

Iron spin relaxation in ferrite $\text{Cd}_{0.8}\text{Ni}_{0.2}\text{Fe}_2\text{O}_4$

I. K. Kamilov, Sh. T. Aliev, Kh. K. Aliev, and L. K. Anokhin
Institute of Physics, Dagestan Branch, USSR Academy of Sciences

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According to experiments on the Mössbauer effect for ^{57}Fe nuclei in ferrite $\text{Cd}_{0.8}\text{Ni}_{0.2}\text{Fe}_2\text{O}_4$, we have found an absence of magnetic hyperfine structure at temperatures significantly lower than the Curie temperature, which is apparently related to an iron spin relaxation process. The studies carried out for external magnetic fields showed that in the ferrite B -sublattice different iron spin groups exist with different relaxation times.

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It is known that the following equation is a condition for observing magnetic hyperfine structure (MHS) in Mössbauer effect experiments

$$\omega_L \tau_s \gtrsim 1, \quad (1)$$

where ω_L is the Larmor precession frequency for nuclear spin in an effective magnetic field H_{eff} , and τ_s is the relaxation time for electron spins producing this field, i.e., the characteristic fluctuation time for the effective field at the nucleus.

Numerous Mössbauer studies carried out for ^{57}Fe nuclei in magnetically-ordered materials have shown that MHS as a rule disappears near the Curie temperature.¹¹⁻⁶¹ This fact is related to a rapid decrease in the electron spin relaxation time in this temperature range.^{17,81} In Mössbauer effect studies with ^{57}Fe nuclei in ferrite $\text{Cd}_{0.8}\text{Ni}_{0.2}\text{Fe}_2\text{O}_4$, we encountered a situation where the spontaneous magnetization of ferrite disappears at $T_c \approx 230$ K (Fig. 1), whereas MHS has not been found even at $T = 80$ K. We note here that the value for T_c found for the temperature dependence of the initial magnetic permeability¹⁹¹ agrees with the data in the present work.

The Mössbauer studies were carried out in the temperature range 80–293 K on a spectrometer operating in a constant acceleration mode with a source ^{57}Co (Cr). Over the entire range of temperature studied the ferrite spectrum remained a slightly broadened asymmetric quadrupole doublet (Fig. 2) whose splitting $e^2q Q \approx 1.56$ mm/sec is independent of the temperature. The value of the quadrupole splitting is in good agreement with the results in Ref. 10. If we take into account the fact that the cadmi-

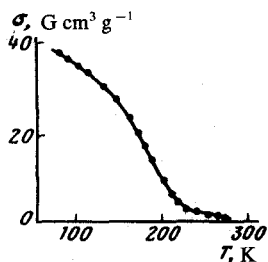
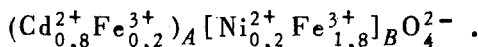


FIG. 1. Temperature dependence of the spontaneous magnetization of ferrite $\text{Cd}_{0.8}\text{Ni}_{0.2}\text{Fe}_2\text{O}_4$.

um ions occupy only tetrahedral positions, we must write the cation distribution in ferrite in the form



It is then possible to interpret the observed asymmetry in the spectrum as the superposition of the quadrupole doublet due to Fe_B^{3+} ions and the single peak due to Fe_A^{3+} ions. This interpretation is justified by the fact that the spectrum of cadmium ferrite, which is a normal spinel, has the form of a symmetrical quadrupole doublet.

Clearly, in our case condition (1) is not satisfied; most likely $\omega_L \tau_s \ll 1$ in the entire temperature range studied. In the external field, however, unresolved MHS appears against the background of the paramagnetic spectrum (Fig. 2). With an increase in the value of the external magnetic field there is an increase in the number of iron nuclei displaying MHS, but the asymmetry of the paramagnetic spectrum is preserved. Evidently, the external magnetic field values used in the experiments are inadequate for independently inducing MHS in ^{57}Fe nuclei. Therefore, the appearance of magnetic structure in the external magnetic field indicates that the iron spin fluctuations in ferrite are reduced, i.e., for certain iron nuclei the equation $\omega_L \tau_s \approx 1$ is satisfied. Since the asymmetry of the paramagnetic spectrum is preserved, the magnetic structure basically appears in iron nuclei located at the B -positions. At the same time not all the B -positions are magnetically equivalent, as long as the number of nuclei displaying MHS increases with increasing external magnetic field intensity. Consequently, iron spin groups with different relaxation times exist in the ferrite B -sublattice. The existence of these B -spin groups may be explained by the magnetic-nonequivalence of the iron ion positions in the B -sublattice, which is characteristic of mixed ferrites.⁽¹¹⁾ The probability for the arrangement of Fe^{3+} ions in nonequivalent positions is given by means of the function:

$$p(n, x) = \binom{6}{n} x^n (1-x)^{6-n}. \quad (2)$$

Here x is cadmium ion density in the ferrite, and n is the number of Fe_A^{3+} ions which, along with Cd^{2+} ions, comprise six closest neighbors of the Fe_B^{3+} action ($n = 0, 1, \dots, 6$). The broadened lines of the ferrite spectrum studied $\Gamma_1 \approx 0.43$ mm/sec in comparison with the lines of a pure-cadmium ferrite spectrum $\Gamma_2 \approx 0.35$ mm/sec also indirectly indicate the existence of nonequivalent iron ion positions in the B -sublattice. Clearly, the B -spin groups with a large value for n will be more stable to disorienting thermal motion, and will have a definite direction in space for a relatively long time.

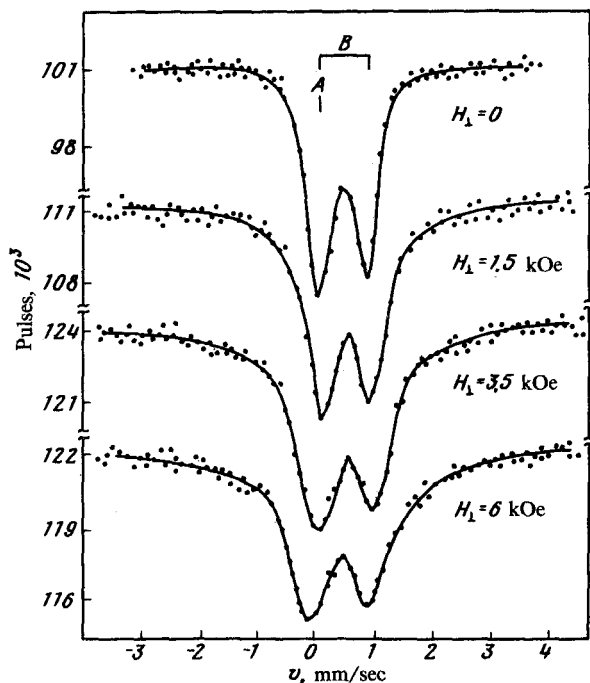


FIG. 2. Mössbauer spectra of ferrite $\text{Cd}_{0.8}\text{Ni}_{0.2}\text{Fe}_2\text{O}_4$ for $T = 123$ K. The external magnetic field is directed parallel to the plane of the absorber and perpendicular to the propagation of the γ -rays.

Therefore, MHS will first appear in Fe_B^{3+} ion nuclei having a larger number of active exchange bonds of the type $A-B$. Consequently, by increasing the strength of the external magnetic field that, in turn, exerts a stabilizing effect on the spin fluctuation process, magnetic structure will subsequently occur in the nuclei, beginning with a larger value for the parameter n .

It also follows from the experimental results that the iron spin relaxation time in the A -sublattice is fundamentally less than in the B -sublattice, although for certain B -spin groups with a smaller value of n this conclusion may turn out to be wrong.

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