(α, t) REACTIONS NEAR $Z = 28$†

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Observation of the charged-particle spectrum resulting from the bombardment of vanadium by 43-Mev alpha particles shows that there is an appreciable cross section for the (α, t) reaction at small angles. It therefore seemed of interest to investigate some (α, t) spectra and angular distributions in order to study the reaction mechanism. The equipment and experimental procedure have been described previously.[1] The spectra of tritons from ${}_{25}Mn^{55}(\alpha, t)_{26}Fe^{56}$, ${}_{27}Co^{59}(\alpha, t)_{28}Ni^{60}$, ${}_{29}Cu^{65}(\alpha, t)_{30}Zn^{66}$, $Rh^{103}(\alpha, t)Pd^{104}$, and $Ta^{181}(\alpha, t)W^{182}$ and of deuterons[2] inelastically scattered from Rh and Ta are shown in Fig. 1.

It is strikingly apparent that the $Mn^{55}(\alpha, t)Fe^{56}$ ground-state transition does not proceed with measurable intensity. This is precisely what would be expected if the (α, t) reaction were a stripping process, wherein a proton is captured by the target nucleus, the angular distribution of the tritons acting as an indicator of the angular momentum of the captured proton. The $Mn^{55}(\alpha, t)Fe^{56}$ ground-state transition would then be forced, by conservation of angular momentum, to proceed by capture of an $f_{5/2}$ proton and would, accordingly, be j-forbidden. Similar considerations would lead one to expect a strong $Co^{59}(\alpha, t)Ni^{60}$ ground-state transition in agreement with the experiment. The transition to the

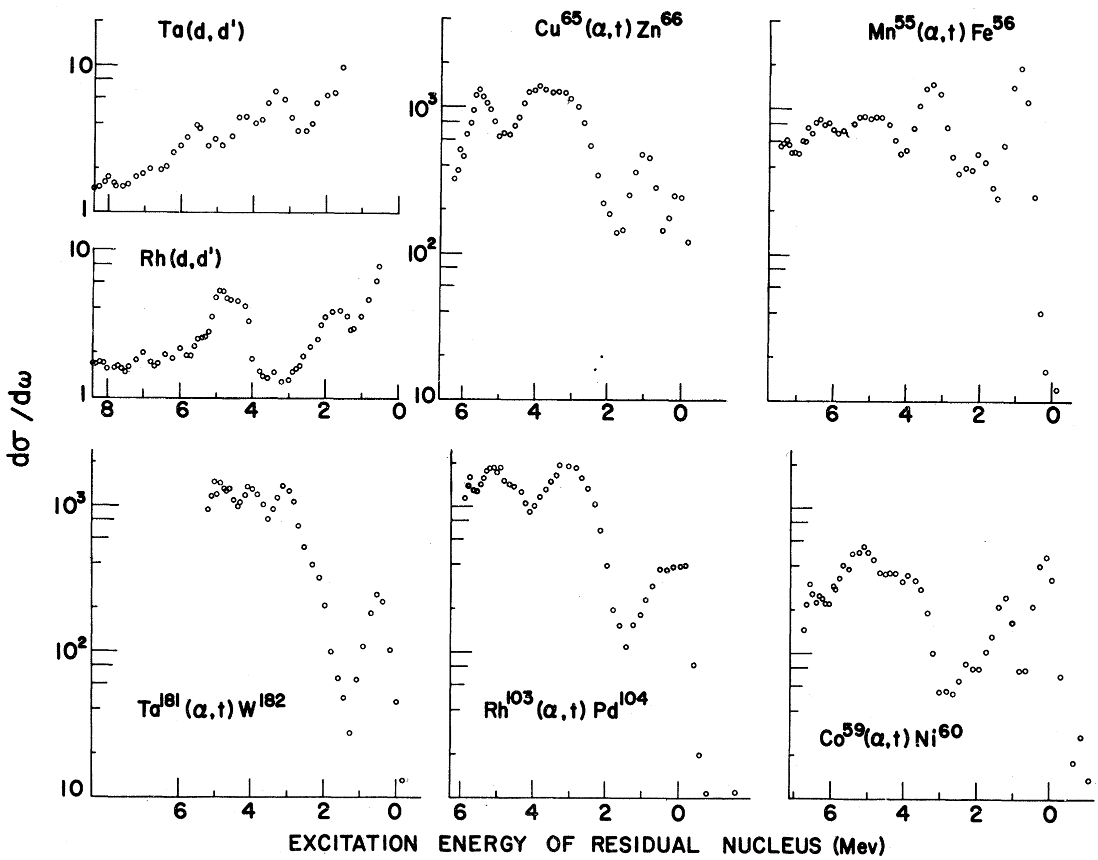

FIG. 1. Triton spectra from the (α, t) reactions on Mn^{55}, Co^{59}, Cu^{63}, Rh^{103}, and Ta^{181}, and deuteron spectra from inelastic scattering on Rh^{103} and Ta^{181} (taken from reference 2). The statistical error on the experimental points varies from 3% to 5% in the case of (α, t) spectra. The triton spectra were obtained at 15° lab, the deuteron spectra at 30° lab. The energies are the excitation energies of the residual nucleus.

2^+ 1-Mev level in Zn^{66} is, however, much stronger than the $Cu^{65}(\alpha, t)Zn^{66}$ ground-state transition.

A sharper test of the "direct" character of the (α, t) reaction mechanism can be obtained by a study of angular distributions of the tritons. In making a detailed study of this matter we cannot proceed from the outset by using the simple Butler[3] theory, since one cannot a priori assume it applicable, at least without serious modifications. One can however proceed empirically by measuring the angular distributions in some cases in which the l value is known with some confidence from shell-model considerations. If this procedure leads to a consistent picture for a number of (α, t) angular distributions the original assumption of a "stripping" type (α, t) process will have been confirmed.

The $V^{51}(\alpha, t)Cr^{52}$, $Fe^{57}(\alpha, t)Co^{58}$, and $Co^{59}(\alpha, t)Ni^{60}$ ground-state reactions (if they proceed by stripping) must involve $l=3$ transitions in contrast to the $l=1$ transition expected in $Cu^{65}(\alpha, t)Zn^{66}$. The angular distributions for Co^{59} and Cu^{65} are shown in Fig. 2, where differential cross sections are given in relative units multiplied by $(k^2+\alpha^2)^2$, where $\vec{k}$ is the momentum-transfer vector and α is a constant determined from the binding energies. Experimentally this is apparently a reasonably satisfactory form factor. The curves $j_1(kR)^2$ and $j_3(kR)^2$ (for $R=7$ fermis) are also shown and are seen to resemble, if not fit, the angular distributions from Cu^{65} and Co^{59}, respectively. The angular distributions of V^{51} and Fe^{57} are quite similar to that of Co^{59}. Since the angular shape of the transition to the first excited (2^+) state of Ni^{60} closely resembles the one to the ground state of Ni^{60} we conclude that it has predominantly $l=3$. Further, since the addition of an $f_{7/2}$ proton can only reach the ground state of Ni^{60}, it must involve the transfer of an $f_{5/2}$ nucleon. The angular distribution of the $Mn^{55}(\alpha, t)Fe^{56}$ reaction to the 840-kev 2^+ level clearly has an $l=3$ shape. The transition to the group observed near 3.5 Mev in Fe^{56} is shown to have a considerable $l=1$ admixture.

It is clear that more (α, t) angular distributions must be measured in order to refine the kind of analysis outlined above. The accumulated evidence so far seems to point strongly to a process of the "stripping" type as the reaction mechanism. Therefore it seemed of interest to analyze a few of the gross-structure groups observed in the Mn^{55}, Fe^{57}, Co^{59}, and Cu^{65} reactions to see whether an analysis of the type used by Schiffer et al.[4] for the gross structure observed in (d, p) reactions would give results consistent with shell-model expectations. The result for the $Mn^{55}(\alpha, t)Fe^{56}$ reaction to the 3.5-Mev group is in excellent agreement with expectations. A preliminary analysis for the other gross structures was also consistent with qualitative shell-model predictions. It seems therefore plausible that the gross structure in (α, t) reactions may be interpreted in terms of single-particle states of the proton.

The gross structure of the triton spectra from Pd^{104} and W^{182} are seen to be very similar[5] to that of the inelastic deuteron spectra from Rh^{103} and Ta^{181}. This suggests that an interpretation in terms of single-particle excitation for the gross structure observed in the spectra of inelastically scattered protons,[6] deuterons, and

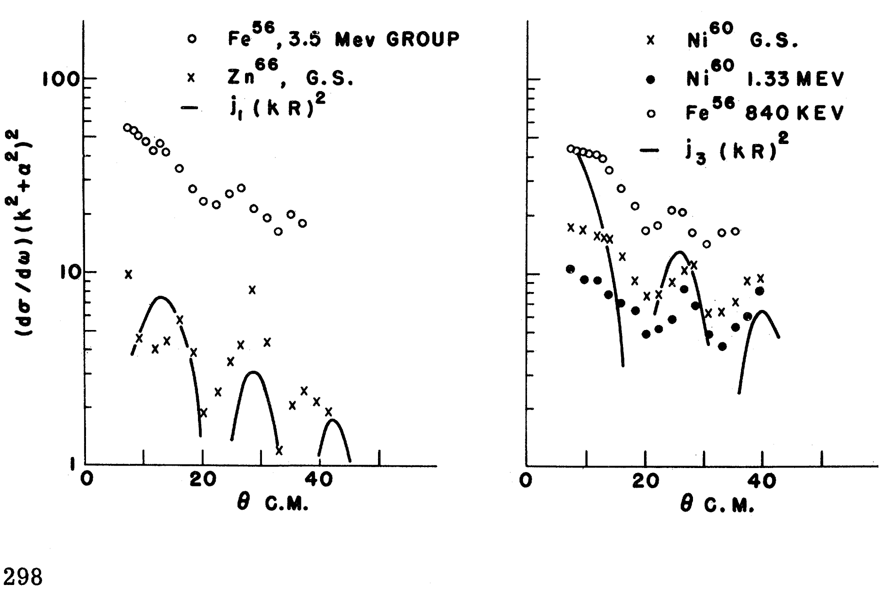

FIG. 2. Angular distributions of $Co^{59}(\alpha, t)Ni^{60}$ ground state, $Co^{59}(\alpha, t)Ni^{60}$ 1.33-Mev level, $Mn^{55}(\alpha, t)Fe^{56}$ 820-kev level, $Mn^{55}(\alpha, t)Fe^{56}$ 3.5-Mev group, and $Cu^{65}(\alpha, t)Zn^{66}$ ground state. The angles are in the center-of-mass system. The relative cross sections have been multiplied by $(k^2+\alpha^2)^2$, where $\vec{k}$ is the momentum-transfer vector and α a constant. The curves $j_1(kR)^2$ and $j_3(kR)^2$ are shown for $R=7$ fermis.

alpha particles[7,8] may be possible.

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POSSIBILITY OF A TEST OF THE CONSERVED VECTOR CURRENT THEORY IN THE $A = 8$ POLYAD*

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The measurement of the β-α angular correlation function in the beta decay of Li^8 and B^8 has been proposed[1] as a test of the conserved vector current theory (C.V.C.T.) of beta decay.[2] In order to interpret recent experimental information,[3] a knowledge of the unknown $M1$ and $E2$ transition probabilities for the transition from the first $J=2$, $T=1$ state in Be^8 to the first excited state ($J=2$, $T=0$) is necessary.[4] It is especially interesting to know how much of the $M1$ transition probability in question is due to the spin part of the magnetic moment operator since only that part gives an enhancement of the corresponding second forbidden matrix element in beta decay, compared to the prediction of the Fermi theory (F.T.).

This Letter reports on an attempt to determine the quantities of interest by an intermediate-coupling calculation.[5] The over-all agreement of Kurath's[6] results with the experimental level scheme in the $A = 8$ polyad, his calculation of the $M1$ widths of the 17.6-Mev state[7] in Be^8, and especially the close agreement of his calculation[8] of the magnetic moment of Li^8 with observation seem to encourage such an attempt.

Using the standard notation as defined in reference 6, we carried through the calculation for force mixtures of the Serber, Kurath, and Rosenfeld types, for values of L/K between 5.3 and 8.3 and of a/K between 0 and 5. We calculated the energy spectrum for $J=2$ states, the magnetic moment of Li^8, the $\log ft$ of the beta decay, the $M1$ and the $E2$ transition amplitudes, and corrections to the magnetic moment and the $M1$ amplitude. These corrections are due to the presence of spin-orbit and exchange forces and have to be introduced in order that the Hamiltonian be gauge-invariant.[9,10] It is hoped that the calculation of these corrections provides an order of magnitude estimate of unknown terms in the magnetic moment operator, such as exchange moments, etc.

The relative position of the low-lying $J=2$ states obtained with the three different types of forces and different values of L/K differ very little from each other over the whole range of a/K if one adopts the scale parameter K properly. The attempt to fit simultaneously the magnetic moment and $\log ft$ fails the Serber forces. This is due to the fact that these forces produce a very strong admixture of $[31]D$ states to the $J=2$, $T=1$ state (which in L-S coupling is $[31]^3P$). These states contribute considerably to the magnetic moment and very little to the beta transition. This result is in agreement with the observation that one cannot reproduce the level scheme of Li^6 using Serber forces. We will therefore not consider Serber forces in the following.

The spread of the other curves obtained for μ,