

# RELAXATION OF THE IRON SPIN IN THE FERROMAGNETIC COMPOUNDS $MnSb$ AND $CrTe$ BELOW THE CURIE POINT

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## Abstract

## Full Text

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## PHYSICS

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# RELAXATION OF THE IRON SPIN IN THE FERROMAGNETIC COMPOUNDS MnSb AND CrTe BELOW THE CURIE POINT

*(Presented by Academician I. K. Kikoin on 19 VI 1967)*

Investigations of the hyperfine magnetic structure of the Mössbauer line make it possible to obtain important information on the mechanism of interaction of the nuclear magnetic moment with the electron shell of the atom. In a number of cases this interaction depends substantially on the relaxation properties of the electron spin, which determine the transition frequency between different projections  $S_z$ , something that is especially pronounced in paramagnets <sup>(1)</sup> (a detailed theory of the hyperfine structure of the Mössbauer line in paramagnets was developed by Yu. M. Kagan and A. M. Afanas'ev <sup>(2)</sup>).

In magnetically ordered systems, in the overwhelming majority of cases the magnitude of the effective field at the nucleus  $\hat{H}_{\text{eff}}$  is determined by only one projection of the electron spin of the given atom, and its temperature dependence coincides with the temperature dependence of the magnetization  $\sigma_s$  of the domain in a ferromagnet (or of the sublattice magnetization in ferri- and antiferromagnets). However, in a number of magnetic systems, such as binary alloys, the character of the correlation between  $H_{\text{eff}}$  and  $\sigma_s$  may prove to be rather complex <sup>(3,4)</sup>. In a number of ferrites a relaxation mechanism of the temperature dependence of  $H_{\text{eff}}$  has been found <sup>(5,6)</sup>.

**Fig. 1.** Absorption spectra of  $\gamma$ -quanta with energy 14.4 keV for  $\text{Fe}^{57}$  nuclei in the compound MnSb.

Experimental data on investigations of the Mössbauer effect in complex magnetic systems are very scanty. In particular, the question of the nature of  $H_{\text{eff}}$  at impurity-atom nuclei has been studied comparatively little.

Fig. 2. Mössbauer spectra for  $\text{Fe}^{57}$  nuclei in the compound CrTe

Figure 2: Fig. 2. Mössbauer spectra for  $\text{Fe}^{57}$  nuclei in the compound CrTe

In view of the importance of the question of the mechanism of interaction of a nucleus with its environment, we undertook investigations of the Mössbauer effect on  $\text{Fe}^{57}$  nuclei introduced into the ferromagnetic compounds MnSb ( $T_C = 587^\circ\text{K}$ ) and CrTe ( $T_C = 333^\circ\text{K}$ ). The samples were prepared by the usual method of powder metallurgy. Iron in an amount of 5 at.% was introduced by diffusion into

in the solid phase (at a temperature of  $1100^\circ\text{C}$  for 8 h in the case of CrTe and at a temperature of  $550^\circ\text{C}$  for 120 h in the case of MnSb). In the experiments on the Mössbauer effect, the radiation source was the isotope  $\text{Co}^{57}$  ( $\sim 10$  mC) in stainless steel at room temperature.

Over the entire temperature range investigated ( $7$ - $770^\circ\text{K}$ ), the spectrum for  $\text{Fe}^{57}$  in MnSb is a well-resolved doublet (Fig. 1). This character of the spectrum is evidently due to the interaction of the quadrupole moment of the iron nucleus with the inhomogeneous electric field of the crystal lattice. The magnitude of the quadrupole splitting does not depend on temperature and is equal to  $1.19 \pm 0.01$  mm/sec.

The absence of magnetic splitting, even at temperatures  $T \ll T_c$ , is apparently connected with the fact that the relaxation frequency of the electronic spin of the iron atom in this case is much greater than the hyperfine-structure frequency. As for the appearance of asymmetry in the spectrum at low temperatures, it can be explained by a decrease in the electronic-spin relaxation time of the iron atom (7).

Mössbauer spectra for  $\text{Fe}^{57}$  nuclei in CrTe are shown in Fig. 2. The change in the shape of the spectra as a function of temperature is a typical pattern associated with a change in the relaxation time of the electronic spin of the iron atom (2).

**Fig. 2.** Mössbauer spectra for  $\text{Fe}^{57}$  nuclei in the compound CrTe

We carried out a calculation of the shape of the Mössbauer spectra for various values of the spin-lattice relaxation time. The electronic spin of the iron atom was taken to be  $1/2$ . For  $\text{Fe}^{57}$  nuclei in MnSb, the quadrupole splitting of the levels was taken into account, and the magnitude of the field at the nucleus was taken to be 300 kOe. In the case of CrTe, because of the considerably greater broadening of the line, it proved possible to estimate the field from the experimental spectra. This estimate gives a value of approximately 250 kOe. As a result of comparing the calculated and experimental data, an estimate was also made of the spin-lattice relaxation time  $\tau$  for iron atoms in both compounds. For iron atoms in MnSb, the value of  $\tau$  obtained under the assumptions indicated above turned out to depend only weakly on temperature and, at a temperature

of 7°K, to be approximately  $5 \cdot 10^{-11}$  sec. The value of  $\tau$  for the case of CrTe was quite unexpected for us: at  $T = 300^\circ\text{K}$ ,  $\tau \simeq 10^{-10}$  sec, while at  $T = 7^\circ\text{K}$   $\tau$  reaches a value of  $10^{-8}$  sec. Taking into account the large concentration of iron atoms, one may conclude that in the present case the influence of spin-spin interaction is insignificant.

For  $\text{Fe}^{57}$  nuclei in CrTe in an external magnetic field  $H = 10$  kOe at a temperature of 7°K, an overall narrowing of the spectrum was observed. One can give the fol-

an explanation of this circumstance. In a magnetic field the degeneracy with respect to the sign of the projection of the electronic spin of the iron atom is removed, which leads to the splitting of each Stark level into two sublevels,  $+S_z$  and  $-S_z$ . In this connection, at large values of  $\tau$  each line of the Mössbauer spectrum is split into two components. The intensities of these components are proportional to the populations of the corresponding sublevels, which are determined by the Boltzmann factor. In the absence of explicit superfine splitting, the shift of the more intense component toward the center of the spectrum obviously leads to an overall narrowing of it. Calculations carried out under these assumptions are in qualitative agreement with the experimental data obtained.

In conclusion, we express our gratitude to I. K. Kikoin for his constant interest in the work, to Yu. M. Kagan and A. M. Afanas' ev for useful discussions, and to V. I. Bogachev for help in setting up the apparatus.

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