MEASUREMENT OF SURFACE TENSION ON THE LAMINATION BOUNDARY OF THE LIQUID PHASES IN AN He^3-He^4 SOLUTION BY THE SURFACE-WAVE METHOD

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The surface-wave method is used to determine the coefficient α of surface-tension on the interface between the liquid phases of an He^3-He^4 solution. α increases monotonically from 0.007 to 0.014 erg/cm^2 when the temperature is lowered from 0.68 to 0.42°K.

The study of surface tension of He^3-He^4 mixtures is of interest in connection with observation of surface impurity levels for the He^3 atom in weak solutions of He^3 in He^4 [1, 2]. A very convenient method for such measurements is that of capillary waves. However, the wave-excitation methods used earlier for liquid He^4 [3, 4] entailed appreciable energy losses; this could lead to the appearance of temperature and concentration gradients in the mixture. We have constructed a surface-wave exciter almost entirely free of parasitic radiation, so that it can be used in a wide range of temperatures and concentrations of the He^3-He^4 mixture. This exciter operates by drawing a dielectric (liquid-helium) into a strong electric field. It consists of a segment of glass tube (5 mm diam, length 11 mm), on which two copper wires of 2 μ diameter were wound turn to turn in a single layer. The cylinder was partly immersed in the liquid (with the axis parallel to the surface). When a voltage was applied, strong electric fields were produced between the neighboring windings and were localized in a layer of thickness on the order of the pitch of the winding. Application of a voltage of frequency ν between the wires caused periodic raising and lowering of the liquid in the layer next to the wall, with double the frequency. The small thickness of this layer ensured sufficiently short surface waves; their frequency could be easily regulated by varying the frequency of the driving generator. The wave picture in a chamber was observed by the dark-field method through a transparent upper cover, and could be photographed when illuminated with a flash lamp.

We used this method to measure surface tension on the interface of the liquid phases of He^3-He^4 solutions in the temperature range from 0.42 to 0.68°K. The proximity of the dielectric constants of both phases decreased the effective nest of the wave excitation by the electric field. In addition, the observation was made difficult by the small difference between the refractive indices. For this reason, we succeeded in obtaining results only with low accuracy (approximately 20%) and in a relatively narrow frequency range (from 16.7 to 40 Hz) at temperatures not exceeding 0.685°K. To verify that it is indeed capillary-gravitational waves that are observed, we have checked on the wave dispersion law in the indicated frequency integral. Figure 1 shows the obtained connection between the frequency and the wavelength λ in the form $\nu^2\lambda^3/2\pi = f(\lambda^2)$ at temperature 0.46 ± 0.1°K. The straight line shows the theoretical relation with α = 0.013 erg/cm^2, given by the classic formula

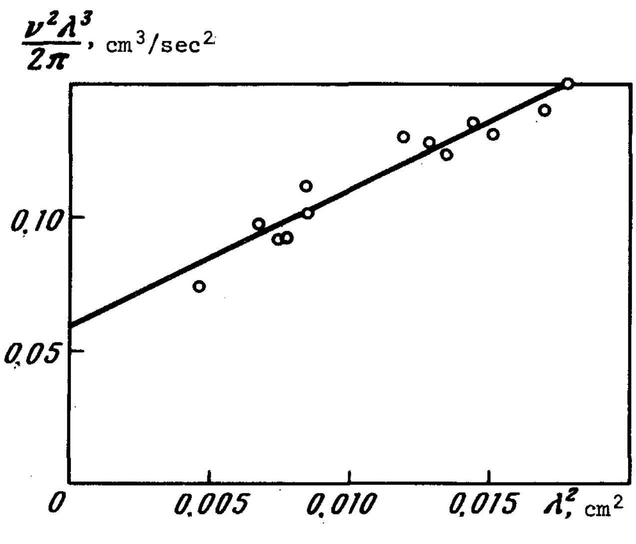

Fig. 1

$$(2\pi\nu)^2 = \frac{\alpha}{\rho_1 + \rho_2} k^3 + g \frac{\rho_1 - \rho_2}{\rho_1 + \rho_2} k \quad (1)$$

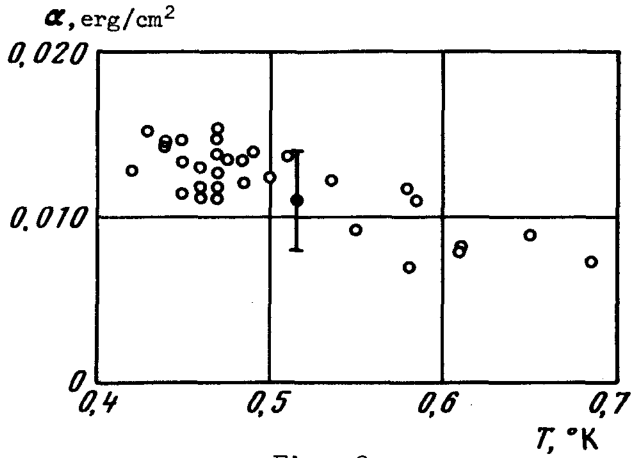

Fig. 2

(here α is the surface-tension coefficient, $k = 2\pi/\lambda$ is the wave number, ρ_1 and ρ_2 are the densities of the lower and upper phases, and g is the acceleration due to gravity). This formula holds also for a superfluid liquid; our measurements on He^4 at ~1.3° have confirmed its validity in the frequency interval from 10 to 1000 Hz, in full agreement with the theory [5]. The measurement accuracy on the liquid-vapor boundary was much higher (about 3%); the results of control measurements of the temperature dependence of the surface tension of pure He^4 (0.8 - 3°K, 500 and 600 Hz) and He^3 (0.4 - 2.2°, 300, 400, and 500 Hz) agreed with the experimental data.

Figure 2 shows the obtained values of the coefficient of surface tension between the liquid phases of the He^3-He^4 solution as a function of the temperature. Most points were plotted at 22 and 30 Hz. In this temperature interval, the surface tension changes by a factor of 2; one can clearly see the monotonic growth with decreasing temperature. The value $\alpha = 0.011 \pm 0.003$ erg/cm², obtained by Guo et al. [6] at 0.515°, is shown in Fig. 2 by a dark circle. The results of Dickson et al. [7], who observed in the same interval (from 0.68 to 0.44°K) an approximate tenfold increase of the coefficient of surface tension, are apparently in error.

We note in conclusion that the proposed method can be recommended for the excitation of surface waves in any liquid dielectric, and its efficiency will be larger the larger the dielectric constant of the liquid. We hope in the future to increase also the accuracy of the measurements by making slight improvements in the optical system of the instrument.

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