MULTI-NUCLEON AND CLUSTER TRANSFER REACTIONS

STUDY OF THE $^{46,48}Ti(\vec{p},\alpha)^{43,45}Sc$ REACTION

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The $(\vec{p},\alpha)$ reaction, initiated with 79.2 MeV polarized protons, has been studied at IUCF. The intent of this study was to examine the nuclear structure and spectroscopy of ^{43}Sc and ^{45}Sc, as well as the mechanism of the (p,α) reaction.

The polarized protons were produced in the IUCF polarized ion source, which resulted in beams on target of 30 to 300 nA. The targets used were nominally 1 mg/cm^2 thick foils of enriched ^{46}Ti or ^{48}Ti. The reaction α-particles were momentum analyzed with the QDDM magnetic spectrograph, and detected with a helical wire counter followed by two plastic scintillators. The wire counter provided the α position information, and the two scintillators provided the necessary particle identification. The energy resolution achieved with the dispersion-matched proton beam, 1 mg/cm^2 thick targets, and the detector system described above was 80-100 keV, FWHM. The beam polarization, typically about 0.75, was monitored with a He polarimeter located between the two cyclotrons.

States were observed up to an excitation energy above 5.0 MeV in both ^{43}Sc and ^{45}Sc. The selectivity of this reaction was found to be quite remarkable, since the level densities in ^{43}Sc and ^{45}Sc are very large at the higher excitation energies. The states which are preferentially selected are generally the high spin ($J>7/2$) states. Angular distributions, of both differential cross sections and analyzing powers, were measured for such states from 10° to 40°.

The angular distributions for the states of known spin exhibit some notable features. The shapes of the differential cross sections are quite characteristic of the ℓ-transfer. The analyzing powers show a striking j-transfer dependence, with portions of these distributions exhibiting a value close to +1 or -1 for nearly every state. Furthermore, the states of highest spins (up to $J^\pi = 23/2^-$) are the most strongly populated states in the spectrum for scattering angles greater than 20°. A sample of the data, for states in ^{43}Sc, is shown in Fig. 1.

The curves shown in conjunction with the data are, except where noted below, the results of DWBA calculations[1], assuming a triton cluster transfer. (Semi-microscopic form factor calculations are in progress.) These are seen to represent both the cross-section and analyzing-power angular distributions quite well for states of known[2] J^π, thereby lending credence to assignment of J^π values to previously unobserved or unassigned states. Those well-identified states include the $7/2^-$, 0.0 MeV; $5/2^-$, 0.84 MeV; $5/2^+$, 1.64 MeV; $11/2^-$, 1.83 MeV; $15/2^-$, 2.99 MeV; and $19/2^-$, 3.12 MeV states. The assignments made to those unassigned states observed are as indicated in Fig. 1. Also shown are some sample curves which are intended to exhibit some of the special features of this study.

For the level observed at 2.87 MeV, the previous assignment[2] was ($1/2^+$ - $13/2^+$). The present differential cross section required an ℓ-transfer of 2 or 4, and the analyzing power rules out the $7/2^+$

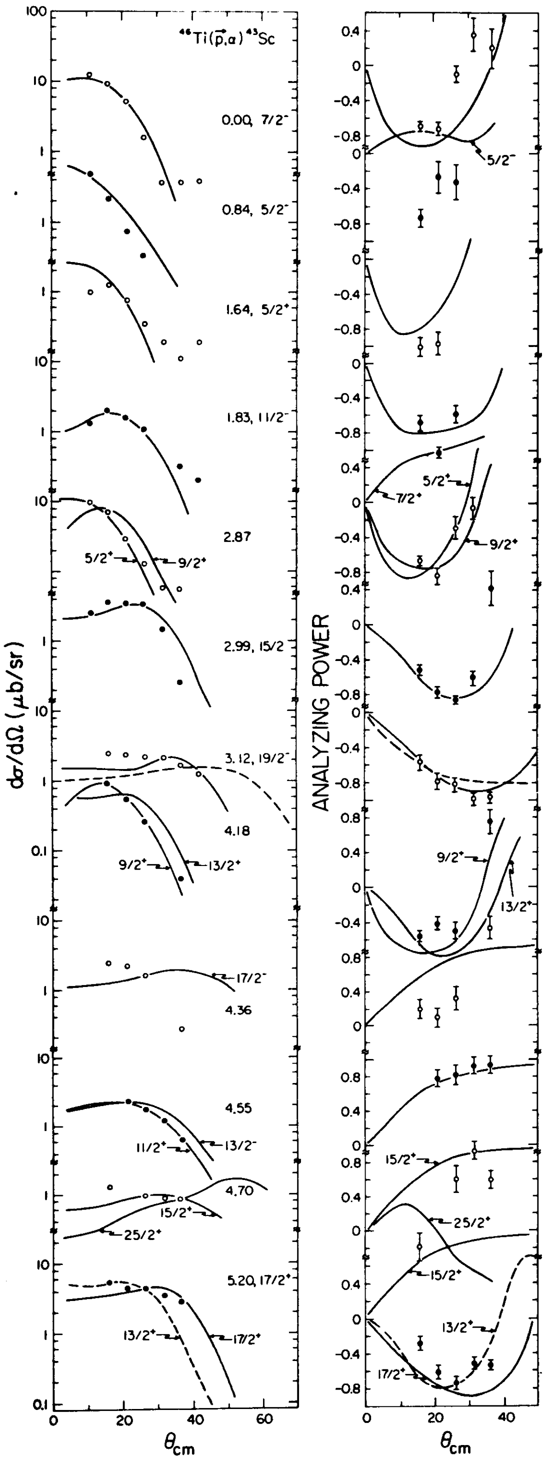

Figure 1. Differential cross sections and analyzing powers for the $^{46}Ti(\vec{p},\alpha)$ reaction. The curves shown in conjunction with the data represent DWBA calculations, except for those cases discussed in the text.

possibly. Thus that state must have a $J^\pi=5/2^+$ or $9/2^+$. A similar argument applies to the 4.18 MeV state, requiring it to have a $J\pi=17/2^+$. A $17/2^-$ state is known[3] to exist at 4.36 MeV. The "state" we see there is probably one or more of the nearby lower spin states identified in the data compilations.[2] The present analysis also identifies the 4.55 MeV state as having $J^\pi = 15/2^+$.

Two other calculations represented in Fig. 1 are worthy of mention. Since it has been suggested[4] that the (p,α) reaction might proceed in some multistep fashion, a calculation was performed for transfer to the $19/2^-$, 3.12 MeV level which assumed (p,t,α) as the reaction process (through the $^{44}Ti(6^+)$ state). The results of this calculation are given by the dashed curves in conjunction with the $19/2^-$ data. That they do a fairly reasonable job of representing the data suggests that further attention should be given to such possibilities.

The curve labelled $25/2^+$ in conjunction with the data for the 4.70 MeV state represents the results of a calculation assuming a high spin state populated by a combination of inelastic excitation and three nucleon transfer. Such a state, the $21/2^-$ or $23/2^-$ state[5] in ^{45}Sc, was strongly populated in the present study, suggesting a similar possibility for ^{43}Sc. The data for the 4.70 MeV state are much better represented by the results of a one-step calculation assuming $J^\pi = 15/2^+$.

Semi-microscopic calculations are in progress, and it is anticipated that this (p,α) work will be completed soon. A preliminary account of this work has been presented[6].

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STUDY OF STRETCHED CONFIGURATION HIGH-SPIN STATES IN THE NICKEL REGION WITH THE(d,α) REACTION

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Previous studies of the (α,d)[1-3] and (d,α)[4,5] reactions have shown that, under suitable kinematic conditions, stretched configuration high-spin states are preferentially excited. This selectivity has been used in the present study of the (d,α) reaction on $^{58,60}Ni$ at 80 MeV bombarding energy to locate high-spin states in the final nuclei $^{56,58}Co$. Of special interest were transitions with L=6 angular distributions which arise from the transfer of the proton-neutron pairs in the $(1f_{7/2})^2_{J=7,T=0}$ or $(1f_{7/2}1f_{5/2})_{J=6,T=0}$ configurations. A typical spectrum, taken with a ^{58}Ni target, is shown in Fig. 1. The dominant peak in the spectrum is the transition to the $J\pi = 7^+$ state in ^{56}Co at 2.28 MeV. This transition provides an experimental shape of an L=6 angular distribution (see Fig. 2) which can be used to identify other L=6 transitions. The transitions to the $J^\pi = 5^+$ states in ^{56}Co at 0.58 and 1.01 MeV exhibit clear L=4 angular distributions (see Fig. 3) which are quite distinquishable from the observed L=6 pattern. Besides the aforementioned transition to the 7^+ state at 2.28 MeV in ^{56}Co, the transitions to states at 2.37, 3.54 and 4.44 MeV also show L=6 angular distributions.

These results have been used to test the predictions of recent multiconfiguration shell-model calculations by Glaudemans et al.[6] based on two different interactions, the surface delta interaction (SDI) and a modified Kuo-Brown interaction (KB). Spectroscopic amplitudes were calculated for the transitions to the theoretical 5^+, 5^+_2, 6^+_1, 7^+_1, and 7^+_2 states in ^{56}Co using only the strongest components in the wave functions of the initial and final states. With these spectroscopic amplitudes distorted-wave Born approximation (DWBA) calculations were performed and

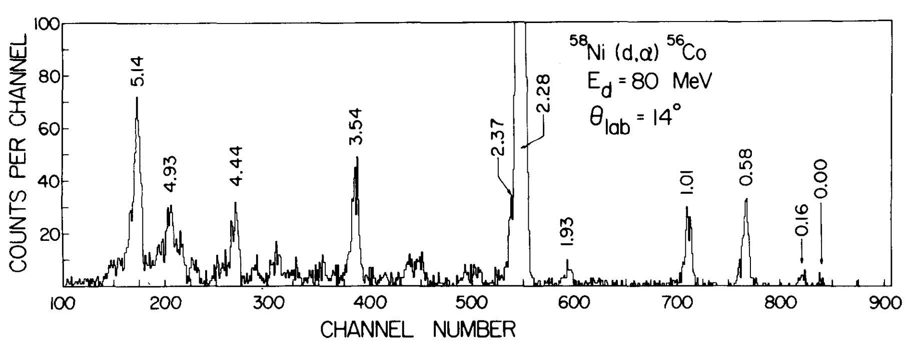

Figure 1. Alpha-particle spectrum for the $^{58}Ni(d,\alpha)^{56}Co$ reaction taken with the QDDM magnetic spectrometer.