The Velocity of Sound in Liquid Helium under Pressure

The authors[1] have previously measured the velocity of sound in liquid helium evaporating under its own vapor pressure, using a resonance method with a quartz oscillator operating at 1338 kc. In these experiments no discontinuity was observed at the λ-point, whereas Ehrenfest's[2] thermodynamic relations for a change of state in which there is no latent heat require a sudden change in the compressibility, amounting to

$$\Delta K_T = -\Delta\alpha/(dp/dT)_\lambda,$$

where $\Delta\alpha$ is the change in the coefficient of expansion. It was possible that the measurements did not give the true velocity in the liquid, owing to the formation of minute bubbles in the sound field, although the liquid helium was not allowed to boil while measurements were in progress, and the hydrostatic pressure was considerably greater than the pressure amplitude of the waves.

The experiment has now been repeated with the liquid helium under an external pressure of 1 to 5 atmospheres. For this purpose the oscillator and reflector were enclosed in a copper bomb inside the cryostat proper. With boiling liquid helium surrounding the bomb in order to maintain any desired temperature, the liquid helium inside the bomb could be subjected to pressure by means of helium gas from a cylinder. Measurements of the velocity made under pressure in the neighborhood of the λ-point are shown in Fig. 1, along with the curve of the previous measurements.

Table I below shows the change ΔK_T in the isothermal compressibility, as calculated from the values of $\Delta\alpha$ and $(dp/dT)_\lambda$ estimated from the data of Keesom and Miss Keesom.[3] The last two columns give the approximate observed change ΔW in the velocity of sound, and the derived change ΔK_φ in the adiabatic compressibility. The calculated ΔK_T, and the experimental ΔK_φ are comparable to within one percent, since the ratio of the specific heats is estimated to be less than 1.01 in both He I and He II near the λ-transition.

It is hoped to continue this work far enough to obtain experimental values of the compressibility throughout the region of pressures less than about 5 atmospheres, where it is difficult to deduce values accurately from the existing pressure-volume data.

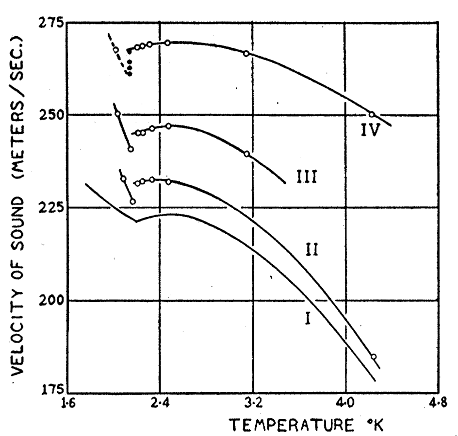

FIG. 1. The velocity of sound in liquid helium under various pressures, I vapor pressure, II 1 atmos., III 2.47 atmos., IV 5.55 atmos.

TABLE I. *Change in the compressibility of liquid helium at the λ-transition for various pressures.*

PRESSURE (ATMOS.)	VAP. PRESS.	1.0	2.47	5.55
$\Delta\alpha$	0.0499	0.036	0.039	0.039
$(dp/dT)_\lambda$ (c.g.s. 10^{-6})	−82	−87	−84	−79
ΔK_T calc. (c.g.s. 10^{10})	− 6.2	− 4	− 4.7	− 4.8
ΔW(m-sec.$^{-1}$)	0	6	5	7
ΔK_φ exp. (c.g.s. 10^{10})	0	− 7	− 5	− 5

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[3] W. H. Keesom and Miss A. P. Keesom, Proc. Kon. Akad. Amsterdam **36**, 482 and 612 (1933), Physica **1**, 128 (1933) (Leiden Comm. 224d, e, Suppl. 76b).

The Multiple Scattering of Charged Particles

The total scattering cross section for a Coulomb interaction is infinite. This fact has been a serious difficulty in the interpretation and calculation of scattering phenomena for charged particles. Attempts have been made to avoid the divergence of the formulas by observing that the field of a nucleus does not extend beyond a certain range because of the screening effect of the orbital electrons. The calculated results, however, have proved to be very sensitive to the choice of the distance and the manner in which the Coulomb field is cut off.

A further analysis of the divergence of the scattering formulas indicates that the "long range" of the Coulomb field is only part of the cause. Another reason is that multiple scattering has not been considered adequately. In the case of long range forces appreciable scattering due to many small deflections is quite prevalent. If this is properly taken into account, it is seen that the final results are no longer so sensitive to the cut-off radius of the Coulomb field. A method for treating this multiple scattering problem is given in a paper by Ornstein[1] which deals with the diffusion of neutrons in water. In this paper expressions are given for the angular distribution after ν collisions for any law of interaction. Combining these results with the well-known formulas for the probability that ν collisions will occur, one obtains a final scattering distribution.

This method, unfortunately, does not yield an explicit distribution function for the scattering angle θ, but gives it in terms of averages of $\cos\theta$, $\cos^2\theta$, etc., or of Legendre polynomials.

For the Rutherford scattering of electrons by a foil of