CALCULATION OF THE ELASTIC SCATTERING CROSS SECTIONS FOR 5.45 Mev PROTONS ACCORDING TO THE OPTICAL MODEL OF THE NUCLEUS

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The differential cross sections for the elastic scattering of 5.45 Mev protons from the separated isotopes $Cr^{52,53}$, Co^{59}, $Ni^{58,60,62,64}$, $Zn^{64,68}$, and Cu^{65} have been calculated with the help of the complex optical model potential. The real part of the potential was chosen in the Saxon form and the imaginary part in the Gaussian form. Satisfactory agreement with the experimental data has been achieved for isotopes whose (p, n) threshold is below the energy of the scattered protons. It has been impossible to make the optical model calculations consistent with the experimental data for isotopes whose cross sections increase at large angles.

THE purpose of the investigation of the elastic scattering of nucleons from nuclei with the help of the optical model is the determination of the parameters of the nuclear potential. Such investigations have been carried out by many authors;[1-3] they have led to an explanation of the basic regularities in the behavior of the angular distribution of the elastic scattering as a function of the optical model parameters. However, the calculations that have been carried out so far have mainly been concerned with the analysis of the experimental data on the elastic scattering of nucleons from targets which contain a natural mixture of isotopes.

In the present paper we report an analysis of the experimental data on the elastic scattering of 5.45-Mev protons obtained by Klyucharev and Rutkevich.[4] Analogous calculations by the authors for the proton energy 6.8 Mev have been reported earlier.[5] The difference between the present calculations and the earlier ones consists in the fact that we did not include the spin-orbit interaction for the energy 5.45 Mev.

The potential used in the calculation was chosen in the form

$$V(r) = V_{\text{coul}}(r) + V_0 f(r) + iW_0 g(r), \qquad (1)$$

where $V_{Coul}(r)$ is the potential of the Coulomb field of the nucleus; V_0 and W_0 are the real and imaginary parts of the nuclear potential, respectively; $f(r)$ and $g(r)$ are the form factors of the real and imaginary parts of the nuclear potential:

$$f(r) = \left[1 + \exp\left(\frac{r - k_0}{a}\right)\right]^{-1}, \quad g(r) = \exp\left[-\left(\frac{r - k_0}{b}\right)^2\right]. \qquad (2)$$

In accordance with the results of a number of investigations,[6,7] we assume that, for a given proton energy, the Gaussian form is more reasonable physically for the imaginary part of the potential than the Saxon form. This is why we have chosen the form (2) for $g(r)$ in the calculations.

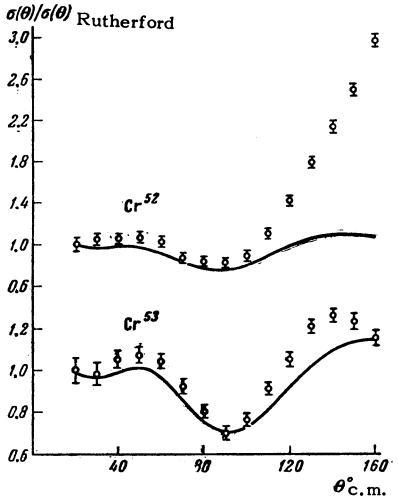

FIG. 1. Results of the calculation for $Cr^{52,53}$ at E_p = 5.4 Mev. The points indicate the experimental data with account of the statistical errors.

In the determination of the optical model parameters, one usually attempts to obtain the same set of parameters for several neighboring nuclei if the energy of the scattered nucleon is given. In the present paper, we choose as the basic criterion for the comparison of the calculated curves with the experimental ones the coincidence of the position and the depth of the minimum of the curve representing the ratio of the differential elastic cross section over the Coulomb cross section. The results of the calculations are shown in Figs. 1 — 3, where we also indicate the experimental data of Klyucharev and Rutkevich.[4] In the table we give the parameters for the calculated curves. These sets of optical model parameters for the elastic scattering at 5.45 Mev were obtained by

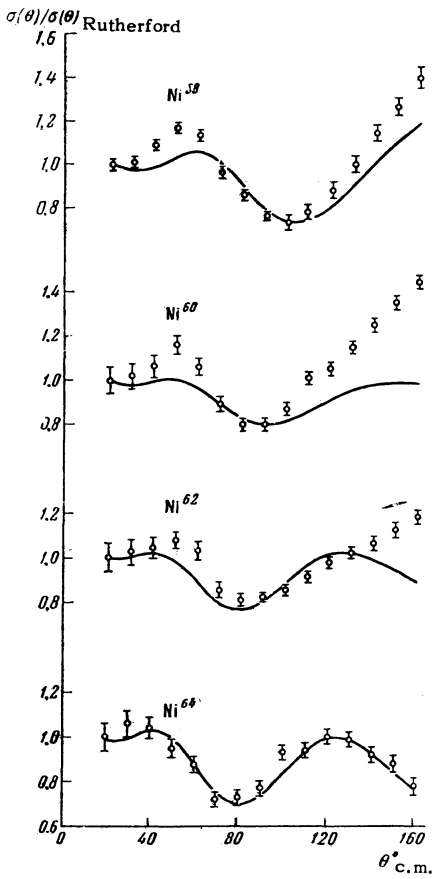

FIG. 2. Results of the calculation for $Ni^{58,60,62,64}$ at $E_p = 5.4$ Mev. The points indicate the experimental data.

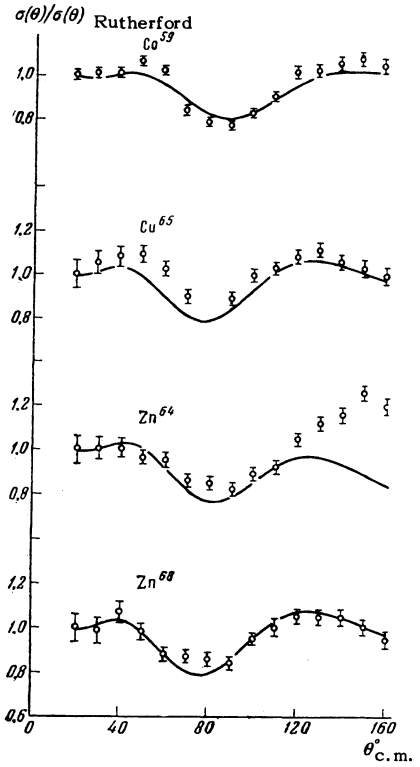

FIG. 3. Results of the calculation for Co^{59}, Cu^{65}, and $Zn^{64,68}$ at $E_p = 5.4$ Mev. The points indicate the experimental data.

the method of least squares and also by empirical methods.

It follows from previous calculations,[2,6] that the form of the differential elastic cross section curve depends practically only on the product $V_0 r_0^2$. The position and the depth of the minimum of the curve depend not only on the values of the parameters V_0 and r_0, but also on the values of the parameters a, b, and W_0. However, it was not possible to make the minima of the calculated curves agree with those of the experimental curves for different nuclei by varying only the parameters a, b, and W_0. We therefore also had to vary somewhat the value of r_0 or V_0. In particular, if we fix the value of r_0 for all nuclei, we must vary the parameter V_0. It is seen from the table that the variation of the value of V_0 reaches 5% even for the isotopes of one and the same element (for example, Ni or Zn).

We may conclude from our earlier calculations[6] that the character of the dependence of the angular distribution on the parameter b is similar to that of the dependence on the parameter W_0.

In order to minimize the ambiguities in the choice of the parameters, we have fixed the value of b at b = 1.2. With this value of b the values of W_0 that we obtained were close to the values obtained by an analysis of the elastic scattering of neutrons.[8]

We did not include the spin-orbit interaction in the present calculations, because in the absence of polarization data it was not possible to get any idea of the magnitude of the spin-orbit potential.

Element	r_0*	a	b	V_0	W_0	Element	r_0*	a	b	V_0	W_0
Cr^{52}	1.23	0.40	1.2	—60	—11.5	Ni^{62}	1.23	0.36	1.2	—60.5	—7.0
Cr^{53}	1.23	0.36	1.2	—60	—7.5	Ni^{64}	1.23	0.40	1.2	—58.5	—5.5
Co^{59}	1.23	0.35	1.2	—58	—8.5	Cu^{65}	1.23	0.36	1.2	—60.5	—6.0
Ni^{58}	1.23	0.35	1.2	—57	—3.5	Zn^{64}	1.23	0.40	1.2	—60	—5.5
Ni^{60}	1.23	0.36	1.2	—57	—8.5	Zn^{68}	1.23	0.40	1.2	—59.5	—5.5

*The potentials are given in Mev and the linear dimensions in 10^{-13} cm.

It is seen from the calculated curves shown above that we did not obtain complete agreement between the theoretical and experimental cross sections. In the case of nuclei for which the cross section increases strongly at large angles, no choice of optical model parameters led to a satisfactory agreement between the cross sections for all measured angles. However, we call attention to the fact that the agreement between the theoretical and experimental cross sections is good for the nuclei Cr^{53}, Co^{59}, Ni^{64}, and Cu^{65}, i.e., for those nuclei whose (p,n) thresholds are considerably below the energy of the scattered protons. For those nuclei, on the other hand, whose (p,n) thresholds lie above the energy of the scattered protons or close to them, the cross section increases sharply at large angles, and we did not succeed in fitting the calculated curves to these cross sections.

We quote here the (p,n) thresholds for the elements under consideration:[9]

	Cr^{52}	Cr^{53}	Co^{59}	Ni^{60}	Ni^{62}	Ni^{64}	Cu^{65}	Zn^{64}	Zn^{68}
$E_{threshold}$, Mev	5.52	1.41	1.87	6.72	4.69	2.50	2.18	8.12	3.45

Since the optical model does not take into account the compound elastic scattering (which cannot be distinguished experimentally from the "pure elastic" scattering), one may assume that the disagreement is due to a large contribution from this type of scattering. Considering the (p,n) thresholds for the above-mentioned nuclei, we may assume that, as long as the (p,n) reaction channel for the decay of the compound nucleus is closed, the decay will proceed mainly through compound elastic scattering, the other channels playing only a minor role. This conclusion was reached by Preskitt and Alford,[10] who showed that the agreement between the theoretical and experimental elastic cross sections at large angles for chromium and vanadium can be improved by taking the compound elastic scattering into account.

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