ANGULAR DISTRIBUTION OF 6.8-Mev *PROTONS ELASTICALLY SCATTERED ON NICKEL AND ZIRCONIUM ISOTOPES*

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The angular distribution of 6.8-Mev protons elastically scattered by Ni^{64}, Zr^{90-92} and Zr^{96} nuclei is investigated. A large difference is found between the angular distributions of the various isotopes.

THE study of the scattering of medium-energy nucleons by atomic nuclei is a source of considerable information on the properties of atomic nuclei. Interest in experiments of this kind is greatly due to the development of the optical model of the nucleus. Very interesting results are those obtained from experiments on elastic scattering of protons by separated isotopes at energies below 10 Mev. A considerable difference was observed in the angular distributions even in scattering by neighboring isotopes.[1-5]

The fact that these effects cannot be fully described theoretically necessitates gathering additional experimental facts to permit subsequent generalization. It is natural to attempt to relate the difference in the scattering to the shell structure of nuclei.

The isotopes of nickel have filled proton shells ($Z = 28$). The filling of the neutron shells has the following singularity: the filling of the sublevel $2p_{3/2}$ ends with the isotopes N^{58} and Ni^{60}, and the filling of the sublevel $1f_{5/2}$ begins with Ni^{62}. The isotope Zr^{90} has filled neutron shells ($N=50$), and completes the filling of the level $1g_{9/2}$. The sublevel $2d_{5/2}$ is filled for the following isotopes of zirconium.

It is therefore quite probable that the nuclei Ni^{62} and $Zr^{91,92,96}$ have a more "diffuse" surface, bringing about an increase in the absorption of neutrons by these nuclei.[6] An experimental manifestation of this is the fact that the differential cross section of elastic scattering at large angles is much less for Ni^{62} than for Ni^{58} and Ni^{60}, and is much greater for Zr^{90} than for the heavier zirconium isotopes.

From this point of view, great interest is attached to a study of the scattering on Ni^{64} and various isotopes of zirconium. The addition of the succeeding neutrons can be expected to "loosen" the surface of the nucleus even more and increase the probability of absorption of the incident protons. This should be accompanied by a reduction in the differential cross section in the region of large scattering angles.

The experimental procedure did not differ in principle from that described earlier.[5] However, several improvements were made to increase the measurement accuracy. Thus, the current of the protons incident on the target was measured with the aid of a current integrator. Simultaneously, the intensities of the scattered protons were measured with a scintillation spectrometer, mounted at an angle of 90° to the direction of the primary protons. Thus, a double check on the measurement of the intensity of the incident protons was accomplished.

The targets were thin free metallic foils, enriched with the investigated isotopes in the following fashion: Ni^{64}—79.8 per cent, Zr^{90}—96.1 per cent, Zr^{91}—73.5 per cent, Zr^{92}—88.6 per cent, and Zr^{96}—31.3 per cent.

MEASUREMENT RESULTS AND DISCUSSION

Nickel. The results of the measurements for Ni^{64} are shown in Fig. 1, in the form of the ratio of the measured scattering cross section to the Coulomb scattering cross section ($\sigma_{exp}/\sigma_{res}$) as a function of the scattering angle. The measurement error did not exceed 3 per cent. As can be seen from Fig. 2, where a comparison is made with the already known data for the other three nickel isotopes,[5] this ratio has the lowest values for Ni^{64} at the largest angles, apparently owing to the stronger absorption of the protons by the Ni^{64}

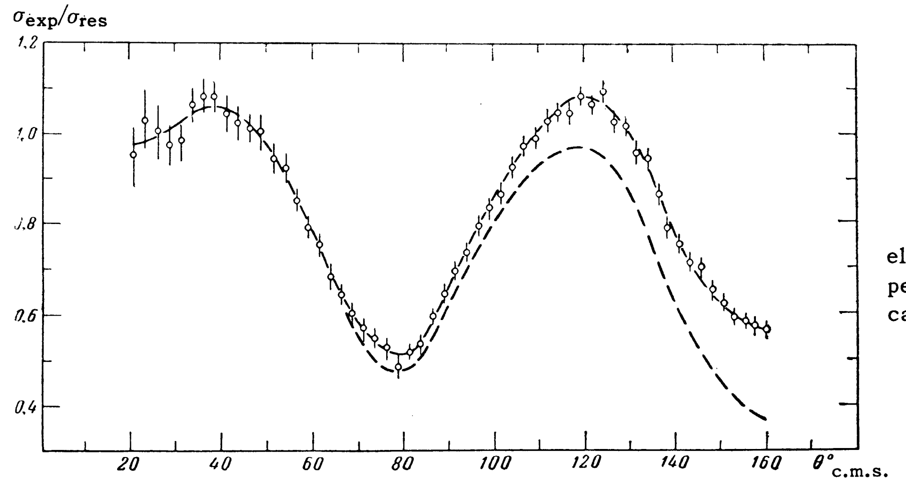

FIG. 1. Angular distribution of protons in elastic scattering on nickel enriched with 79.8 per cent Ni^{64}. The dotted curve has been recalculated for pure Ni^{64} ($E_p \approx 6.8$ Mev).

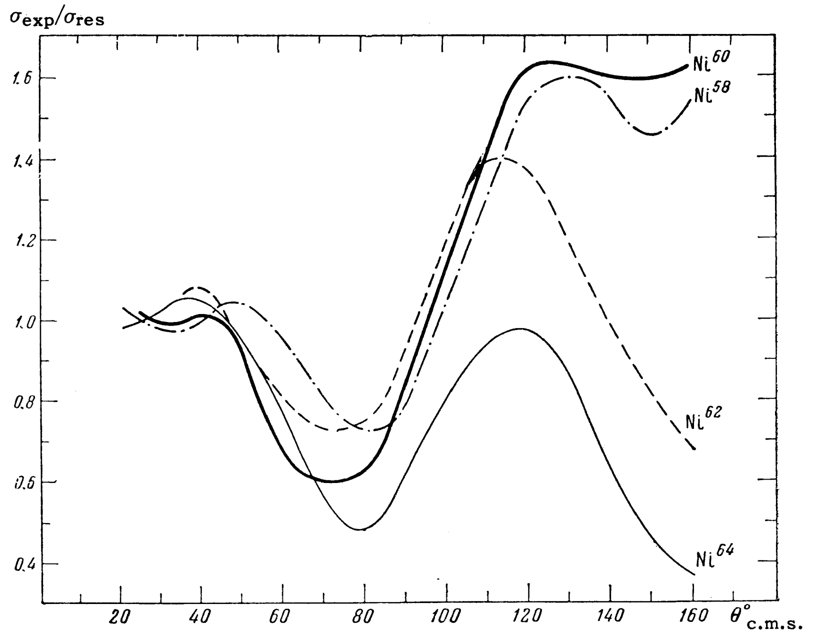

FIG. 2. Comparison of angular distributions of protons elastically scattered by different nickel isotopes, at $E_p = 6.8$ Mev.

nucleus, compared with other isotopes. An analogous result was observed earlier in the scattering of 5.4-Mev protons by the same isotopes.[4] We can therefore expect for Ni^{64} a much larger cross section for the reactions that compete with elastic scattering with capture. In particular, this takes place for the (p, n) reaction, the thresholds of which are 4.77 and 2.49 Mev for Ni^{62} and Ni^{64}, respectively.

Zirconium. In connection with the noticeable solubility of molybdenum in zirconium at high temperatures, molybdenum impurities were found in the zirconium targets. It was established by x-ray spectroscopy that this impurity is the same for all targets, 10 per cent by weight.

The results of the investigation of elastic scattering of 6.8-Mev protons by enriched zirconium targets are shown in Fig. 3. The ratio $\sigma_{exp}/\sigma_{res}$ is much higher for Zr^{90} than for the heavier isotopes in the large-angle region. Addition of merely one odd neutron to the Zr^{90} nucleus greatly reduces this ratio, which is much less in the maximum region than for Zr^{90}.

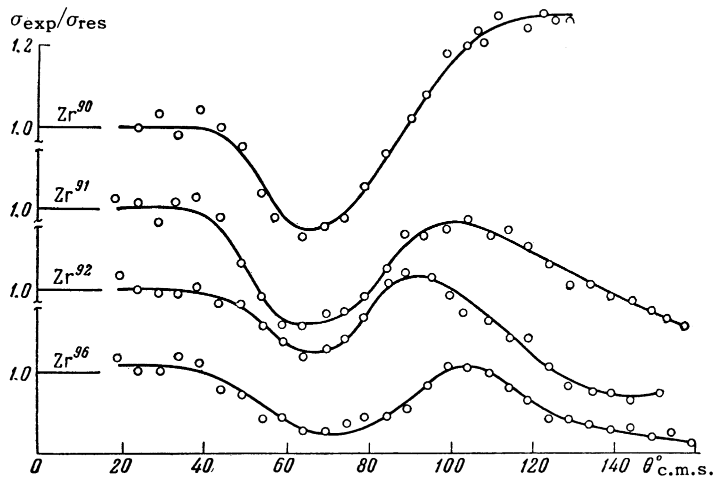

FIG. 3. Angular distribution of protons in elastic scattering by zirconium isotopes ($E_p = 6.8$ Mev).

Inasmuch as the enrichment of the target with

Zr^{96} was merely 31 percent, we can only note that in the large-angle region the cross section for the elastic scattering by this isotope is apparently much smaller than for scattering by light isotopes.

Our results on Zr^{90} and Zr^{91} agree with the results of an investigation of elastic scattering of 5.45-Mev protons by the same isotopes.[7]

Thus, in the scattering of protons by zirconium isotopes, a noticeable difference is observed in the course of the angular dependence of $\sigma_{exp}/\sigma_{res}$. A comparison of this course of the angular dependence with the magnitude of the (p, n) reaction threshold for the same isotopes again confirms the important role played by the reactions that compete with the (p, p) reaction with capture.

In conclusion, the authors are grateful to the cyclotron crew of the Institute of Physics of the Ukrainian Academy of Sciences for producing the proton beam.

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