energy is observed. It must therefore be assumed that the role of dissociation via momentum transfer to the nuclei is effective in this case in a much wider range of kinetic energies, and plays a relatively larger role than dissociation via electronic transitions. We note here that our estimates of the dependence of the cross section for the dissociation of strongly excited H_2^+ ions by momentum transfer to the nucleus agrees qualitatively with experiment. The differences between the plots of the dissociation cross sections for H_2^+ ions with v = 0 and v = 3, and the strong influence of vibrational excitation on the cross section in the kinetic energy range from 0 to 10 eV, were noted also in [11].

It follows also from the figure that the ratio of the dissociation cross section of the strongly-excited (curve IV) and weakly excited D_2^+ ions (curve III) is equal to 4.1 at low energies and to 2.5 at high energies. The analogous ratio for the dissociation of H_2^+ (H_2) and H_2^+(CH_4) at 3.8 keV energy on Ne is equal to 2.3 [12]. Thus, the dissociation of hydrogen ions at low energies is much more sensitive to the excitation of the initial ions.

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RESONANT BRAGG SCATTERING OF GAMMA RAYS BY NUCLEI IN HIGH ORDERS OF REFLECTION, AND PRODUCTION OF DIRECTED BEAMS OF PURE MOSSBAUER RADIATION

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On going over to high reflection orders, the intensity of the γ radiation resonantly scattered by nuclei in a single crystal decreased compared with the first order only because of the change of the Lorentz factor[1)], whereas the cross section of the Rayleigh scattering by electrons decreases very sharply. This circumstance makes it possible to suppress almost completely the scattering by electrons, at the expense of attenuating the intensity of the radiation reflected by the nuclei only by a factor 2 - 4 compared with the first order, and to observe only nuclear scattering.

Diffraction by nuclei in high orders of reflection makes it also possible to obtain directional beams of pure Mossbauer radiation.

The experimental setup for the observation of Bragg scattering of γ rays by a single crystal is shown in Fig. 1.

[1)] The resonant-fluorescence cross section depends weakly on the scattering angle.

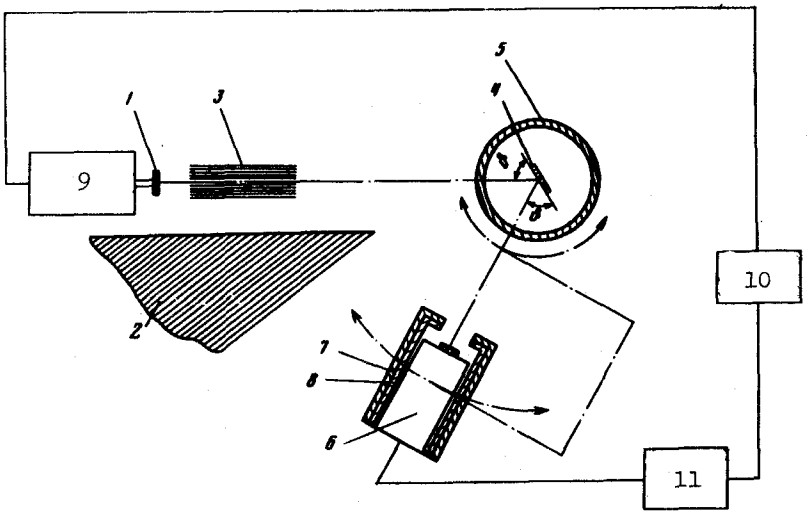

Fig. 1. Diagram of experimental setup: 1 - $Sn^{119m}O_2$ source, 2 - lead shield, 3 - multislit collimator, 4 - scattering Sn^{119} crystal, 5 - evacuated chamber of cryostat, 6 - scintillation counter, 7 - lead screen, 8 - steel screen, 9 - electromagnetic vibrator, 10 - control and registration block, 11 - pulse-height analyzer.

The apparatus is a combination of a constant-velocity Mossbauer spectrometer and a diffractometer. The collimated beam of γ quanta (from an $Sn^{119m}O_2$ source) is incident on an Sn^{119} single crystal at the Bragg angle. The surfaces of the crystal are parallel to the (020) crystallographic planes. The radiation reflected by the signal is registered by a scintillation counter (NaI(Tl) with FEU-85 photomultiplier). The scattering crystal is mounted on a copper cold finger in the evacuated chamber of a cryostat.

Figure 2 shows the diffraction peak obtained in nuclear scattering at resonance of γ rays from Sn^{119m} by a perfect Sn^{119} single crystal in the tenth order of reflection (Bragg angle 63°) at 100°K. The half-width of the diffraction peak is determined mainly by the angular divergence of the collimated beam (20'). At a relative velocity of the source and scatterer (v) far from resonance, there is no diffraction peak. The angular dependence of the intensity of the reflected radiation in the eleventh order of reflection (Bragg angle 79°30') has a similar appearance.

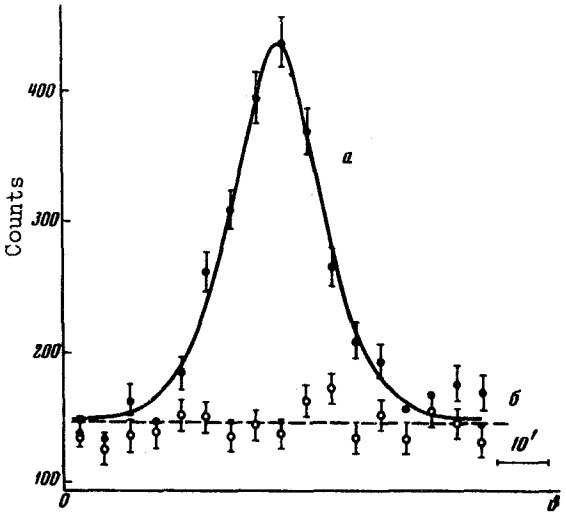

Fig. 2. Diffraction of resonant γ radiation in a perfect single crystal, in tenth order of reflection. The angular dependence of the intensity of the scattered radiation in the region v_B = 63°: a - at resonant velocity (2.55 mm/sec), b - at a velocity of 13 mm/sec.

Figure 3 shows the experimental Mossbauer scattering spectra (dependence of the intensity of the scattered radiation on the relative velocity of the source and scatterer) in tenth order of reflection for a single-crystal film of Sn^{119} of 1 μ thickness (μt = 1.5; μ is the coefficient of resonant absorption and t is the thickness of the crystal) at 100°K and for a perfect Sn^{119} single crystal 420 μ thick at 100 and 210°K. The crystals were made of specially purified material. Figure 3 shows also the Mossbauer scattering spectrum for ideal mosaic Sn^{119} crystals (crystal thickness 5 and 16 μ) at 100°K.

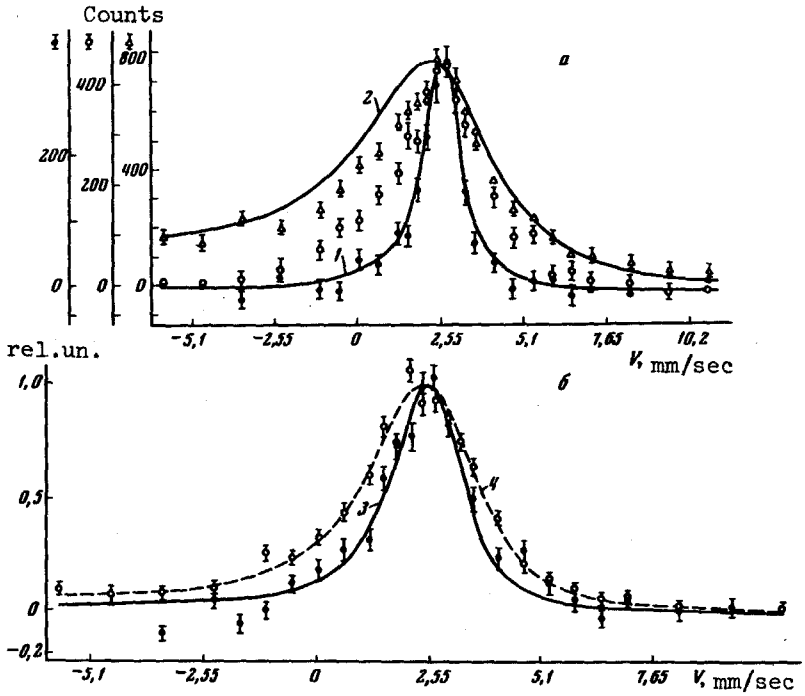

Fig. 3. Experimental and calculated (in the kinematic approximation) Mossbauer spectra of scattering for Bragg reflection in the tenth order: a) • and 1 - for a thin crystal (1 μ), T = 100°K; o - perfect crystal 420 μ thick, T = 210°K; Δ and 2 - perfect crystal 420 μ thick, T = 100°K; b) • and 3 - mosaic crystal (5 μ), T = 100°K; o and 4 - mosaic crystal (16 μ), T = 100°K.

The dynamic character of the resonant interaction of the γ rays with the nuclei in a thick ideal crystal has a strong influence on the character of the Mossbauer spectrum of the radiation reflected at the Bragg angle. Unlike the case of a thin crystal, for which the scattering spectrum represents a narrow Lorentz line with half-width close to 2Γ (Γ - natural width), in a thick ideal crystal the spectrum does not have a Lorentz form and is described at large values of v by a 1/v dependence with gently sloping "tails."

As seen from Fig. 3, whereas in the case of a thin crystal and of crystals 5 and 16 μ thick the experimental spectra are in good agreement with calculations for crystals with an ideal mosaic structure, for a perfect crystal 420 μ thick the form of the spectrum differs from that predicted by calculations made in the kinematic approximation.[2)]

A characteristic of the Mossbauer spectra of Fig. 3 is their sharp asymmetry, which results from the interference of the resonant nuclear and electron Rayleigh scattering for the case when the coherent part of the amplitude of the resonant scattering (f^R_{nuc}) is very large compared with the amplitude of the electron scattering (f_e). (In the tenth order of reflection, for one of the polarizations, $f^R_{nuc}/f_e = 150$, and for the other $f^R_{nuc}/f_e = 50$.) The scattering is observed at a Bragg angle $v_B > \pi/4$, and therefore the sign in front of the term corresponding to interference in the total cross section is reversed,

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[2)] The calculation of the spectrum corresponding to the dynamic theory entails considerable difficulties, since the two-wave approximation customarily employed in the dynamic theory does not hold for the reflections (20, 0, 0) and (22, 0, 0). It should be noted, however, that a comparison of the form of the Mossbauer spectra in these reflection orders with the rigorous calculation is of independent interest, since it permits an experimental verification of the results of the dynamic theory of resonant interaction of γ rays with a regular system of nuclei not only in the two-wave approximation.

and the asymmetry of the spectrum is opposite to the asymmetry observed in low reflection orders [2]. With increasing temperature, the asymmetry in the Mossbauer scattering spectra is much less pronounced.

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ON THE POSSIBILITY OF POLARIZING NUCLEI WITH ULTRASOUND

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It is well known that in diamagnets the relaxation of the nuclear spin is due to dipole-dipole interaction of the nuclei with the paramagnetic impurities. The main contribution is made here by the part of the dipole-dipole interaction leading to the flipping of only the nuclear spin [1].

$$H_{IS} = \frac{1}{2} \sum_{in} (v_{in}^{+z} I_i^- + v_{in}^{-z} I_i^+) S_n^z , \qquad (1)$$

where I and S are the nuclear and electron spins, respectively.

If the concentration of the paramagnetic impurities is sufficiently low and the dipole-dipole interaction between the impurities can be neglected, then the change of the electron spin is determined by its interaction with the lattice. For simplicity, this interaction can be represented in the form [2]

$$H_{LS} = \sum_n \mathbf{L}_n \mathbf{S}_n , \qquad (2)$$

and under conditions when the single-phonon relaxation mechanism is decisive, the lattice operator L_n is linear in the phonon production and annihilation operators.

The interactions (1) and (2) lead in second-order perturbation theory to the so-called flip-flip and flip-flop transitions, accompanied by emission or absorption of phonons of frequency $\omega_S \pm \omega_I$ [3]. If the rate $1/T_0$ of the relaxation of the phonons with the thermostat is large compared with the rate of spectral diffusion in the frequency interval $2\omega_I$ about the frequency ω_S of the phonon spectrum, i.e., if $T_0 \ll (2\omega_I)^2/D$, where D is the coefficient of spectral diffusion, then the phonon frequencies $\omega_S \pm \omega_I$ in the relaxation process can be regarded as subsystems characterized by reciprocal temperatures $\beta^{\pm}$.

Introducing, in addition, the Zeeman electronic and nuclear subsystems with reciprocal temperatures β_S and β_I, respectively, and using the method of non-equilibrium statistical operator [4], we obtain for the evolution of the