THE $^{13}C(p,d)$ REACTION AT 120 MeV

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Differential cross section and analyzing power measurements for the $^{13}C(p,d)$ reaction at 120 MeV bombarding energy have been obtained for the final states in ^{12}C at 12.71, 14.08, 15.11, 16.11, 16.58, 17.76, 18.13, 18.80, 19.9, 20.3, and 20.6 MeV.[1] The current experiment used the QDDM spectrometer and polarized proton beam and these data complement those from a similar experiment done previously at the IUCF in conjunction with a $^{13}C(p,p')$ run.[2] In that experiment, states up to 16 MeV were analyzed, but the resolution was typically 200-300 keV. Data were collected for laboratory angles between 4° and 50°.

An overall resolution of 40-80 keV was obtained. Good agreement exists between the differential cross sections and analyzing powers for the deuteron groups populating the 15.11 and 16.11 MeV states of ^{12}C, which were measured in both experiments.

The main objective has been to obtain information on those states in ^{12}C above 16 MeV that were indicated in the earlier run, and on the nature of the ^{13}C ground state, in particular its relationship to the configuration ^{12}C ground state plus one neutron.

The intermediate coupling calculations of Cohen and Kurath[3] predict that most of the $1p_{1/2}$ and $1p_{3/2}$ single particle transfer strength should lie in the ground, 4.44-, 12.71-, 15.11- and 16.11-MeV states. The current results are consistent with this, as are those at lower energies [7,9]. Since those calculations were done within a 1p-shell basis, only even parity states with $J_f \leq 2$ are predicted to be populated. The presence of the odd parity states at 9.64 MeV (3^-) and 16.58 MeV (2^-), and the possible presence of the 13.35 MeV (2^-) state thus indicate the importance of higher shell contributions to the ^{13}C ground state. Shell model calculations by Jager and Kirchbach, and Gillet and Vinh Mau[4] indicate the importance of the $(1p^{-1},1d)$ configurations for the 9.64- and 16.58-MeV states and analysis of the $^{12}C(p,p')$ experiment by Comfort et al.[5] shows that the $(1p_{3/2}{}^{-1}, 1d_{5/2})$ and $(1p_{3/2}{}^{-1}, 2s_{1/2})$ configurations are both necessary for the reproduction of the differential cross section of the proton group populating the 16.58-MeV state.

Figure 1 shows that considerable structure exists above 16 MeV. In recent years much interest has been

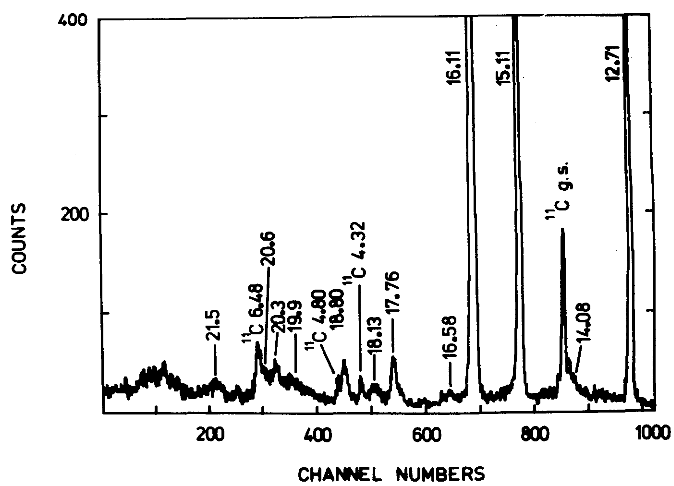

Figure 1. Composite spin-up spectrum (3 spectrograph bites) taken at a laboratory angle of 30°. The numbers give excitation energies of the final states in MeV.

shown in intermediate energy (p,d) reactions since many more high excitation states are significantly populated than at lower (T_p < 100 MeV) energies, thus providing new spectroscopic data. Standard DWBA analyses indicate, however, that the reaction mechanism is not simple, and that multi-step mechanisms may be important. There are indications in the present experiment of their importance in the transitions to the 14.08-, 18.8-, and 20.6-MeV states. The shapes of these cross sections show major differences from the others. Further, both the 14.08- and 20.6-MeV states are dominant at 800 MeV,[6] but are only weakly present (20.6 MeV)[7] or absent (14.08 MeV)[8] at energies of around 60 MeV. This is particularly significant for the 14.08 MeV state, since it has a spin-parity of 4^+, which would require the pick-up of a $1f_{7/2}$ neutron if a single step mechanism were appropriate. The absence of this state at the lower energy, together with the suggested importance of multi-step mechanisms shows that little $f_{7/2}$ amplitude exists in the ^{13}C ground state wave function.

The cluster of states at about 20 MeV has been resolved into the 19.9-, 20.27-, and 20.6-MeV states of Ref. 1. None of these is well known; however, a tentative value of 3^- has been assigned to the 20.6-MeV state, which is consistent with its weak presence in this reaction at 62 MeV. This same value has recently been deduced from $^{11}B(p,p')$ scattering data by Borchers et al.,[10] who also give a 1^+ spin-parity assignment to the 20.3 MeV state. It is well known that analyzing powers should be sensitive to the j-transfer value and this is clearly seen in the j_t = 1/2 and 3/2 transfers. An isospin dependence is also evident for transitions of the same j-transfer with the analyzing powers of deuterons to T=1 states being somewhat weaker (especially for j_t = 1/2) than those for T=0 states.

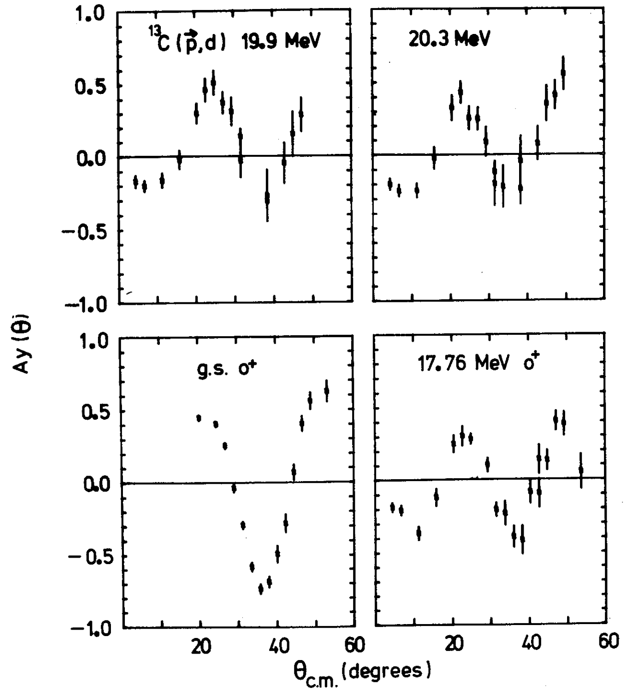

Figure 2. Analyzing powers measured for 19.9- and 20.3-MeV states, and also the ground state (0^+;T=0) and 17.76 (0^+;T=1) MeV states of ^{12}C.

Comparisons between the 19.9-MeV and 20.3-MeV states and the 17.76-MeV state (0^+;T=1) and ground state (0^+;T=0) analyzing powers suggest that an assignment (j^π;T) = (0^+;1) should be made for both the 19.9 and 20.3-MeV states. Further analysis is proceeding.

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$^{17}O(\vec{p},t)^{15}O$ at E_p = 90 MeV AS A TEST FOR SEQUENTIAL PICKUP ASPECTS

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Zero or finite range one-step DWBA calculations for two-nucleon transfer processes can account for angular distributions and their L dependence as well as for effects due to selection rules. However, one does not reproduce absolute cross sections or the observed J dependence of analyzing powers for a given L using even very sophisticated one-step approaches. Recent analyzing power measurements ($^{207}Pb(\vec{t},p)$, $^{48}Ca(\vec{t},p)$ [Ref. 1], and $^{90}Zr(\vec{p},t)$ [Ref. 2] could be understood qualitatively by including important sequential transfer channels explicitly. To study the effects of sequential two-nucleon transfer mechanisms at medium energy in a simple nucleus, we chose ^{17}O as a target for our (p,t) experiment as the nuclear wave functions near the p-shell closure are considered to be well understood. The measurements were made with the IUCF QDDM Spectrometer using SiO_2 targets enriched to 55% ^{17}O, 25% ^{18}O, and 20% ^{16}O. In order to distinguish final states of ^{15}O from those of ^{16}O we also took data with an almost pure ^{18}O target (SiO_2 enriched to 95% ^{18}O). The beam energy (E_p=90 MeV) was chosen to match the capabilities of the magnetic spectrometer. The average beam polarization was about 75% for both spin directions.

The triton spectrum for the two momentum bites of the spectrograph taken at Θ_{lab} = 10° is shown in Fig. 1.

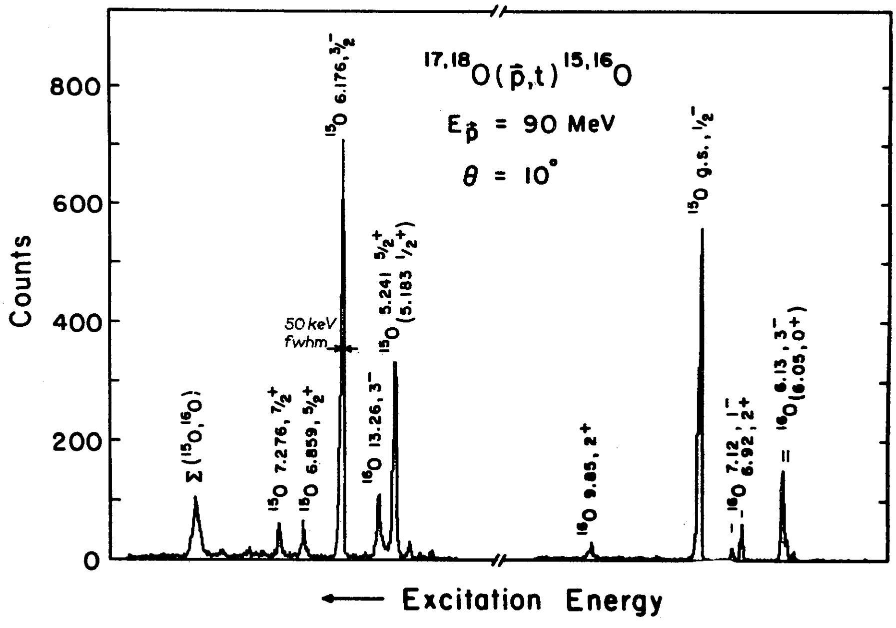

Figure 1. Triton spectrum from $^{17,18}O(\vec{p},t)^{15,16}O$ for the two spectrograph settings at Θ_{Lab}=10°.