ON THE POSSIBILITY OF INVESTIGATING THE ACOUSTIC PROPERTIES OF LIQUIDS IN THE FREQUENCY RANGE \(10^8\)-\(10^{10}\) Hz FROM DATA ON THE INDICATRIX OF SCATTERED LIGHT

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ON THE POSSIBILITY OF INVESTIGATING THE ACOUSTIC PROPERTIES OF LIQUIDS IN THE FREQUENCY RANGE 10^8-10^{10} Hz FROM DATA ON THE INDICATRIX OF SCATTERED LIGHT

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It is known that thermal motion in liquids gives rise, in particular, to adiabatic density fluctuations, which may be represented in the form of a spectrum of Debye sound waves. These waves make their contribution to light scattering. This quantity depends on the wavelength λ of the incident radiation, the scattering angle θ, and the adiabatic compressibility of the liquid β_s. However, in studies of the intensity of light scattered by liquids at various θ, the fact has so far not been taken into account that the adiabatic compressibility of liquids in the general case is also a function of θ. It will be shown below that taking into account the dependence of β_s on θ leads in a number of cases to an indicatrix of the light scattered by density fluctuations whose form differs substantially from the Rayleigh one. Connected with this is the possibility of studying acoustic dispersion in liquids at high frequencies of sound oscillations.

For given λ and θ, only those sound waves whose wavelength Λ satisfies the Bragg condition participate in the scattering of light (see, for example, ([1], p. 85)), so that

$$\Lambda = \frac{\lambda}{2n\sin\theta/2}, \tag{1}$$

where n is the refractive index. Let us take the refractive index $n = 1.5$; θ may have values from 1° to 180°, and λ from 4000 to 6500 Å. Then, according to (1), Λ may vary from $1.33 \cdot 10^{-5}$ to $248 \cdot 10^{-5}$ cm. This corresponds to sound frequencies lying in the interval 10^8-10^{10} Hz.

Suppose that acoustic dispersion can be described by means of a single value of the relaxation time τ. Then

Fig. 1. Dependence of $I_{\theta,\mathrm{pl},s}/(1+\cos^2\theta)$ on the scattering angle θ, calculated from equation (3); a—benzene; b—cyclohexane.

Figure 1: Fig. 1. Dependence of $I_{\theta,\mathrm{pl},s}/(1+\cos^2\theta)$ on the scattering angle θ, calculated from equation (3); a—benzene; b—cyclohexane.

$$\beta_s = |\beta_{s\infty} + (\beta_{s0} - \beta_{s\infty})/(1+\omega^2(\tau')^2). \tag{2}$$

Here $\omega = 2\pi v/\Lambda$ is the angular frequency of the sound oscillations, v is the speed of sound; β_{s0} and $\beta_{s\infty}$ are the values of the adiabatic compressibility at frequencies satisfying the relations $\omega\tau' \ll 1$ and $\omega\tau' \gg 1$, respectively. Using equations (1) and (2), one may write for the intensity of light scattered at an angle θ by adiabatic density fluctuations, $I_{\theta,\mathrm{pl},s}$, the expression:

$$I_{\theta,\mathrm{pl},s} = \frac{\pi^2}{2\lambda^4}\frac{I_0 V}{r^2}\left(\rho\frac{\partial\varepsilon}{\partial\rho}\right)^2 kT\left\{\beta_{s0} + \frac{\beta_{s0}-\beta_{s\infty}}{1+(4\pi n\tau' v\sin{}^1/_2\theta/\lambda)^2}\right\}(1+\cos^2\theta). \tag{3}$$

If the value of τ' is such that for some values of θ the relation

$$(4\pi n\tau' v\sin{}^1/_2\theta/\lambda)^2 \approx 1, \tag{4}$$

is satisfied, then in the frequency range $\sim 10^8$-10^{10} Hz acoustic relaxation will take place, and the indicatrix of light scattering by adiabatic fluctuations

density may differ substantially from the Rayleigh one. This effect may be observed in measurements of light scattering in benzene, carbon tetrachloride, cyclohexane, toluene, thiophene, pyridine, carbon disulfide, and many other liquids.

Figure 1 presents plots of the dependence of $I_{\theta,\mathrm{pl},s}/(1+\cos^2\theta)$ on θ for benzene ($\tau' \simeq 2.3\cdot10^{-10}$ s) and cyclohexane ($\tau' \simeq 3.6\cdot10^{-11}$ s) ([2,3]), calculated from equation (3). The dashed lines show plots of the dependence of $I_{\theta,\mathrm{pl},s}/(1+\cos^2\theta)$ on θ that would have to be observed if dispersion of the sound velocity in the frequency range 10^8-10^{10} Hz were absent.

Fig. 1. Dependence of $I_{\theta,\mathrm{pl},s}/(1+\cos^2\theta)$ on the scattering angle θ, calculated from equation (3); a—benzene; b—cyclohexane

Measuring the intensity I_θ of the light scattered by the liquid at an angle θ, and the degree of depolarization Δ of the light scattered at an angle of 90°, from the formulas

$$I_\theta = I_{90^\circ}\left\{1 + \frac{1-\Delta}{1-\Delta}\cos^2\theta + \frac{6-7\Delta}{6+6\Delta}(1+\cos^2\theta)\frac{\beta_s(\theta)-\beta_s(90^\circ)}{\beta_s(90^\circ)}\right\}, \tag{5}$$

$$\beta_s = 1/v^2\rho, \tag{6}$$

one can calculate $\beta_s(\theta)$ and determine the sound velocity, the wavelength of which satisfies equation (1). After the creation of powerful gas lasers, it is in principle possible to measure I_θ at $\theta \sim 1^\circ$ and $\sim 179^\circ$ with an accuracy on the order of 1-2%. The accuracy of the values of $\beta_s(\theta)$ is determined mainly by the accuracy of the measurements of I_θ. Thus, using data on I_θ, it appears possible to find the values of the sound velocity with an accuracy of $\sim$ 1-2% at any frequencies from the ultrasonic range up to $\sim 10^{10}$ Hz. Knowing from experiment the dependence of v on ω, one can calculate the value of the absorption coefficient ([4]).

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CITED LITERATURE

[1] I. L. Fabelinskii, *Molecular Scattering of Light*, "Nauka," 1965.
[2] G. G. Sukhotina, M. I. Shakhparonov, *ZhETF*, **39**, 2237 (1965).
[3] G. G. Sukhotina, M. I. Shakhparonov, *Vestn. Mosk. Univ.*, Ser. Chemistry, No. 1, 9 (1966).
[4] K. F. Herzfeld, T. H. Litovitz, *Absorption and Dispersion of Ultrasonic Waves*, N. Y., 1959, p. 135.

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