COMPARISON OF THE EXCITATION OF "STRETCHED" 6^-, T=1 STATES IN MASS-28 BY THE (p,n) AND (p,p') REACTIONS

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We report measurements of the ^{28}Si(p,n) reaction with unpolarized protons of 135.2 MeV and with polarized protons of 133.5 MeV, and we compare the angular distributions of the differential cross section and the analyzing power of the 6^-, T=1 "stretched" state at E_x = 4.95 MeV in ^{28}p with those published for the analog ^{28}Si(p,p')^{28}Si (6^-, T=1 14.35 MeV) reaction at 134.1 MeV.[1,2]

In the absence of electromagnetic and charge-dependent nuclear interactions, the transition matrix elements M for these analog reactions are related by

$$M(p,n) = \sqrt{2}\,M(p,p') \,. \qquad (1)$$

The proportionality constant $\sqrt{2}$ is the ratio of the isospin Clebsch-Gordan coefficients which couple the final ^{28}P(T=1, T_z=-1)+n and ^{28}Si(T=1, T_z=0)+p channels to the initial ^{28}Si(T=0)+p channel. Under these assumptions, the (p,n) differential cross section and the analyzing power angular distributions should be identical.

The experiments were performed with the beam-swinger system at the Indiana University Cyclotron Facility (IUCF). The first experiment was made with an unpolarized proton beam at 135.2 MeV; and the experimental arrangement was described previously.[3] The energy resolution was 310 keV for laboratory angles less than 45° and 380 keV for larger angles. The second experiment used a 133.5 MeV proton beam with a polarization of about 70 percent; in this experiment, the energy resolution for 115 MeV neutrons was about 410 keV for the detectors in the 0° and 24° stations and about 825 keV for the detector in the 45° station. The neutron detectors in the 0°, 24°, and 45° stations at flight-paths of 71.0, 71.0, and 37.3 m, respectively, each consisted of two mean-timed[4] NE-102 neutron detectors[5] with combined frontal areas of 1.03, 1.55, and 2.32 m^2. Since the beam swinger is capable of deflecting the incident proton beam through an angle up to 24°, we detected scattered neutrons out to 69° in steps of about 6°. Anticoincidence counters vetoed charged particles from the target and cosmic rays. The same 42.1 ± 0.9 mg/cm^2 thick natural silicon target was used for both experiments. Yields were extracted by summing the events between appropriate channels and subtracting a linear background. Despite the difference in resolution, the differential cross sections from the two experiments agreed within statistics, which suggests the dominance of a single contribution.

Plotted as triangles in Fig. 1 are the results of our differential cross section measurements for the ^{28}Si(p,n)^{28}p (6^-, T=1, 4.95 MeV) reaction; plotted as squares are the cross sections measured by Yen et al.[1] for the analog (p,p') reaction. The (p,p') cross sections are multiplied by two to account for the ratio of the isospin Clebsch-Gordan coefficients as indicated in Eq. (1). Within the combined uncertainties of the two experiments, there is no evidence in Fig. 1 for any deviation from charge independence. A similar comparison between the differential cross sections for the excitation of the strongest isovector 4^- state in

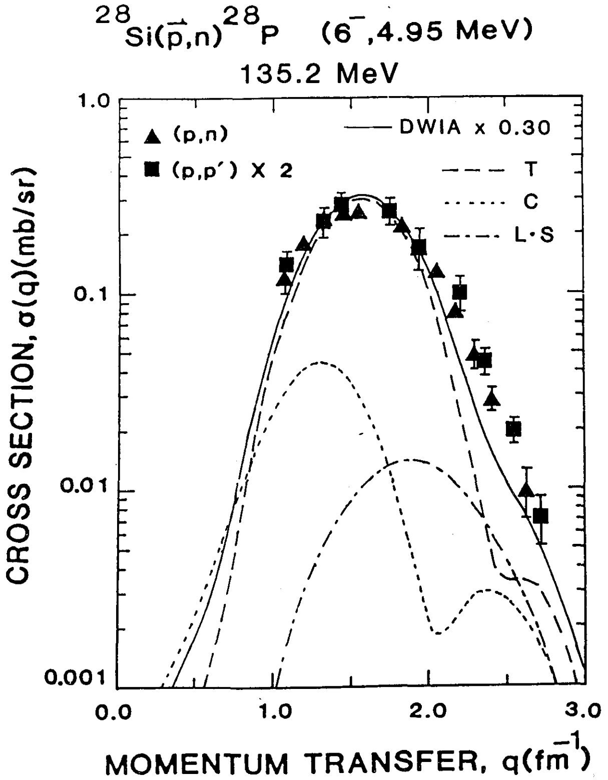

Figure 1. The differential cross section at 135.2 MeV versus the momentum transfer for the transition to the 6^- state in the reaction ^{28}Si(p,n)^{28}p (4.95 MeV). Shown for comparison are the (p,p') data of Yen et al.[1] which are multiplied by two to account for the isospin Clebsch-Gordan coefficients. Shown also are the results of a DWIA calculation for this transition to a single stretched particle-hole ($\pi f_{7/2}$, $\nu d^{-1}{}_{5/2}$) configuration. [This calculation uses the effective interaction of Love and Franey[10] at 140 MeV, the optical potential parameters of Schwandt et al.,[11] and a harmonic-oscillator bound-state wavefunction with a parameter b = 1.733 fm.]

the ^{16}O(p,n)^{16}F and ^{16}O(p,p')^{16}O reactions was also consistent with charge independence.[6,7]

The (p,n) and (p,p') analyzing-power data, spanning momentum transfers between 1.0 and 2.8 fm^{-1}, are compared in Fig. 2. Over most of the angular range, these data sets agree within their uncertainties. Beyond 2.4 fm^{-1} there is an apparent discrepancy between the analyzing powers for these reactions. At q = 2.6 fm^{-1}, the magnitude of this difference appears to be 0.38 with a statistical uncertanty of ± 0.12. It is clear that the uncertainty in this difference is larger than the statistical uncertainty alone. Although it is not known whether there are statistically significant contributions from unresolved states, the density of states is large in this region of excitation energy. While the (p,n) experiment doesn't suffer from the background of isoscalar states, the 825 keV resolution for the (p,n) analyzing-power measurement was significantly worse than the ~70 keV resolution for the (p,p') experiment.[1,2]

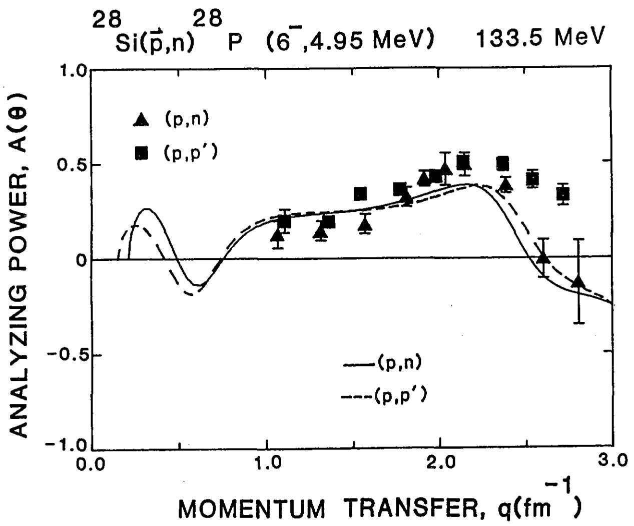

Figure 2. The analyzing power versus the momentum transfer for the ^{28}Si(p,n)^{28}p (6^-, 4.95 MeV) reaction at 133.5 MeV. Shown for comparison are the (p,p') data of Olmer et al.[2] Shown also are the results of DWIA calculations for the (p,n) and (p,p') reactions. The solid curve represents the DWIA calculation for the (p,n) reaction, and the dashed curve is the DWIA calculation for the analog (p,p') reaction.

The curves shown in Figs. 1 and 2 represent distorted-wave-impulse-approximation (DWIA) calculations made with the code DWBA70.[8] We used a bound-state harmonic-oscillator wavefunction for the single stretched ($\pi f_{7/2}$, $\nu d^{-1}{}_{5/2}$) configuration with the oscillator parameter b = 1.733 fm which we determined from electron scattering data.[9] The 140-MeV free nucleon-nucleon interaction of Love and Franey was used.[10] As in Refs. 1 and 6, neglect of the imaginary isovector tensor component improved the description of the analyzing power without producing a significant change in the differential cross section. The distorted waves were generated with the optical potential parameters determined by Schwandt et al.[11] for the scattering of 135 MeV protons from ^{28}Si. The Coulomb distortion in the exit channel for the (p,p') reaction is responsible for the small shift of the (p,p') analyzing-power calculation relative to the (p,n) calculation.

The contribution of the tensor interaction, shown as the dashed line in Fig. 1, dominates the cross section. The spin-orbit contribution, shown as the dash-dot line in Fig. 1, is negligible below about 2 fm^{-1}. The spin-dependent central contribution, shown as the dotted line, is significant only at small momentum transfers. At the peak of the angular distribution, the ratio between the experimental and the calculated cross section is 0.31 determined from electron scattering;[12,13] therefore, the impulse approximation based upon the Love-Franey t-matrix provides a consistent description of the strength and momentum-transfer dependence of the differential cross sections in the momentum transfer range from 1.0 to 2.8 fm^{-1}. Snover et al.[14] find that both of these spectroscopic strengths for direct one-step inelastic scattering are about 30 percent smaller than those inferred from their determination of the $(\pi f_{7/2}, \nu d^{-1}{}_{5/2})$ particle-hole amplitude of the 6^- state, which they excited via proton transfer in the $^{27}Al(p,\gamma)$ reaction. This discrepancy in the spectroscopic strengths may result from neglect of meson exchange currents and/or second-order core polarization, and/or from ambiguities in the impulse approximation descriptions.

In summary, we used the (p,n) reaction at a nominal energy of 135 MeV to measure the differential cross section and the analyzing power in the momentum transfer range between 1.0 and 2.8 fm^{-1} for the excitation of the isovector stretched 6^- state in ^{28}P. In comparison to similar cross sections for the analog (p,p') reaction, these (p,n) cross sections are consistent with charge independence, as were similar (p,n) and (p,p') cross sections for the 4^-, T=1 state in mass-16. With form factors and spectroscopic amplitudes determined from electron scattering, both the cross section and analyzing-power data are described well by the DWIA based upon the free two-nucleon interaction; therefore, the isovector selectivity of the (p,n) reaction provides a useful spectroscopic tool.

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THE ^{39}K(p,n)^{39}Ca REACTION

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The ^{39}K(g.s.) is predominantly $(\pi 1d^{-1})$. The transition to the ^{39}Ca(g.s.) carries essentially all of the $(d^{-1}_{3/2}) \rightarrow (d^{-1}_{3/2})$ strength. The $(\nu d^{-1}_{5/2})$ strength seen in ^{40}Ca(p,d)^{39}Ca and ^{40}Ca(d,t)^{39}Ca reactions is distributed in several states between 5 and 10 MeV of excitation. In the data from our March, 1983 measurements of the ^{39}K(p,n)^{39}Ca reaction at 135 MeV, we observe the excitation of ~20 known states between 4.5 and 10.5 MeV of excitation energy. Ten of these states have $\Delta\ell = 0$ angular distributions (peaked at 0°. The other states have $\Delta\ell \geqslant 1$ angular distributions. Every state identified as $(\nu d^{-1}_{5/2})$ in the 40-MeV ^{40}Ca(p,d)^{39}Ca work of Martin et al.[1] has a $\Delta\ell = 0$ angular distribution in the ^{39}K(p,n) reaction; however, several states identified as $(\nu d^{-1}_{5/2})$ in the 52-MeV ^{40}Ca(d,t)^{39}Ca work of Doll et al.,[2] clearly do not have $\Delta\ell = 0$ angular distributions in the ^{39}K(p,n)^{39}Ca reaction. Thus, the (p,n) reaction provides a valuable cross check on the spectroscopy of ^{39}Ca.

When we add up the strength seen in the (p,n) reaction for the 10 $(\nu d^{-1}_{5/2})$ states we identify between 5 and 10 MeV of excitation and compare this with the Gamow-Teller strength for the (p,n) reaction to the ^{39}Ca(g.s.), we obtain a ratio:

$$\frac{(\nu d^{-1}_{5/2})}{(\nu d^{-1}_{5/2})} \sim 2.71$$

This can be compared with the extreme single-particle value:

$$\frac{|\langle d_{5/2}|||\vec{\sigma}\cdot\vec{\tau}|||d_{3/2}\rangle|^2}{|\langle d_{1/2}|||\vec{\sigma}\cdot\vec{\tau}|||d_{3/2}\rangle|^2} = 4$$

With the effective s-d shell matrix elements of Brown and Wildenthal[3] this ratio is reduced to 3.78.