EFFECTIVE MAGNETIC FIELDS AT TIN NUCLEI IN SUBSTITUTED IRON GARNETS $Ca_xY_{3-x}Sn_xFe_{5-x}O_{12}$

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The Mössbauer effect of Sn^{119} nuclei, introduced into the lattice of substituted yttrium iron garnets, was investigated. It was found that the nuclei of tin ions, located in the octahedral ferrite sublattice, were acted upon by a strong effective magnetic field H_{eff}, which was evidently due to the polarization of the electron core of tin ions by the exchange field of iron ions. For small values of x ($x \lesssim 0.7$), H_{eff} in the $Y_{3-x}Ca_xFe_{5-x}Sn_xO_{12}$ system was due to the simultaneous influence of the a—a and a—d exchange interactions, but for large values of x ($x \gtrsim 0.7$), H_{eff} was mainly due to the a—d interaction.

RECENTLY,[1] we discovered that the nuclei of nonmagnetic tin, located in the iron garnet $Ca_{0.3}Y_{2.7}Sn_{0.3}Fe_{4.7}O_{12}$, were acted upon by a strong internal effective magnetic field (H_{eff} = 211 kOe). We concluded that this field was due to the polarization of the electron core of the tin atoms by the exchange field of the 3d-electrons of the iron atoms.[1]

In the iron garnet system $Ca_xY_{3-x}Sn_xFe_{5-x}O_{12}$, the Sn^{4+} ions, which replace iron ions, are mainly located in the octahedral sublattice a up to x = 1.5,[2,3] and this weakens the exchange interaction within that sublattice (the a—a interaction). It is interesting to investigate how the value of H_{eff} at tin nuclei in the a-sublattice varies as x is increased: whether it is proportional to the magnetic moment of the sublattice a only or whether it is proportional to the resultant magnetic moment of the ferrite, associated with the exchange interaction between the octahedral and tetrahedral (d) iron sublattices (the a—d interaction). The ferrite system $Ca_xY_{3-x}Sn_xFe_{5-x}O_{12}$ lends itself to the solution of this problem because the magnetic moment of the a-sublattice decreases when there is an increase in x, while the resultant magnetic moment of the ferrite increases, passing through a maximum at $x \approx 0.55$.[2,3]

We measured the Mössbauer effect in Sn^{119} nuclei in substituted iron garnets $Ca_xY_{3-x}Sn_xFe_{5-x}O_{12}$ ($0 < x \leq 3$), whose magnetic properties we investigated in detail earlier.[3,4]

The experimental conditions were the same as in [1]. The source of 23.8-keV γ-quanta, in the form of the compound Mg_2Sn, was kept at the temperature of liquid nitrogen. The absorbers, in the form of the investigated iron garnets, contained tin enriched, from 50 to 87%, with the Sn^{119} isotope.

Figure 1 shows the Mössbauer spectra of the iron garnet system $Ca_xY_{3-x}Sn_xFe_{5-x}O_{12}$ for various values of x, recorded at the temperature of liquid nitrogen. The value of the chemical shift was, within the limits of the experimental error, the same for all the investigated compositions and temperatures and it amounted to ≈ -1.85 mm/sec (cf. [1]).[1)]

Figure 2 shows the dependence on x of the field H_{eff}, acting on tin nuclei at 77°K. The same figure gives the dependence of the spontaneous magnetization σ_S (at 77°K) on x [3] and the values of the magnetization σ_0 (at 0°K) of the a-sublattice, calculated in accordance with Néel's scheme. It is evident that at low values of x, H_{eff} does not decrease as rapidly as the magnetization σ_0 of the a-sublattice and, conversely, at high values of x, H_{eff} decreases more rapidly than σ_0. On the other hand, a comparison of the $H_{eff}(x)$ and $\sigma_S(x)$ curves shows that at high values of x the nature of the $H_{eff}(x)$ and $\sigma_S(x)$ curves is similar, although they differ at low values of x. As long as σ_S increases, H_{eff} decreases very slowly (in spite of the fact that the magnetization σ_0 decreases rapidly). Hence, we

[1)]The appearance of a peak in the center of the spectrum was possibly due to small amounts of the SnO_2 impurity or due to the presence of the perovskite phase $CaSnO_3$.[1]

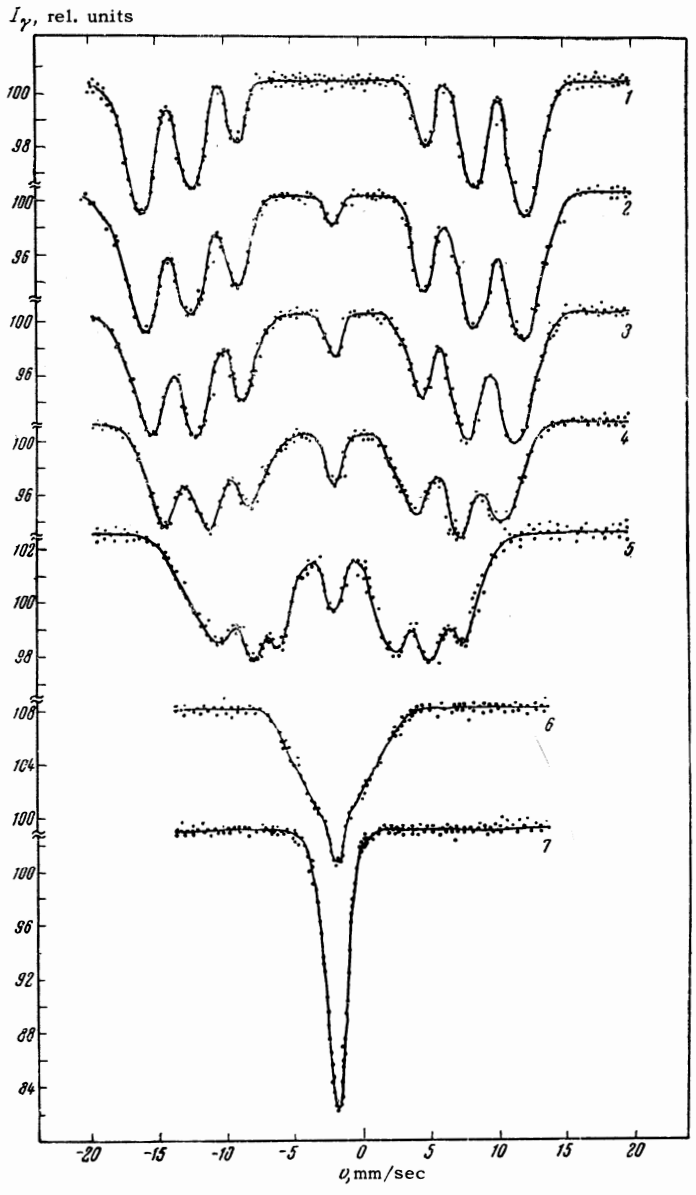

FIG. 1. Absorption spectra of the iron garnet system $Ca_xY_{3-x}Sn_xFe_{5-x}O_{12}$ (α is the absorber thickness in mg/cm^2, β is the enrichment with the Sn^{119} isotope in %): 1) x = 0.1 (α = 55.6, β = 87); 2) x = 0.3 (α = 54, β = 87); 3) x = 0.5 (α = 40, β = 55); 4) x = 0.7 (α = 31, β = 56); 5) x = 0.9 (α = 17, β = 50); 6) x = 1.2 (α = 14, β = 50); 7) x = 1.5 (α = 10, β = 50). The number of pulses at each point of the spectrum was $\approx (1-1.5) \times 10^5$. The positive velocity represented the motion of the absorber toward the source.

x	T, °K	H_{eff}, kOe	$\frac{H_{eff}(77°\,K)}{H_{eff}(295°\,K)}$	$\frac{\sigma_s(77°\,K)}{\sigma_s(295°\,K)}$	Θ, °K	x	T, °K	H_{eff}, kOe	$\frac{H_{eff}(77°\,K)}{H_{eff}(295°\,K)}$	$\frac{\sigma_s(77°\,K)}{\sigma_s(295°\,K)}$	Θ, °K
0.1	77	210±2	1.32	1.34	530±2	0.9	77	135±6	3.86	3.8	345±5
	295	159±3					295	35±6			
0.3	77	211±2	1.39	1.4	502±2	1.2	77	26±6	—	—	244*
	295	152±3					295	0			
0.5	77	201±2,5	1.57	1.57	463±3	1.5	77	0	—	—	140*
	295	128±5					295	0			
0.7	77	188±5	2.0	1.96	410±5						
	295	94±5									

*Theoretical value (cf.[3]).

may conclude that at high values of x (when the exchange interaction within the a-sublattice is much weakened) the polarization of the electron core of tin atoms is mainly due to the exchange field of the a—d interaction. At low values of x, some contribution to this polarization may be made also by the exchange field of the a—a interaction, and therefore the $H_{eff}(x)$ curve no longer follows the $\sigma_S(x)$ curve.

The table lists the values of H_{eff} at tempera-

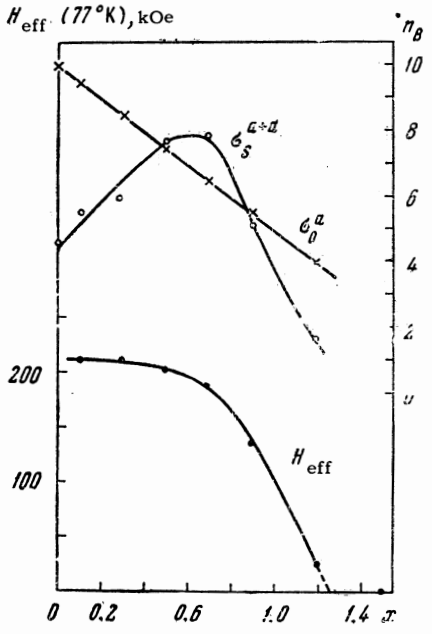

FIG. 2. Dependences of the effective magnetic field H_{eff} (77°K) at Sn^{119} nuclei, of the resultant spontaneous magnetization of the two iron sublattices σ_s^{a+d} (77°K), and of the magnetization of the a-sublattice σ_0^a on x for the iron garnet system $Ca_xY_{3-x}Sn_xFe_{5-x}O_{12}$.

tures of 77 and 295°K and the ratios of the effective fields and magnetizations [3] at these temperatures. The table gives also the values of the Curie point of the investigated iron garnets.[3] It is worth noting the surprising coincidence of the ratios $H_{eff}(77°K)/H_{eff}(295°K)$ and $\sigma_s(77°K)/\sigma_s(295°K)$ for ferrites with different x. This indicates that the temperature dependence of H_{eff} at tin nuclei is analogous to the temperature dependence of σ_s, which is the resultant spontaneous magnetization of the iron sublattices in the garnet. A similar result was recently reported in a theoretical paper,[5] which showed that the temperature dependence of the field H_{eff}, acting on rare-earth nuclei in ferrite garnets, and of the spontaneous magnetization of the rare-earth sublattice were the same.

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