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Abstract

Full Text

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ELASTIC SCATTERING OF 6.9 MeV PROTONS BY CHROMIUM AND ZINC ISOTOPES

Studies carried out on separated isotopes have shown that the angular distributions of elastically scattered protons on individual isotopes reveal a noticeable difference ([1–6]). First, in a number of cases a difference is observed in the behavior of the differential cross sections in the region of large scattering angles. Second, the shift of maxima and minima in the angular distributions for isotopes close in mass number is considerably greater than could be expected from the optical-model conception of the nucleus under the assumption that the nuclear radius varies as $R = r_0 A^{1/3}$ ([7]). The study of such effects is of considerable interest for investigating the nuclear potential, especially since the experimental material on scattering by individual isotopes is still comparatively limited.

Scattering by the isotopes Cr^{52} and Cr^{53} was studied in work ([3]) at 5.45 MeV and in our work at an energy of 6.8 MeV ([4]). A qualitative difference in the scattering by these isotopes was found. The study of scattering by zinc isotopes at an energy of 5.45 MeV was carried out in works ([8], [9]), and at an energy of 11 MeV in work ([10]). In this case a considerable shift of the extrema in the angular distributions was found.

In the present work, elastic scattering of protons of energy 6.9±0.07 MeV by the isotopes Cr^{50}, Cr^{54}, and Zn^{64}, Zn^{68}, Zn^{70} was studied. In addition, in order to obtain comparable results, the experiments for Cr^{52}, Cr^{53} were repeated, since in work ([4]) the experiments were performed with insufficient energy resolution on relatively thick targets.

The experimental method in principle did not differ from that described in work ([4]). In the experiment two scintillation spectrometers were used, differing in the diameter of the entrance diaphragms and in the distance to the target. The spectrometers consisted of a thin CsJ(Tl) crystal and an FEU-15 photomultiplier, the output of which was fed to a 50-channel amplitude analyzer AIMA-2. The spectrometers on movable brackets could be set at different angles to the direction of the primary beam. Measurements were carried out in the angular range 20—160° at 5° intervals, with an angular error of ±0.3°. The presence of two spectrometers made it possible to carry out simultaneous

Figure 1

Figure 1: Figure 1

Table 1

Isotopic composition of the targets (in %)

Target	Cr^{50}	Cr^{52}	Cr^{53}	Cr^{54}	Target	Zn^{64}	Zn^{66}	Zn^{67}	Zn^{68}	Zn^{70}
Cr^{50}	87.7	11.1	0.9	0.3	Zn^{64}	91.0	4.8	1.3	2.3	0.6
Cr^{52}	0.2	99	0.7	0.1	Zn^{68}	3.7	4.9	3.9	86.6	0.9
Cr^{53}	0.2	13.8	84.3	1.7	Zn^{70}	14.7	15.8	3.9	20.6	45.0
Cr^{54}	0.4	10.9	10.1	78.6						

measurement of two different portions of the angular distribution, or to use the second spectrometer as a monitor.

Measurement of the beam current was carried out with a Faraday cylinder connected to a current integrator. In addition, auxiliary monitoring was performed with a separate scintillation counter placed at an angle of 30°. The targets were thin, self-supporting metallic foils, the isotopic composition of which is given in Table 1. The ratio of the measured cross section to the Rutherford cross section ($\sigma_{\text{exp}}/\sigma_{\text{res}}$) was found from normalization measurements of scattering on chromium isotopes at angles of 40, 50, and 60° by a relative method with respect to gold, for which, in our energy region, purely Coulomb scattering takes place. The intensity of the scattered protons was measured over the entire angular range with a statistical error not exceeding 3%.

Fig. 1. Angular distribution of elastically scattered protons of energy 6.9 ± 0.07 MeV by the isotopes Cr^{50}, Cr^{52}, Cr^{53}, Cr^{54} and Zn^{64}, Zn^{68}, Zn^{70}, in the form of the dependence of $\sigma_{\text{exp}}/\sigma_{\text{res}}$ on the angle θ (c.m.).

The results obtained by us are presented in Fig. 1; in the data on scattering by chromium the effect of isotopic impurities has been excluded.

The curves for the isotopes Cr^{52} and Cr^{53} are in qualitatively good agreement with the data of Ref. (4), but lie somewhat lower in the region of large angles, especially for Cr^{53}. This is connected with the insufficient energy resolution in the earlier measurements, as was pointed out in Ref. (4).

Scattering by Cr^{50} is considerably more intense at large angles than by Cr^{52}. We note that the threshold of the (p, n) reaction for Cr^{50} is 8.35 MeV, while for Cr^{52} it is 5.63 MeV. At an energy of 6.9 MeV, the process of elastic scattering of protons that have passed through the compound-nucleus stage gives a noticeable contribution to the total intensity of elastically scattered protons on Cr^{50}, whereas for Cr^{52} this process is appreciably suppressed by competing reactions, especially (p, n) (8). The heavier isotopes of chromium and zinc have thresholds for the (p, n) reaction substantially below the energy used by us. The scattering pattern for them is qualitatively the same and, as our calculations for the analysis of elastic proton scattering at an energy of 5.45 MeV (9) have shown, can be satisfactorily described by the optical model. However, in such a description, in order to bring into agreement the dependence of the positions of the extrema in the angular distribution on the mass number, it would be necessary to change noticeably the nuclear radius or the real part of the potential.

Attention should be drawn to the results for scattering by Zn^{64}. The threshold of the (p, n) reaction for this nucleus is 8 MeV. One might have expected a large increasing intensity of elastically scattered protons on this nucleus at large angles, by analogy with scattering by Cr^{50}. This, however, is not observed. At an energy of 6.9 MeV—1.1 MeV below the threshold of the (p, n) reaction—the scattering pattern is typically diffraction-like.

To explain such an "anomalous" angular dependence in the scattering

for Zn^{64}, it will be necessary to carry out a detailed investigation of the $Zn^{64}-p$ system over a wide energy range, with a study of elastic scattering and possible nuclear reactions.

In conclusion, the authors express their gratitude to the staff of the cyclotron laboratory, who made the measurements possible, to Wang Chen-lin for assistance in the measurements, and to V. N. Medyanik for the preparation of the isotopic targets.

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REFERENCES

1. R. A. Vanetsian, A. P. Klyucharev, E. D. Fedchenko, *Atomic Energy*, **6**, 661 (1959).

2. N. Ya. Rutkevich, V. Ya. Golovnya et al., DAN, **130**, 1008 (1960).

3. A. P. Klyucharev, N. Ya. Rutkevich, ZhETF, **38**, 286 (1960).

4. A. K. Valter, I. I. Zalyubovskii et al., ZhETF, **38**, 1419 (1960).

5. A. P. Klyucharev, *Izv. AN SSSR, Ser. Fiz.*, **24**, 887 (1960).

6. A. K. Valter, I. I. Zalyubovskii et al., ZhETF, **41**, 71 (1961).

7. I. Benveniste, R. Booth, A. Mitchell, *Phys. Rev.*, **123**, 1818 (1961).

8. A. P. Klyucharev, *Proc. of Intern. Conf. on Nucl. Structure*, Kingston, 1960, p. 169.

9. R. A. Vanetsian, A. P. Klyucharev et al., ZhETF, **40**, 1199 (1961).

10. R. Beurtey, P. Catillon et al., *Nucl. Phys.*, **13**, 347 (1959).

Note: Figure translations are in progress. See original paper for figures.