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NUCLEON DISTRIBUTION IN THE NUCLEI $\mathrm{Cr}^{50,\,52,\,54}$, $\mathrm{Fe}^{54,\,56}$, and $\mathrm{Ni}^{58,\,60,\,62,\,64}$

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The recently published reformulated optical model of Greenlees et al. [1] relates the real part of the central potential with the distribution of nuclear matter and the potential of the nucleon-nucleon interaction. Assuming functional forms of the nucleon-density distribution in the nucleus and the potential of the two-particle interaction, it is possible to obtain from an analysis of the experimental differential cross sections for elastic scattering of the protons the values of the rms density-distribution radius of the nuclear matter and of the volume integral of the real part of the central potential. It has been shown [1 - 2] that these quantities provide definite radial and dynamic information that does not depend on individual values of the model parameters within a range of reasonable values of the rms deviation of the calculated curve from the experimental dependence.

Using the proton-density parameters that are obtained with good accuracy in experiments on the scattering of electrons and on the spectra of transitions in mesic atoms, it is possible to obtain information on the distribution of the neutrons in the investigated nuclei.

We measured the differential cross sections for elastic scattering of 9.6-MeV protons by $\mathrm{Cr}^{50,\,52,\,54}$, $\mathrm{Fe}^{54,\,56}$, and $\mathrm{Ni}^{58,\,60,\,62,\,64}$ in the angle range 15 - 170°. The experimental and analysis procedures are described in [3]. Figures 1 and 2 show the rms radii of the distribution of nuclear matter $\langle r^2\rangle_m^{1/2}$ and of the neutrons $\langle r^2\rangle_n^{1/2}$ obtained as a result of an analysis based on the reformulated optical model. Figure 2 shows also the rms charge-distribution radii obtained by investigating the scattering of 225-MeV electrons by $\mathrm{Ni}^{58,\,60,\,62,\,64}$ [4, 5]. It is of interest to compare the change of the charge and nuclear-matter distribution parameters obtained in the present case for isotope nuclei.

Khvastunov et al. [4] relate the change of the rms radii of the charge distribution with the values of the angular momenta of the added neutrons, but with account taken in this case of the influence of the residual interactions. Since the investigated nuclei Fe and Ni are deformed, the process of filling the nucleon shells should lead to a charge in the residual interactions due to the pair interactions.

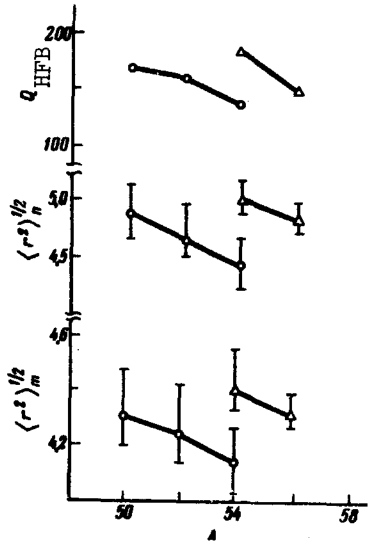

Fig. 1. Change of rms distribution radii of the density of nuclear matter $\langle r^2\rangle_m^{1/2}$, of the neutrons $\langle r^2\rangle_n^{1/2}$, and of the internal quadrupole moments, calculated by the HFB method, of axially deformed states of the nuclei $\mathrm{Cr}^{50,\,52,\,54}$ and $\mathrm{Fe}^{54,\,56}$ with filling of the neutron shells. The lengths are in Fermi units and the quadrupole moments in Fermi units squared.

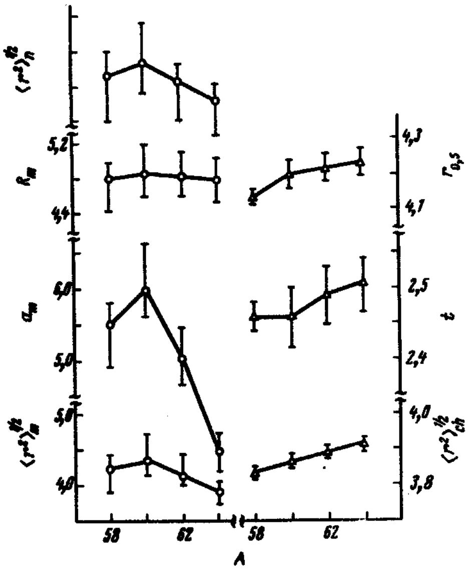

Fig. 2. Dependence of the parameters of the distribution of the charge, of the nuclear matter, and of the neutrons on the mass number for the nuclei $Ni^{58, 60, 62}$. R_m, a_m - parameters of nuclear-matter distribution for the Woods-Saxon form factor, $r_{0.5}$ and t - the analogous quantities for the charge distribution, $\langle r^2\rangle_{ch}^{1/2}$, $\langle r^2\rangle_m^{1/2}$, and $\langle r^2\rangle_n^{1/2}$ - rms radii of the distributions of the charge, nuclear matter, and neutrons (in Fermi units).

It is well known [6] that the residual interactions strive to retain the spherical shape of the nucleus on moving away from closed shells. This is apparently why Litvinenko et al. [5] obtained for Fe and Ni a result that does not agree well with the angular-momentum hypothesis proposed by the authors. Figure 1 shows the values of the internal quadrupole moments Q_{HFB} of the axially-deformed states of nuclei, calculated by the Hartree-Fock-Bogolyubov (HFB) method, using the Elliott nucleon-nucleon interaction [7]. A correlation is observed between Q_{HFB}, $\langle r^2\rangle_m^{1/2}$, and $\langle r^2\rangle_n^{1/2}$ for the nuclei $Cr^{50, 52, 54}$ and $Fe^{54, 56}$. For the nuclei $Cr^{50, 52, 54}$ the protons manifest a small pairing effect, whereas paired interactions of the neutrons increases in a ratio 1:1.27:1.98, respectively, leading to a more spherical form of the nucleus with increasing number of neutrons [7].

For the Fe^{54} nucleus, the pair correlations are weak for both protons and neutrons, but they become quite appreciable for the nucleus Fe^{56}. From this point of view, the Ni nuclei manifest a certain peculiarity. The rms charge radii $\langle r^2\rangle_{ch}^{1/2}$ for the Ni nuclei increase monotonically with increasing number of neutrons (see Fig. 2, right-hand side), and the analogous quantity for the distributions of the nuclear matter and neutrons has a tendency to decrease when two neutrons are added to Ni^{60}. The charge-distribution diffuseness parameter t changes little for the nuclei $Ni^{58, 60}$ and increases for $Ni^{62, 64}$. The diffuseness parameter for the distribution of nuclear matter decreases noticeably for Ni^{62}.

Our results agree with the calculation of the structure of the nuclei $Ni^{58, 60, 62, 64}$ by the HFB method [7], and exhibit the characteristic features of the relation between the pair correlation and the self-consistent field. According to these calculations, the nuclei $Ni^{58, 60}$ have a sharp Fermi surface for protons and a diffuse one for neutrons. The addition of two neutrons to Ni^{60} changes the self-consistent field to such a degree that the internal deformation decreases by ∿35%, leading to a "smearing" of the Fermi surface for the protons, and the surface of the neutron distribution becomes sharper. This result casts light on the hypothesis that the $1f_{7/2}$ shell is closed for protons. Our results for Cr^{52} and Fe^{54} qualitatively supplement the conclusions of [8], where it is stated that the $1f_{7/2}$ neutron shell is ∿70% closed. The general behavior of the rms distribution radii of the nuclear matter with changing mass number, which agrees with the HFB calculations of the structure of atomic nuclei, apparently offers evidence of the propagation of the neutrons beyond the limits of the proton distribution.

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NUCLEAR MAGNETIC RESONANCE OF Fe^{57} IN $FeBO_3$ SINGLE CRYSTALS

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The recently synthesized compound $FeBO_3$ [1, 2] is a ferromagnet transparent in the visible region, with a Neel temperature $T_N = 348°K$. Its structure is rhombohedral and the magnetic anisotropy is of the "easy plane" type.

We present here a report of the first observation of nuclear magnetic resonance (NMR) in the hyperfine fields of single-crystal $FeBO_3$ on Fe^{57} nuclei. The crystals were not artificially enriched with Fe^{57} during their synthesis.

The sample comprised a large number of arbitrarily oriented single-crystal plates grown by the method of spontaneous crystallization from the solution in the melt [3]. The NMR signals were registered by the method of spin echo and free precession in the temperature range 4.2 - 300°K. The measured values of the NMR gain η and of the relaxation times T_1, T_2, and T_2^* are listed in the table.

T, °K	Resonant frequency ν_0, MHz	Field at nuclei H_n, kOe	NMR gain, η	Relax. times			Resonant line width	
				T_1, msec	T_2, msec	T_2^* μsec	$\Delta\nu = \frac{1}{2\pi T_2^*}$, kHz	ΔH, Oe
77,0	75,48	549	$0,12 \cdot 10^6$	3,3	1,2	67	2,4	17.5
63,0	75,93	551	$0,22 \cdot 10^6$	–	–	–	–	–
4,2	76,45	555	$0,25 \cdot 10^5$	10	2,9	68	2,3	17,0

An essential feature of the NMR in the $FeBO_3$ is the anomalously large gain of the NMR, reaching $\eta = 0.22 \times 10^6$ at $T = 63°K$. The average gain was measured by the method of spin precession and spin echo under the assumption that the signals reach a maximum at the resonant frequency if $\gamma_n H_x \eta \tau = \pi/2$ and $\gamma_n H_x \eta \tau = 2\pi/3$, respectively. Here γ_n is the gyromagnetic ratio, H_x the rotating component of the exciting pulse, and τ the duration of this pulse. Such large values of η can be explained in the following manner. The gain connected with the rotation of the magnetization in the domain in a zero external field is $\eta_{rot} \sim H_n/H_a$, where H_n is the hyperfine field and H_a the anisotropy field. In the