

skin layer with the aid of standing sound wave excited in the sample by the ponderomotive force  $F = c^{-1} \vec{j} \times \vec{H}$  ( $\vec{j}$  - current density in the skin layer); the frequencies of these waves are determined by the relation

$$f_{\text{res}} = \frac{\omega_{\text{res}}}{2\pi} = \frac{s_t(2n+1)}{d}$$

( $s_t$  - velocity of transverse sound,  $d$  - thickness of plate,  $2n+1$  - number of half-waves in the standing wave). A maximum standing sound wave intensity, and consequently satisfaction of the condition (2), was obtained by varying  $\delta$  with increasing  $H$ . The value of the magnetic field  $H_m$  at which the thickness of the skin layer was equal to  $\delta(f_{\text{res}}, H_m) = \lambda/\sqrt{2\pi}$  was determined from the position of the maximum at a fixed frequency  $f_{\text{res}}$ .

Figure 3 shows the results of these measurements. In the chosen coordinate system, the straight line drawn from the origin is the line of constant impedance  $Z$ , equal to  $v_s/c$ , under the condition that the normal skin effect is always present (see Fig. 3). The deviation of the experimental points corresponding to the conditions at which  $Z \sim v_s/c$  from this straight line thus is connected with the deviation from the static value. The experimental points corresponding to the first numbers of the resonances,  $n = 1, 2$ , fit this straight line well, i.e., the skin effect is close to normal. This is natural, for under these conditions the inequality  $\delta < \ell$  is not strong ( $\delta(H_m) = 0.1$  mm when  $n = 2$ ). Further increase of the frequency intensifies the inequality  $\delta < \ell$  and leads to an increase of  $H_m$  relative to the expected values (dashed in Fig. 3). This indicates that  $\sigma(\omega, H)$  deviates from the static value, owing to the diffuse scattering of the electrons from the surface (Fig. 1, curve b). In the case of pure specular reflection,  $H_m$  should only decrease monotonically.

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#### CERTAIN DISPERSION EFFECTS IN MOLECULAR GASES IN PARALLEL CONSTANT AND ALTERNATING MAGNETIC FIELDS

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In 1967, Scott et al. [1] observed that a heated cylinder in a molecular gas rotates when a magnetic field directed along the axis is turned on (the Scott effect). The authors of [2, 3] have shown that the dependence of the angle of rotation of the cylinder on the ratio  $H/p$  ( $H$  - field intensity,  $p$  - gas pressure) is determined by the kinetic coefficient that connects the

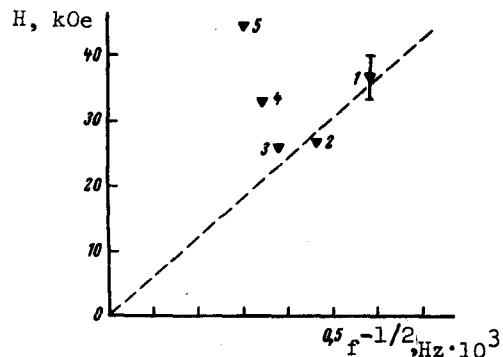


Fig. 3. Dependence of  $H_m$  on the frequency. The experimental points correspond to resonances numbered  $n = 1, 2, 3, 4, 5$ ;  $f_{\text{res}} = 0.93(2n+1)$  MHz;  $T = 4.2^\circ\text{K}$ .

tensor of the viscous stresses with the second derivative of the temperature in the second Chapman-Enskog approximation. In [4, 5] they investigated the dispersion (frequency dependence) of the effect in parallel constant and alternating magnetic fields. It was shown that at small values of the constant field the frequency dependence is monotonic, in analogy with the dispersion of the Senftleben effect [6]. In strong constant fields, the frequency dependence has a maximum. The dispersion of the viscosity in parallel fields was analyzed in [7]<sup>1)</sup>, but the authors did not explain the aforementioned singularities of the Scott effect.

In the present paper we consider the behavior of the transport coefficients of non-paramagnetic molecular gases in parallel constant and alternating magnetic fields and explain the indicated singularities of the Scott effect. We show that the number of maxima in the frequency dependence of this effect is connected with the form of the anisotropy of the distribution function in the space of the velocities ( $\vec{v}$ ) and moments ( $\vec{M}$ ) of the molecules.

Using the results of [8, 9, 3], we can show that the dependence of the thermal-conductivity and viscosity tensors and of the kinetic coefficient determining the Scott effect on the constant magnetic field ( $H_0$ ) and on the amplitude ( $H_1$ ) and frequency ( $\omega$ ) of the alternating field are given by the expressions

$$\bar{C}_{lm}^{(2)} = \epsilon^2 \sum_{n_0 n_0' n n'} B_{n_0 n_0' n n'}^{lm} (j^{(1)})_{n_0 n} (j^{(1)})_{n n_0'} \frac{\omega}{2\pi} \int_0^{2\pi/\omega} K_{nn'} dt, \quad (1)$$

where

$$\hat{K}^{-1} = \frac{\partial}{\partial t} + (\gamma_0 + \gamma_1 \cos \omega t) \frac{\partial}{\partial \phi_M} + \hat{j}^{(0)}, \quad (2)$$

$$\gamma_a = \frac{\mu_0}{\hbar} [g_{\perp} + (g_{\parallel} - g_{\perp}) \sigma^2] H_a, \quad a = 0, 1,$$

$\mu_0$  is the nuclear magneton,  $g_{\parallel}$  and  $g_{\perp}$  are the components of the tensor of the molecular g-factor, corresponding to the parallel and perpendicular directions relative to the symmetry axis of the molecule, and  $\sigma$  is the cosine of the angle between the axis and the angular momentum of the molecule. The remaining symbols are analogous to those introduced in [8, 9].

The action of the operator  $\hat{K}$  on  $\psi_n$  will be represented in the form

$$\hat{K} \psi_n = Z_n(t) \psi_n. \quad (3)$$

The function  $Z_n(t)$  satisfies the equation

$$\frac{dZ_n}{dt} + \lambda_n Z_n + im_2 (\gamma_0 + \gamma_1 \cos \omega t) Z_n = 1. \quad (4)$$

By solving this equation and using (3), we obtain an expression for  $\Delta K_{nn'}$ , which depends on  $H_0$ ,  $H_1$ , and  $\omega$ :

$$\Delta K_{nn'} = -\lambda_n^{-1} \sum_{m_1 + m_2 = m} C_{l_1 m_1 l_2 m_2}^{lm} C_{l_1 m_1 l_2 m_2}^{l'm'} L_{m_2}, \quad (5)$$

<sup>1)</sup> The authors are grateful to L.L. Gorelik for calling their attention to this paper.

$$L_{m_2} = \sum_{k=-\infty}^{\infty} \frac{(k\omega + m_2\gamma_0)^2 - i(k\omega + m_2\gamma_0)^2 \lambda_n}{\lambda_n^2 + (k\omega + m_2\gamma_0)^2} J_k^2\left(\frac{m_2\gamma_1}{\omega}\right).$$

Here  $C_{\dots}$  are Clebsch-Gordan coefficients and  $J_k(x)$  is a Bessel function.

If the amplitude of the alternating field is small ( $m_2\gamma_1 \ll \omega$ ), then we can confine ourselves to the terms with  $K = 0$  and  $\pm 1$  in (5). In this case the number of maxima in the frequency dependence is determined by the values of  $m_2$ , and consequently by the values of  $\ell_2$  ( $|m_2| \leq \ell_2$ ).

Let us examine the frequency dependence in greater detail. As follows from (1), the indices  $\ell_2$  are determined by the selection rules for the operator  $\hat{I}^{(1)}$ , which describes the "transitions" between the spherically symmetrical distribution in M space ( $n_0 = 1m, 10, r_1r_2$ ) and the anisotropic distribution described by the functions

$$\psi_{\ell_2, m_2} \sim \sum_{m_1} C_{1 m_1 \ell_2 m_2}^{1 m_1} Y_{\ell_2 m_2}(\nu) Y_{\ell_2 m_2}(M).$$

In the case of the simplest models, the matrix elements differ from zero only for transitions to the "states" with  $\ell_2 = 1, 2$ , or  $4$  [10, 11]. Then the dependence of  $\text{Im } \Delta \bar{C}_{11,11}^{(2)}$  ( $\text{Im } \Delta \bar{C}_{11,11}^{(2)}$  determines the effects that are odd in  $H_0$ ) on  $H_0, H_1$ , and  $\omega$  takes the form

$$\text{Im } \Delta \bar{C}_{11,11}^{(2)} = \begin{cases} \frac{1}{2} \Lambda_1 F_1, & \text{for } \ell_2 = 1 \\ \Lambda_2 \left[ \frac{3}{10} F_1 + \frac{3}{5} F_2 \right], & \text{for } \ell_2 = 2 \\ \Lambda_4 \left[ \frac{1}{12} F_1 + \frac{1}{6} F_2 + \frac{1}{4} F_3 + \frac{1}{3} F_4 \right], & \text{for } \ell_2 = 4 \end{cases} \quad (6)$$

$$F_{m_2} = \phi(\theta, m_2 \xi, m_2 \zeta) = \frac{(m_2 \xi - \theta)}{1 + (m_2 \xi - \theta)^2} \left( m_2 \frac{\zeta}{\theta} \right)^2 + \frac{m_2 \xi}{1 + (m_2 \xi)^2}$$

$$\theta = \omega/\beta_{10}, \quad \xi = \gamma_0/\beta_{10}, \quad \zeta = \gamma_1/\beta_{10}$$

( $\beta_{10}$  is the collision frequency). The resonance condition for  $\text{Im } \Delta \bar{C}_{11,11}^{(2)}$  is determined by the relation

$$\omega_p = m_2\gamma_0 \pm \beta_{10}. \quad (7)$$

It follows therefore that the number of maxima in the frequency dependence of the effect is determined by the values of  $m_2$ . Taking the results of [12] into consideration, we can put for diatomic molecules  $\ell_2 = 2$  and, in accordance with (9), two maxima should be observed at  $\omega = \gamma_0$  and  $\omega = 2\gamma_0$ ; this agrees with the experimental results on NO in [5]. It should be noted that the authors of [5] determined the molecular g-factor of a number of diatomic molecules from the resonance peak corresponding to double the precession frequency. From (9),

however, we see that the precession frequency in a constant field is equal to the difference of the frequencies at  $m_2 = 1$  and  $m_2 = 2$ .

To demonstrate the absence of resonance singularities at small  $\gamma_0/\beta_{10}$  and arbitrary values of  $\gamma_1/\beta_{10}$  and  $\omega/\beta_{10}$ , it is convenient to seek an approximate solution of (4) in the form

$$Z_n(t) = a_n + b_n \cos \omega t + c_n \sin \omega t. \quad (8)$$

Such a solution leads to the following expression

$$\text{Im } \Delta L_{m_2} = \beta_{10}^{-1} \frac{\frac{1}{2}(m_2 \zeta)^2 m_2 \xi \left[ 3 + \theta^2 + \frac{1}{2}(m_2 \zeta)^2 - (m_2 \xi)^2 \right]}{\left[ 1 + \theta^2 + \frac{1}{2}(m_2 \zeta)^2 - 3(m_2 \xi)^2 \right]^2 + (m_2 \xi)^2 \left[ 3 + \theta^2 + \frac{1}{2}(m_2 \zeta)^2 - (m_2 \xi)^2 \right]^2}. \quad (9)$$

As seen from (11), at small values of  $\xi$  (corresponding to  $\alpha = H/H_0 < 1$  of [5]) the frequency dependence of the effect has a monotonic character and corresponds to the analogous dependence observed in [6] for  $\xi = 0$ . At large  $\xi$  ( $\alpha > 1$ ), resonant singularities should be observed in the frequency dependence. It should be noted that one of the resonance conditions in (11) predicts the presence of a maximum in the region of frequencies larger than double the precession frequency in a constant field. From the same expression we can obtain a dependence of the amplitude of the effects on  $\zeta$  ( $\beta$  in [5]) which agrees with the experimental data of [5].

Thus, the solution (11) yields a relation that explains qualitatively the behavior of the effect at arbitrary  $\xi$  and  $\zeta$ .

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The term  $m_2 \xi \beta^{-1} [1 + m_2 \xi]^2$  should be subtracted from expression (9) on p. 224; where reference is made in the article to Eqs. (9) and (11), read (7) and (9), respectively. These errors were made by the authors.