INFLUENCE OF ALTERNATING ELECTRIC FIELD ON TRANSPORT PHENOMENA IN POLAR GASES

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Submitted 30 July 1966
ZhETF Pis'ma 5, No. 4, 105-108, 15 February 1967

Experiments [1,2] have shown that the thermal conductivity of polar gases with tetrahedral molecules decreases in an electric field. This effect can be attributed, just as in the case of a magnetic field (cf, e.g. [3]), to precession of the molecules in the electric field; this precession, in view of the inherent non-sphericity of the molecules, changes their effective collision cross section. The relative decrease of the coefficient of thermal conductivity ($\epsilon = -\Delta\kappa/\kappa$) of a given gas is, at a specified temperature, a single-valued function of the ratio of the electric field to the pressure (ϵ/p). It follows therefore that ϵ is determined by the ratio of the frequency of molecule precession in the field (Ω) to the molecule-collision frequency (ν).

The earlier experiments [2] have shown that when an alternating electric field is used ϵ does not depend on the field frequency (f) up to 20 kHz. We report briefly in this paper the results of an investigation of the dependence of ϵ on f in a wide range of f. It was natural to expect ϵ to decrease to zero when $f \gg \Omega$; the angle through which the angular momentum of the molecule is deflected by the precession then becomes close to zero. Accordingly we can expect an appreciable decrease in ϵ at $f \approx \Omega$.

The proposed dependence of ϵ on f was investigated by us in NF_3 (whose molecule is a trihedral pyramid with dipole moment d = 0.24 D) at room temperature, $p \approx 0.2 - 1$ mm Hg, and $E \approx 30 - 100$ V/cm. For symmetrical-top molecules, such as NF_3, Ω can be estimated from the formula

$$\Omega = \frac{dE}{M}, \quad (1)$$

where M is the angular momentum.

Since the moment of inertia of NF_3 is $I = 3.3 \times 10^{-37}$ g-cm^2 [4], we find from (1) that $\Omega \approx 5 \times 10^5$ Hz for E = 100 V/cm and T = 300°K. The experiments were made with f ranging from 50 Hz to 2.5 MHz.

The setup used for the investigation is similar to that described in [2]. The pickup comprised two interconnected cylindrical glass chambers of 15 mm diameter, with electrically-heated platinum wires (50 μ dia) drawn along their axes. These wires are two arms of a Wheatstone bridge. One of the chambers was placed in a homogeneous alternating field of a parallel-plate capacitor, to the plates of which there were applied alternating voltages of equal magnitude but opposite phase relative to the chamber filament. Particular attention was paid to the symmetry of the voltages, since any asymmetry leads to the appearance of capacitive current flowing through the chamber filament. Heating of the filament by this current leads to further unbalance of the bridge, apart from the change in the thermal conductivity of the gas. We note that this circumstance has prevented us from using in experiments of this type a pickup in which the electric field is produced by applying a voltage between the filament and external cylindrical electrodes.

When $\epsilon(f)$ is determined by this method, parasitic phenomena can set in, connected both with the flow of a weak discharge current through the gas and with the presence of partial screening of the field by the charges within the volume of the chamber and on its walls. Nor can we exclude partial irreversible dissociation of the molecules of the investigated gas. The correctness of our measurements was confirmed by a number of control experiments. Measurements made over the entire range of p, E, and f have confirmed that the bridge does not become unbalanced when the pickup chambers are filled with air. Measurements made by applying simultaneously to the plates two voltages of equal amplitude by significantly different frequency (50 Hz and 2MHz) yielded for ϵ a value quite close to that obtained at 50 Hz. This allowed us to assume that there were no extraneous effects due to screening charges or gas dissociation. One proof of the correctness of the results was their reproducibility at 50 Hz before and after each high-frequency measurement.

It is convenient to assess the influence of the alternating electric field on the thermal conductivity of the gas with the aid of the quantity ϵ_f/ϵ_0, where ϵ_f and ϵ_0 are the values of ϵ at frequencies f and 50 Hz respectively. Figure 1 shows a plot of ϵ_f/ϵ_0 against f for NF_3, obtained at p = 0.6 mm Hg and E = 111 V/cm. We see from the figure that under these conditions ϵ_f/ϵ_0 decreases noticeably when f changes from 50 Hz to 2 MHz. In accord with the considerations advanced above and with the experimental data shown in Fig. 1, it would be natural to assume that one of the characteristic parameters governing the relative change in the effective collision cross section of the molecules in the alternating field would be the ratio f/Ω. To check on this assumption, we investigated the dependence of ϵ_f/ϵ_0 on f/E for two values of E/p (see Fig. 2). It is seen from the figure that ϵ_f/ϵ_0 is uniquely determined by a relation of the form

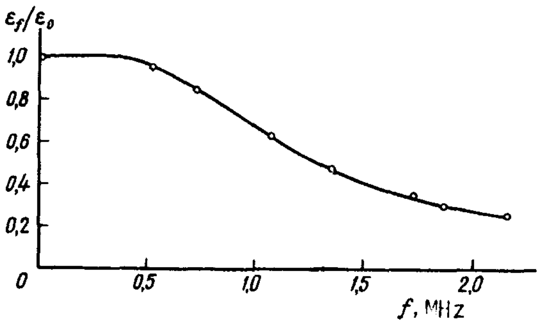

Fig. 1

$$\frac{\epsilon_f}{\epsilon_0} = \phi\left(\frac{E}{p}, \frac{f}{E}\right), \tag{2}$$

i.e., by the ratio of Ω/ν and f/Ω. This means that under the conditions of our experiments ϵ_f/ϵ_0 is a single-valued function of any of two ratios of the three frequencies f, ν, and Ω. Figure 3 shows a plot of ϵ_f/ϵ_0 against f/p. We see that within the limits of experimental accuracy the value of ϵ_f/ϵ_0 is determined by only one parameter - the ratio f/p. This result can apparently be explained by the fact that, at least in the range of E, p, and f investigated by us, the relative decrease of ϵ with increasing f is determined only by the ratio of

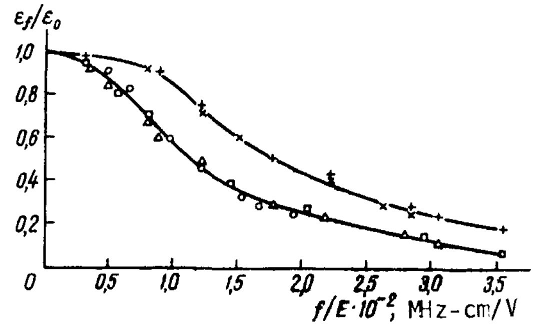

Fig. 2. ϵ_f/ϵ_0 vs. f/E: upper and lower curves are for E/p = 102 and 184 V/cm-mm Hg, respectively.

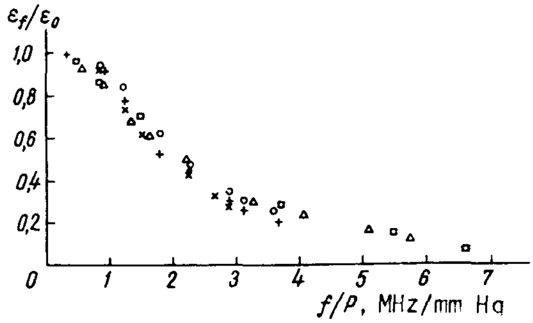

Fig. 3. ϵ_f/ϵ_0 vs. f/p; notation same as in Fig. 2.

the time of molecule precession in one direction to the time between molecule collisions. It can be assumed, however, that in the general case ϵ_f/ϵ_0 is determined by two ratios of the aforementioned frequencies.

We observed a similar influence of an alternating magnetic field on the thermal conductivity of oxygen. These results will be published.

The authors thank I. K. Kikoin for a stimulating discussion and valuable advice, V. Kh. Volkov for interest in the work, Yu. M. Kagan, L. A. Maksimov, and Yu. A. Mikhailova for useful discussions, and V. I. Nikolaev for help with the experiments.

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NONSTATIONARY SELF-FOCUSING OF LASER PULSES IN A DISSIPATIVE MEDIUM

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Submitted 18 November 1966
ZhETF Pis'ma 5, No. 4, 108-113, 15 February 1967

We discuss in this letter the influence of relaxation processes in a nonlinear medium on the dynamics of self-focusing of laser pulses [1,2]. Since the characteristic amplitude variation time is $\approx 10^{-9}$ sec even in "ordinary" giant pulses (see [3]; this time is even shorter in lasers with synchronized modes, $\approx 10^{-12}$ - 10^{-13} sec, see [4]), we cannot assume that the nonlinear response of the medium follows the field quasistatically. This pertains in particular to striction effects, which apparently determine the "fine" structure of self-focusing beams in liquids with large Kerr constants, and the "coarse" structures in such