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SCATTERING OF COLD NEUTRONS IN IRRADIATED KBr and NaCl CRYSTALS

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There is unquestioned interest in the investigation of the scattering of neutrons in irradiated alkali-halide single crystals. To this end, we irradiated KBr and NaCl single crystals with gamma rays. The gamma source was the In-Ga radiation loop built into the reactor of the Georgian Academy Physics Institute. The dose intensity was 0.8×10^6 r/hr [1].

Before irradiation, the crystal was cooled in a cryostat and placed in the path of a neutron beam monochromatized by a multiple-slit mechanical monochromator. The resolution was 25% in terms of the wavelength, which ranged from 1 to 12 Å. The initial beam divergence was 5', and the divergence of the beam scattered by the sample was 50'. The maximum background with the shutter open and the monochromator rotor standing still was 0.08 neut/cm^2. Under no conditions can rotation of the monochromator increase this background, which is three orders of magnitude lower than the intensity of 1-Å neutrons passing through the crystal, and one order lower for 12-Å neutrons (Fig. 1).

From the point of view of the procedure for measuring neutron transparency, we consider the sample thicknesses chosen (6.3 mm for KBr and 2.2 mm for NaCl) to be optimal, since they afforded a transmission 0.6 - 0.9 in the indicated wavelength interval.

To suppress the inelastic scattering of neutrons by thermal lattice vibrations, the experiment was carried out at liquid-air temperature.

The intensity of the neutron beam passing through the irradiated crystal was compared with the intensity through the same crystal prior to irradiation. The variation shown for KBr is shown in Fig. 2. The ordinates represent the quantity $(I_0 - I)/I_0$ (per cent), where I_0 and I are the intensities of the neutrons passing through the KBr crystal before and after irradiation, respectively. We see from this figure that a neutron scattering maximum is observed at wavelengths 5 and 8 Å. With increasing irradiation time, the height of the maxima increases in proportion to the irradiation time. A similar curve was obtained also for 20 hours' irradiation, but the measurement error was quite large and did not permit an unambigu-

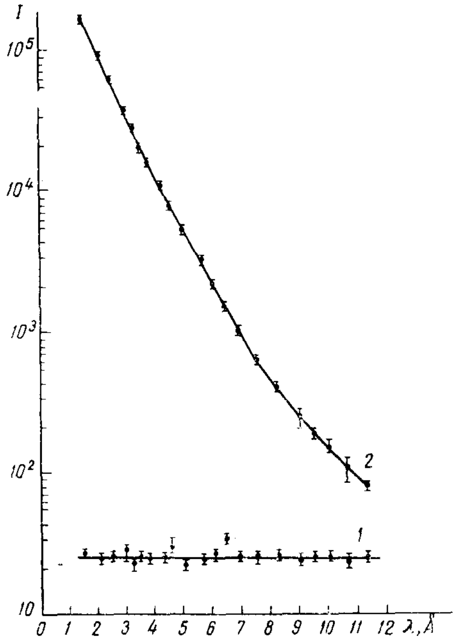

Fig. 1. Relation between the intensity of monochromatic neutrons passing through the crystal and the maximum background. 1 - Background distribution, 2 - number of neutrons registered by the detector after passing through a non-irradiated NaCl crystal vs. wavelength.

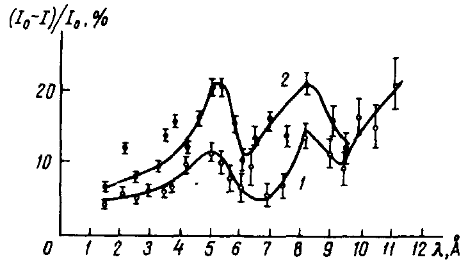

Fig. 2. Plot of the quantity $(I_0 - I)/I_0$ (per cent) vs. neutron wavelength for KBr. 1 - Irradiation time 50 hours, 2 - 100 hours.

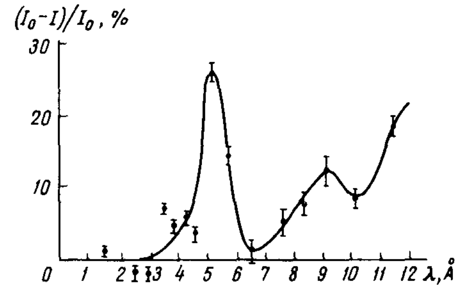

Fig. 3. Plot of the quantity $(I_0 - I)/I_0$ (per cent) vs. neutron wavelength for NaCl. Irradiation time 50 hours.

ous determination of the positions of the maxima.

The scattering of neutrons by defects in irradiated crystals is even more strongly pronounced in NaCl crystals (Fig. 3).

The preliminary experiments have shown that at wavelengths corresponding to the maximum on the curve, the intensity of the neutrons scattered at an angle increases somewhat. Detailed investigations of the intensity of the laterally scattered neutrons are now under way.

It was natural to assume that the observed effect is connected with the occurrence of color centers in the irradiated single crystals of the alkali-halide salts. To check on this assumption, we measured the concentration of F and M centers with a spectrophotometer (SFD-2) in the wavelength interval 220 - 1000 nm. According to these measurements, the maximum F-center concentration is 7×10^{17} cm^{-3}. Naturally, the number of M centers is much lower. Such small concentrations cannot explain the observed appreciable change in neutron transmission. The same point of view is verified also by an experiment with a KBr crystal discolored with white light. As a result of such a discoloring, the F-center concentration decreased by one-half, but the change in the number of F centers did not cause any significant changes in the scattering curve.

Nevertheless, we cannot exclude the possibility that we are dealing here with neutron scattering in some "damage region" produced during the irradiation of the crystal. Such "damage regions" were observed by NMR methods in alkali-halide crystals around impurity atoms [2]. We are presently carrying out experiments on neutron scattering in crystals containing impurities (impurity atom concentration varies from 0.1 to 5 mol.%).

These results should be compared with the already discussed data obtained for irradiated crystals that contain no impurity atoms. This can establish the nature of the defects responsible for the observed neutron scattering.

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USE OF SUBSTANCES CONTAINING RARE-EARTH IONS WITH EVEN NUMBER OF ELECTRONS TO OBTAIN INFRALOW TEMPERATURES

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Only rare-earth ions with an odd number of electrons have been used so far to obtain low temperatures by magnetic cooling. Ions with an even number of electrons are assumed to be unsuitable, since their energy levels are completely split in the crystalline field, owing to the lack of Kramers degeneracy. We wish to call attention to a possibility of advantageously using rare-earth ions with an even number of electrons.

1. The splitting in the crystalline field of the ground level of a rare-earth ion with an even number of electrons is frequently such that the lowest level is a singlet separated from the nearest level by an interval $\Delta \simeq 10$ - 100 cm^{-1}. Consequently, at sufficiently low temperatures, the electronic magnetic moment of the ion vanishes. It must be borne in mind, however, that practically all isotopes of rare-earth triply charged ions with an even number of electrons (Pr^{3+}, Tb^{3+}, Ho^{3+}, Tm^{3+}) have a nuclear spin $I \neq 0$. Furthermore, the magnetic hyperfine interaction of rare earths is relatively large; the hfs constant is $A \simeq 0.1$ - 0.4 cm^{-1}. Owing to this interaction, some moment of the order of $(A/\Delta)\beta$, where β is the Bohr magneton, is added to the nuclear magnetic moment. The magnetic moment of the ion in the ground state is thus increased 10 - 100 times. The resultant consequences for the magnetic-resonance phenomenon were first considered theoretically [1], and then observed experimentally on V^{3+} in corundum [2]. Owing to the weaker hyperfine interaction, the increase in the magnetic moment of the iron-group ions is less pronounced.