EXCITATION OF HIGH-SPIN STATES BY INELASTIC PROTON SCATTERING

G.S. Adams, A.D. Bacher, G.T. Emery, W.P. Jones, R.J. Kouzes*, D.W. Miller, A. Picklesimer, G.E. Walker

The (p,p') reaction has been widely used as a tool for studying nuclear structure. It is desirable to study this reaction at energies greater than about 100 MeV for several reasons: the reaction mechanism may be more easily understood than at lower energies, distortion effects on the incoming and outgoing proton wave functions are more easily handled, and measurements involving large momentum transfer to the target nucleus are facilitated. Until the completion of the Indiana University Cyclotron Facility it was not possible to perform such measurements with sufficient energy resolution to study excitation energies above a few MeV.

One of the more interesting aspects of this type of study is the possibility of exciting high-spin "particle-hole" states at large momentum transfer. States of this type have been identified in ^{28}Si via the (e,e') reaction[1], and angular distributions have been predicted for exciting them in several light, even-even targets by using the (e,e')[2] and (p,n)[3] reactions. Since these states involve 1 $\hbar\omega$ excitations that are aligned to near-maximum total angular momentum, their identification is important both from a spectroscopic point of view,[2,4] and for studying nuclear reaction mechanisms. (The latter is especially interesting because a selective study of specific spin and isospin dependent parts of the interaction between free and bound nucleons can be performed).[5]
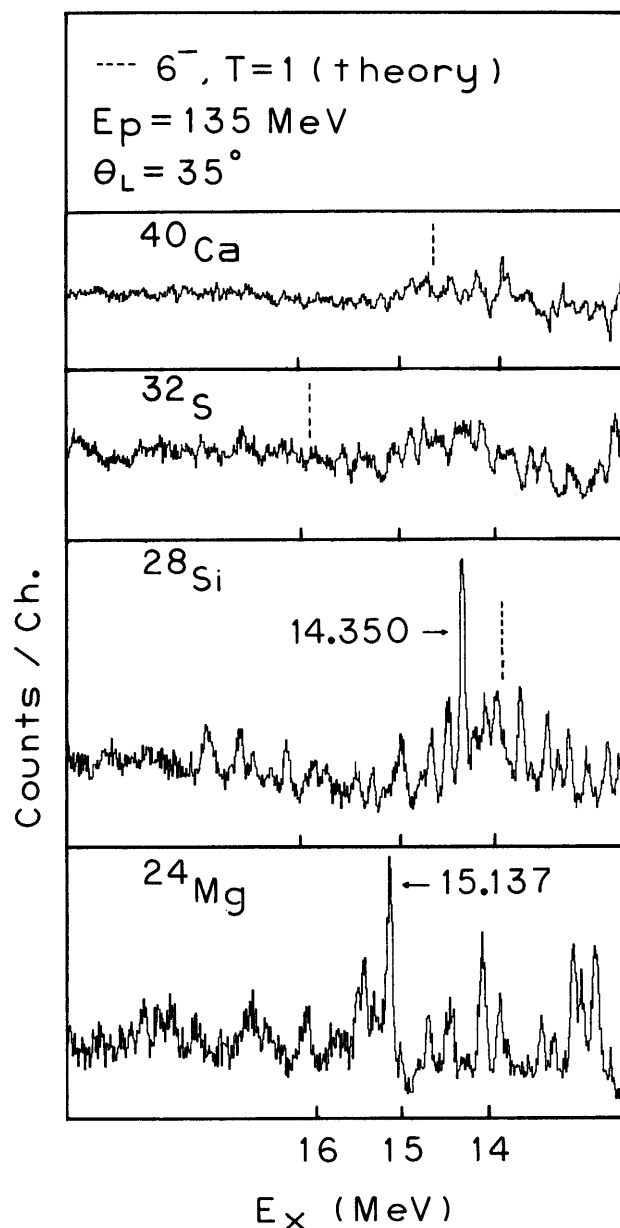

Figure 1. Inelastic proton spectra taken with the QDDM magnetic spectrograph. The positions of the 6^-,1 peaks are indicated by their excitation energies. Theoretical predictions for the energies of these states by Donnelly and Walker (Ref.2) are indicated by a dashed line.
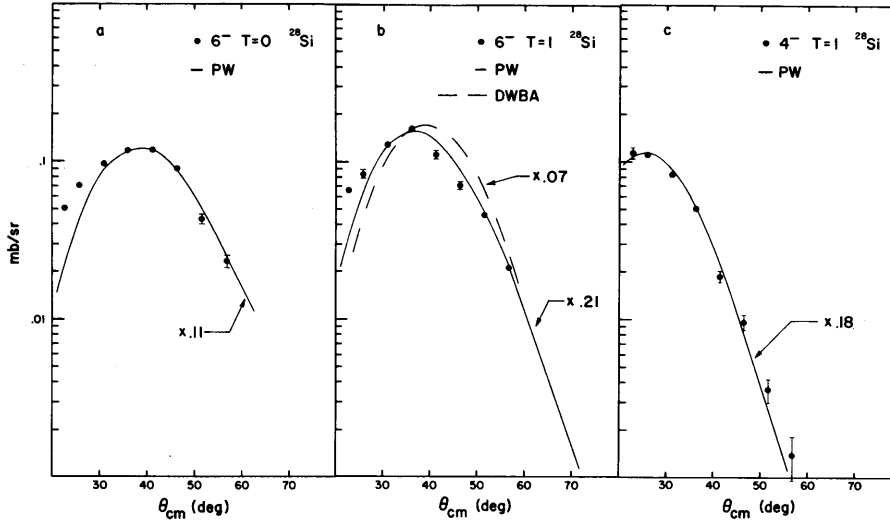
Figure 2. Angular distributions for scattering to high-spin particle-hole states in ^{28}Si.

We have measured angular distributions of differential cross sections for the reactions ^{28}Si, ^{24}Mg, ^{40}Ca, ^{208}Pb (p,p') using 135-MeV protons. We also have obtained data at a few angles for the reactions ^{32}S, ^{26}Mg, ^{90}Zr (p,p') (E_p = 135 MeV) and ^{28}Si(p,p') (E_p = 80 MeV). The maximum excitation energy studied in the lighter targets was about 17 MeV, and in ^{208}Pb about 8 MeV. The energy resolution for most of the data was about 70 keV fwhm. Figure 1 shows proton spectra taken at a laboratory angle of 35° using the QDDM magnetic spectrograph. The most striking feature of these data is the absence of strong peaks in ^{40}Ca and ^{32}S corresponding to excitation of the 6⁻, T=1 state with a configuration $1f_{7/2}$ $(1d_{5/2})^{-1}$. As indicated by the figure, this state is strongly excited in ^{28}Si and ^{24}Mg. Since the predicted excitation energies for this level are well above particle thresholds, the proton spectra may be indicating an increase in the level width as one goes from the lighter to the heavier targets in the sd shell.

States of J^π,T=6⁻,1 (E_x=14.350±0.013 MeV), 4⁻,1 (E_x = 12.656 ±0.005 MeV), and 6⁻,0 (E_x = 11.580 ± 0.006 MeV) have been identified in ^{28}Si and the 6⁻,1 (E_x = 15.137 ± 0.022 MeV) state has been located in ^{24}Mg. These values for the excitation energies are in good agreement with published values for levels in ^{28}Si,[6,7] and with recent inelastic electron scattering results from BATES laboratory[8] which yield a value of about 15.1 MeV for the 6⁻,1 state in ^{24}Mg. These states are believed to have configurations[2] that are predominantly of a $1f_{7/2}$ $(1d_{5/2})^{-1}$ character. Differential cross sections for exciting these states in ^{28}Si are shown in Figure 2. The DWBA calculation shown was similar to those performed by Moffa and Walker[3] in that use was made of an effective interaction that was fitted to low energy (p,p') and (p,n) data. The other curves are PWIA calculations
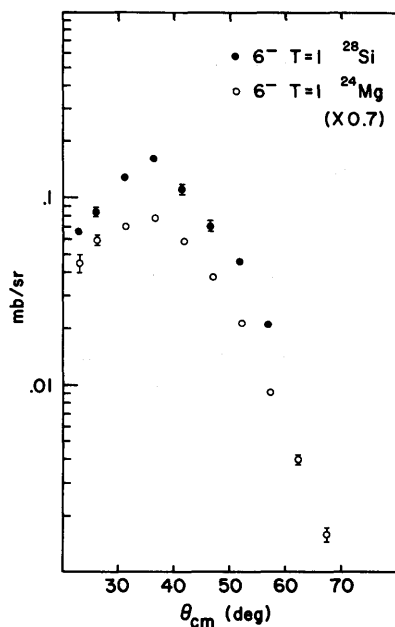
Figure 3. Comparison of angular distributions for excitation of the 6^-, 1 states in ^{28}Si and ^{24}Mg. The peak cross section in both cases occurs at 315 MeV/c momentum transfer. The experimental points for Mg have been multiplied by 0.7 for display purposes.

that were performed so that a new nucleon-nucleon pseudo-potential[9] could be used instead of an effective interaction. The normalization factors needed for the T=1, PWIA angular distributions are well understood, and expected to be about 0.25 (including absorption effects and possible ground state renormalization)[10]. Exchange effects have been included in the T=0 calculation.

A comparison between the differential cross sections for scattering to the 6^-,1 state in ^{28}Si and the similar state in ^{24}Mg is shown in Figure 3. Based upon the similarity of these angular distributions, and the location of the state seen in (e,e') at BATES, we have assigned the quantum numbers 6^-,1 to the Mg state.

Of immediate interest in the future is the extension of the data analysis to DWBA calculations. We expect to continue our survey of s-d shell nuclei, including T≠0 targets. ^{27}Al offers the prospect of having a multiplet of states, formed by coupling a single particle (or hole) to the particle-hole states, which may be strongly excited by inelastic proton scattering. Recently acquired ^{208}Pb spectra are now being analyzed in hopes of identifying the $j_{15/2}$ $(i_{13/2})^{-1}$ level with $J^{\pi} = 14^-$.

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