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

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Original submitted 15 February 1965.

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

for nuclei of magnetic atoms, for example, for iron nuclei in ferrites.

Our results prove that magnetic fields are produced at nuclei of non-magnetic Sn^{119} atoms introduced into an iron-garnet structure with general chemical formula $Y_{3-x}Ca_xSn_xFe_{5-x}O_{12}$. Magnetic and crystallographic investigations of this system indicate that at low tin concentrations practically all the Sn atoms occupy octahedral sites, and the structural formula of the composition has in the conventional notation the form[5]:

$$\{Y_{3-x}Ca_x\}[Sn_xFe_{2-x}](Fe_3)O_{12}.$$

The ferrite was prepared by the usual technique of sintering the component oxides.

Investigations with the aid of nuclear gamma resonance (Mossbauer effect) yield, for example for a sample with x = 0.25, a distinct picture of hyperfine magnetic splitting of the ground and first excited states of the Sn^{119} nuclei (Fig. 1).

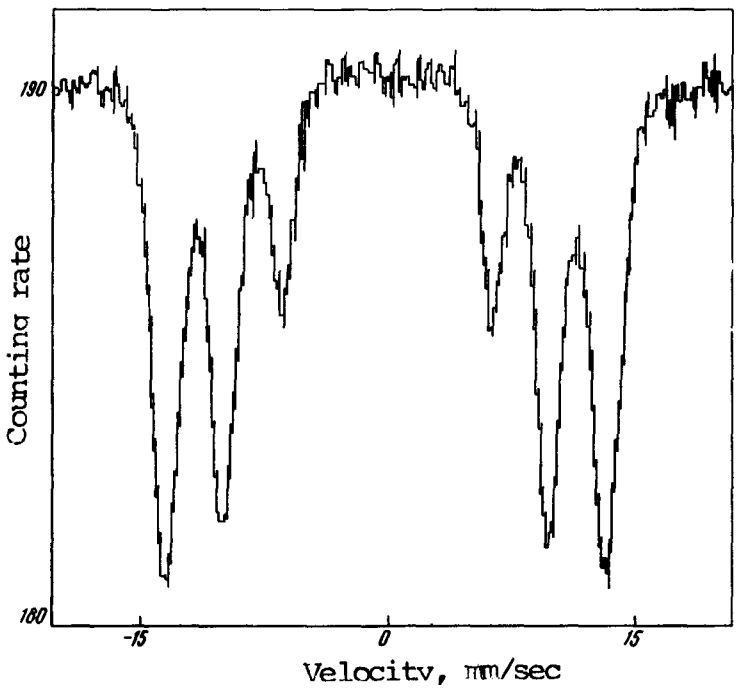

Figure 1. Mossbauer spectrum of the garnet $\{Y_{3-x}Ca_x\}[Sn_xFe_{2-x}](Fe_3)O_{12}$ (with x = 0.25) for tin. Temperature 77°K. The ordinates reperesent the number of counts (in thousands).

In this system the interaction between the Sn ions and the magnetic iron ions is apparently produced by the mechanism of indirect exchange via the oxygen ions, and such an indirect exchange induces at the tin nuclei rather large magnetic fields, exceeding 200 kOe at t = -196°C. The fact that there is no chemical shift of the center of gravity of the spectrum relative to the $Sn^{119}O_2$ source is evidence against the direct interaction of the tin and iron atoms (the chemical shift of Sn in Fe would be about 1.6 mm/sec[6]).

The gamma-resonance spectrum for iron (obtained with a Co^{57} source in chromium) has a fine structure typical of the two sublattices of yttrium iron garnet, with two values of magnetic fields at the iron. The values of the magnetic fields at the Sn^{119} and Fe^{57} nuclei in the two sublattices at various temperatures are shown in Fig. 2.

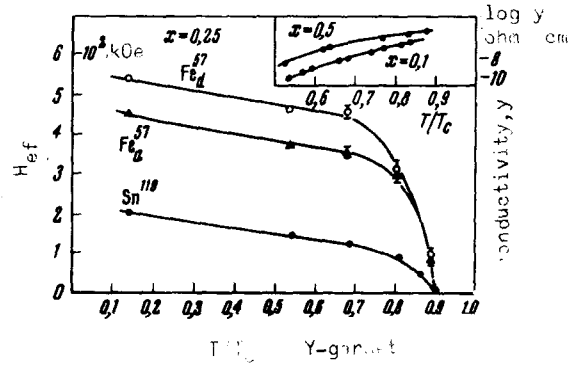

Figure 2. Temperature dependence of the magnetic field at the iron nuclei (in the two sublattices d and a) and at the tin nuclei for x = 0.25, and also of the garnet conductivity (at various values of x). The temperature is given in fractions of the Curie temperature T_C = 273°C of yttrium garnet (x = 0).

It is obvious that with increasing temperature the magnetic field at the Sn^{119} nuclei decreases simultaneously with the decreasing field at the Fe^{57} nuclei and disappears completely when the iron ions go over into the paramagnetic state. The same figure shows the temperature dependence of the conductivity for two ferrite samples with lower and higher tin content. We note that the conductivity is quite small and furthermore increases with increasing temperature, whereas the magnetic field on the iron and tin nuclei

increases at the same time.

The magnetic moment of the first excited state of Sn^{119}, calculated from the obtained nuclear gamma-resonance spectra, is 0.67 ± 0.01 nuc. magnetons, in agreement with the data of [6].

The authors are sincerely grateful for very useful discussion to Yu. M. Kagan, who previously called attention to the importance of experiments on the polarization of nuclei in a ferrodielectric matrix[7]. It is also a pleasure to thank E. F. Makarov for help with the work, S. S. Kurochkin for the use of the 2048-channel analyzer with which the spectra could be obtained with high resolution, and E. L. Frankevich for help with measuring the conductivity of the samples.

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ISOTOPIC EFFECT IN THE FERROELECTRIC $NaH_3(SeO_3)_2$

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The ferroelectric properties of sodium hydroselenite $NaH_3(SeO_3)_2$ (Curie point $T_c = -79^\circ C$) were investigated by Pepinsky and Vadam[1, 2]. Of great interest in explaining the nature of the spontaneous polarization in this compound is the isotopic effect when the hydrogen is replaced with deuterium.

We report here the results of a study of the temperature dependence of the dielectric constant of powdered samples of $NaD_3(SeO_3)_2$.