Dielectric Loss Measurement by Differential Thermal Analysis (DTA)

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Dielectrics with an imaginary part, ε'', of electric susceptibility absorb energy proportional to $\varepsilon'' E_0{}^2 \omega$ per unit of time per unit of volume from an applied electric field, $E_0 \sin \omega t$. This suggests the possibility of measuring the dielectric loss factor of substances by temperature measurements. In fact, we observed this effect by the DTA technique which we have been developing.

The construction of the main part of the DTA apparatus has been reported elsewhere.[1] Electrodes for applying the field are a pair of 2.0-by-0.7 cm^2 aluminum foils attached to the outer surface of the DTA-specimen glass tube. The electrodes are electrically insulated from the copper block by a thin sheet of polyethylene, which also serves to keep the electrodes in place. A fine copper lead is pressed to the electrode beneath the polyethylene sheet.

The alternating voltage source is a 6CL6-807 high-frequency amplifier driven by a commercial test oscillator. A suitable output voltage was obtained by adjusting the position of the output tap of the 807-plate tank coil. The terminal voltage, usually 10—100 V., was monitored by a valve voltmeter. This assemblage worked satisfactorily between 200 kc. and 20 Mc.

As examples, results on glycerol and cyclohexanol are presented below. The dielectric properties of the former were studied extensively by Davidson and Cole[2] and by others. Our results are illustrated in Fig. 1 as a maximum-loss temperature-vs.-frequency relation.

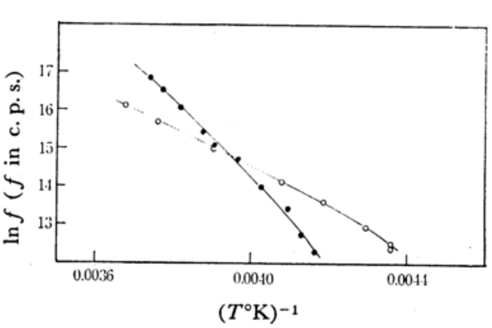

Fig. 1. Frequency vs. maximum-loss-temperature relation for glycerol and cyclohexanol.
—●— Glycerol —○— Cyclohexanol

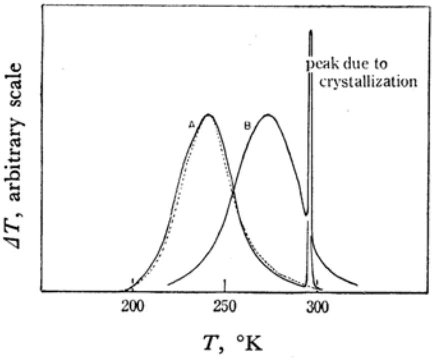

Fig. 2. ΔT vs. temperature plot for cyclohexanol.
A: At 0.81 Mc.
The broken line is the Debye type loss factor with $\tau = \tau_0 \exp(E/\boldsymbol{R}T)$.
B: At 10.1 Mc.

The dielectric behavior of cyclohexanol has been reported on by several authors.[3] On cooling, the crystal takes a metastable form which shows a dielectric loss maximum. In Fig. 2, the ΔT value for this crystal is compared with a normalized Debye-type loss factor with a single $\tau = \tau_0 \exp(E/\boldsymbol{R}T)$ ($\tau_0 = 1.38 \times 10^{-15}$ sec., $E = 9.78$ kcal./mol). The Arrhenius plot for the evaluation of τ_0 and E is given in Fig. 1. These values are in fair agreement with those given in the literature. An interesting feature of this crystal is seen in the ΔT curve for 10.1 Mc., in which the peak due to the crystallization is superposed on the higher-temperature side of the dielectric loss peak without breaking the continuity of the latter. This provides evidence that the mode of the rotational motion of the molecules does not change essentially upon crystallization.

Finally, it should be added here that recently the thermal method of detecting dielectric loss has been applied independently to barium titanate by Pilawski and Danielewicz.[4] Their method seems to be useful for substances with large ε'' values, while for those with smaller ε'' values, our method is more suitable.

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[1] H. Suga, H. Chihara and S. Seki, *J. Chem. Soc. Japan, Pure Chem. Sect.* (*Nippon Kagaku Zasshi*), **82**, 24 (1961).

[2] D. W. Davidson and R. H. Cole, *J. Chem. Phys.*, **19**, 1484 (1951).

[3] G. Corfield and M. Davies, *Trans. Faraday Soc.*, **60**, 10 (1964).

[4] A. Pilawski and M. Danielewicz, *Acta Phys. Pol.*, **28**, 3 (1964).