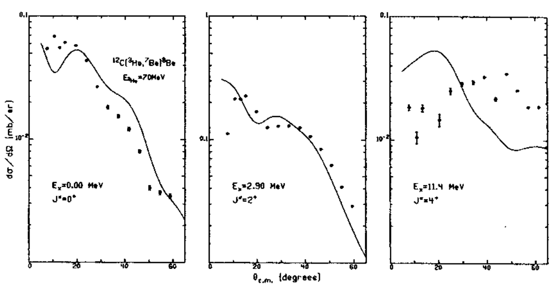


Fig. 4

# Multistep Processes in $^{186}W(p,d)^{185}W$

C. H. King, F. M. Bernthal, T. L. Khoo, J. A. Nolen, Jr., and J. Creasy

Multistep processes in transfer reactions which involve inelastic scattering in the target and final nuclei ("inelastic plus transfer" processes) are known to be important in a number of reactions on collective nuclei. One interesting case is the (p,d) reaction on the rotational nucleus $^{186}W$. In the low-lying spectrum of the residual nucleus $^{185}W$ there are two $3/2^-$ states (0 keV and 94 keV) and one $1/2^-$ state (24 keV). In a first order reaction model (e.g., DWBA) the (p,d) transitions to all three of these states involve only $\ell=1$ transfer. Thus, since the states lie within 100 keV of each other, the resulting angular distributions are expected to have similar shapes. An experiment performed at 18 MeV, however, revealed significantly different angular distribution shapes.[1] Moreover, calculations using the coupled-channel Born approximation (CCBA), a reaction model which explicitly includes the multistep inelastic-plus-transfer processes, were quite successful in accounting for the observed differences between the experimental shapes.[1]

The CCBA calculations implied that the observed angular distributions resulted both from inherent differences between the angular dependence of the direct ("one-step") and multistep contributions and also from interference between the two. Because the multistep effects allow transfers other than $\ell=1$ to contribute to the transitions, one would expect the one-step and multistep mechanisms to behave somewhat differently with changes in the projectile energies. Therefore, we thought it would be useful to examine this reaction at a different energy to test the adequacy of the CCBA to explain the results.

We elected to measure the reaction at 35 MeV using protons from the MSU cyclotron. The target was approximately 700 $\mu g/cm^2$ of metallic $^{186}W$, and the outgoing particles were detected on the focal plane of our Enge split-pole magnetic spectrograph with a 5 cm long position-sensitive silicon surface barrier detector. The resolution obtained was approximately 15 keV FWHM, determined principally by target thickness. The angular distributions for the transitions to the three states mentioned above are shown in the figure and can be seen to have significant differences, just as at 18 MeV.

CCBA calculations were made using the computer code LISA of R. J. Ascuitto. The model assumed for the structure of the nuclear states was the same as that used in the 18 MeV calculations.[1] The optical parameters used were taken from the average set of Becchetti and Greenlees[2] using the Johnson-Soper prescription for the deuterons.[3] The results, shown in the two figures, reproduce both the shapes and relative strength of the cross sections very well, indicating that the CCBA reaction model works as well at 35 MeV as it does at 18 MeV. The partial contributions to the transitions from the one-step (direct) and multistep processes indicated in the figures demonstrate the reasons for the differences in the angular distributions. The strong transition to the $3/2^-$ (94 keV) state is dominated by the one-step contribution and therefore has an angular distribution shape which is essentially the same as that of the direct process. The shape of the angular distribution for the transition to the $1/2^-$ (24 kev) state is determined by interference between the one-step and multistep contributions, which for this transition are of approximately equal magnitude. On the other hand, the transition to the ground state is dominated by the multistep processes, and these processes principally determine its angular distribution.

Angular distributions were obtained for transitions to states in $^{185}W$ up to approximately 1 MeV in excitation. Although some more examples of differences between angular distributions of the same $\ell$ were observed, none are as significant as those for the low-lying $\ell=1$ transitions. These higher-lying transitions are still being analyzed.

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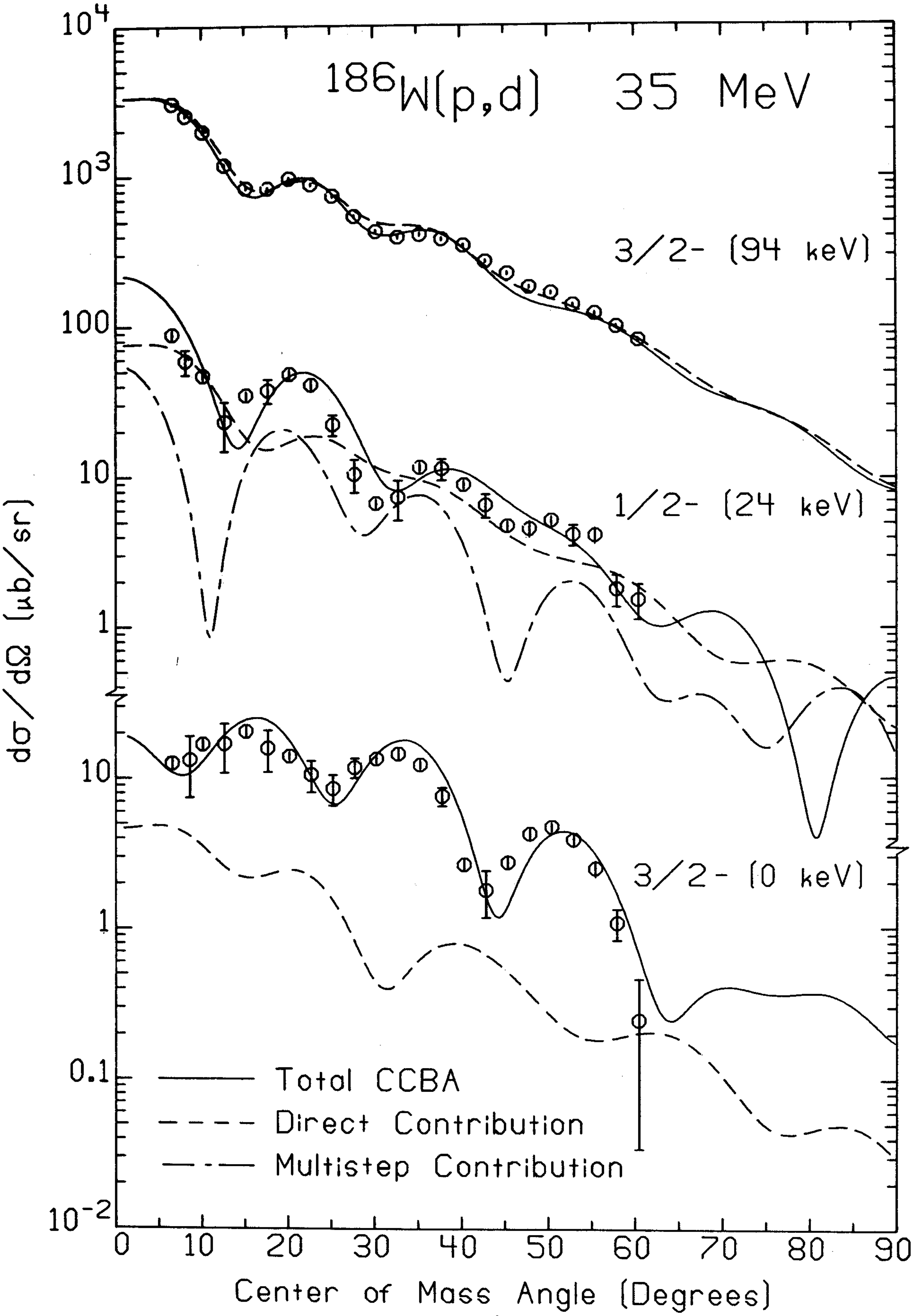

$^{186}W(p,d)$ 35 MeV
3/2- (94 keV)
1/2- (24 keV)
3/2- (0 keV)
Total CCBA
Direct Contribution
Multistep Contribution
$d\sigma/d\Omega$ (μb/sr)
Center of Mass Angle (Degrees)
$10^4$
$10^3$
100
10
1
10
1
0.1
$10^{-2}$
0
10
20
30
40
50
60
70
80
90

# Isospin Violations in (d,d') Reactions

P. A. Smith, G. M. Crawley, and J. A. Nolen

A study of the (d,d') reaction at 25 MeV has been initiated with the hope of shedding light on the mechanism of isospin violation seen in this reaction. Preliminary data have been recorded on $^{10}B$, $^{12}C$, and $^{24}Mg$ targets. The cases of interest are the isospin forbidden $\Delta T=1$ transitions in these nuclei. In the work of Braithwaite, et al.[1] on the $^{12}C(d,d')$ reaction at 28 MeV the 15.11 MeV $1^+(T=1)$ level was populated with a yield of 0.7% of the cross section to the 12.71 MeV $1^+(T=0)$ level at a scattering angle of 55°. The Q-value correction changes this ratio to 1.2%. This implies a charge dependent mixing matrix element of about 250 keV between these levels, assuming the yield is entirely due to wave function mixing of these two $1^+$ states. However, another possible source for this large amount of isospin mixing is in the reaction mechanism. It has been suggested,[2] for example, that the $1^+T=1$ state could possibly be populated via the two step processes $^{12}C(d,n)^{13}N(n,d)$ and $^{12}C(d,p)$ $^{13}C(p,d)^{12}C$. Further studies of (d,d') reactions are necessary to determine the mechanism of the observed isospin violation.

We have measured the ratios of the yields $\sigma(15.11)/\sigma(12.71)$ in the $^{12}C(d,d')$ at 25 MeV at three scattering angles. The Q-value corrected ratios at the angles indicated are: $\theta_{Lab}=10°$, 2.8±0.4%, $\theta_{Lab}=15°$, 3.6±0.4%, and $\theta=25°$, 2.3±0.4%. These ratios are 2-3 times larger than that of reference 1 definitely confirming the existence of a large isospin mixing in this reaction but not localizing the source of the mixing. The Q-value corrections were made via microscopic DWBA calculations, assuming the states to be pure $(p_{3/2},p_{1/2})^{1^+}$ configurations and the deuteron-nucleon force to be $V=V_0\Sigma_d\cdot\sigma_i$ with a 1 fm Yukawa shape.

Preliminary spectra of the $^{10}B(d,d')$ reaction at 25 MeV have been recorded. The isospin forbidden $3^+$ T=0 (G.S.)→$0^+$ T=1 (1.74 MeV) transition was not seen, with an upper limit of 0.5 μb/sr on the cross section at $\theta_{Lab}=45°$. Since there are no known states in $^{10}B$ nearby to induce wave function mixing this transition should be a good measure of isospin mixing in the reaction mechanism. At lower energies such transitions are usually seen via mixing in the compound nucleus[3] but at sufficiently high energies this mechanism should vanish. Any explanation of the $^{12}C$ case via a two step reaction mechanism should also give a consistent explanation of this transition in $^{10}B$.

A brief look at the $^{24}Mg(d,d')$ reaction has also been taken with a resolution of 8 keV FWHM. The purpose is to detect possible isospin violating cross sections to T=1 states in the spectrum at 9.52 MeV and above. There are two $1^+$ levels of isospin 0 and 1 at 9.827 and 9.965 MeV excitation, respectively, which may mix significantly if their configurations are similar. In the preliminary spectra both states seem to be populated weakly. This data should provide further quantitative tests of a two step reaction theory of the type proposed for $^{12}C$.[2]

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# A Study of $^{12}C$, $^{24}Mg$, $^{40}Ca(\alpha,{}^{6}Li)$

R. G. Markham and M.A.M. Shahabuddin

A systematic study of the $(\alpha,{}^{6}Li)$ reaction has been undertaken with the hope of furthering our understanding of transfer reactions involving medium weight ions. Such reactions, e.g. $({}^{6}Li,d)$, $({}^{6}Li,t)$, $({}^{6}Li,{}^{3}He)$, $({}^{7}Li,t)$ etc.--have some of the characteristics of heavy ion reactions such as recoil and finite range effects but still have angular distributions characteristic of the transfered angular momentum. Thus, they pose as the most likely means of obtaining structure information from multinucleon transfer reactions.

In particular the $(\alpha,{}^{6}Li)$ reaction--as also $({}^{6}Li,\alpha)$--should yield direct information about the more studied, but more problematic $({}^{6}Li,d)$ reaction. Analysis of both reactions requires accurate knowledge of the little studied $^{6}Li$ optical potential and of the alpha-deuteron relative motion in $^{6}Li$. But the transfer of two nucleons is by now well understood compared to the great uncertainties associated with four nucleon transfer; thus, we have one less ambiguity to deal with here.

The experiment was performed on targets of $^{12}C$, $^{24}Mg$ and $^{40}Ca$ at an alpha energy of 46 MeV with a typical beam current of 400 namp. The $^{6}Li$ nuclei were detected in a pair of proportional counters mounted in the focal plane of the split-pole spectrometer. The counters were operated in coincidence to reduce backgrounds with the first counter determining the position of the event. Mass identification was performed solely on the basis of energy loss versus position; thus, it was necessary to restrict the solid angle to 2 ms and use thick targets to obtain a reasonable data rate. As a result the energy resolution was typically 150 keV. See Figure 1. Angular distributions were taken in fine steps from 10° C.M. up to 80° C.M. (in the case of $^{24}Mg$, Figure 2). For the $^{24}Mg(\alpha,{}^{6}Li)$ experiment an additional data point was taken at 120° C.M. to look for possible symmetry about 90°. The tentative result of this observation is that the cross sections for the first three states are down by at least a factor of three relative to 60° C.M. Further large angle measurements to confirm that the mechanism is direct are planned; however, the angular distributions are well structured and forward peaked so that compound nuclear contributions at forward angles are most likely small.

The states seen all have T=0 consistent with the isospin selection rule for this reaction. Low lying $J^{\pi}=0^{+}$, T=1 states which we do not see lie at 1.74 MeV in $^{10}B$, 0.656 MeV in $^{22}Na$ and 0.130 MeV in $^{38}K$. For the last two states better energy resolution is needed to more clearly demonstrate their absence.

A DWBA analysis is in progress using the exact finite range code LOLA.[1] As yet good fits to the data have not been obtained, but it is too early to attach any significance to this.

REFERENCES

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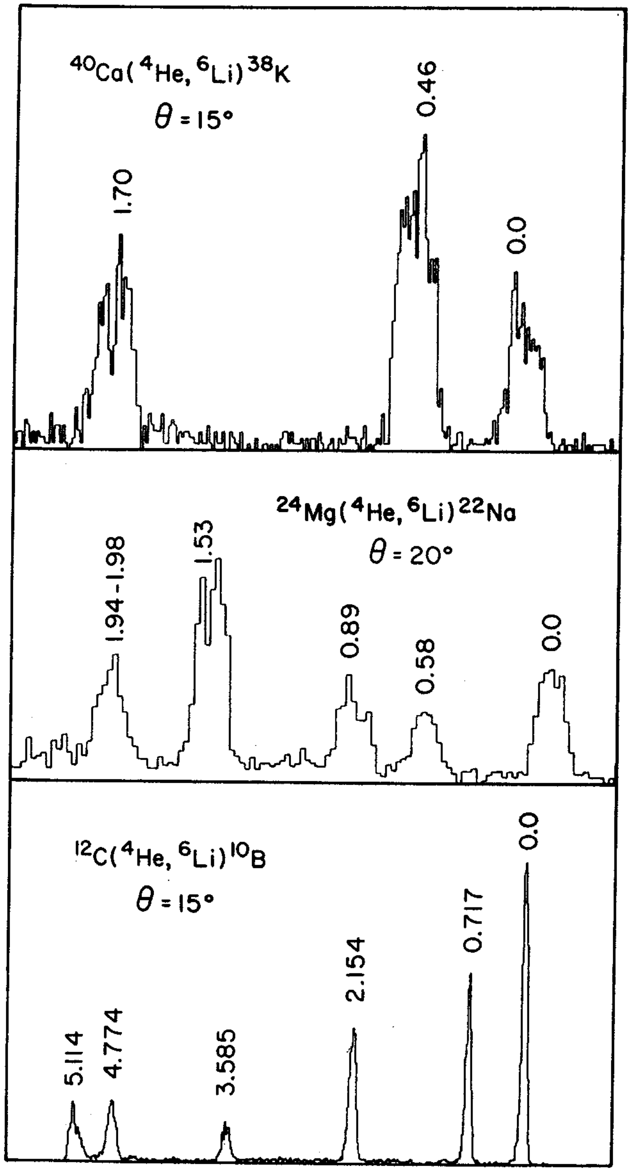


FIGURE 1.--Spectra obtained for the three targets studied. The flat-topped peaks clearly show the effect of target thickness.

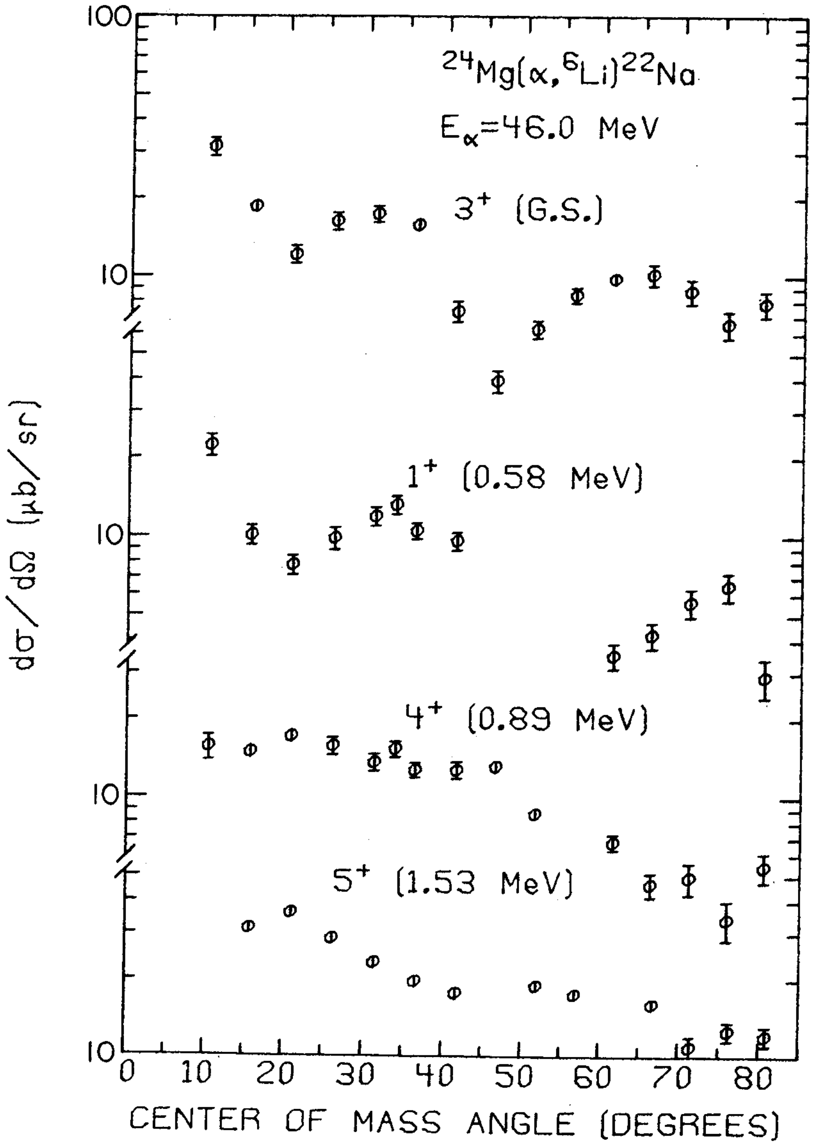


FIGURE 2.--Angular distributions obtained in the $^{24}Mg(\alpha, ^{6}Li)^{22}Na$ experiment.

A High-Spin State in $^{45}Ca$

D. Mueller and E. Kashy

We have investigated the $^{48}Ca(^{3}He,^{6}He)$ reaction to check a prediction by Bayman and Evinay that the ground state of $^{45}Ca$ would be much less strongly excited in this reaction than the first and second excited states.[1] The result of the measurement was that the three states were nearly equally populated, indicating a contradiction to the prediction. In the course of this measurement a $^{6}He$ peak at 1.5 MeV in the spectrum of $^{45}Ca$ was observed and appears to correspond to a state which is only very weakly excited in the excited in the $^{44}Ca(d,p)$ reaction. and not observed in the $^{46}Ca(d,t)$ reaction. This state is a likely candidate for a high-spin $(f_{7/2})^3$ configuration in $^{45}Ca$. We plan to investigate this possibility.

REFERENCES

1. B. Bayman and A. Evinay, University of Minnesota, Private communication.