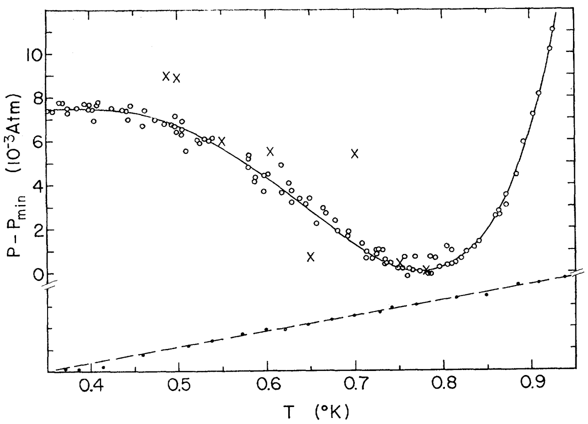

FIG. 2. The He^4 melting curve below 1°K. P_{min} is the minimum pressure of 24.96 atm. Open circles, this work; X's, Le Pair et al.[6,7] The dashed straight line is the temperature effect on the capacitive strain gauge which was subtracted from the raw data to obtain the melting curve.

rather than 0.052, which is much closer to the measured value of 7.5×10^{-3} atm.

Each of the samples was prepared by keeping the chamber temperature near 1.2°K, but different in each case, with the filling capillary at ~0.35°K, then increasing the external pressure to about 35 atm. The capillary did not block instantly at P_{min} but near 25.2 atm, about 0.2 atm above P_{min}. This procedure gave samples with a very small amount of solid along the melting curve, the freezing temperatures being between 1.19 and 1.32°K, corresponding to molar volumes from about 23.10 to 23.06 cm^3/mole according to the data of Grilly and Mills.[10] Coincidence of the isochores in the P-T plane below 1.19°K indicated that the melting curve was being followed. Several other samples with higher freezing points, and consequently with more solid present, were also studied. For these samples, the minimum could not be reproduced consistently on an absolute scale, being displaced in pressure by $\Delta P \sim 10^{-3}$ atm. The reason for this is not clearly understood, but it is believed that with more solid present the very slight motion of the chamber is inhibited.

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TEMPERATURE DEPENDENCE OF THE CRITICAL VELOCITY OF POSITIVE IONS IN LIQUID HELIUM*

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Measuring the dependence of the mobility of positive ions in liquid helium, Careri, Cunsolo, and Mazzoldi[1] found small periodical discontinuities at velocities which are integral multiples of a characteristic critical velocity, $\langle v_c\rangle$. The interesting phenomenon has been confirmed with two different techniques,[2] and also in another laboratory.[3] In the temperature range investigated (from 0.88 to 1.02°K) the critical velocity, $\langle v_c\rangle$, has the temperature-independent value of 5.2 m/sec. Some tentative explanations have been proposed,[1,4-6] all based on the two essential experimental facts, namely the periodical nature of the phenomenon and the temperature independence of the critical velocity.

We want to point out here that the critical velocity, $\langle v_c\rangle$, is no longer temperature independent above 1.1°K. We have carried out experiments at higher temperatures, and we find the following new results: (a) $\langle v_c \rangle$ is a temperature-dependent quantity from 1.1°K upwards; (b) it goes through a strong minimum around 1.3°K; (c) from 1.4°K it decreases slowly, approaching zero at the λ point. The apparatus and the technique involved in the measurements are essentially the same as those described in Ref. 1, apart from a new square-wave generator needed at the highest electric fields. Since the main aim of this work was to measure the temperature dependence of the critical velocity, $\langle v_c \rangle$, we usually stopped the measurements as soon as the first discontinuity was detected. Nevertheless, in some runs we have raised the electric field high enough to detect also the second discontinuity. This always occured at drift velocities $(2.0 \pm 0.2)\langle v_c \rangle$, thus confirming the periodical nature of the phenomenon at high temperatures. The relative change of the mobility, $\Delta\mu/\mu$, lies between 4 and 8% with no systematic temperature dependence, as already found around 1°K by previous workers. No metastability effects, of the type reported by Careri, Cunsolo, and Mazzoldi,[1] have been observed at high temperatures.

The critical velocities observed are plotted in Fig. 1 as a function of temperature. The measurements have been performed in several different runs and with two slightly modified cells. Black points represent measurements concerning the first discontinuity only, whereas in those represented by white dots, both the first and the second discontinuities have been detected. All values of $\langle v_c \rangle$ have been evaluated as the mean of the two measured velocities between which the break was found. Therefore the inaccuracy of $\langle v_c \rangle$ is mainly due to the number of experimental points around the discontinuity.

We are unable to explain the behavior of $\langle v_c \rangle$. The strangest situation occurs around 1.3°K, where no relevant properties of liquid helium that may be expected to produce a minimum are known. A similar unexplained behavior has been reported recently by Tough, McCormick, and Dash in supercritical counter-flow experiments.[7] They found that the excess damping in small-amplitude vibrations of a fine wire undergoes a strong discontinuity around 1.35°K. The low-field mobility of positive ions under pressure shows a different temperature dependence above and below 1.3°K, as reported by Cunsolo and Mazzoldi.[8] This fact has not found a satisfactory explanation either. However, we want to recall that around this temperature the roton gas starts to lose its ideal character.[9]

The dotted line drawn in Fig. 1 represents the temperature dependence of the function $v = v^*\rho_s/\rho_n$, where ρ_s and ρ_n are the superfluid and normal densities and v^* is a temperature-indenpendent velocity. The function has been arbitrarily normalized to the value of $\langle v_c \rangle$ at 1.5°K. While at the present time no theoretical meaning can be attributed to this function, one can see that it displays a qualitatively good fit to the experimental results above 1.4°K.

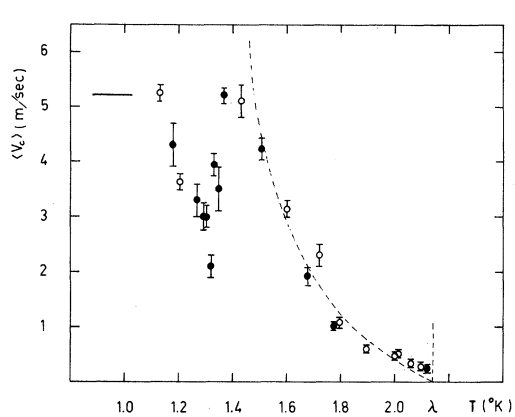

FIG. 1. Experimental values of the critical velocity $\langle v_c \rangle$ for positive ions as a function of temperature. The symbols and the dotted line are explained in the text. The short horizontal heavy line around 1°K represents the mean value of $\langle v_c \rangle$ found by Careri, Cunsolo, and Mazzoldi.[1]

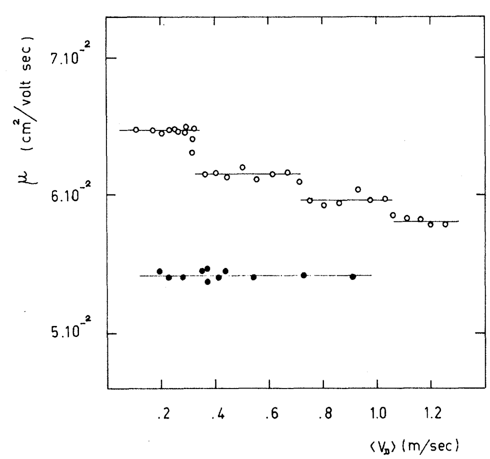

FIG. 2. Plot of the mobility versus drift velocity at two temperatures near the λ point. The measurements below λ temperature [upper curve, $T = 2.06$°K vapor pressure] display four mobility levels. Above the λ point [$T = 2.29$°K ($P = 1$ atm)] and for the same range of velocities the mobility is constant within ±1.5%.

Above the λ temperature no discontinuties in the mobility have been found until now for drift velocity ranging between 20 and 100 cm/sec. For sake of comparison we report in Fig. 2 typical results of the measurements of the mobility taken below and above the λ point.

The behavior of the critical velocity, $\langle v_c \rangle$, above 1.4°K, together with the apparent lack of discontinuities above the λ point, leads us to believe that the phenomenon in question is peculiar to liquid helium II only.

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BRILLOUIN SCATTERING IN LIQUID HELIUM II

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Using the technique of Brillouin scattering, we have measured the attenuation and velocity of high-frequency (556 and 723 Mc/sec) acoustic phonons (first sound) in liquid helium below the lambda point. Previous workers,[1,2] using conventional ultrasonic pulse techniques, have measured the temperature and frequency dependence of the attenuation $[\alpha(T,\Omega)]$ to temperatures as low as 0.1°K and recently[3] to frequencies as high as 150 Mc/sec. A peak in α near 1°K broadly defines two regimes: the hydrodynamic regime on the high-temperature side of the peak up to $T\approx 1.9$°K, and the collisionless regime on the low-temperature side. In the hydrodynamic regime, α is proportional to Ω^2.[4] The temperature dependence of α is determined by certain collision processes[5] which can be roughly characterized by a temperature-dependent relaxation time, $\tau(T)$. The peak in $\alpha(T)$ is predicted[5] to occur at a temperature, $T_p(\Omega)$, where $\Omega\tau(T_p)\approx 1$. In the collisionless regime $[\Omega\tau(T)>1]$, α is postulated to arise from three-phonon collisions which depend indirectly on $\tau(T)$. The theories of this process[6-9] give $\alpha\sim\Omega T^4$ from temperatures near $T_p(\Omega)$ to $T\approx 0.1$°K. In the region $0.2°\mathrm{K}<T<0.5°\mathrm{K}$, Abraham et al.[3] find $\alpha\sim T^4$, while Jeffers and Whitney[2] find $\alpha\sim\Omega^{3/2}T^3$. In addition, the data at 30 Mc/sec[3] seem to show a less rapid variation than T^4 near $T_p(\Omega)$. The situation in this regime is therefore somewhat uncertain.

The Brillouin scattering technique allows one to measure, at high frequencies, a much larger attenuation than is possible with conventional ultrasonic methods. We therefore felt that, aside from the intrinsic interest in a light-scattering experiment, such a measurement would provide additional information on the behavior of sound in liquid helium.

In Brillouin scattering, the incident photon (frequency ω_i, wave vector $\vec{k}_i$) interacts with a longitudinal phonon $(\Omega,\vec{K}_0)$ and is scattered through some angle 2Θ. Since the total energy and momentum are conserved in the collision process, the scattered photon $(\omega_s,\vec{k}_s)$ has $\omega_s=\omega_i+\Omega$ and $\vec{k}_s=\vec{k}_i+\vec{K}_0$. Since $\Omega\ll\omega_i$, $k_i\cong k_s\equiv k$ and therefore,

$$\Omega/v\equiv K_0=2nk\sin\Theta, \tag{1}$$

where Θ is the Bragg angle, v the velocity of sound, and n the index of refraction of the medium. In a simple wave picture, the incident light is diffracted and Doppler shifted by the moving grating set up by the periodic density fluctuations of the sound wave. In the classic Brillouin-scattering experiment,[10] the incident