for the first-excited-state analogs yield

$$\Delta E_C(\text{Mg}^{25}-\text{Na}^{25}) = 4.732 \text{ MeV},$$

$$R_0(\text{Mg}^{25} \text{ analog state}) = 1.372 \text{ F},$$

$$\Delta E_C(\text{Al}^{25}-\text{Mg}^{25}) = 5.165 \text{ MeV},$$

$$\text{and } R_0(\text{Al}^{25} \text{ analog state}) = 1.373 \text{ F};$$

averaging these results then yields $\Delta E_C(\text{Mg}^{25} - \text{Na}^{25}) = 4.737 \pm 0.007$ MeV, $\Delta E_C(\text{Al}^{25}-\text{Mg}^{25}) = 5.160 \pm 0.006$ MeV, and $R_0 = 1.371 \pm 0.002$ F.

Finally, one can predict the mass of the fourth member of this isobaric-spin quartet, namely Si^{25}, from the relation

$$M = a + bT_z + cT_z^2, \qquad (4)$$

where $T_z = -\frac{3}{2}$, whence the mass excess for Si^{25} is 3793 ± 32 keV.

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SELECTIVE ORBITAL ANGULAR MOMENTUM TRANSFER IN (^{3}He, t) REACTIONS*

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Angular distributions previously found to be characteristic of the spin change for (^{3}He, t) transitions in even-mass $f_{7/2}$-shell nuclei are found to characterize transitions for a number of even- and odd-mass nuclei in the s-d shell. It appears that this may be due to certain strong selectivities in the orbital angular momentum transfer.

Recent studies[1-5] of the (^{3}He, t) reaction on even-mass $f_{7/2}$-shell nuclei have shown that there is a striking similarity in the shape of the angular distributions of tritons leading to states of the same J^π and that the transitions proceed primarily via the highest allowed orbital angular momentum transfer[6] L. It is important to determine whether these effects are general features of the reaction, i.e., whether they are present in transitions involving other shell-model orbitals and involving odd-mass as well as even-mass nuclei. Such general characteristics would make the (^{3}He, t) reaction a most valuable spectroscopic tool. The present study indicates that the strong similarities in angular distributions are, indeed, quite characteristic of the (^{3}He, t) reaction over the mass range 19 to 54. On the other hand, the preference for transitions to proceed via the highest allowed L is found to be limited to even-mass nuclei.

The (^{3}He, t) reaction on ^{19}F, ^{27}Al, and ^{26}Mg has been studied at incident energies of 24 and 26 MeV using Stanford University's Model FN tandem Van de Graaff. Emergent tritons were identified in an E-ΔE counter telescope over the angular range 10°-60° in 5° intervals with an energy resolution of 60 keV. Angular distributions were extracted for all well-resolved and statistically significant transitions. A number of typical angular distributions for each nucleus are presented in Fig. 1 as well as a number of angular distributions reported previously[2,3,5] in studies of the (^{3}He, t) reaction on ^{42,48}Ca and ^{54}Fe (also at an incident energy of 26 MeV). All angular distributions presented in Fig. 1 involve transitions to states of known spin and parity.

Transitions to even-J positive-parity states in even-mass nuclei proceed via a unique L while

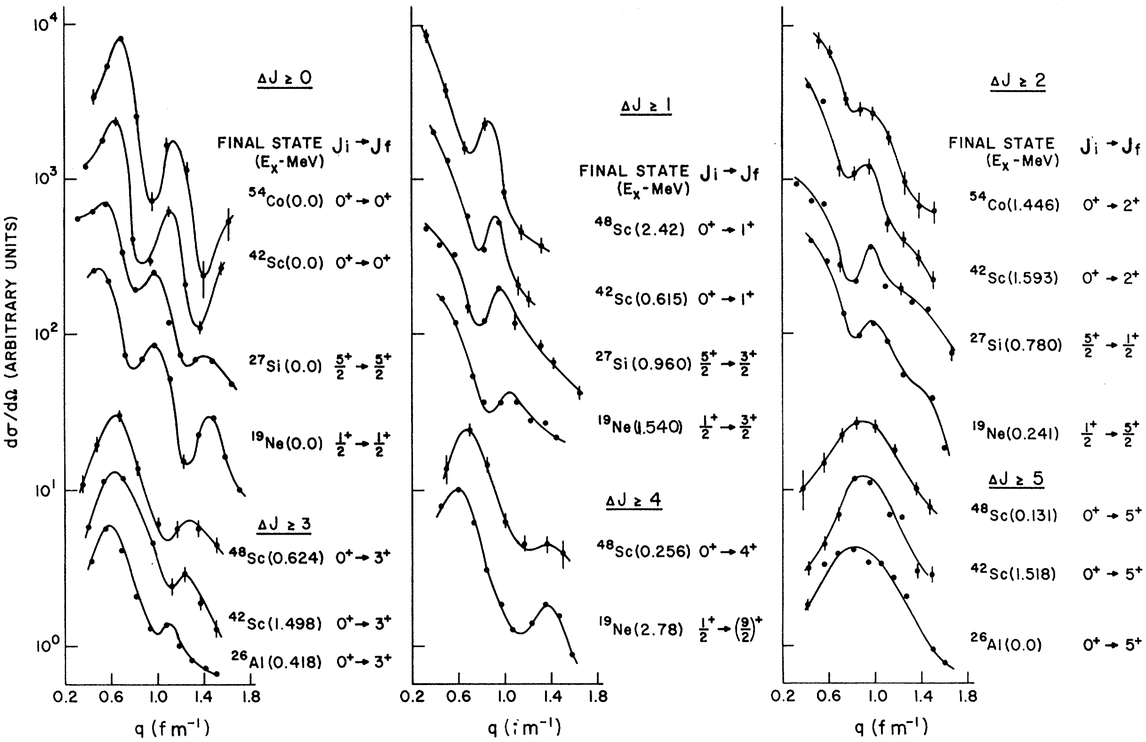

FIG. 1. Typical angular distributions observed in the (^{3}He,t) reaction on several s-d and $f_{7/2}$ shell nuclei. The incident energy is 26 MeV for all transitions other than those to ^{26}Al, where the incident energy is 24 MeV.

those to odd-J positive-parity states or to states of odd-mass nuclei may involve several L values. In the latter cases, the relative contribution of various orbital angular momentum transfers to each transition is expected to depend upon the effective two-body interaction between the pairs of nucleons involved in the charge exchange, as well as the wave functions describing the initial and final nuclear states. In general, then, angular distributions are expected to vary considerably over the nuclidic range of fluorine to cobalt. However, it is clear from Fig. 1 that over this range there are numerous transitions with essentially the same angular distribution. In particular, in even-mass nuclei, angular distributions for transitions to states of the same J^π are nearly identical. Transitions involving states of even J have angular distributions which are quite distinct, while transitions to states of odd J have angular distributions which are similar to those for transitions to states having even spin of $J+1$. It is also apparent that each angular distribution for a transition to the odd-mass nuclei ^{19}Ne and ^{27}Si matches an angular distribution for a transition in the even-mass nuclei. In each case, ΔJ in the even-mass transition equals the lowest allowed ΔJ in the odd-mass transition. For example, the angular distribution for the $\frac{1}{2}^+ \to \frac{5}{2}^+$ transition in ^{19}Ne (the lowest allowed ΔJ is 2) is essentially identical to that for the $0^+ \to 2^+$ transition in ^{42}Sc.

The similarity of angular distributions over such a wide range of nuclei indicates that (^{3}He, t) transitions are, in general, dominated by a single L value. In the case of even-mass nuclei this may be explained by the contribution from the tensor interaction. It has been found that a tensor interaction produces the observed preference for the highest allowed L value in transitions to unnatural parity levels.[7-9] Such transitions necessarily proceed via a spin flip. The relative importance of the tensor interaction has not been determined for the case of odd-mass nuclei, where both spin-flip and spin-nonflip interactions may contribute to a given transition. If the transitions in these nuclei were dominated by the spin-nonflip part of the interaction, a preference for low L values could result from the reduction in cross section with increasing multipolarity of L values. This is found to be the case with the transitions to the odd-mass nuclei studied here. For example, as shown in Fig. 1, the $\frac{1}{2}^+ \to \frac{1}{2}^+$ and

$\frac{5}{2}^+ \to \frac{5}{2}^+$ transitions to ^{19}Ne and ^{27}Si, respectively, have angular distributions which match those of the $0^+ \to 0^+$ transitions. These two transitions therefore proceed primarily via $L=0$ although $L=0$ and 2 are allowed in the former case and $L=0$, 2, 4, and 6 are allowed in the latter. Similarly, the $\frac{1}{2}^+ \to \frac{5}{2}^+$ and $\frac{5}{2}^+ \to \frac{1}{2}^+$ transitions, which may both proceed via $L=2$ or 4, have angular distributions which match those of the $0^+ \to 2^+$ transitions and are therefore primarily $L=2$. A preference for the lowest allowed L value would in certain cases require an accompanying spin flip. The strength of the spin-flip interaction, however, has been found to be significantly smaller than that of the spin-nonflip interaction.[10] The present study indicates that in such cases the transitions do not proceed via the lowest allowed L value but rather via the lowest allowed L value which does not require an accompanying spin flip. For example, the $\frac{1}{2}^+ \to \frac{3}{2}^+$ and $\frac{5}{2}^+ \to \frac{3}{2}^+$ transitions to ^{19}Ne and ^{27}Si, respectively, may both proceed via $L=0$ only with a spin flip. As shown in Fig. 1 these transitions clearly proceed primarily via $L=2$ rather than $L=0$. Light odd-mass nuclei have also been studied with (p,n) reactions and with (^{3}He, t) reactions at higher energies.[10] While in both cases microscopic calculations were somewhat successful in accounting for general features of the data, the studies do not appear to show the systematic characteristics observed in the present investigation.

In the present study all prominent transitions to well-resolved levels of ^{19}Ne, ^{26}Al, and ^{27}Si are found to have angular distributions which have essentially the same shape as those found in earlier work on ^{42,48}Sc and ^{54}Co. These strong similarities in the angular distributions together with the apparent selectivity in orbital angular momentum transfer permit the assignment of spins and parities to numerous levels in ^{19}Ne, ^{26}Al, and ^{27}Si. This information will appear in a detailed report to be published elsewhere.

It therefore appears that the (^{3}He, t) reaction may be an exceptionally valuable tool for the investigation of numerous nuclei – many of which cannot be studied with other well-understood nuclear reactions. It would be most interesting to determine whether the features observed in the present study extend to (^{3}He, t) transitions involving larger changes of spin and heavier nuclei. In this regard it should be noted that a number of the angular distributions observed in a recent study[11] of the (^{3}He, t) reaction on ^{90}Zr are quite similar to those shown in Fig. 1 of the present report with the exception of a noticeable amount of damping – perhaps due to the significantly lower bombarding energy used in the Zr work. It would also be of interest to investigate, over a broad range of nuclei, the angular distributions for (^{3}He, t) transitions involving a change in parity. At present there is little information concerning such transitions.

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