ELASTIC SCATTERING OF ELECTRONS BY NICKEL AND TIN ISOTOPES

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Submitted 13 August 1968
ZhETF Pis. Red. 8, No. 8, 420 - 424 (20 October 1968)

We measured the elastic scattering of 225-MeV electrons by the isotopes $Ni^{58,60,64}$ and $Sn^{112,118}$ for the purpose of determining the influence of the neutrons on the charge distribution. The choice of these nuclei was governed by the fact that tin is magic with respect to the number of protons (Z + 50), and nickel has a subshell $1f_{7/2}$ completely filled with protons (Z = 28).

The experiment was performed with the linear electron accelerator of our institute, using an experimental setup described by us earlier [1]. The targets were metallic foils with the following enrichment: Ni^{58} - 96.8%, Ni^{60} - 95.1%, Ni^{64} - 90.3%, Sn^{112} - 80.6%, and Sn^{118} - 96.1%. The target thicknesses were 380 mg/cm^2 and 251 mg/cm^2 for the nickel and tin isotopes, respectively (about 0.03 radiation length). The measurements were made with successive alternation of the targets at one and the same angle.

The experimental data were analyzed within the framework of the high-energy approximation with a Fermi charge-density distribution in the form [2]

$$\rho(r) = \rho_0 \{1 + \exp[4.4(r - c)/t]\}^{-1}.$$

Matching of the theoretical curves to the experimental cross sections yielded the parameters and of the charge distribution for Ni^{58} and Sn^{112} (see the table). Figure 1 shows a comparison of the absolute experimental cross section for Ni^{58} with the theoretical one. The comparison was made for angles $\theta \geq 55°$, since the analysis method is subject to limitations on the side of small momentum transfers.

In order to discern the smallest possible differences in the charge distribution parameters, we analyzed the quantity

$$D_{exp}(\Delta C, \Delta t) = [\sigma_\ell - \sigma_h]/[\sigma_\ell + \sigma_h],$$

which was obtained from the experimental results, where σ_ℓ - cross section for the light isotope and σ_h - cross section for the heavy isotope of the same element. The experimental values of D_{exp} were fitted to the theoretical curves, and the charge-distribution parameters for the heavy isotope were found in the form $c + \Delta c$ and $t + \Delta t$, where c and t are the charge distribution parameters of the light isotope.

Figure 2 is a plot of D_{exp} for the Ni^{64} - Ni^{58} pair. The solid line is the theoretical curve with the best values of Δc and Δt. A similar reduction of the experimental data was performed for the isotope pairs Ni^{60} - Ni^{58}, Ni^{64} - Ni^{60}, and Sn^{118} - Sn^{112}. The obtained values of c and t are listed in the table. Positive values of Δc and Δt signify that an increase takes place in the radius of the density decay curve and of the surface thickness in the heavy isotope.

The available exact measurement data on the isotopic shifts for the isotope pair Ni^{60} - Ni^{58} (3.23 ± 0.14 keV) [3] agree well with calculations obtained from the results of our experiment (3.6 keV).

We calculated $\gamma = 3A\delta R/R\delta A$, which characterizes the deviation of the radius of the equivalent homogeneous distribution from the value $R = r_0 A^{1/3}$ [4] when neutrons are added to the nucleus. It is seen from the table that two neutrons added to Ni^{58} (these neutrons have an orbital angular momentum $\ell = 1$ and fill the neutron subshell $2p_{3/2}$) increase the charge radius practically in proportion to $A^{1/3}$($\gamma = 0.88 \pm 0.26 \approx 1$). The next 4 neutrons added to Ni^{60} (with orbital momentum $\ell = 3$, starting to fill the $1f_{5/2}$ subshell) increase the charge radius much less rapidly than in proportion to $A^{1/3}$($\gamma = 0.51 \pm 0.19 \approx 0.5$). This effect can possibly be explained by assuming that these 4 neutrons stay only part of the time (approxi-

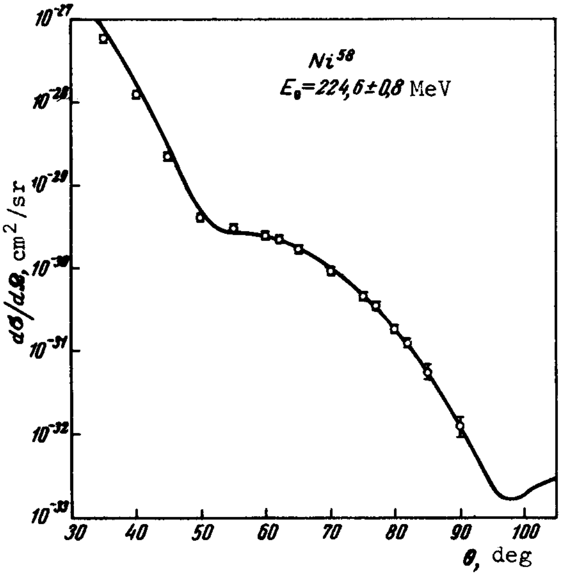

Fig. 1. Differential cross section of elastic scattering of electrons by the Ni^{58} nucleus. Solid line - best theoretical curve, calculated by the method of [2]. The fitting was carried out for the angles $\theta \geq 55°$. The total errors are marked on the experimental points.

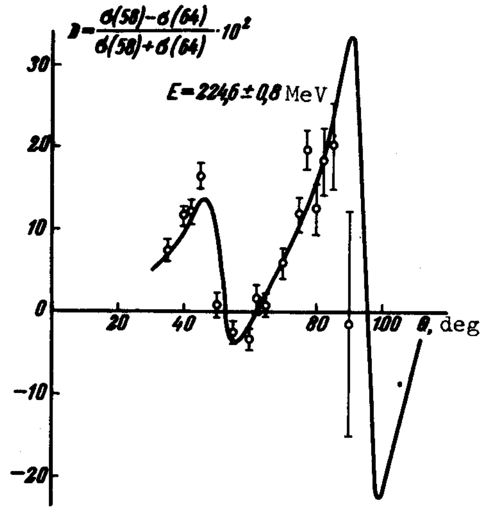

Fig. 2. Cross section ratio $D = [\sigma(58) - \sigma(64)]/[\sigma(58) + \sigma(64)]$ for the isotopes Ni^{58} and Ni^{64} as a function of the angle. Solid line - best theoretical curve, calculated by the method of [2]. Only statistical errors are taken into account and indicated in the figure.

Parameters c, t, and R of the charge distribution for the Fermi model in tin and nickel isotopes. γ - quantity characterizing the deviation of the radius R of the equivalent homogeneous distribution from $A^{1/3}$ when neutrons are added to the nucleus.

Nuclei	c, F	t, F	R, F
Ni^{58}	4.140 ± 0.017	2.46 ± 0.02	4,940
Sn^{112}	5.375 ± 0.026	2.46 ± 0.045	6.009

	Δc, F	Δt, F	ΔR, F	γ
$Ni^{60} - Ni^{58}$	0.062 ± 0.018	0.000 ± 0.023	0.051	0.88 ± 0.26
$Ni^{64} - Ni^{60}$	0.044 ± 0.016	0.026 ± 0.020	0.055	0.51 ± 0.19
$Ni^{64} - Ni^{58}$	0.095 ± 0.018	0.045 ± 0.021	0.106	0.62 ± 0,12
$Sn^{118} - Sn^{112}$	0.021 ± 0.020	0.000 ± 0.030	0.019	0.18 ± 0.17

mately one half) in the region occupied by the protons, and are located during the rest of the time on the surface of the nucleus.

It is of interest to compare our results of measurement of the charge radii with the results of measurements of the radii of proton interactions with nickel isotopes [5], where interaction radii 15.1 ± 0.5, 17.6 ± 0.9, and 17.6 ± 0.9 F were obtained for Ni^{58}, Ni^{62}, and Ni^{64} respectively. In this case the two neutrons of the $2p_{3/2}$ subshell have little effect on the interaction radius, but then the next four neutrons do alter it strongly. The two experiments can be qualitatively reconciled by assuming that the neutrons of the $1f_{5/2}$ subshell lie on the surface of the nucleus, outside the proton-occupied shell.

According to the shell model, on going from Sn^{112} to Sn^{118} the additional two neutrons with $\ell = 4$ fill the neutron subshell $1g_{7/2}$, and the remaining four with $\ell = 5$ begin to fill the new subshell $1h_{11/2}$. Our results show that these six neutrons added to Sn^{112} exert no noticeable influence on the charge radius ($\gamma = 0.18 \pm 0.17 \approx 0$) and therefore probably spend most of the time on the surface of the nucleus.

We thus note a clear-cut correlation between the change of the charge radius in the isotopes and the orbital angular momenta (or the filling of the neutron subshells) of the added neutrons. Addition of neutrons with small orbital angular momenta (which in the case of nickel is accompanied by filling of the subshell) leads to an increase of the charge radius approximately in proportion to $A^{1/3}$, and addition of neutrons with equal (in the case of nickel) or larger angular momentum (Sn) leads to a much smaller increase of the charge radius.

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