ENERGY ANALYSIS OF RESONANCE γ RAYS DIFFRACTED BY AN α-$Fe_2^{57}O_3$ SINGLE CRYSTAL

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A Mössbauer analysis of resonance γ rays diffracted by Fe^{57} nuclei in an α-$Fe_2^{57}O_3$ single crystal shows that only a purely elastic component is involved in nuclear diffraction.

WE used a procedure developed in[1-3] to investigate the energy (Mössbauer) spectrum of resonant γ rays diffracted by single-crystal α-$Fe_2^{57}O_3$. The experimental setup is shown in Fig. 1. The resonant 14.4-keV γ rays from the source (Co^{57} in Cr, ~ 50 mCi) were incident on an α-Fe_2O_3 single crystal (85% Fe^{57}) mounted in the position of the symmetrical Bragg reflection (888). The crystal was in a magnetic field of intensity ~ 1 kOe perpendicular to the scattering plane. The vibrator I could move the source at a given constant velocity, making it possible to excite selectively in the scatterer individual sublevels of the hyperfine structure of the 14.4 keV state. The vibrator II could move a single-line absorber (10 μ of stainless steel containing 20% Fe^{57}) with variable velocity, and this made it possible to measure the Mössbauer spectrum of the scattered radiation. The Mössbauer spectra were registered with an NTA-512B multichannel analyzer.

An auxiliary experiment was performed to measure the dependence of the intensity of the diffracted γ rays on the source velocity. (The source moved with variable velocity, the absorber-analyzer was removed.) The obtained spectrum (Fig. 2a) shows six lines corresponding to all the allowed transitions between the sublevels of the hyperfine structure of Fe^{57} in hematite. The peaks are slightly asymmetrical because of the interference of the scattering by nuclei and electrons[4]. This spectrum enables us to determine the source velocity necessary for selective excitation of any particular transition.

In the main experiment, the result of which is shown in Fig. 2b, we measured the spectrum of the diffracted γ rays, i.e., the dependence of their intensity on the velocity of the absorber-analyzer. The source moved with constant velocity −0.6 mm/sec, at which the transition $+1/2_{gr} \to -1/2_{exc}$ (designated by the double arrow on the level scheme of Fig. 2) was excited in the scattering crystal. The selection rules permit transitions from the sublevel $-1/2_{exc}$ to both sublevels of the ground state: $-1/2_{exc} \to 1/2_{gr}$ and $-1/2_{exc} \to -1/2_{gr}$.

It is seen from Fig. 2b that the spectrum contains only one line corresponding to the transition $-1/2_{exc} \to +1/2_{gr}$ (thick arrow in the level scheme), i.e., to the elastic coherent scattering process $+1/2_{gr} \to -1/2_{exc} \to +1/2_{gr}$. The scattering process $+1/2_{gr} \to -1/2_{exc} \to -1/2_{gr}$ is incoherent because of the difference between the spin projections of the initial and final states. The corresponding γ quanta do not take part in the diffraction, although the change in their energy is so small ($\Delta E/E = \Delta\lambda/\lambda \sim 2 \times 10^{-12}$) that the Bragg conditions continue to be satisfied for them. These γ quanta have in first approximation an isotropic distribution and very few of them enter the detector (their position in the

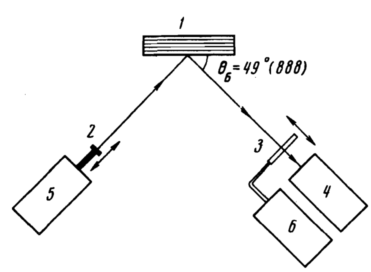

FIG. 1. Experimental setup: 1–α-$Fe_2^{57}O_3$ single crystal, 2–source, 3–absorber, 4–detector, 5–vibrator I, 6–vibrator II.

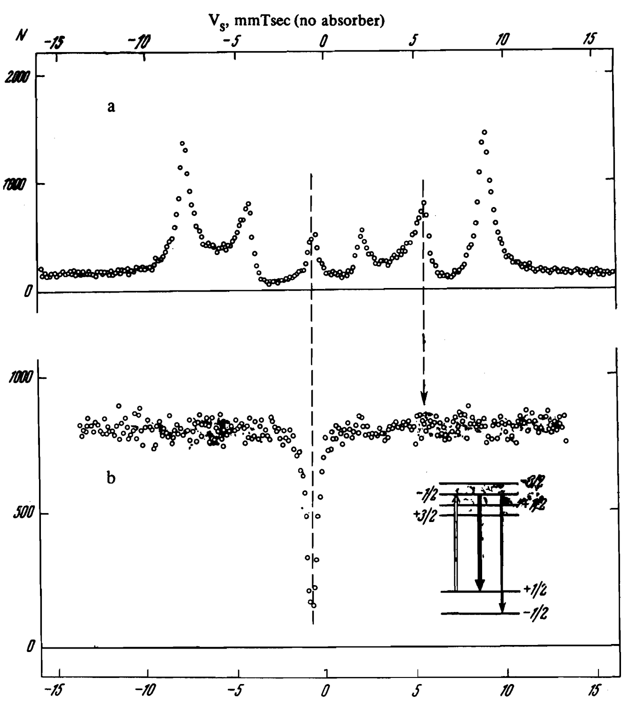

FIG. 2. a–Dependence of the intensity of the diffracted γ rays on the source velocity. Here and below, N is the total number of pulses in the analyzer channel. b–Result of analysis of diffracted beam with the aid of a single-line absorber. Lower right–level scheme of Fe^{57}. The double arrow shows the excited transition; the solid arrows show the possible transitions from the excited sublevel. (In the construction of the spectra we took into account the isomeric shift of the Co^{57} in chromium relative to the stainless-steel absorber).

spectrum is shown by the arrow). The analogous spectrum measured by us earlier for a polycrystalline iron sample contained two lines corresponding to both scattering processes[1].

Thus, the high energy resolution of the Mössbauer effect has made it possible to demonstrate that the spectrum of the resonant γ rays diffracted by the single-crystal nuclei consist of only a purely elastic component. It should be noted that an experiment of this type is practically impossible to perform with neutron or x-ray diffractometry.

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