

MOSSBAUER THERMOMETER USING Sn^{119} NUCLEI IN THE MILLIDEGREE REGION

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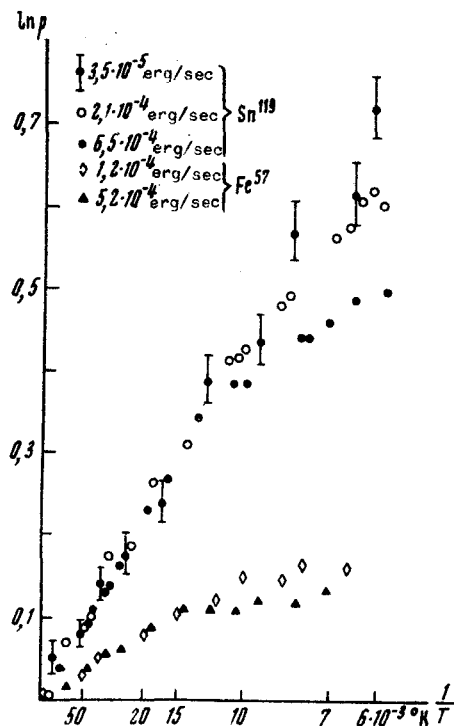
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An anomaly in the temperature dependence of the asymmetry of the Mossbauer spectrum of iron was noted in [1] at temperatures near 0.01°K . To explain the possible causes of this anomaly, we performed the following experiments: Sn^{119} atoms were introduced into the carbonyl iron samples used in [1], in order to be able to measure the "Mossbauer temperatures" of the Sn^{119} and Fe^{57} nuclei in the same sample, and essentially simultaneously.

The sample was prepared in the following manner: the isotope Sn^{119} was evaporated in vacuum on the surface of an iron foil, which was then annealed for four hours at 800°C . The sample absorption spectrum, measured with an $\text{Sn}^{119\text{m}}\text{O}_2$ source, was a superposition of six lines of approximate width 2 mm/sec each. The average magnetic field at the Sn^{119} nucleus was 76 ± 4 kOe, corresponding to a ground-state splitting $\Delta = (5.8 \pm 0.3) \times 10^{-3}^\circ\text{K}$. A second annealing of the sample for three hours in a hydrogen atmosphere at 900°C did not change the spectrum noticeably. The absorption spectrum of the same sample, measured with a Co^{57} source in chromium, did not differ from the spectrum of the initial iron, with only a negligible (about 0.05 mm/sec) line broadening. The total thickness of the absorber (Sn^{119} content about 1.5 at.%) was 0.68 mg/cm² in terms of Sn^{119} and 0.48 mg/cm² in terms of Fe^{57} .

We used in the experiment the dissolution cryostat and the Mossbauer spectrometer described in [1], without any changes other than replacing the absorber and the sources. As before, we measured the logarithm of the intensity ratio of the symmetrical absorption lines. The results are shown in the figure, which indicates also the heat W supplied to the sample as a result of the γ -quantum absorption; this heat was calculated on the basis of the geometry of the experiment. We see that at low powers the temperature dependence of the quantity $\ln p$ does not deviate in the case of the tin nuclei from the Boltzmann formula $\ln p \sim \Delta/T$ (the corrections for the thickness amount in this case to 20 - 25%). The deviations from this dependence, which occur when the heat supply is increased, can be described, within the limits of the accuracy, by the relation $\delta T/W = (1.5 - 2.5) \times 10^{-6} T^{-3}$ deg-sec/erg, and are probably connected mainly with the Kapitza jump. We emphasize that this heat rise does not depend on the γ -quantum energy. We have verified this statement for the Mossbauer and x-ray lines of Sn^{119} (23.8 and 25.8 keV, respectively), and the 14.4-keV Fe^{57} lines.

At the same time, in the case of the Fe^{57} nuclei the deviations from the Boltzmann formula at the same value of heat supply and at noticeably larger temperatures can, as before, not be attributed to



Asymmetry of the absorption spectra of Sn^{119} and Fe^{57} in an iron matrix.

a simple superheating of the sample.

The results make it possible, first, to state that the Mossbauer effect on Sn^{119} nuclei in an iron matrix can serve as a perfectly suitable method for measuring temperatures at least to 6×10^{-3} °K; second, they indicate that the level population of the hyperfine splitting of the spins of the Fe^{57} nuclei in the same sample, at temperatures below 0.015°K, remains almost unchanged and does not correspond to thermal equilibrium with the lattice.

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[1] A.Ya. Parshin, V.P. Peshkov, B.G. Egiazarov, A.I. Shamov, and V.P. Romashko, ZhETF Pis. Red. 15, 44 (1972) [JETP Lett. 15, 30 (1972)].

NMR IN PARAMAGNETIC TERBIUM ETHYL SULFATE AND IN ANTIFERROMAGNETIC TERBIUM TRIFLUORIDE

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Great interest attaches to investigations of NMR of diamagnetic atoms in magnetically-concentrated crystals at temperatures so low that the degree of electron polarization is large and the energy of the magnetic dipole-dipole interaction of the paramagnetic ions is comparable with kT .

We have chosen as the object of such an investigation single crystals of terbium ethyl sulfate (TbES) and terbium trifluoride (TbF_3). The splitting of the two lower levels of the Tb^{3+} ion in TbES in a magnetic field is described by a spin Hamiltonian ($S = 1/2$)

$$\mathcal{H} = g_{\parallel} \beta H_z S_z + \Delta_x S_x + \Delta_y S_y$$

with parameters $g_{\parallel} = 18$ and $\Delta = (\Delta_x^2 + \Delta_y^2)^{1/2} \approx 0.4 \text{ cm}^{-1}$ [1]. Owing to the large value of g_{\parallel} only the lower level is actually populated at 0.35°K already in a field $H \sim 3000 \text{ Oe}$, and

$$\{ \exp[-(g_{\parallel} \beta H + \Delta)/kT] \sim 5 \cdot 10^{-6} \}.$$

Since the inter-ion distances in rare-earth ethyl sulfates are large (the smallest distance in a chain along the C axis is 7 Å), there is practically no exchange interaction [2]. At the same time, the Tb^{3+} ions are coupled by a strong dipole-dipole interaction. For example, the energy of this interaction for the closest ions is of the order of 1°K. We have therefore assumed the possibility of magnetic ordering in TbES in the region of the temperature of liquid He³. A study of the proton magnetic resonance (PMR) spectrum has shown, however, that there is no long-range order all the way to the $T = 0.33^\circ\text{K}$. This is probably due to the low interaction energy of the ions of the neighboring chain, owing to singularities in the crystal structure.

To observe the PMR we used a pulsed NMR spectrometer with operating frequency $\nu = 13.4 \text{ MHz}$. Figure 1 shows a plot of the spin-echo signal amplitude against the magnetic field ($H_0 \parallel C$), obtained at a fixed interval between two pulses. The positions of the line in the spectrum are confirmed also by a calculation performed under the assumption that the crystal is paramagnetic.