STUDIES OF TEMPERATURE DEPENDENCE OF MÖSSBAUER SPECTRA OF Fe^{57} *AND* Sn^{119} *IN ANTIFERROMAGNETIC* $FeSn_2$

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PRELIMINARY results were reported earlier[1] of studies of the Mössbauer effect in both components of the intermetallic compound $FeSn_2$. Here we give the results of temperature measurements of the resonance absorption of γ quanta with energies 14.4 and 23.8 keV by Fe^{57} and Sn^{119} nuclei in this compound. A brief description of the experimental procedure is given in [1].

To study the temperature dependence of the local magnetic field at the Fe^{57} nuclei, we prepared samples of $FeSn_2$ containing iron enriched to 63.0% in Fe^{57}. Figure 1a shows the absorption spectrum for 14.4-keV γ quanta measured for one such sample at room temperature. The large effect enables us to resolve clearly all six components in the hyperfine structure. The table gives values for the relative velocity v of the source at which the maximum γ ray absorption is observed. As we see from the data, no shift of the energy levels due to quadrupole interaction is observed: the separations of the components 1 and 2, 2 and 3, 4 and 5, 5 and 6 are the same within the limits of error. From the data in the table we can compute the splittings g_0 and g_1 of the ground and first excited states of Fe^{57}. These computations give:

$$g_0 = 1.37 \pm 0.07 \text{ mm/sec}, \quad g_1 = 0.77 \pm 0.05 \text{ mm/sec},$$

$$g_0/g_1 = 1.78 \pm 0.15.$$

The ratio g_0/g_1 does not depend on the value of the local magnetic field, and is characteristic of the particular isotope. Our value for g_0/g_1 is in good agreement with similar results obtained in the work of Hanna et al[2] with metallic iron ($g_0/g_1 = 1.75$), and also with the data of Kistner and Sunyar[3] for Fe_2O_3 ($g_0/g_1 = 1.77$).

Knowing the parameters of the Mössbauer spectrum for metallic iron,[2] we can use the data in the table to find the magnetic field H_n acting at the Fe nucleus in the crystal lattice of $FeSn_2$ at room temperature. This field is 115 ± 6 kOe. Similarly we found the values of H_n at other temperatures. At 372°K one can still resolve the outermost components, while at higher temperatures one observes a single-line absorption spectrum. In the paramagnetic region the width of the line is $(5.0 \pm 0.5)\Gamma$ (where Γ is the natural line width). Figure 1b shows the temperature dependence of the magnetic field $H_n(T)$. A striking feature is the close resemblance of this curve to the curve of spontaneous magnetization of the sublattice of the antiferromagnet $J_S(T)$. It appears that the Mössbauer effect can be used to determine $J_S(T)$ for antiferromagnetic compounds whose crystal lattice contains a nucleus suitable for studying resonance absorption of γ quanta. Extrapolating the steep part of the $H_n(T)$ curve to the abscissa, we can determine the magnetic transition temperature T_N for the antiferromagnetic compound $FeSn_2$. The extrapolation gives $T_N = 377 \pm 3$°K (according to magnetic data,[4] $T_N \approx 380$°K).

The study of the Mössbauer effect for Sn^{119} was done on samples of $FeSn_2$ prepared from ordinary iron and tin. Figure 2a shows the resonance absorption spectrum for 23.8 keV quanta taken at room temperature. The spectrum consists of six hyperfine structure components, corresponding to magnetic splitting of the absorption line. Complete resolution of the spectrum is made difficult by the low value of the local magnetic field

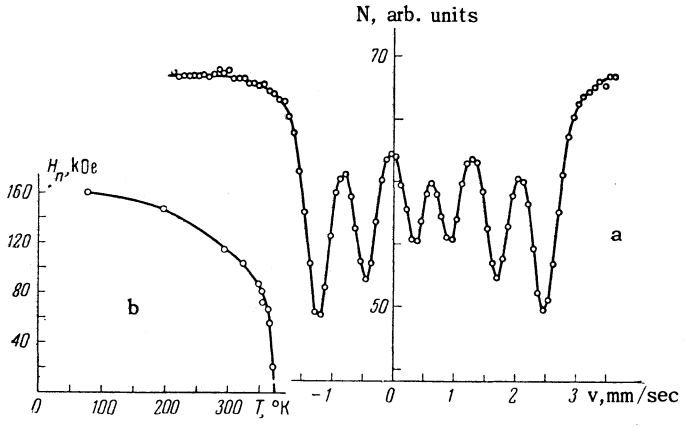

FIG. 1. a) Resonance absorption spectrum of 14.4-keV γ rays by Fe^{57} nuclei in $FeSn_2$ at room temperature; absorber thickness 10 mg/cm²; stainless steel source. b) Temperature dependence of local magnetic field H_n at Fe nuclei in $FeSn_2$.

hfs component	transition	v, mm/sec
1	$+1/2 \rightarrow +3/2$	-1.23 ± 0.07
2	$+1/2 \rightarrow +1/2$	-0.46 ± 0.05
3	$+1/2 \rightarrow -1/2$	$+0.35 \pm 0.05$
4	$-1/2 \rightarrow +1/2$	$+0.94 \pm 0.07$
5	$-1/2 \rightarrow -1/2$	$+1.69 \pm 0.09$
6	$-1/2 \rightarrow -3/2$	$+2.46 \pm 0.12$

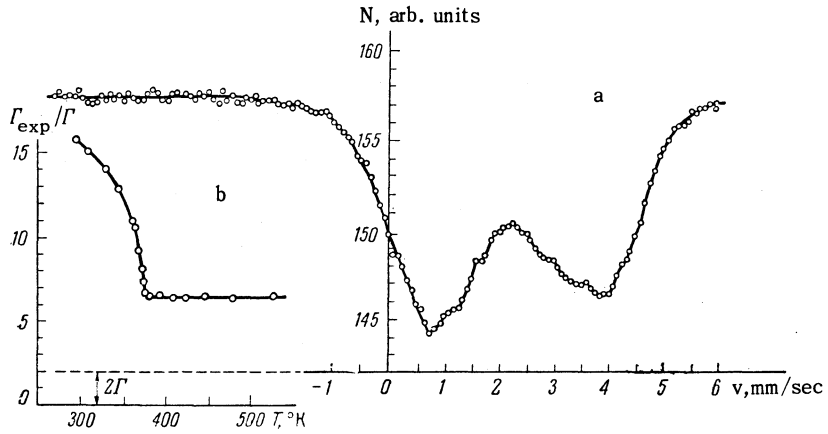

FIG. 2. a) Resonance absorption spectrum for 23.8-keV γ quanta in Sn^{119} nuclei contained in $FeSn_2$ at room temperature; absorber thickness 28 mg/cm^2; source was SnO_2. b) Temperature dependence of spectrum width Γ_{exp} for Sn^{119} nuclei in $FeSn_2$.

H_n at the tin nuclei in $FeSn_2$. An estimate based on data for the Mössbauer effect for impurity tin nuclei in iron[5] gives a value of approximately 25 kOe for H_n at room temperature. The asymmetry of the spectrum indicates that in addition to the magnetic splitting there is also a shift of the components due to quadrupole interaction of the Sn^{119} nucleus with the inhomogeneous electric field.

Such an interpretation of the spectrum shown in Fig. 2a agrees with the data on the temperature dependence of the Mössbauer effect. Figure 2b shows the temperature dependence of the spectrum width Γ_{exp} measured at half height. This dependence also indicates a magnetic origin of the splitting of the line when $T < T_N$ (cf. Fig. 1b). The considerable broadening of the line for $T > T_N$ can be explained by the assumption that there is quadrupole interaction (the width of the source line was approximately 2.5 Γ).

The experimental data on the Mössbauer effect for the tin nuclei also give us a value for the magnetic transition temperature of the compound by observing the kink in the curve of $\Gamma_{exp}(T)$. This gives $T_N = 378 \pm 3$°K.

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211

OBSERVATION OF RADIOACTIVE DECAY WITH EMISSION OF PROTONS

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As the number of neutrons in the nucleus decreases with constant Z, the binding energy of the last proton decreases. Proton decay then becomes energetically possible. This question has been discussed by a number of authors.[1-7] The proton can be emitted either from the ground state of the nucleus or from an excited state after β^+ decay. In the case of the former the half-life is determined by the penetrability of the Coulomb barrier and the reduced width for the proton; in the case of the latter it is equal to the half-life of the β^+ activity of the parent nucleus. The possibility of the simultaneous emission of two protons by the nucleus has been considered by Gol'danskiĭ.[5,6]

Neutron deficient nuclei are produced with a large probability by accelerated heavy ions. We have reported[8,9] on experiments in which it was shown that isotopes emitting protons in radioac-