On the Electric Properties of Ice Doped with NH₄F

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Measurements of the dielectric constant and the electric conductivity of ice doped with about 10⁻² N NH₄F led to an activation energy of the relaxation time of 0.10 eV = 2.4 kcal/Mol. Despite the fact that the relaxation times of pure and doped ice are about the same at temperatures close to — 10 °C, the statement of Dengel et al. [1], that NH₄F doping does not affect the dielectric relaxation, cannot be maintained in view of the large difference in activation energies.

Les mesures de la constante diélectrique et de la conductibilité électrique de la glace dotée d'environ 10⁻² N NH₄F ont livré une énergie d'activation du temps de relaxation de 0,10 eV = 2,4 kcal/mol. Bien que les valeurs du temps de relaxation de la glace pure et dotée soient presque les mêmes à des températures voisines de — 10 °C, la comparaison des énergies d'activation montre que la conclusion tirée par Dengel et al. [1], qu'une dotation de NH₄F n'influence pas la relaxation diélectrique de la glace, n'est pas valable.

Messungen der Dielektrizitätskonstanten und der elektrischen Leitfähigkeit von Eis, welches mit einer Konzentration von etwa 10⁻² N NH₄F dotiert war, ergaben eine Aktivierungsenergie der Relaxationszeit von 0.10 eV = 2.4 kcal/mol. Obwohl im Bereich von — 10 °C die Relaxationszeiten reinen und dotierten Eises praktisch gleich sind, wird durch den Vergleich der Aktivierungsenergien die Behauptung widerlegt, daß eine NH₄F-Dotierung die DK-Relaxation nicht beeinflußt (Dengel et al. [1]).

1. Introduction

Dengel et al. [1] have published some results on the electric behaviour of ice doped with NH₄F, which they consider to be in disagreement with previously published data [2].

They measured the dielectric constant and the electrical conductivity as a function of the frequency on ice crystals containing varying concentrations of NH₄F (3.4 × 10⁻⁵ to 10⁻² N). Each sample was studied at one temperature in the range between — 10° and — 14 °C. The authors observed that in the region of the Debye dispersion the curves of doped ice were independent of the NH₄F concentration. The curves coincided with that of pure ice at — 10 °C or could be reduced to it, taking the effect of the temperature on the relaxation time τ into account by the expression

\[ \tau = \tau_0 \cdot \exp \left( \frac{E}{RT} \right). \]  

(1)

For the constants \( \tau_0 \) and \( E \) the values for pure ice [3] \( \tau_0 = 5.3 \times 10^{-16} \text{ sec} \) and \( E = 13.2 \text{ kcal/mol} \) were used. They assumed that the difference between their results and the lower activation energy observed by Zaromb and Brill [4] and by Brill et al. [2] were due to differences in the technique of crystal growth. In fact in the two papers of Brill and coworkers [2, 4] a rapid freezing process and a controlled growth technique involving a stirring of the solution were used respec-
tively. As their results for crystals from both methods are in reasonable agreement, the explanation of DENGEL et al. [1] can hardly be justified.

2. Experimental

For our own studies ice samples have been grown from a $10^{-1}$ N NH$_4$F solution by a method described elsewhere [5], which is similar to the one used by DENGEL et al. [1].

The samples were grown in tubes of polyethylene of about 25 mm diameter. They consisted of a few crystallites and the NH$_4$F concentration in the solid was roughly $10^{-2}$ N. The peripheral parts of the samples were not taken off in our case, but, as the solution was stirred during growth, a high radial doping gradient needs not to be expected. The electrical measurements were taken with a capacitance bridge (General Radio, 1610-B).

The sample temperatures were stabilized to $\pm 0.1^\circ$C and kept at their new value for about 15 hours before the electric readings were taken.

![Diagram](image)

**Fig. 1.** Dielectric constant $\varepsilon'$ (curves a, b, c) and electric conductivity $\sigma$ ($a'$, $b'$, $c'$) of a typical NH$_4$F doped ice sample. The sample was not removed from the cryostat before the whole set of measurements was completed.