MOSSBAUER EFFECT AT Sn^{114} NUCLEI INTRODUCED INTO YTTRIUM IRON GARNET LATTICE

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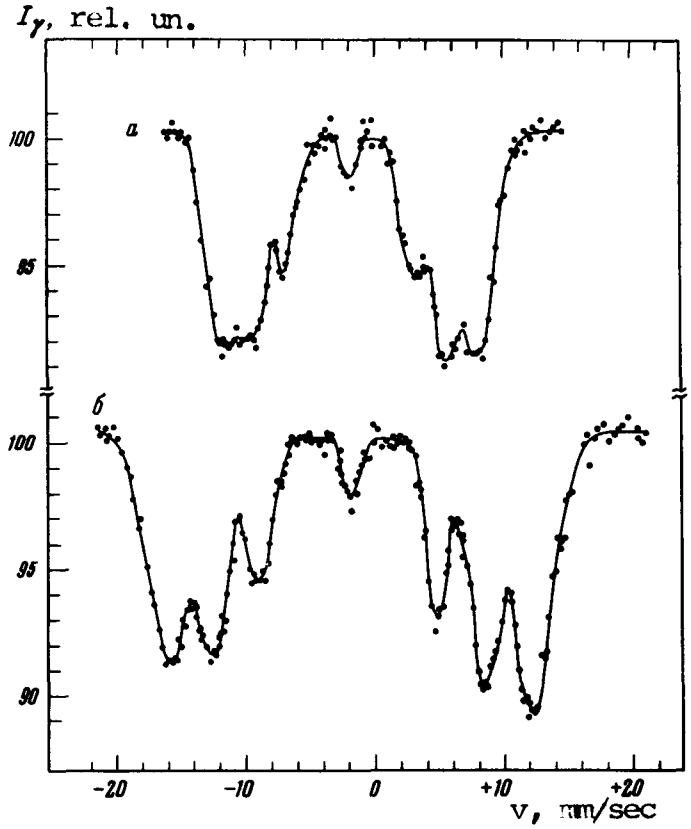
To understand the mechanism of the occurrence of effective magnetic fields H_{ef} in nuclei, it is of interest to investigate the H_{ef} of paramagnetic-ion nuclei introduced into ferromagnetic, ferrimagnetic, and antiferromagnetic matrices. It was observed in recent years that nuclei of such ions are under the influence of strong internal magnetic fields[1-3]. Great interest is attached to the study of ferrodielectrics, in which the conduction electrons make no contribution to H_{ef} of the nonmagnetic-ion nucleus.

We have prepared an yttrium iron garnet $Ca_{0.3}Y_{2.7}Sn_{0.3}Fe_{4.7}O_{12}$, in which the Fe^{3+} ions were replaced by Sn^{4+} ions. The resistance of the YIG is on the order of 10^{10} - 10^{12} ohm-cm, i.e., it can be regarded as a dielectric.

The source of 23.8-keV gamma radiation was Sn^{119} in Mg_2Sn. Powdered active Mg_2Sn was deposited on a copper substrate; the thickness of the radioactive layer was 6.5 mg/cm^2. The choice of a source in the form of the compound Mg_2Sn is important in such measurements because the emission line width is close to the natural width for such a compound[4], affording better resolution of the hyperfine splitting of the absorption-spectrum lines. Experiments with Mg_2Sn absorbers 5.2 mg/cm^2 thick yielded a value of 0.7 mm/sec for Γ^{exp} of the absorber at room temperature, in good agreement with the data of Bryukhanov et al.[4] The absorber was prepared by depositing powdered ferrite $Ca_{0.3}Y_{2.7}Sn_{0.3}Fe_{4.7}O_{12}$ on aluminum foil. The absorber thickness was 54 mg/cm^2. This iron garnet was prepared from SnO_2 enriched to 87% of Sn^{119}. In our experiments the source was at the temperature of liquid nitrogen. The absorber was set in motion relative to the source by means of a cam mechanism. Positive velocity corresponded to motion of the absorber towards the source.

Both at room and at liquid-nitrogen temperature the absorption spectrum consists of six components (see the figure).



Absorption spectrum for an absorber of $Ca_{0.3}Y_{2.7}Sn_{0.3}Fe_{4.7}O_{12}$ 54 mg/cm^2 thick: a - at room temperature, b - at liquid nitrogen temperature (abscissas - absorber velocity, ordinates - intensity of gamma-quantum flux; the number of pulses at each point of the spectrum is approximately 10^5).

In addition, a small peak is observed in the center of the spectrum, possibly due either to a small amount of non-reacting SnO_2 or to formation of a $CaSnO_3$ phase with perovskite structure. This is evidenced by the magnitude of the chemical shift of this peak relative to the emission line, -1.85 mm/sec (the width of the peak is approximately 1.5 mm/sec)[4, 5]. We present below the values of H_{ef}, the quadrupole splitting ε, and the chemical shift δ for 80° and 295°K:

	T = 80°K	T = 295°K
H_{ef}, kOe	210.5 ± 2	152 ± 3
ε, mm/sec	0.17 ± 0.05	0.0 ± 0.1
δ, mm/sec	-1.9 ± 0.1	-1.9 ± 0.1

The value of H_{ef} was calculated from the splitting of the ground state. The magnetic moment of the ground state of Sn^{119} was assumed to be -1.041 nuc. magnetons.

It follows from this conclusion that the magnetic fields at the tin nuclei in the investigated iron garnet reach large values. Watson and Freeman[6] proposed that the occurrence of the effective fields at the nuclei of nonmagnetic ions may be due to the following mechanisms: 1) admixture of spin density of 3d-electrons from the ferromagnetic ion in the filled compensated shells of the nonmagnetic ions leads to uncompensation of the latter, and this makes a definite contribution to H_{ef}; 2) the nonmagnetic ion is polarized by the exchange field of the magnetic electrons of the ferromagnetic ions, and this leads to uncompensation of the s-electrons, which then cause, as a result of the contact Fermi interaction, the occurrence of H_{ef} at the nucleus; 3) the conduction electrons may become polarized in the magnetic matrix, and this polarization leads, via the contact Fermi term, to the appearance of H_{ef} at the nucleus.

We have found that for the investigated sample the values of the chemical shifts are the same for both temperatures, and are equal, within the limits of error, to the value of the chemical shift of the absorption line for SnO_2 relative to the emission line in Mg_2Sn[4]. This may be evidence that the electron density at the nucleus of the tin atom in the iron garnet has not changed compared with the density of the electrons at the Sn atom in SnO_2, i.e., in our case mechanism 1) can be eliminated as a cause of H_{ef} at the tin nuclei. Mechanism 3) is likewise eliminated, since our iron garnet is dielectric. Thus, within the framework of the Watson-Freeman model, we can conclude that the field H_{ef} at the tin nuclei in yttrium iron garnet is due to polarization of the electronic core of the tin atom by the exchange fields of the 3d-electrons of the iron atoms [mechanism 2)]. This conclusion is also confirmed by the fact that the magnitude of the ratio $H_{ef}(80^\circ K)/H_{ef}(295^\circ K)$ coincides with the ratio $\sigma_s(80^\circ K)/\sigma_s(295^\circ K)$ of the magnetizations at these temperatures, and amounts to ~ 1.4 (the spontaneous magnetization of the investigated iron garnet was measured by us earlier[7]).

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SUPER-EXCHANGE INDUCTION OF MAGNETIC FIELDS AT THE NUCLEI OF NONMAGNETIC ATOMS

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We report here the experimental observation of indirect exchange induction of magnetic fields at nuclei of nonmagnetic atoms.

The investigations made to date have shown that magnetic fields can be induced at nuclei of diamagnetic atoms either upon direct interaction of these atoms with the magnetic atoms (ions), or via the conduction electrons. We cite as examples the occurrence of magnetic fields at diamagnetic nuclei dissolved in ferromagnets (a phenomenon discovered by B. N. Samoilov, V. V. Sklyarevskii, and E. P. Stepanov[1]) and at fluorine nuclei in transition-metal salts[2]. The Mossbauer effect was recently used to observe also interaction between paramagnetic atoms via the induction electrons, leading to the occurrence of antiferromagnetism of strongly diluted solutions of iron in gold.[3, 4]

The induction of magnetic fields at nuclei by indirect exchange interaction was observed only as the consequence of the ordering of electron spins