$R(E_p)$ as determined from the (p,n) reaction on several odd-A and even-A targets. The points for energies larger than 50 MeV are from data obtained in (p,n) experiments at IUCF. The lower energy points are from (p,n) cross sections obtained by other investigators at MSU, ORNL, LLL, Colorado, and Harwell. Our analysis[3] shows that the empirical quantity $R(E_p)$ is well represented by the linear form $R(E_p) = (54.9 \pm 0.9\ \text{MeV})^{-1} E_p$ for energies larger than about 50 MeV.

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THE (p,n) REACTION AT INTERMEDIATE ENERGIES WITH $^{16,17,18}O$ AND ^{9}Be AS PART OF A UNIFIED APPROACH TO THE STUDY OF THESE NUCLEI

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Neutron energy spectra have been determined for 135 MeV protons on targets of $Be^{16}O$, $Be^{17}O$, $Si^{18}O_2$, and ^{9}Be. Cross sections and analyzing powers were obtained for various transitions in each target. Analysis of measurements of analyzing powers is still in progress.

Some energy spectra and an angular distribution for the $^{16}O(p,n)^{16}F$ (4^-, 6.37 MeV) reaction have been presented in previous reports. The analysis of the $^{16}O(p,n)^{16}F$ energy spectra and angular distributions was used to identify several new states in ^{16}F. A paper describing this spectroscopic analysis in detail has been accepted for publication in the Physical Review.[1] Besides the strong excitation of the 4^-, T = 1 "stretched" state at E_x = 6.37 MeV, two strongly excited 2^- states are seen at E_x = 0.40 MeV and 7.6 MeV and two 1^- states at E_x = 9.4 and 11.5 MeV. The cross-section angular distributions to these states are described well by a DWIA calculation using the nucleon-nucleon effective interaction of Love and Franey[2] and simple 1p-1h wave functions obtained by Picklesimer and Walker.[3] Three weakly-excited 1^+ states are observed at E_x = 3.75, 4.65, and 6.23 MeV. These states are analogs of known[4] 1^+ (M1) states in ^{16}O and directly indicate correlations in the ground state of ^{16}O. All of the most strongly-excited states align (to within 200 keV) with known T = 1 analog states in ^{16}O for a common net displacement energy of 12.6 MeV.

The $^{18}O(p,n)^{18}F$ forward-angle spectra are dominated by the strong transition to the 1^+ ground state of ^{18}F, and the wide-angle spectra by the transition to the "$0\hbar\omega$" 5^+ stretched state at E_x = 1.12 MeV. Unfortunately, the 5^+ state is unresolved from the 0^+ isobaric analog state (IAS) at E_x = 1.04 MeV and a 3^+ state at E_x = 0.94 MeV. A careful analysis of this complex is in progress. The 0° spectrum [with $^{28}Si(p,n)$ and $^{16}O(p,n)$ subtractions] is presented in Fig. 1. Besides the very strong transition to the 1^+, T = 0 ground state, transitions to the 0^+, T = 1 IAS at E_x = 1.04 MeV, and four transitions to known[5] 1^+, T = 0

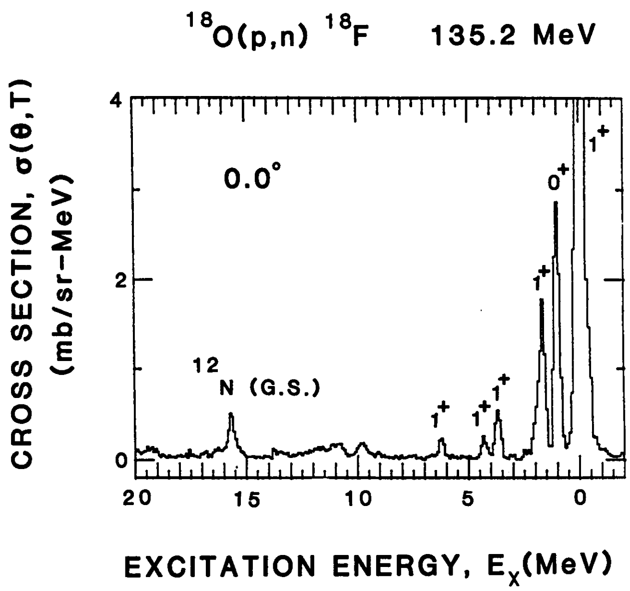

Figure 1. Excitation-energy spectrum for the $^{18}O(p,n)^{18}F$ reaction at 135 MeV and 0°. The 0^+, IAS and known 1^+ states in ^{18}F are labeled.

states at E_X = 1.70, 3.72, 4.36, and 6.26 MeV are seen. Additional strength, peaked at 0°, is seen between E_X = 9 and 12 MeV. The relatively sharp state at E_X = 15.7 MeV is actually the $^{12}C(p,n)^{12}N$ (g.s.) peak from carbon contamination in the target. (A subsequent electron elastic-scattering measurement verified the existence of carbon in the target.) The 1^+ states up through the 6.26 MeV state are known and identified to be T = 0.[5] No 1^+ states above E_X = 7 MeV have been identified previously. The strength seen near E_X = 10 MeV agrees reasonably well with a shell-model prediction of T = 1, 1^+ strength by Wildenthal and Chung.[6] Tentatively, we identify three T = 1, 1^+ states in this region.

Following the method of Goodman et al[7] for their analysis of the $^{42}Ca(p,n)^{42}Sc$ reaction, we estimated the Gamow-Teller strength seen in the $^{18}O(p,n)^{18}F$ reaction. Most of the GT strength is concentrated into the transition to the ^{18}F ground state (as seen in Fig. 1). This concentration of the GT strength into one T = 0 state, which is almost degenerate with the IAS, is suggestive of spin-isospin [SU(4)] symmetry where both belong to the same supermultiplet. The LS-coupling scheme is then more appropriate than the jj-coupling scheme and, as has been noted previously,[7] the T = 1 GT strength would vanish identically if ^{18}O had the 2 excess neutrons coupled to L = 0, S = 0, and T = 1. The ground-state transition GT matrix element can be associated with the GT matrix element for the analog β-decay, $^{18}N(\beta^+)^{18}O$ (g.s.). Using the relationship between measured ft values and GT matrix elements of Wilson et al.,[8] we find from the β-decay (log ft = 3.088) that B(GT) = 3.23 for this transition [in units such that B(GT) for free neutron decay is 3]. From the ratio of the total 1^+ strength observed in the 0° (p,n) spectrum to the observed strength in the ground-state transition alone, we find that the total GT matrix element is approximately 3.94. Thus the total strength observed in the (p,n) reaction is about 66% of the simple sum rule 3(N − Z) = 6. This fraction of the expected sum rule is significantly larger than that observed for medium and heavy nuclei, but is consistent with that reported for ^{14}C by Goodman et al.[9] A more detailed analysis of the 1^+ spectrum in ^{18}F is in progress and will be reported later.

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ANALYZING POWER MEASUREMENTS FOR $(\vec{p},n)$ REACTIONS

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We measured the analyzing power for the $^{16}O(\vec{p},n)^{16}F$ (4^-, 6.37 MeV) reaction at 134.0 MeV and the differential cross section for the same reaction at 135.2 MeV. The shape of the cross section for the transition to this unnatural-parity, stretched state is described well by a distorted-wave-impulse-approximation (DWIA) calculation using a $(\pi d_{5/2}, \nu p_{3/2}^{-1})_{4^-}$ configuration and the effective interaction derived by Love and Franey from nucleon-nucleon phase shifts. The analyzing power from this calculation reproduces all of the qualitative features of the data and supports the use of the impulse approximation as an excellent starting point for describing the reaction mechanism. Figure 1 is a plot of the angular distribution of the analyzing power for the $^{16}O(\vec{p},n)^{16}F$ (4^-, 6.37 MeV) reaction at 134.0 MeV. The points represent our data and the error bars denote statistical uncertainties. The curves represent DWIA calculations with the optical potential of Comfort and Karp[1] and with the 140 MeV nucleon-nucleon t-matrix given by Love[2] (dotted curve), Love and Franey[3] (dashed curve), and Love (Sussex)[2] (solid curve) wherein the tensor force is derived from the Sussex oscillator matrix elements. The agreement with experiment is best for the effective interaction of Love (Sussex), which has no imaginary tensor term.

DWIA calculations of both the analyzing power and the shape of the cross section with a modified Love and Franey interaction that uses the tensor term of Love (Sussex) is essentially the same as that obtained from use of the complete Love (Sussex) interaction; however, the use of the tensor term from Love (Sussex) results in a reduction of the normalization factor for the differential cross section from 0.37 to 0.27. The

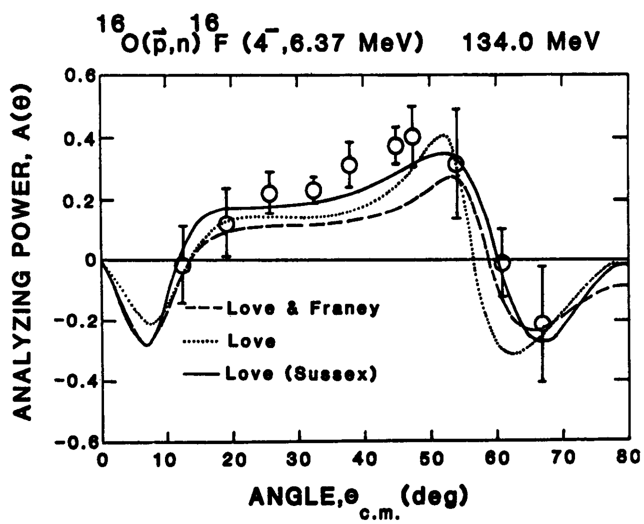

Figure 1. The angular distribution of the analyzing power for the $^{16}O(p,n)^{16}F$ (4^-, 6.37 MeV) reaction at 134.0 MeV. The curves represent DWIA calculations with three different effective interactions as discussed in the text.