INELASTIC SCATTERING OF DEUTERONS ON SILICON, TITANIUM, AND IRON NUCLEI

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The results of measuring the angular distributions of 13.6-MeV deuterons inelastically scattered by silicon, titanium, and iron nuclei are described. At small scattering angles a rise is observed in the curves which may be due to the elastic interaction.

THE value of studying the inelastic scattering of deuterons for clarifying the nature of the deuteron-nucleus interaction has already been emphasized in our previous article. [1]

Since the measurements made for various nickel isotopes yielded, on the whole, similar results (if one does not consider the absolute values of the inelastic scattering cross sections, which differed considerably from isotope to isotope), an investigation of the angular distributions of deuterons inelastically scattered by other (lighter) nuclei seemed interesting; it was hoped that the regularities associated with change in atomic weight would appear more distinctly. To this end we chose iron, titanium, and silicon as target nuclei. It seemed particularly interesting to measure the angular distribution oi deuterons inelastically scattered on Si^{28}, since earlier measurements for this nucleus at a deuteron energy of 8.9 MeV [2] yielded results which differed markedly in nature from those obtained for many other nuclei, including nuclei close to Si^{28}.

Our measurement technique was based upon the principle of simultaneous measurement of the energy E and the loss dE/dx for scattered charged particles, and is described in [1]. The spectrum of deuterons (initial energy 13.8 MeV) inelastically scattered by iron nuclei at $\theta = 50°$ which was obtained by this method is presented in Fig. 1. As can be seen from the figure, the peak for the inelastically scattered deuterons is quite satisfactorily distinguished. The resolution at angles greater than 30° varied from 4.5 to 6%. At angles smaller than 30° the resolution deteriorated considerably, so that measurements at very small angles (which are the most interesting for testing the applicability of theories) were not feasible.

The absolute differential cross section for silicon was determined to be accurate to approximately 50%, and those for titanium and iron to approximately 20—25%.

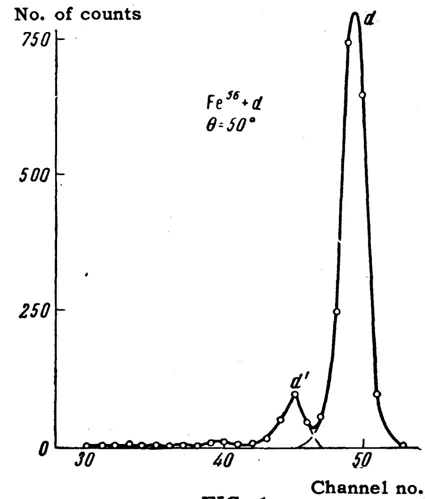

FIG. 1

SILICON

The work was done with a target of natural isotopic composition (92.27% Si^{28}). The first or 1.78-MeV level of Si^{28} is the most intensely excited when deuterons are inelastically scattered by silicon nuclei. The angular distribution of the inelastically scattered deuterons with the excitation of this level is shown in Fig. 2. Here, as in the succeeding figures, the experimental results are indicated by dots, the calculations from electric interaction theory [3] by solid lines, and the calculations from nuclear interaction (stripping type) theory [4] by dashed lines. In all cases the initial deuteron energy was 13.6 MeV. Because the Si^{28} nucleus is even-even, an orbital angular momentum transfer of two was adopted.

Electric interaction theory, with the parameter a = 7.2 F, gives a description of the increase of the cross section at small angles, where the electric interaction is most important. At large angles, however, the experimental results diverge from both electric and nuclear interaction theory predictions. It was necessary to adopt an increased value for the interaction radius (r_0 = 8.8 F) at

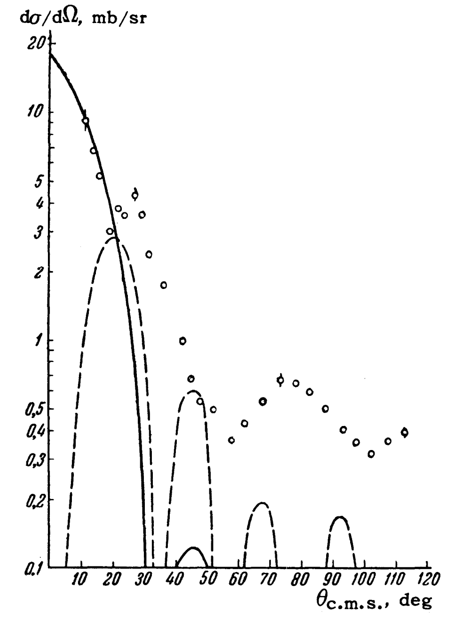

FIG. 2. Angular distribution of inelastically scattered deuterons from the reaction $Si^{28}(d, d')Si^{28*}$ (Q = −1.8 MeV). Solid curves are calculated with r_0 = 7.2 F, dashed with a = 8.8 F.

45° in order to match the theoretical (nuclear interaction) curve with the experimental data.

A still worse agreement was obtained with inelastic diffraction scattering theory.[5] Since we are dealing here with an even transition, according to this theory a "phase shift" must be ob-

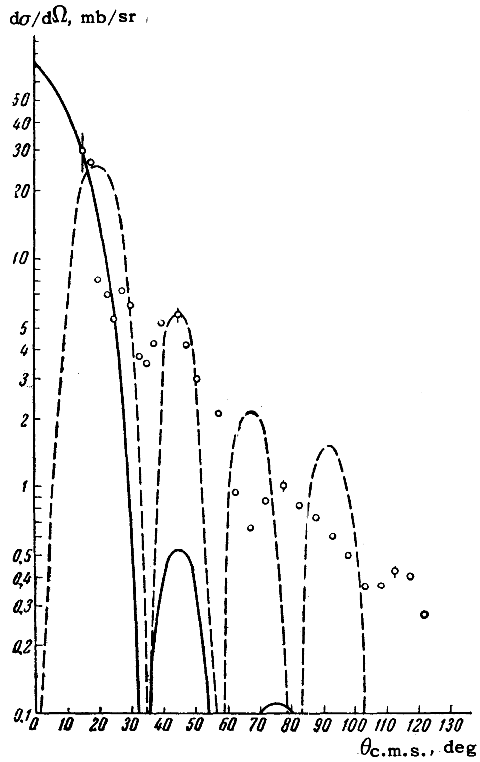

FIG. 3. Angular distribution of inelastically scattered deuterons from the reaction Ti^{48} (d, d') (Q = −0.99 MeV). Solid curves are calculated for r_0 = 6.2 F, dashed for a = 8 F.

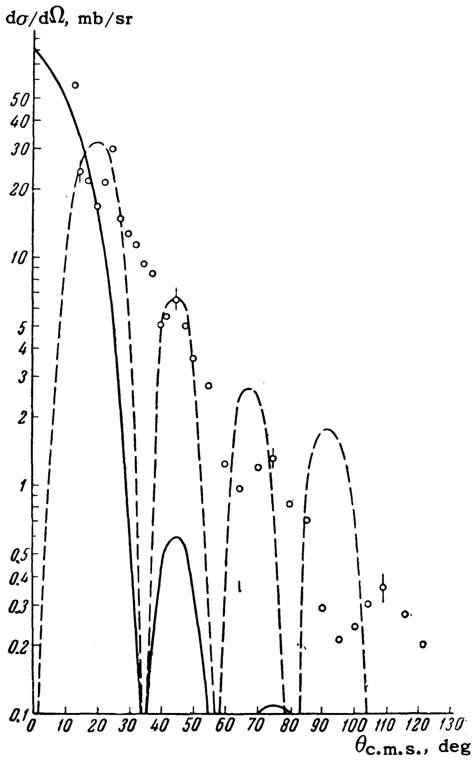

FIG. 4. Angular distribution of inelastically scattered deuterons from the reaction Fe^{56} (d, d') (Q = −0.85 MeV). Solid curves are calculated for r_0 = 7 F, dashed for a = 8.8 F.

served between the positions of the maxima and minima of the differential cross sections of elastic and inelastic scattering. No such behavior was observed.

TITANIUM

A natural target was also used in this case (73.45% Ti^{48}). An angular distribution was obtained for the most excited, 0.99-MeV first level of Ti^{48} (Fig. 3). Here, as in the case of silicon and iron, the experimental and theoretical (nuclear interaction) differential cross sections were matched at the second maximum of the angular distributions. Titanium is also an even-even nucleus, so that $l = 2$ was also adopted here.

As can be seen from Fig. 3, the rise of the differential cross section in the small angle region can only be explained by the electric interaction. The second maximum, located at 45°, can also be explained by the same mechanism. However, the measured differential cross section exceeds the cross section predicted by electric interaction theory in absolute value by an order of magnitude. The absolute value of the cross section can only be explained with the aid of nuclear interaction theory. We may assume that the nuclear interaction begins to be important at 20°, which is confirmed by the inflection observed at this point.

Inelastic diffraction scattering theory was found not to be in agreement with the experiment.

IRON

The natural iron target contained 91.68% Fe^{56}. The angular distribution of inelastically scattered deuterons with excitation of the first, 0.85-MeV level of Fe^{56} is shown in Fig. 4. In this case also l was taken to equal two.

As can be seen from the figure, the increase of the cross section at small angles is satisfactorily described by electric interaction theory, as in the preceding cases. The nuclear interaction probably begins to play a role at 20°. However, the positions of the maxima in the theoretical and experimental distributions do not coincide for angles greater than 50°, and the experimental cross sections fall off rather more rapidly than the theory requires (as is also the case for the other nuclei).

The results show that the electric interaction makes a comparatively large contribution to the cross section at small angles. Let us also note that when the cited even-even nuclei are irradiated with deuterons, the 2^+ level is most intensely excited, as follows from Fig. 1 for the case of iron.

Moreover, a comparison of Figs. 2, 3, and 4 shows that in our case the experimental angular distribution of deuterons inelastically scattered on silicon nuclei is essentially different from the distributions for titanium and iron (which resemble one another). In this connection, we propose to measure the angular distributions of inelastically scattered deuterons for other light nuclei in the future.

[1] Gofman, Nemets, and Stryuk, JETP **42**, 653 (1962).

[2] Hinds, Middleton, and Parry, Proc. Phys. Soc. **A70**, 900 (1957).

[3] C. J. Mullin and E. Guth, Phys. Rev. **82**, 141 (1951).

[4] R. Huby and H. C. Newns, Phil. Mag. **42**, 1442 (1951).

[5] J. S. Blair, Phys. Rev. **115**, 928 (1959).

[6] Yu. V. Gofman and O. F. Nemets, JETP **40**, 477 (1961), Soviet Phys. JETP **13**, 333 (1961).

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