Transition of H_2O into the conducting state at static pressures $P \approx 1$ Mbar

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We investigated the resistivity of water at $P \approx 1$ Mbar and at temperatures from -80 to -10°C. A decrease of the electric resistivity by six orders of magnitudes was observed. The observed "unfreezing" of the conducting state allows us to conclude that the discontinuity is connected with a phase transition.

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The conductivity of water (H_2O) is determined by the degree of dissociation of its molecules. At high temperatures $T \approx 1000$ °C and pressures (dynamic and static) $P \approx 100$ kbar, the resistivity of water decreases from $\rho \approx 10^8$ Ωcm ($T = 0$ °C, $P = 1$ atm) to $\rho \approx 1$ Ωcm, i.e., by seven or eight orders of magnitude. [1–5] The solid modifications of water, namely ices, are insulators.

An important role in the formation of different structures of ice and water is played by the hydrogen bond. The hydrogen bond is weaker than the ionic or covalent bond but is stronger than the Van der Waals forces of intermolecular attraction. The unusual properties of H_2O are attributed to the strong intermolecular attraction due to the hydrogen bond. [6]

At present there are nine known crystalline modifications of H_2O that are produced at high pressures. [7] The question of the existence of a metallic modification of H_2O, insofar as we know, was discussed only in connection with the construction of the planets of the solar system, particularly Neptune. [8,9]

To investigate the electric property of water at pressures $P \sim 1$ Mbar, we used a procedure developed earlier for the study of the electric resistivity of diamond and other substances. [10,11] According to the method developed in[10,11], the dielectric is placed between anvils of carbonado-type diamond. In the investigation of ice, a danger arises of pressing it out of the high-pressure range. This is due to the high plastic properties of ice. As recently observed, the plasticity of ice at 100 kbar pressure is even higher than that of so "soft" a material as NaCl. [12]

In our experiments we investigated the electric resistivity of ice precipitated from water vapor on the cooled surfaces of the anvils. It is known, [7] that when water vapor condenses on a cold substrate, depending on the temperature of the substrate, there is produced either amorphous ice, or a cubic modification, or else the hexagonal (normal) phase of ice I_h.

Our experiments were carried out at temperatures in the range -80 °C $< T < -10$ °C. In this temperature range, normal ice I_h is produced on the anvils.

We note that water has an increased capability of dissolving various substances. The production of specially purified water is a problem in itself. [6] No special control on the impurity contents of the investigated ices was exercised in the present study.

The results of one of the experiments $T = 200$ °K are shown in Fig. 1.

To confirm the phase transition, just as in the earlier studies, [11] the metastable modification was "unfrozen." Figure 2a shows a plot of the electric resistance of ice

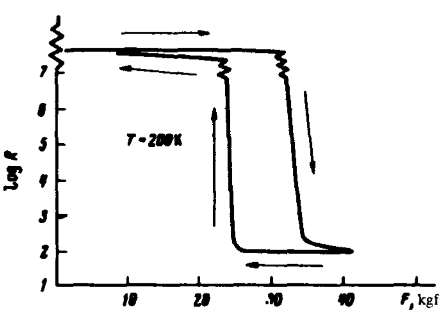

FIG. 1. Electric resistance of ice (H_2O) vs. the force applied to the anvils.

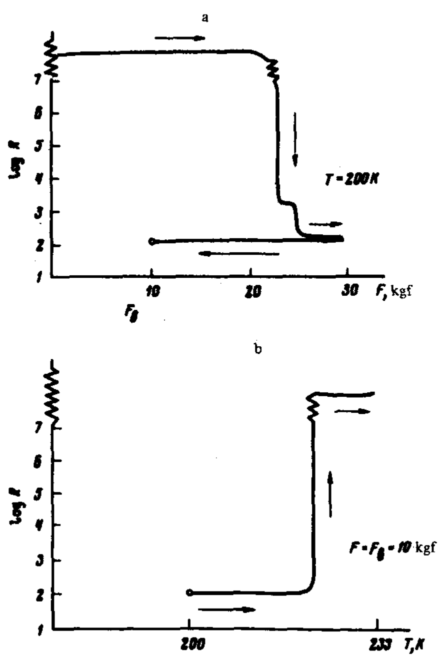

FIG. 2. a) Electric resistance of ice (H_2O) at a fixed temperature $T = 200$°K. During the return, the force was fixed at $F = F_b$; b) temperature dependence of the electric resistance of ice (H_2O) at a fixed force $F = F_b$.

against the force, $R(F)$, with increasing and decreasing load F applied to the anvils. At $F=F_b$, near the expected inverse transition to the initial dielectric phase, the sample was heated. The dependence of the resistance on the temperature at $F=F_b$ is shown in Fig. 2b. Heating of the sample by only 20° leads to an increase of the resistance to a value corresponding to the resistance of the initial dielectric phase. The observed aggregate of phenomena confirms the presence of a metastable conducting state, and consequently the presence of a phase transition of H_2O.

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