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ELASTIC SCATTERING OF 5.45 Mev *PROTONS BY ZIRCONIUM NUCLEI*

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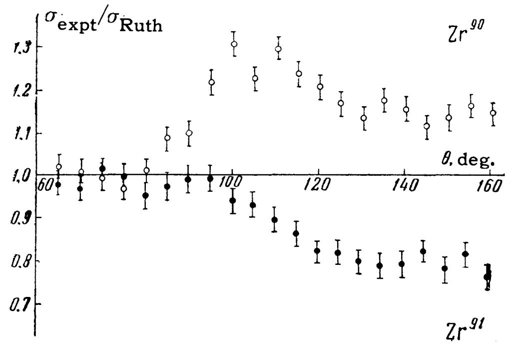
The angular distributions of 5.45-Mev protons elastically scattered by Zr^{90} and Zr^{91} nuclei were measured by the scintillation method. It is hardly possible that the great difference in the angular distribution curves can be explained only by the different threshold of the (p, n) reaction which competes with elastic pp scattering involving capture.

A change in the form of the angular distribution curves for elastically scattered protons, as a result of a change in mass number of the scattering nucleus by one or several units, shows up appreciably for energies of the bombarding protons below the Coulomb barrier. We have previously studied the angular distribution of elastically scattered protons by targets of separated isotopes of nuclei of medium atomic weight with an initial proton energy (5.45 Mev) lower than the Coulomb barrier by 1.0 — 1.5 Mev.[1,2] In the present work we present results of an investigation of the angular distribution of 5.45-Mev protons from Zr^{90} and Zr^{91} targets, which are considerably heavier than nuclei previously studied (the values of the Coulomb barriers in Zr^{90} and Zr^{91} are equal, respectively, to 8.66 and 8.63 Mev).

A scattering chamber described by Fedchanko and Vanetsian[3] was used in this work. The scattered protons were detected by a CsI scintillation crystal and a FÉU-S type photomultiplier with amplitude resolution not worse than 5%. The geometrical conditions of the experiment made it possible to obtain an angular resolution with a precision of ± 2.5%. A current integrator[4] was used as monitor. Proton angular distribution curves can be measured reliably by this method. The inelastically scattered protons are easily differentiated from those elastically scattered, since the energies of the first levels of the Zr^{90} and Zr^{91} nuclei are 1.77 and 1.21 Mev respectively[5] and the targets were fairly thin: 3.5 and 2.2 μ. These targets were produced by thermal dissociation[6] from "raw material" with enrichment of 96.1 and 79.5% respectively for the Zr^{90} and Zr^{91} targets. A molybdenum substrate was used to obtain the targets. An x-ray structure analysis carried out showed a (10 ± 1) % molybdenum impurity for both targets. The contribution from scattering by molybdenum to the general scattering picture can, therefore, be considered the same.



The angular dependence of the ratio of the experimentally measured cross-section to the Rutherford cross-section for the nuclei Zr^{90} and Zr^{91}.

The figure shows the results of the investigation. One notices first the effect of large nuclear elastic scattering at large angles, regardless of the considerable Coulomb barrier. The angular dependences of the scattering for nuclei differing by only one neutron differ appreciably. The form of the angular distribution curves of protons elastically scattered by Zr^{90} and Zr^{91} nuclei differ considerably from the form of the analogous curves for scattering by isotopes of nickel, cobalt and copper,[1] which have a clearly marked diffraction character. However, the qualitative dependence of the form of the curves on whether the mass number is even or odd remains.[2]

It was noted earlier[7,8] that the influence of reactions proceeding through elastic and inelastic channels, with capture of the primary proton, shows on the form of the angular distribution curves of elastically scattered protons. If the energy of the primary protons is higher than its threshold, the (p, n) reaction can have a considerable effect. As a result of the strong competition of the (p, n) reaction, the emission of protons produced by pp scattering with capture, is greatly reduced. In our case the energy of the primary protons is above the threshold of the (p, n) reaction for both zirconium nuclei (the threshold is 5.22 Mev for Zr^{90} and 2.17 Mev for Zr^{91}). Consequently, the downward displacement of the curve of the ratio of the experimentally measured cross section to the Rutherford cross section for the Zr^{91} nucleus (compared with the curve for Zr^{90}), in the region of large angles, can be explained to some extent by the greater effectiveness of the (p, n) reaction for Zr^{91} at the given proton energy, because of its lower threshold. In order to elucidate this problem it is necessary to measure the neutron emission cross section for the (p, n) reaction as well as studying the angular distribution of elastically scattered protons.

The explanation of the different forms of the angular distribution curves for Zr^{90} and Zr^{91} only by the difference in the (p, n) reaction threshold, is not the unique possibility. The Zr^{90} nucleus has a completely filled neutron shell, while the Zr^{91} nucleus has one neutron in addition to the filled shell. From the point of view of the shell model, there are anomalously small level densities near the nuclear magic numbers and, as a result, a small proton capture cross section. The probability of processes which take place with the capture of protons is therefore reduced. Related to this, the contribution from (p, p) processes, with the formation of a compound nucleus, to the general elastic scattering balance may turn out not as great as for nuclei in the region $Z = 24 - 30$.

We have carried out preliminary studies of the angular distribution of elastically scattered protons for the Zr^{96} nucleus. As would be expected for a nucleus "overloaded" with neutrons, the form of the curve of the ratio of the experimentally measured cross section to the Rutherford cross section as a function of angle hardly differs from the form of the analogous curve for the Zr^{91} nucleus. However, the data obtained for Zr^{96} require further confirmation.

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