Differential Cross Sections for the $C^{13}(He^3,p)N^{15}$ Reaction

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The differential cross sections for the $C^{13}(He^3,p)N^{15}$ reaction leaving N^{15} in the ground state have been measured at 17 angles for bombarding energies of 2.0 and 4.5 Mev and at 6 angles in 0.2-Mev intervals from 1.8 to 3.8 Mev. The angular distributions are generally peaked in the forward and backward directions and change relatively slowly with bombarding energy. The angular distributions at 2.0 and 4.5 Mev have been fitted with Legendre polynomial expansions by using the method of least squares. The data indicate a weak resonance at a bombarding energy of about 3.6 Mev.

DIFFERENTIAL cross sections of He^3-induced reactions have been investigated for several light nuclei as a function of bombarding energy. In some cases, the angular distributions are quite complex and energy-dependent. At present, there is no simple theoretical model of the interaction which can provide a satisfactory interpretation of the experimental results. On the other hand, theoretical progress is hampered by the lack of sufficient experimental information. The present paper is a contribution to the latter, being a report of an investigation of the ground-state proton group produced by He^3 bombardment of C^{13}. The experiments were performed using the U. S. Naval Research Laboratory 2-Mv and 5-Mv Van de Graaff accelerators.

The differential cross sections were studied at 17 angles extending from 10 to 150 degrees in the center-of-mass system for bombarding energies of 2.0 and 4.5 Mev. Ilford C-2 200-micron nuclear emulsions were used as detectors and the absorbers were chosen so that the ground-state protons stopped in the emulsion. While the ground state of the residual nucleus, N^{15}, is well separated from other states, the first and second excited states are not sufficiently separated to permit the resolution of the associated proton groups with nuclear emulsions. The absorbers in most cases stopped the protons from all higher states as well as the scattered He^3 particles. The target chamber was the same as the one used by Holmgren *et al.*[1] The targets and method of measuring the absolute cross section have been described by Holmgren.[2]

Table I. Least-squares Legendre polynomial expansions of the differential cross section for the $C^{13}(He^3,p)N^{15}$ reaction. σ_0 is the total cross section for the reaction leaving N^{15} in the ground state. $\sigma(\theta)=(\sigma_0/4\pi)[P_0+a_1P_1(\cos\theta)+a_2P_2(\cos\theta)+\cdots]$.

E_{He^3} Mev	σ_0 mb	a_1	a_2	a_3	a_4	a_5	a_6
2.00	2.1	+0.03	+0.74	−0.005	+0.30	+0.02	+0.07
4.5	14	+0.45	+0.97	+0.06	+0.51	+0.09	+0.45

Figure 1 shows the observed differential cross secsections at 2.0 and 4.5 Mev. The uncertainties indicated on the experimental points are due to the statistical fluctuations, the uncertainty in the determination of the camera solid angles, and an estimated counting uncertainty of 1%. The uncertainties in the absolute differential cross sections arise almost entirely from the measurement of the target thickness and are estimated to be about 20%. The distributions show pronounced forward and backward peaking, and are nearly symmetrical about 90 degrees. In order to fit the data within the experimental uncertainties with Legendre polynomial expansions, it is necessary to include polynomials of the sixth degree. These solutions are indicated on the graph by solid lines.[3] Table I presents coefficients computed for the Legendre polynomials and the total cross sections, σ_0. On the basis of compound nucleus formation, the Legendre polynomial expansions imply that contrutions due to angular momentum including $l=3$ are important.

In order to determine the manner in which the angular distributions vary with bombarding energy, the yield was measured at six angles and the energy was raised in 0.2-Mev steps from 1.8 to 3.8 Mev. The target chamber had apertures at 0, 30, 90, 120, and 150 degrees, and thin CsI scintillation counters were mounted at these positions. Each aperture subtended a solid angle of 0.013 steradian at the target. This study showed that the angular distribution changes relatively slowly throughout the energy range investigated. The yields at all angles indicate a possible weak resonance at about 3.6 Mev. The data are presented in Fig. 2. Where comparison can be made, the differential cross sections reported here are in agreement with the results of Schiffer *et al.*[4]

The validity of the concept of a compound state at an excitation energy of 25 Mev is questionable; however, if this concept is meaningful, the character of the angular distributions at 2.0 and 4.5 Mev is consistent with compound-nucleus formation, the lack of symmetry about 90° being explained by an interference

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[1] Holmgren, Bullock, and Kunz, Phys. Rev. **104**, 1446 (1956).
[2] H. D. Holmgren, Phys. Rev. **106**, 100 (1957).
[3] The least-squares solutions were performed on the SEAC computer at the National Bureau of Standards.
[4] Schiffer, Bonner, Davis, and Prosser, Phys. Rev. **104**, 1064 (1956).

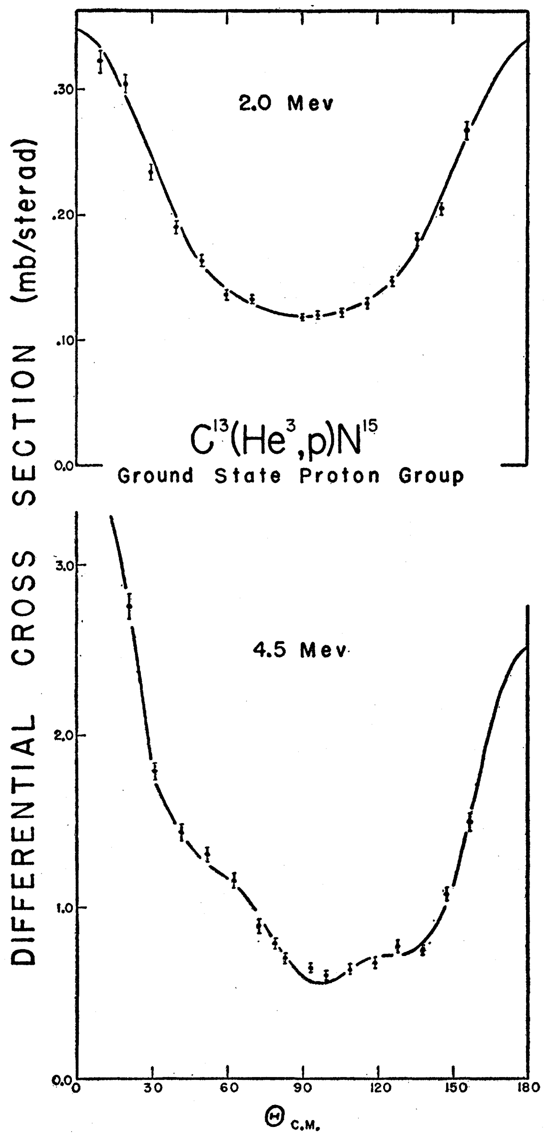

FIG. 1. The center-of-mass differential cross sections as functions of the center-of-mass angle for the $C^{13}(He^3,p)N^{15}$ reaction leaving N^{15} in the ground state at bombarding energies of 2.0 and 4.5 Mev. The solid lines are Legendre polynomial expansions fitted to the data by the method of least squares.

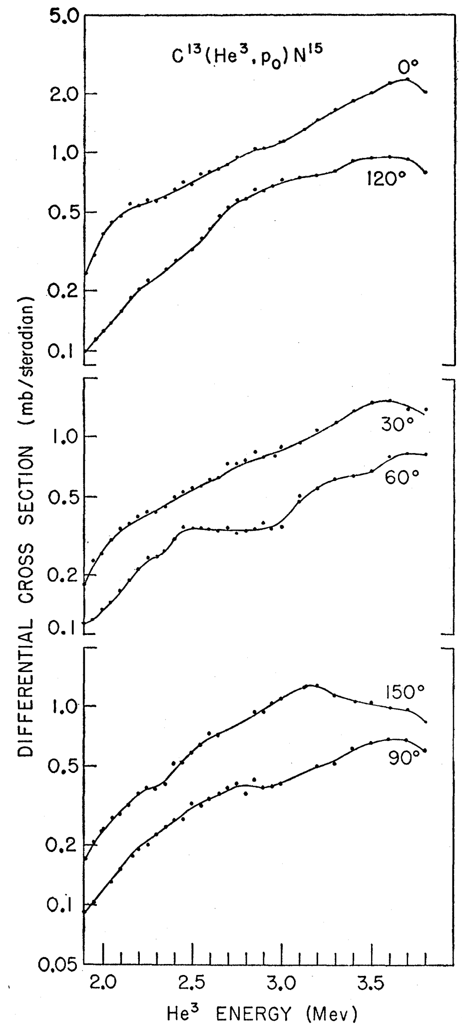

FIG. 2. The laboratory differential cross sections for the $C^{13}(He^3,p)N^{15}$ reaction leaving N^{15} in the ground state at laboratory angles of 0, 30, 60, 90, 120, and 150 degrees as a function of the bombarding energy.

between states of opposite parity.[4] On the other hand, the strong forward and backward peaking (recent calculations by Owen and Madansky[5] indicate that exchange interaction effects in He^3 reactions may give rise to complex angular distributions, as well as forward and backward peaking) together with the slow change in the angular distribution with bombarding energy suggest a direct-interaction mechanism. This possibility is further strengthened by the observations that the forward peaking becomes stronger with increasing bombarding energy and that the resonances are small variations superposed on a large smoothly varying yield.

[5] G. Owen (private communication).