Low-temperature (212 °K) phase transition in Rochelle salt

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An optical oscillation whose frequency decreases to 12 cm^{-1} when $T = 212$ °K is approached has been observed by methods of submillimeter spectroscopy. An anomaly of the coefficient of linear expansion was also found at this temperature.

An investigation of Rochelle-salt crystals in the submillimeter wavelength band has revealed a low-frequency optical oscillation, with a frequency that varies critically with temperature when $T_c = 212$ °K is approached reaching at this temperature a minimum value 12 cm^{-1}. This effect is analogous to the behavior of "soft water" in the vicinity of the antiferroelectric phase transition. The setup of[1] was used to investigate the dielectric properties of Rochelle salt with E polarization parallel to the ferroelectric axis "a" of the crystal.[2] The temperature dependence of the moduli of the reflection coefficient R_a and of the transmission coefficient n_a of plane-parallel Rochelle-salt plates of thickness $d = 0.38$ and $d = 0.88$ mm and area 25×25 mm was investigated at fixed frequencies (Fig. 1). The errors in the measurements of R_a, η_a, and d did not exceed 0.01 dB, 0.3 dB, and 0.01 mm, respectively. The complex dielectric constant $\epsilon_a = \epsilon_a' - i\epsilon_a''$ was calculated from the formulas for the plane wave[3]. The temperature dependences of ϵ_a' and ϵ_a'' (Fig. 2) have clearly pronounced maxima whose positions depend on the frequency of the applied field. Figure 3 shows the dependence of the temperature T'', at which ϵ_a'' has a maximum, on the square of the frequency. With decreasing frequency, starting with $\nu = 9.7$ cm^{-1}, the maximum of ϵ_a'' ceases to shift towards higher temperatures and stays at $T_c = 212 \pm 1.5$ °K. In the entire region of the frequencies and temperatures indicated above, the behavior of ϵ_a can be described by a dispersion oscillator with resonant frequency $\nu_0^2 = a^2 |T - \Theta|/T$ and with a damping $\gamma = bT$:

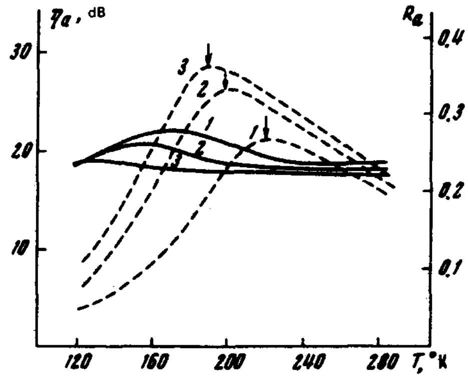

FIG. 1. Temperature dependence of the reflection coefficient R_a (solid line) and of the transmission coefficient η_a (dashed line) of a Rochelle-salt plate of thickness $d = 0.38$ mm: 1—$\nu = 10$, 2—$\nu = 13.3$, 3—$\nu = 15$ cm^{-1}.

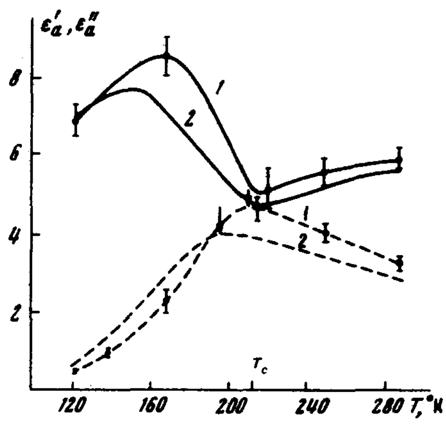

FIG. 2. Temperature dependence of ϵ_a' (solid) and ϵ_a'' (dashed): 1—$\nu = 10$, 2—$\nu = 13$ cm^{-1}.

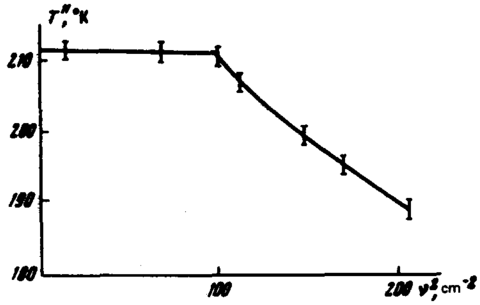

FIG. 3. Dependence of the temperature T'' at which ϵ''_a has a maximum on the square of the frequency.

$$\epsilon_a = \epsilon_\infty + \frac{\mu^2}{\nu_0^2 - \nu^2 + i2\gamma\nu},$$

where $\epsilon_\infty = 5.2 \pm 0.4$, $\mu^2 = 2100 \pm 100$ cm^{-2}, and $b = 0.1 \pm 0.01$ cm^{-1} deg^{-1}. At $T < T_c$ we have $a^2 = 1200 \pm 100$ cm^2 and $\theta = 237$ °K, and at $T > T_c$ we have $a^2 = 600 \pm 50$ cm^{-2} and $\theta = 164$ °K. In addition to the temperature anomaly of ϵ_a, we observed at 212 °K, with the help of N. V. Gorbokon', a considerable anomaly of the linear-expansion coefficient. Thus, a phase transition that can be classified as antiferromagnetic[4] has been observed in Rochelle salt.

[1]V. N. Aleshechkin, G. A. Kraftmakher, V. V. Meriakri, and E. F. Ushatkin, Prib. tekh. eksp. No. 4, 150 (1971).
[2]F. Jona and G. Shirane, Ferroelectric Crystals, Pergamon, 1962.
[3]V. V. Meriakri, Yu. M. Ponlavko, and E. F. Ushatkin, Fiz. Tverd. Tela 15, 3082 (1973) [Sov. Phys.-Solid-State 15, 2054 (1974)].
[4]W. Cochran and A. Zia. Phys. Stat. Sol. 25, 273 (1968).