The experimental data do not differ from the theoretical predictions shown in the table and in Fig. 3 by more than a factor of 2, if at all. Unfortunately, the need to shut down the reactor for reconstruction prevented us from continuing the investigations.

The flux of ultracold neutrons was negligible in the present experiments not only because of the low power of the IBR reactor, but also because of the pressure drop of the neutron gas in the tube as a result of absorption in its walls. The use of a specular neutron duct or one with a larger cross section with a weakly-absorbing coating (say of beryllium) makes it possible to extract an ultracold-neutron flux cloase to the maximum, namely

$$\phi = \frac{1}{8}\,\phi_0(V_{lim}/V_0)^4,$$

where ϕ_0 - thermal-neutron flux at the start of the neutron duct, V_0 - the most porbable velocity of the thermal neutrons. If the moderator is at room temperature, a beryllium coating is used (V_{lim} = 6.8 m/sec), and $\phi_0 = 10^{14}$ neut/cm^{2}sec, we get $\phi = 1.1 \times 10^3$ neut/cm^{2}sec, which is far from small.

The foregoing results show that ultracold neutrons are produced and propagate in accordance with the theoretical expectations. This allows us to plan experiments aimed at measuring the neutron half-life and its electric dipole moment. We can assume that ultracold neutrons will find also other applications, based on the use of their low energy ($\sim 10^{-7}$ eV), their focusing ability, and other properties.

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NUCLEAR SPIN-LATTICE RELAXATION IN THULIUM ETHYLSULFATE

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It is known [1] that in solids the direct coupling between the nuclear spin and the lattice vibrations is very weak. The spin-lattice relaxation of nuclei having no qudrupole moment is therefore determined, as a rule, by the dipole-dipole interaction of the nuclear moments with the electronic moments of the rapidly-relaxing paramagnetic ions which are always present in the form of a slight impurity.

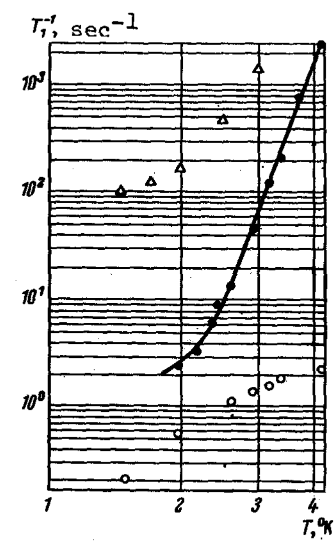
The foregoing pertains to the nuclei of diamagnetic atoms; the question of the mechanisms of the relaxation of nuclei belonging to paramagnetic ions in crystals has remained so far unclear, owing to the lack of experimental data. We recall that recently several experiments were performed [2 - 5] on magnetic resonance on rare-earth ions (Pr^{3+}, Tm^{3+}), the ground state of which in the crystal field is an electronic spin singlet. The unusual feature of this version of NMR is essentially that the hyperfine interaction $a\bar{J}\bar{I}$ and the electron Zeeman energy $g\beta\bar{H}\bar{J}$ cause the Hamiltonian describing the behavior of the nuclear sublevels of the ground-state singlet in the crystal and magnetic fields to contain terms that depend on the excited states of the ions. These terms, which appear in the second approximation of perturbation theory, lead to splittings that can exceed by dozens of times the splitings due to the nuclear moments proper.

The spin-lattice relaxation of paramagnetic ions in the singlet state should also exhibit distinctive features. Indeed, the hyperfine spin-orbit interactions couple the nuclear spin with the orbital motion of the electrons; as a result, the reorientation of the nuclear spins can occur under the influence of the modulation of the electrostatic interactions of the paramagnetic ions with the surroundings by the lattice vibrations. Obviously, this nuclear relaxation channel should play a noticeable role only when the time of the electronic spin-lattice relaxation of the paramagnetic ion is small.

We report in this paper measurements of the spin-lattice relaxation time T_1 of Tm^{169} nuclei and protons, made at liquid-helium temperature in single-crystal thulium ethylsulfate (TmES) [5]. A comparative analysis of the relaxation curves makes it possible to establish differences in the character of the coupling of the Tm^{169} and H^1 nuclei with the lattice. An undisputed advantage is the fact that the spins of both nuclei equal 1/2, so that the picture is not complicated by quadrupole-relaxation processes. The measurements were made with the constant and radio-frequency magnetic field perpendicular to the hexagonal axis of the crystal; in this case the effective gyromagnetic ratio for the Tm^{169} nuclei is $\gamma_\perp = 26.05$ kHz/Oe [5], i.e., approximately 6 times larger than the proton ratio.

We used "spin-echo" apparatus at a fixed frequency, 13 400 kHz, with coherent radio-frequency pulses and with a receiver bandwidth of approximately 300 kHz. The spin-lattice relaxation time was determined by measuring the ratio of the amplitudes of the "solid-echo" signals obtained at different repetition periods of the pulse pair. The long relaxation times were also measured by saturation with a series of pulses with subsequent restoration of the signal. The time of transverse relaxation T_2 of the Tm^{169} nuclei turned to be very short (~3 μsec) and no free induction signals were observed in this case, since the recovery time of the appratus amounted to approximately 8 μsec. For the Tm nuclei, the pulse duration was about 2 μsec, and it was necessary to decrease greatly the radio-frequency field in the coil with the sample, owing to to the large value of $\gamma_\perp(Tm^{169})$.

The figure shows the measured rates of nuclear relaxation as functions of the temperature. The results of relaxation measurements on Er^{3+} impurity ions in our samples are also shown for comparison. The characteristically weak temperature dependence of the relaxation rate of the proton spins indicates that the proton



Measured relaxation rates of H^1 and Tm^{169} nuclei and Er^{3+} ions in single-crystal $Tm(C_2H_5SO_4)_3 \cdot 9H_2O$ as functions of the temperature: o - protons, ● - Tm^{169} nuclei, Δ - Er^{3+} ions. Each experimental point corresponds to an average of several measurements.

relaxation proceeds via the paramagnetic impurity. On the other hand, the relaxation rate for the Tm nuclei changes very strongly with temperature in the 2 - 4.2°K range, and is descreibed by a relation of the type (solid curve in the figure):

$$T_1^{-1}(\sec^{-1}) = 0{,}7\,T + 2\cdot 10^{-3} T^9 + 1{,}76\cdot 10^8 \exp\left(-\frac{1{,}44\cdot 32}{T}\right).$$

The third term in this expression corresponds to the relaxation process via an intermediate level with an energy interval $\Delta = 32$ cm^{-1}, well known for the Tm^{3+} ion in TmES from other measurements [6]; for the Er^{3+} ions in the ethylsulfate lattice we have $\Delta \approx 45$ cm^{-1}.

It is obvious that the relaxation of the Tm^{169} nuclei in ethylsulfate of thulium proceeds in the main not throug the Er^{3+} impurity ions, but through the proper 4f shell of the Tm^{3+} ion. Such a temperature dependence of the spin-lattice relaxation in NMR has apparently been observed here for the first time.

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CARRIER DRAGGING IN A SOLID UNDER THE INFLUENCE OF LASER EMISSION

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1. It is known that when photons are absorbed in a medium containing free carriers, the photon momentum is transferred to these carriers, and this leads to the appearance of an electric current. In a bounded crystal, this results in an electric field parallel to the Poynting vector of the electromagnetic wave, hindering the displacement of the carriers [1,2]. To observe this effect, we undertook a study of the longitudinal electric field that appears in CdS single crystals under the influence of laser light.

2. The CdS crystal was illuminated along the x axis by a light pulse from a Q-switched ruby laser. The pulse duration was about 35 nsec; the light intensity could be raised by focusing to 150 MW/cm^2. The CdS single crystals, which had a darc conductivity $\sim 10^{-8}$ ohm^{-1}cm^{-1}, were in the form of parallelepipeds with well-polished faces measuring 10 x 3 x 2 mm. The crystal was placed in a screened rotating chamber and had eight ohmic contacts connected in two groups near each end (Fig. 1a). Such an arrangement and connection of the contacts eliminates almost completely the potential difference due to the dc-effect [3] and its influence on the free carriers and other transverse effects. Special screens guarded the contacts against