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ELASTIC SCATTERING OF 3.4--4.2 MeV *PROTONS BY* Ni^{62} *AND* Ni^{64} *ISOTOPES*

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Angular distributions of 3.4, 3.65, 3.76, and 4.2 MeV protons elastically scattered by Ni^{62} and Ni^{64} nuclei are measured in the angular range between 30 and 90° (laboratory system). The nuclear interaction range between the incident proton and nucleus is determined on the basis of the starting point of the deviation of the angular distribution curves from the Rutherford law in the quasiclassical approximation. The ranges derived from the experimental data systematically exceed those calculated by formula (2).

INVESTIGATIONS of elastic scattering of sub-barrier-energy protons by targets made of separated isotopes have disclosed many interesting laws which explain to a considerable degree both the elastic scattering process itself and a few structural features of the investigated nuclei[1-4]. It is to be hoped that the investigation of the processes of elastic scattering in the angle region 40—90° will make it possible to obtain important information on the structure of the nuclear surface [4].

The present investigation is a continuation of the experiments undertaken by us to this end.

EXPERIMENTAL METHOD AND RESULTS

The work was carried out with the electrostatic generator of the Physico-technical Institute of the Ukrainian Academy of Sciences, using an experimental procedure which we described in an earlier paper[5]. The investigated single-isotope targets Ni^{62} and Ni^{64} were prepared electrolytically in the form of free metallic foils 1.0—1.3 μ thick. The enrichment of the targets reached 95 per cent.

The angular distributions of the elastically-scattered protons with initial energy 3.40, 3.65, 3.76, and 4.20 MeV were measured in the angle range 30—90° (l. s.) in steps of 5°. The experimental curves were obtained by comparison with Gold[6] and are shown in Fig. 1 in the form of a ratio of the experimental cross section to the Rutherford cross section σ_e/σ_K.

From the foregoing data we see that the curves of the angular distribution of protons elastically scattered by Ni^{62} and Ni^{64} coincide within the limits of experimental error over the entire energy and angular range and represent a smooth decrease in the cross section from the Rutherford value, starting with some angle θ_0. The start of the deviation from the Rutherford distribution shifts with increasing energy towards smaller angles[4,7]. The angle corresponding to the start of the deviation θ_0 was determined by us with an accuracy of ± 5°. The total experimental error of the cross section ratio σ_e/σ_K did not exceed ± 1 percent.

From the start of the deviation of the experimental angular distribution curves from the Rutherford curves we can determine the distance D_{min} of the closest approach of the incoming proton to the nucleus, which in the quasiclassical approximation corresponds to the radius of the nuclear interaction between the proton and the nucleus:

$$D_{\min} = \frac{Zze^2}{2E_{\text{cms}}}\left(1 + \frac{1}{\sin(\theta_0/2)}\right), \qquad (1)$$

where E_{cms}—c.m.s. energy of the incoming particle, and θ_0—angle of the start of the deviation from the Rutherford distribution (in the same system).

The values of D_{min} obtained with the aid of (1) are listed in the table. Within the limits of experimental accuracy, they remain constant, although some tendency of the parameter D_{min} to increase with decreasing energy of the incoming protons is observed.

DISCUSSION OF THE RESULTS

According to the results of Hill and Ford[8], the potential of a uniformly charged nucleus dif-

(E_p) lab MeV	θ_0, deg	D_{min}, F
3.40	60±5	18±1
3.65	55±5	18±1
3,76	55±5	17±1
4,20	45±5	17±2

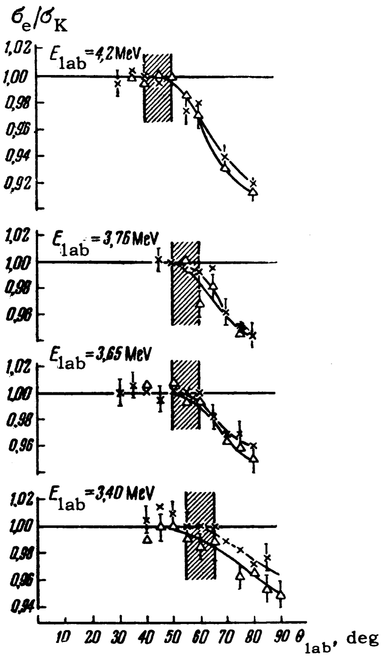

FIG. 1

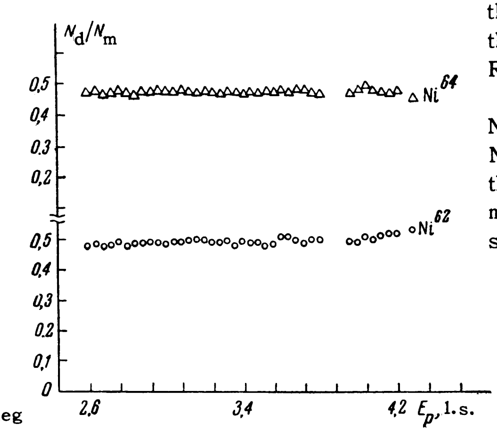

FIG. 2

FIG. 1. Angular dependence of the ratio of the experimentally measured cross section of elastic scattering of protons by Ni^{62} (x) and Ni^{64} (▲) to the Rutherford cross section. The shaded area is the region where the curves deviate from the Rutherford distribution.

FIG. 2. Excitation functions (p,p) for Ni^{62} and Ni^{64} nuclei, represented in the form of ratios N_d/N_m, where N_d are the detector readings and N_m the corresponding monitor readings. The measurement errors do not exceed the geometrical dimensions of the points.

fers from a Coulomb potential (for a point charge) by not more than 0.1 per cent. Such a distortion of the value of the Coulomb potential does not noticeably influence the value of D_{min}, determined from (1). To clarify the possible effects of resonant proton scattering, we measured the excitation function for elastic scattering of protons by Ni^{62} and Ni^{64} at an angle $\theta = 120°$ in the energy range 3.0—4.2 MeV (Fig. 2). The curves given here do not show any noticeable resonant character in the entire range of bombarding proton energies, this being practical evidence of the absence of any influence of resonant scattering on the obtained results.

If the quasiclassical approximation is satisfied sufficiently rigorously ($\eta = Zze^2/\hbar v \gg 1$), then the parameter D_{min} can be represented in the form:

$$D'_{min} \approx R + r_p + \lambda\!\!\!^{-}{}', \qquad (2)$$

where R—radius of the nucleus, r_p—radius of the proton, $\lambda\!\!\!^{-}$ —width of wave packet of incident proton.

Let us estimate the value of D'_{min}, using Eq. (2), starting from the conditions of our experiment. If $R = r_0A^{1/3}$ and $r_0 = 1.5 \times 10^{-13}$ cm, then R = 6 F, $r_p \leq 1.5$ F, and $\lambda\!\!\!^{-}_p = 2$ F. We put $\lambda\!\!\!^{-} = \lambda\!\!\!^{-}_p$, where $\lambda\!\!\!^{-}_p$ is the reduced de Broglie wavelength of the proton. Then $D'_{min} = 10$ F.

The experimentally obtained values of D_{min} were 17—18 F. The inequality $D_{min} > D'_{min}$ is probably due to the fact that a rigorous quasiclassical analysis is not applicable in this case, owing to the smallness of the parameter η (in the investigated energy range $\eta = 2.2—2.5$). However, this conclusion cannot be regarded as exhaustive. For a more definite explanation of the experimentally obtained values of the parameter D_{min} it is necessary to investigate the elastic scattering of protons by nuclei that are known to have sharp boundaries ('magic' nuclei) and diffuse boundaries.

The inequality $D_{min} > D'_{min}$ can also be obtained from the results of several other experimental investigations devoted to elastic scattering of protons and deuterons by various nuclei, in the energy range of 3—25 MeV[7,9-11]. The quasiclassical analysis is more justified here, since $\eta = 3.4$. The parameters D_{min} calculated on the basis of these results for the scattering of protons and deuterons by identical nuclei coincide within the limits of experimental accuracy.

In this connection, we regard as unconvincing the interpretation of the inequality $D_{min} > D'_{min}$ given by Gofman and Nemets[12], who investigated elastic scattering of 13.6 MeV deuterons by medium and heavy nuclei. In this investigation the indicated inequality is unambiguously explained by the electrical splitting of the deuteron in the Coulomb field of the heavy nuclei (Pt, Au, Pb). However, the differential cross sections obtained by the authors themselves, on the basis of such conclusions, for the breakup of the deuterons in the Coulomb field of Pt^{78} ($d\sigma/d\Omega \approx 300$ mb/sr) exceed not only the theoretical value of the total cross section for the electric breakup of the deuterons on the Pt^{78} nucleus ($\sigma_t = 200$ mb), but are practically comparable with the experimentally obtained value of the total cross section for the breakup of deuterons with energy 14.8 MeV on the Pt^{78} nucleus ($\sigma_t = 380$ mb), which is due not only to the electrical, but equally well to diffractional nuclear splitting of the deuterons[13].

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