Dielektrische Eigenschaften von Eiskristallen

VON DER
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Dynamische Theorie der Dielektrizitätskonstante

von Ad. Steinemann

Summary. The dielectric properties of crystals obeying a Debye-dispersion are surveyed. Deviations at very low frequencies are due either to a d.c.-conductivity or to the appearance of a new dispersion region caused by space-charge effects. The criteria permitting an experimental distinction among the two possibilities are pointed out.

An ideal ice crystal having no imperfections in the proton arrangement cannot have a high dielectric constant. As Bjerrum suggested, one has to assume orientational defects generated by rotation of molecules and ionized states formed by a proton transfer along the hydrogen bond. Fröhlich's general dynamic theory applied to these imperfections gives the correct dispersion behaviour. Ionized states lead to a static permittivity of about 25, whereas orientational defects give the observed value of \( \approx 100 \) for pure ice and an anisotropy of about 15% due to the hexagonal symmetry. The relaxation time is shown to depend exponentially on the temperature with an activation energy equal to the sum of the energies of formation and diffusion of lattice defects. The theoretical results agree very well with the known dielectric properties of \( \text{H}_2\text{O} \) and \( \text{D}_2\text{O} \) crystals.

The theory is expanded for substitutions of oxygen by impurity atoms in the lattice which influence the polarization mechanism. In the case of mixed crystals of ice with hydrogen fluoride it is found that at sufficiently high HF content the translational mechanism becomes predominant. In addition there is a contribution to the conductivity which varies as the square root of the fluorine concentration. This leads to a pronounced space-charge dispersion for low frequency measurements.

A. Einleitung und Problemstellung.

Wasser und Eis zeigen eine grosse Zahl interessanter physikalischer Eigenschaften, die immer wieder Anreiz geben für neue theoretische und experimentelle Arbeiten. Weil im Wassermolekül \( \text{H}_2\text{O} \) der Sauerstoff und die beiden Wasserstoffatome ein stumpfwinkeliges Dreieck mit einem Winkel von 109° zwischen den beiden O–H-Bindungen bilden, weist das Molekül ein permanentes elektrisches Dipolmoment auf, dessen Vektor längs der Winkelhalbierenden gerichtet ist. Im elektrischen Feld richten sich die Dipole möglichst parallel. Im Wasser wirkt dieser Einstellung nur die Temperatur-