INFLUENCE OF A MAGNETIC FIELD ON THE THERMAL CONDUCTIVITY OF GASES WITH NONSPHERICAL MOLECULES

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It is known that a magnetic field affects the transport processes in paramagnetic gases (O_2 and NO).[1-3] At a constant temperature, this effect (the Senftleben effect) is a single-valued function of H/p, where H is the magnetic field and p is the pressure. The theory of the effect has been developed in a number of papers.[4-6] The effect is due to the fact that the precession of paramagnetic nonspherical molecules in a magnetic field alters their effective collision cross sections.

Beenakker et al.[7] have suggested that the magnetic field should affect transport processes of all the diatomic gases due to the nonsphericity of their molecules and their nuclear and rotational magnetic moments. To check this, Beenakker et al. investigated the influence of a magnetic field on the viscosity of nitrogen. The measurements were carried out at pressures of 5 and 12 mm Hg in fields up to 21 kOe. They showed that at sufficiently high values of H/p the relative change of the viscosity was of the same order as that for oxygen. The curve obtained was similar to that for oxygen.

The present note describes the preliminary results of an investigation of the influence of a magnetic field on the thermal conductivity of N_2. Figure 1 shows the basic layout of the apparatus.1) The unit consisted of two interconnected chambers (of 20 mm internal diameter) in which electrically heated platinum wires were stretched. These wires formed two arms of a Wheatstone bridge. One of the chambers was placed inside a solenoid. A microvoltmeter, having a sensitivity of 10^{-6} V per division, was connected across the bridge diagonal. The change of the thermal conductivity could be judged from the bridge unbalance on application of the magnetic field. The measurements were carried out at a pressure of 3.5×10^{-2} mm Hg in fields up to 340 Oe.

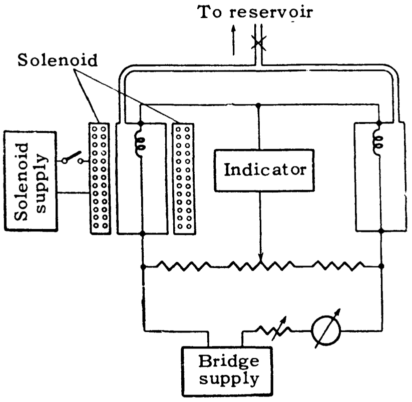

FIG. 1.

Figure 2 gives the dependence of the relative change of the thermal conductivity $\Delta\lambda/\lambda$ on H/p. The curve is similar to the viscosity curve given by Beenakker et al.[7] The value of $\Delta\lambda/\lambda$ at the inflection point of the curve in Fig. 2 is approximately equal to the value of the same quantity (0.2%) for O_2 (Fig. 2 gives the values of $\Delta\lambda/\lambda$ with allowance for the temperature discontinuity [3]). The absence of secondary phenomena was confirmed by the fact that the effect was zero for He and Ar.

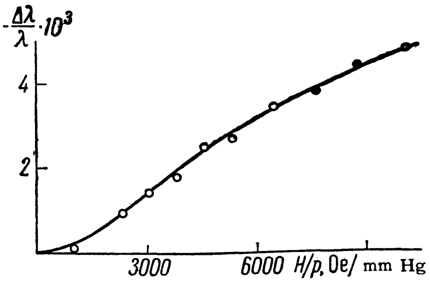

FIG. 2.

The value of H/p at the inflection point of our curve, found with a relative error of less than 30%, was 3300 Oe/mm Hg, which is, to within a factor of 2, equal to the value of H/p at the inflection point of the viscosity curve of N_2. Since the pressures used by us and by Beenakker et al[7] differed by about two orders of magnitude, the cited agreement does not contradict the approximate dependence of the effect on H/p.

A theoretical treatment by Yu. M. Kagan and L. A. Maksimov (private communication) showed that in different gases the effect should depend only on $K\mu_{\text{eff}}H/p$, where μ_{eff} is the effective magnetic moment of the molecule which is responsible for the change of the viscosity and thermal conductivity of the gas in a magnetic field, and K is a coefficient which is constant for a given gas. Hence, comparing the curves for O_2 and N_2, we can estimate μ_{eff} for N_2. In fact, since $K(N_2)$ is close in value to $K(O_2)$, the ratio of the values of H/p at the inflection points of the curves for N_2 and O_2 (3300 and 2.7 Oe/mm Hg) is equal to 1200, and μ_{eff} for O_2 is one Bohr magneton,[6] it follows that μ_{eff} for N_2 is ≈ 1.5 nuclear magnetons. Moreover, since the nuclear magnetic moment of the N_2 molecule is ≈ 0.4 nuclear magnetons, we can regard it as highly likely that the effect observed in nitrogen is due to the rotational as well as the nuclear magnetic moments. The more accurate measurements which are proposed should give us quantitative data on the rotational magnetic moment of N_2. It is also proposed to carry out measurements on other gases.

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[1)] The layout was similar to the oxygen gas analyzer with a constant magnetic field, described in [8].

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EXCITATION AND DISSOCIATION OF MOLECULES IN AN INTENSE LIGHT FIELD

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THE purpose of the present note is to indicate the possibility of and conditions for the efficient direct dissociation of molecules in a very intense light field and to estimate the magnitude of the effect by means of simple quasiclassical calculations, since the classical energy transfer (cf., for example,[1]) determines the excitation probability of a quantum oscillator. This direct dissociation process is related to the resonance excitation of the vibrational oscillations of atoms in a molecule or to the tunnel breakup of a molecule on the appearance of pulsating interaction forces between atoms polarized by the wave field (this mechanism applies in the case of homopolar molecules) or on the direct action of the field on atoms considered as ionic fractions of molecules (in the case of heteropolar molecules or molecular ions).

First, we shall consider homopolar molecules. The short-range interaction force between atoms, polarized by a light-wave field $E = E_0 \sin \omega t$ and located in a molecule at distances r comparable with atomic dimensions a, is equal to

$$f(t) \approx q_{\text{eff}}^2(t)\, r^{-2} \approx \alpha^2 E_0^2\, a^{-4} \sin^2 \omega t \approx \tfrac{1}{2} a^2 E_0^2 (1 - \cos 2\omega t),$$

where α is the polarizability of the atoms; $\alpha \approx q_{\text{eff}}\, a/E \approx e^2/m_e\omega_{0e}^2 \approx a^3$ for frequencies ω which are small compared with the electronic frequencies ω_{0e}. The appearance of this pulsating force may excite the vibrational oscillations of the molecule. The buildup of these oscillations is strongest when the pulsation frequency of the force is $\Omega_f = 2\omega \to \Omega_a$, where Ω_a is the natural vibrational frequency of the atoms in the molecule (Ω_a lies in the infrared region). In this case, the amplitude of the oscillations rises linearly with time:

$$x_0(t) = f_0 t/2M_a\Omega_a = (a^2E_0^2/4M_a\Omega_a)\, t.$$

When the oscillation amplitude is close to critical ($x_c \gtrless a$), the molecule will break up. For this, we require a time $\tau \approx M_a\Omega_a/aE_0^2$. For example, when