ELECTRON-SCATTERING STUDY OF THE CHANGE OF THE CHARGE RADII OF NUCLEI OF IRON AND NICKEL ISOTOPES

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The elastic scattering of electrons from $Fe^{54, 56, 58}$ and $Ni^{58, 62}$ was studied. An analysis in the high-energy approximation yielded the changes in the parameters of the Fermi distributions of the charges of these nuclei following addition of nucleons.

In an earlier study [1], we investigated the change of the parameters of the charge-density distribution in the isotopes $Ni^{58, 60, 64}$ and $Sn^{112, 118}$ and noted the connection between the change of the mean-square radius and the angular momenta of the added neutrons. It was therefore of considerable interest to study the behavior of the changes of the mean-square radii of the nuclei Ni^{58} and Ni^{62}, which has not been investigated earlier, and also of the isotopes $Fe^{54, 56, 58}$ which, unlike the nickel and tin isotopes, have an unfilled proton subshell. The nuclei Fe^{58} and Ni^{62} have not been investigated before with the aid of elastic scattering.

We measured the cross sections for elastic scattering of electrons having an initial energy 225.0 ± 0.2 MeV from the isotopes $Fe^{54, 56, 58}$ and $Ni^{58, 62}$ and determined the parameters c and t of the Fermi distribution and their changes Δc and Δt following addition of neutrons and protons. The measurements on Ni^{58} were made in order to reconcile the measurement data with the results of [1].

The experimental setup was described by us in [2].

The experimentally obtained cross sections were fitted by least squares to the theoretical cross sections calculated in the high-energy approximation with a Fermi charge-density distribution [3], and the parameters c and t were determined. For a more accurate determination of the changes of the parameters, Δc and Δt, the calculated curves were fitted to the experimental ratios

$$D_{exp} = [\sigma(A_1) - \sigma(A_2)] / [\sigma(A_1) + \sigma(A_2)],$$

where $\sigma(A_1)$ and $\sigma(A_2)$ are the values of the experimental scattering cross sections as functions of the scattering angles for the two nuclei whose parameter differences are being determined.

Figures 1 - 3 show the values of D as functions of the electron-scattering angles for the pairs Fe^{54} - Ni^{58}, Fe^{56} - Ni^{58}, and Ni^{58} - Ni^{62}. Besides the experimental points, the figures show the results of the best fitting of the calculated D to the experimental values. The increments Δc and Δt, obtained in this manner for the parameters of the Fermi distribution of the charge density are listed in the table [1]. The table also lists the changes of the mean-squared radius of the nucleus $\Delta\langle r^2\rangle^{1/2}$ and the quantity $\gamma = 3\Delta\langle r^2\rangle^{1/2}A/\langle r^2\rangle^{1/2}\Delta A$ [4], which characterizes the deviation of the radius from the $A^{1/3}$ law.

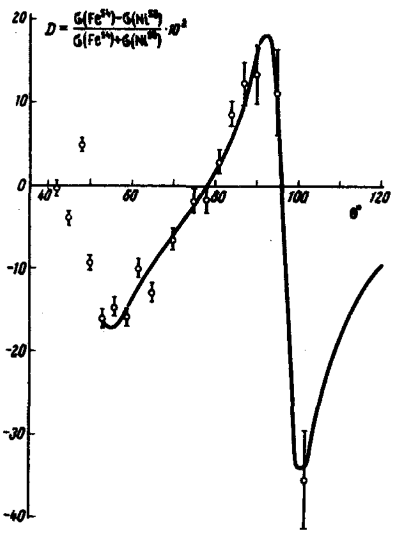

Fig. 1. Cross section ratio $D = [\sigma(Fe^{54}) - \sigma(Ni^{58})]/[\sigma(Fe^{54} + \sigma(Ni^{58})]$ vs. the scattering angle. Solid curve - best fit of the calculated cross section ratio to the experimental points.

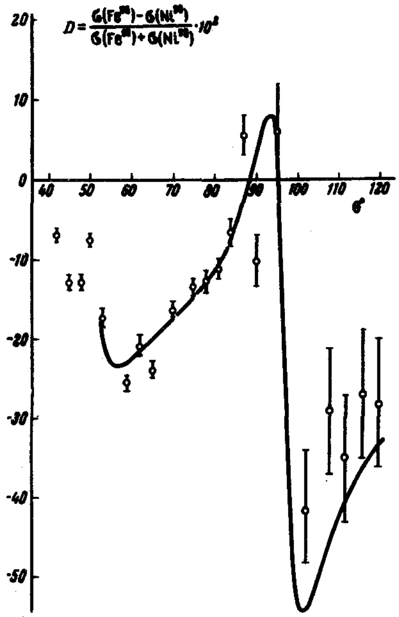

Fig. 2. The same as in Fig. 1, but for $Fe^{56} - Ni^{58}$.

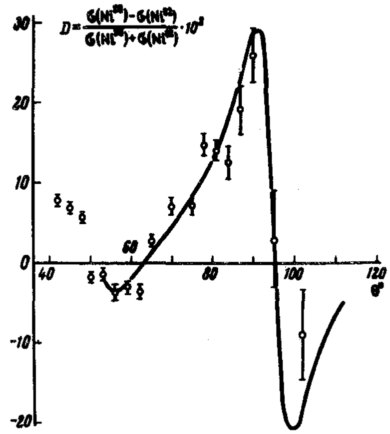

Fig. 3. The same as in Fig. 1, but for $Ni^{58} - Ni^{62}$.

Increment of the parameters of the Fermi distribution of the charge density c and t, of the mean-squared radius, and of the value of γ. The following charge-distribution parameters were used for Ni^{58} [1]: c = 4.140 ± 0.017 F, t = 2.46 ± 0.02 F, and $\langle r^2\rangle^{1/2}$ = 3.820 ± 0.014 F.

	$Ni^{58} - Fe^{54}$	$Ni^{58} - Fe^{56}$	$Ni^{58} - Fe^{58}$	$Ni^{62} - Ni^{58}$	$Fe^{56} - Fe^{54}$	$Fe^{58} - Fe^{56}$
Δc, F	0.064±0.008	0.107 ±0.014	0.005 ±0.014	0.081 ±0.009	−0.052 ±0.017	0.092 ±0.020
Δt, F	0.010 ±0.013	−0.200 ±0.019	−0.071 ±0.018	0.028 ±0.014	0.280 ± 0.020	−0.114 ±0.026
$\Delta\langle r^2\rangle^{1/2}$, F	0.050 ±0.008	−0.022 ±0.013	−0.025 ±0.012	0.061 ±0.008	0.069 ±0.014	0.004 ± 0.018
γ	0.54 ±0.09	−0.48 ± 0.28	—	0.68 ±0.09	1.50 ± 0.30	0.08 ± 0.39

It is seen from the table that the isotopic shift γ for the nuclei $Ni^{58} - Ni^{62}$ is equal to 0.68 ± 0.09. Such a change agrees with the hypothesis of the angular momenta [1], for on going from the nucleus Ni^{58} to the nucleus Ni^{62}, in accordance with the shell model, two of the nuetrons, which enter in the $2p_{3/2}$ state, should change charge in accordance with the $A^{1/3}$ law (γ = 1), and the other two, which enter in the $1f_{5/2}$ state, give $\gamma \simeq 0.5$. In the mean, we should have obtained $\gamma \simeq 0.75$ on going from Ni^{58} to Ni^{62}.

The value γ = 0.68 ± 0.09 obtained by us is in good agreement with the results of an experiment with μ-mesic atoms (γ = 0.69 ± 0.06) [5]. The change of the radius on going from Fe^{54} to Fe^{56} is characterized by γ = 1.5 ± 0.3, and by γ = 0.08 ± 0.39 on going from Fe^{56} to Fe^{58}. Starting from the hypothesis that the changes of the charge radii are connected with the angular momenta

[1], we should expect $\gamma = 1$ for both $Fe^{54} - Fe^{56}$ and $Fe^{56} - Fe^{58}$. We see that this is in poor agreement with the experimentally obtained values. This may be due to the fact that the $1f_{7/2}$ proton subshell of the iron isotopes, unlike that of the nickel isotopes, is not filled. Experiments with μ-mesic atoms [5] yielded $\gamma = 0.94 \pm 0.05$ for $Fe^{54} - Fe^{56}$. This value differs from that obtained by us, but also indicates a strong change of the radius.

On going from the nuclei $Fe^{56,58}$ to Ni^{58}, the increments of the mean-square radii turn out to be negative. This decrease of the mean-square radius is apparently due to the fact that the state $1f_{7/2}$ is completely filled in the Ni^{58} nucleus, which becomes more compact.

It is of interest to compare our data with the results of measurements of the relative radii of the interaction of protons with the isotopes of Fe and Ni [6], which turned out to be 13.7 ± 0.7, 15.5 ± 0.6, 15.8 ± 0.6, 15.1 ± 0.6, and 17.6 ± 0.9 F for Fe^{54}, Fe^{56}, Fe^{58}, Ni^{58}, and Ni^{62}, respectively. We see that the behavior of the changes of the charge radii and of the interaction radii is qualitatively the same for these nuclei. It is interesting that the interaction radius for Ni^{58}, like the charge radius, is smaller than for Fe^{56} and Fe^{58}, thus indicating that filling of the proton shell exerts an influence on the mass radius of the nucleus.

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RESONANT CHARACTER OF THE CHANGE OF THE SURFACE SELF-DIFFUSION ENERGY OF TUNGSTEN IN STRONG ELECTRIC FIELDS

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According to the present notions, the influence of an external electric field on the diffusion of atoms in their own lattice reduces to a lowering of the surface-diffusion energy as a result of the interaction of the induced dipoles with the external field. According to Drechsler, the decrease of the energy is given by

$$\Delta Q_M = \alpha F^2/2 \quad , \tag{1}$$

where α is the polarizability of the atoms on the surface and F is the applied field. The expected change in the energy of diffusion of tungsten over tungsten, in observable fields (-3 × 10^7 to 3 × 10^7 V/cm), at a polarizability $\alpha = 7 \times 10^{-24}$ cm³ [1], amounts to $\Delta Q_M = 0.044$ eV.