INELASTIC SCATTERING OF 13.6-*MeV DEUTERONS ON NICKEL ISOTOPES*

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The angular distributions of 13.6-MeV deuterons inelastically scattered on $Ni^{58,60,62,64}$ isotopes were investigated. The results (especially those pertaining to small angles) indicate that an electric-interaction mechanism between deuterons and nuclei plays a significant role.

INELASTIC scattering of deuterons is of great interest since it can provide information on the mechanism of the interaction between deuterons and nuclei. As a result, the number of experiments devoted to this question is rapidly increasing. Theoretical attempts to interpret the results of these experiments, however, encounter a number of difficulties. All the assumptions of the theory of inelastic scattering thus far have proved to be unsuitable when applied to deuterons. For such nuclei as Mg and Al it has been possible to show qualitatively on the basis of a diffraction picture that at some energies and scattering angles something like a "phase shift"[1-3] is observed between the elastic and inelastic scatterings, but no such effect is observed for other nuclei and for other angles.

Sometimes the theory of nuclear interactions of the stripping type[4] gives more or less satisfactory results. Good agreement with experiment as regards the distribution of the maxima of the angular distributions is obtained with the theory of electric interaction,[5] but the experimental values of the cross sections in the angular region >30° prove to be several times the values predicted by this theory. A rise in the experimental curves as $\theta \to 0$ would be a strong argument in favor of this theory, but in most experiments on inelastic scattering the small-angle region has not been investigated sufficiently. A more general theory, for example, that of El-Nadi and Wafik,[6] gives more or less good agreement with experiment for some nuclei, but gives unsatisfactory agreement for others.

Very promising (at least, in its application to protons and α particles) is the method of distorted waves.[7] One should, however, exercise great caution in applying this method to the case of deuterons. Indeed, Rost and Austern[8] showed that in the limiting case of small deformations the adiabatic method[1-3] is equivalent to the method of distorted waves in the calculation of inelastic scattering. However, Blair and Hamburger,[9] who compared the results of this method with their experimental data on the inelastic scattering of deuterons, did not find any agreement between theory and experiment in the small-angle region.

In order to obtain additional experimental information on the character of the inelastic scattering of deuterons and on how the scattering changes from isotope to isotope, we measured the angular distributions of deuterons scattered inelastically on the isotopes $Ni^{58,60,62,64}$.

The measurements were carried out with the extracted 13.6-MeV deuteron beam from the cyclotron of the Institute of Physics, Academy of Sciences, Ukrainian S.S.R. The isotope targets and the method of measurement were the same as in[10].

As monitors, we used scintillation counters situated at 30° relative to the deuteron beam and a current integrator operating from a Faraday box located on the axis of the incident beam at a distance of ~1 m from the target and shielded by 10 cm of lead. A description of the integrator is given in[11].

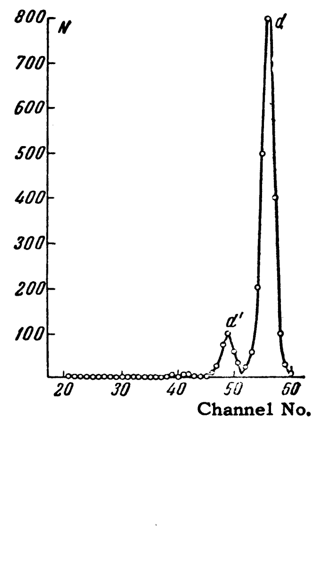

FIG. 1. Deuteron spectrum from Ni^{62} (d, d′) reaction, $\theta = 45°$, Q = −1.17 MeV (N is the number of counts)

The statistical errors of the measurements were of the order 3—5%. The accuracy of the angular setting was 0.2%. The background at angles 30—100° did not exceed 5% of the area of the peak. The half-width of the inelastic peak (apart from angles < 20°) varies from 5 to 7%. The spectrum of deuterons scattered by Ni^{62} nuclei is shown in Fig. 1. The spectra for the other cases are of similar form.

The obtained angular distributions are shown in Figs. 2—5. Attention is drawn to the fact that quite distinct maxima are observed close to 45, 75, and 115° in all the experimental curves. In the case of Ni^{60} (and also, perhaps, Ni^{62}), we note a small maximum in the 25—30° region. No sign of this maximum is seen in the case of Ni^{64}. The intensity of the peaks clearly varies from isotope to isotope, Thus, for Ni^{58} and Ni^{62} the peaks at 45° and 75° are rather distinct, while for Ni^{60} and Ni^{64} the peaks become more distinct at 115°.

Attempts to compare these results with the known theories based on the nuclear interaction [4]

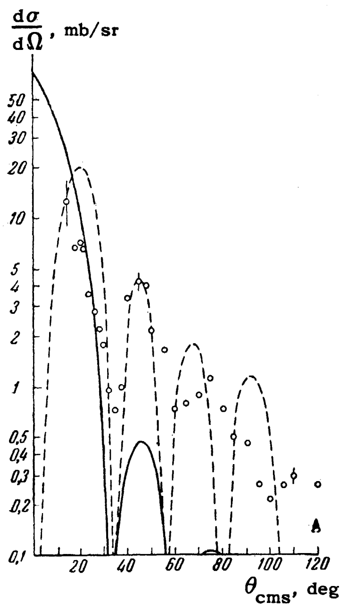

FIG. 2. Angular distribution of deuterons scattered inelastically on Ni^{58} ($Q = -1.45$ MeV). The points represent the experimental data, the solid curve represents the calculations based on the electromagnetic theory with $r_0 = 7 \times 10^{-13}$ cm, and the dashed curves represent the calculations based on the theory of nuclear interaction with $a = 8.8 \times 10^{-13}$ cm.

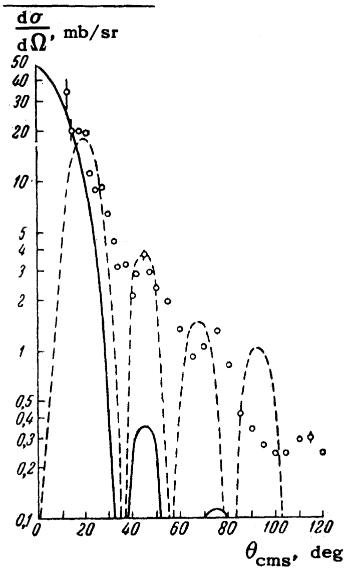

FIG. 3. Angular distribution of deuterons scattered inelastically on Ni^{60} ($Q = -1.33$ MeV). The notation is the same as in Fig. 2.

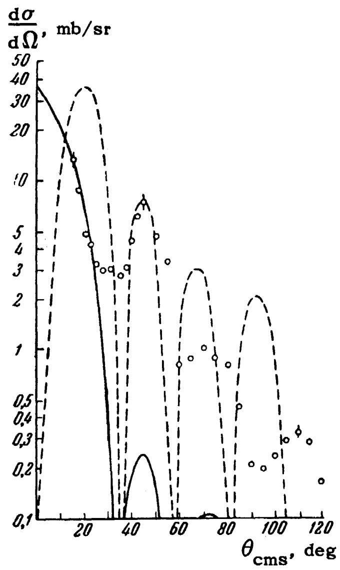

FIG. 4. Angular distribution of deuterons scattered inelastically on Ni^{62} ($Q = -1.17$ MeV). The notation is the same as in Fig. 2, but the calculations are for $r_0 = 6.9 \times 10^{-13}$ cm and $a_0 = 8.65 \times 10^{-13}$ cm.

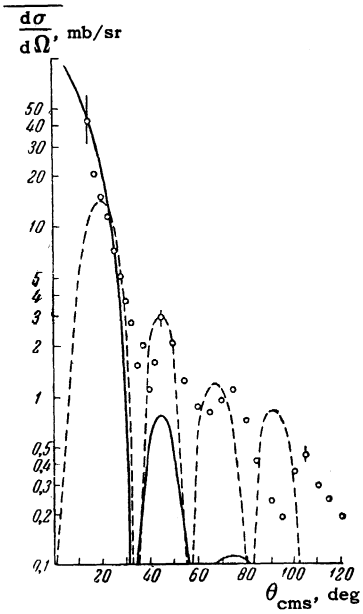

FIG. 5. Angular distribution of deuterons scattered inelastically on Ni^{64} ($Q = -1.34$ MeV). The notation is the same as in Fig. 2.

and the electric interaction,[5] as seen from the figures, give incomplete agreement (r_0 and a are the radii of the interaction forces in the respective theories; the angular-momentum transfer l has been set equal to 2 everywhere).

The theory of inelastic diffraction scattering[1-3] likewise fails to give agreement with experiment, either as regards the positions of the peaks or their amplitudes. Moreover, comparison of our results with data on the elastic scattering of deuterons [12] indicates that no "phase shift" is observed in this case.

Thus, we are forced to conclude that in inelastic scattering of deuterons none of the known mechanisms for the reaction can be considered preferable in our case. We can only say that in the small-angle region the electric interaction is predominant in inelastic scattering; its contribution is already comparable with the nuclear interaction at angles 20—30°. A very important indication in favor of this mechanism in the small-angle region is also the fact that, in contrast to previous experiments,[13-14] agreement with theory is obtained for reasonable values of the parameter r_0 of the theory.

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