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ANGULAR DISTRIBUTION OF PROTONS FROM THE $C^{12}(dp)C^{13}$ *REACTION WITH 5 — 13 Mev DEUTERONS*

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Angular distributions of protons corresponding to the ground state of C^{13} have been measured for five deuteron energies in the interval 5 — 13 Mev, and for protons corresponding to the three lowest excited states for deuteron energies of 13.3 and 12.1 Mev. The parities and possible spin values of these states were determined. It is shown that, with decreasing energy, reactions other than stripping become more important.

THE deviation of experimental angular distributions of protons and neutrons from (dp) and (dn) reactions from those predicted by the simple stripping theory[1] are known to indicate the occurrence in the reaction of other mechanisms[2,4] and of interaction of the incident deuteron and the outgoing particle with the nucleus.[5] The magnitude of this interaction and the relative importance of the various mechanisms depend both on the properties of the nucleus and on the energy of the bombarding deuterons. It was therefore of interest to make corresponding measurements over a wide range of deuteron energies.

We have measured angular distributions of protons corresponding to the ground state of C^{13}, for deuteron energies of 13.3 ± 0.2, 12.1 ± 0.2, 9.55 ± 0.2, 7.15 ± 0.2, and 4.65 ± 0.2 Mev (Fig. 1), and of the protons corresponding to the three lowest excited states of C^{13} for deuteron energies of 13.3 ± 0.2 and 12.1 ± 0.2 Mev (Figs. 2, 3).

For the measurements we used the external beam of deuterons from the cyclotron of the Institute of Physics of the Academy of Sciences of the Ukrainian S.S.R., with a deuteron energy of 13.6 Mev. The proton detector and the experimental geometry were the same as described in reference 6; to reduce the load on the amplifier, an absorber was placed at the entrance to the chamber to cut off the deuterons. Unfortunately the experimental geometry limited the maximum angle at which measurements could be made to values ~ 140°

The deuteron energy was changed by using a set of aluminum foils placed at the entrance to the reaction chamber; the beam of deuterons was collimated further beyond the absorbers. The reduction in energy of the deuterons was accompanied by a considerable decrease in beam intensity and by the appearance of a noticeable spread in angle and energy, which made measurements at large angles for low energies unsatisfactory. The results of these measurements are not given here.

A comparison of the experimental angular distributions with theory enables one to assign values of spins to the ground state and the three lowest excited states of C^{13} with values of $1/2^- - 3/2^-$, $1/2^+$, $1/2^- - 3/2^-$ and $3/2^+ - 5/2^+$, respectively.

The angular distribution of protons corresponding to the excited states of C^{13} is in good agreement with the predition of the Butler theory[1] for $r_0 = 4.6$f. At the same time, there are various peculiar features in the proton distribution corresponding to the ground state of C^{13} which we feel should be pointed out.

First of all, the distributions obtained for deuteron energies of 4.65 and 7.15 Mev differ from the distributions for energies of 9.55, 12.1 and 13.3

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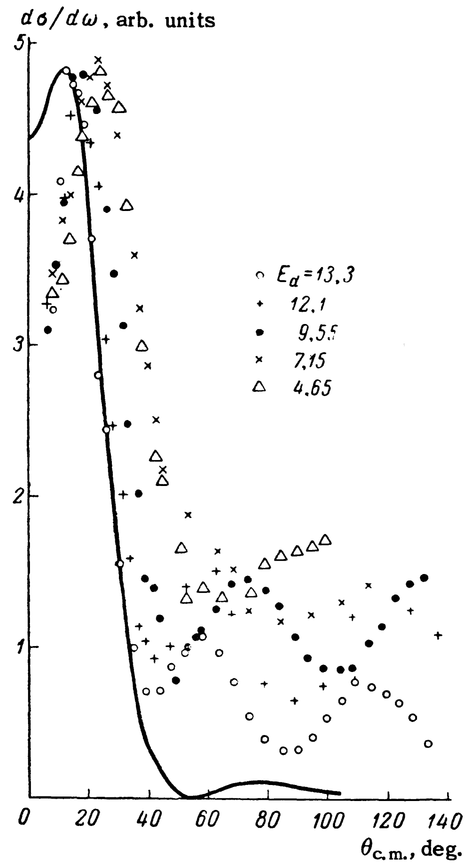

FIG. 1. Angular distributions of protons from the $C^{12}(dp)C^{13}$ reaction corresponding to the ground state of C^{13}, for various values of E_d in Mev. The solid curve is calculated from the Butler theory for $E_d = 13.3$ Mev, $l_n = 1$ and $r_0 = 4.6 \times 10^{-13}$ cm.

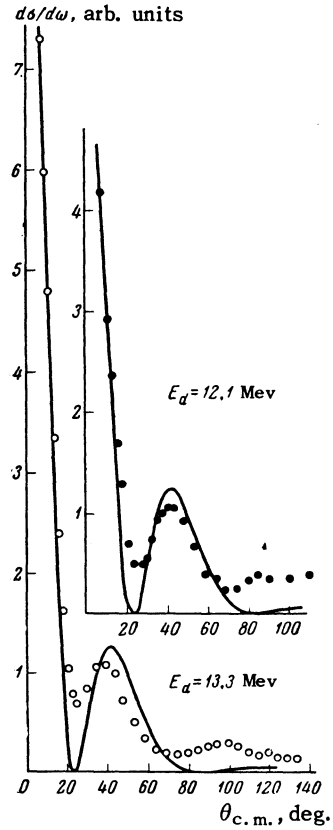

FIG. 2. Angular distributions of protons corresponding to the excited state of C^{13} at 3.09 Mev, for two values of E_d. The solid curves are calculated from the Butler theory for these energies; $l_n = 0$, $r_0 = 4.6 \times 10^{-13}$ cm.

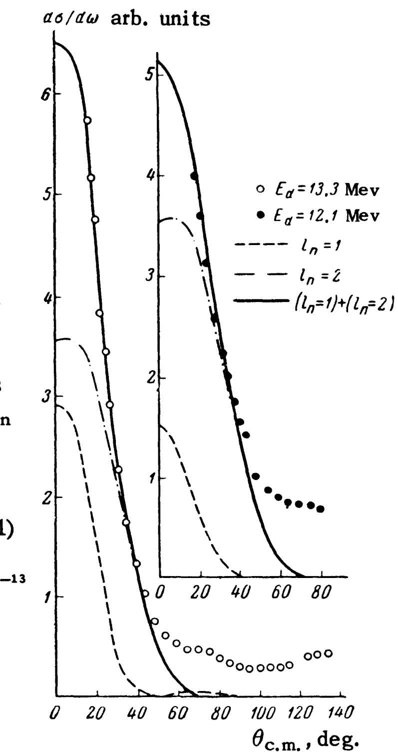

FIG. 3. Angular distribution of protons corresponding to the first (3.68 Mev) and the second (3.86 Mev) excited states of C^{13}. The curves are calculated from the Butler theory for the corresponding energies and for various values of l_n (the ratio of the curves for $l_n = 1$ and $l_n = 2$ was selected by calculating the best fit of the curve ($l_n = 1$) + ($l_n = 2$) with the experimental data); $r_0 = 4.6 \times 10^{-13}$ cm.

Mev. While the first distributions are characterized by a distribution peak wider than theoretical and an indication of a rise at large angles, in the second distributions the peak appears to be the theoretical value, but instead of the rise at large angles there are two additional maxima which recall a diffraction distribution. A similar picture has been observed by other authors for deuteron energies exceeding[7,8] and less than[9] the energies used by us.

The change in character of the angular distribution occurring in the energy interval 7 — 9 Mev may be related to a change in the contributions of the various mechanisms in the reaction and to a changing relative importance of nuclear and Coulomb interactions. The presence of nuclear interaction in the $C^{12}(dp)C^{13}$ reaction is indicated by a narrowing of the peak which occurs for $E_d \geq 9$ Mev.[5] For energies $E_d \leq 7.15$ Mev one should assume increasing importance of compound nucleus formation[4] and stripping of heavy particles,[2] which give an increase in cross section at large angles as well as a broadening of the peak. The work of other authors[9,10] shows that for $E_d = 2.7 - 3.3$ Mev agreement with theory is attained for $r_0 = 6.5$f. and a distribution at the peak which is broader than the theoretical. Similarly, for agreement with theory of our data for an energy of $E_d = 4.65$ Mev we had to increase the value of the radius up to 5.5 f.

We also measured the differential cross section of the reaction $C^{12}(dp)C^{13}_{gr}$ for angles corresponding to the maximum in the distribution and energies of 7.15, 9.55, 12.1, and 13.3 Mev. The cross section values were equal respectively to 24, 18, 14 and 13 mb/sr. The error in the measurement of the absolute value of the cross section was ±30% To measure the cross section we used the current integrator[11] with Faraday cup developed earlier.

In conclusion, the authors take this opportunity to express their gratitude to Prof. M. V. Pasechnik for his interest in the work; to A. M. Korolev and Yu. V. Tsekhmistrenko for participating in discussion of the results, and to the personnel of the cyclotron for assuring uninterrupted operation.

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1