NEUTRON INELASTIC SCATTERING FROM LIQUID HELIUM AT SMALL MOMENTUM TRANSFERS

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It has been predicted by Hohenberg and Martin[1] that the slope of the dispersion curve for long-wavelength excitations in liquid helium ($p/\hbar \sim 0.1$ Å^{-1}) should not be the velocity of ordinary sound (c_1) but $c_1(\rho_S/\rho)^{1/2}$, where ρ_S and ρ are the density of the superfluid component and the total density of liquid helium II, respectively. The superfluid density ρ_S is a strong function of temperature, and thus the theory predicts a strong temperature dependence for the slope of the dispersion curve. This Letter presents experimental evidence which disagrees with the predictions of this theory; the measured slope of the dispersion curve is almost independent of temperature, even at temperatures above the lambda transition temperature (2.17°K). Previous measurements[2] in this momentum region were carried out at 1.12°K, where $\rho_S/\rho \approx 1$, and thus did not provide a test of the theory.

The present experiment was carried out using the rotating crystal spectrometer[3] at the NRU reactor, Chalk River. A pulsed beam of neutrons of incident wavelength 4.05 Å (energy = 5.0 meV) was incident upon a cylindrical specimen of liquid helium 5 cm in diameter. The energies of the scattered neutrons were determined by measurements of their times of flight over a known distance. Time-of-flight distributions of the scattered neutrons were observed at three different angles of scattering and at a series of temperatures between 1.5 and 4.2°K.

The observed distributions are shown in Fig. 1. The peak at the elastic position is not due to scattering from the liquid helium and is present in the distribution scattered from the empty cryostat. The second peak represents neutron scattering from liquid helium with the excitation of a phonon. The position of this neutron group does not change significantly with

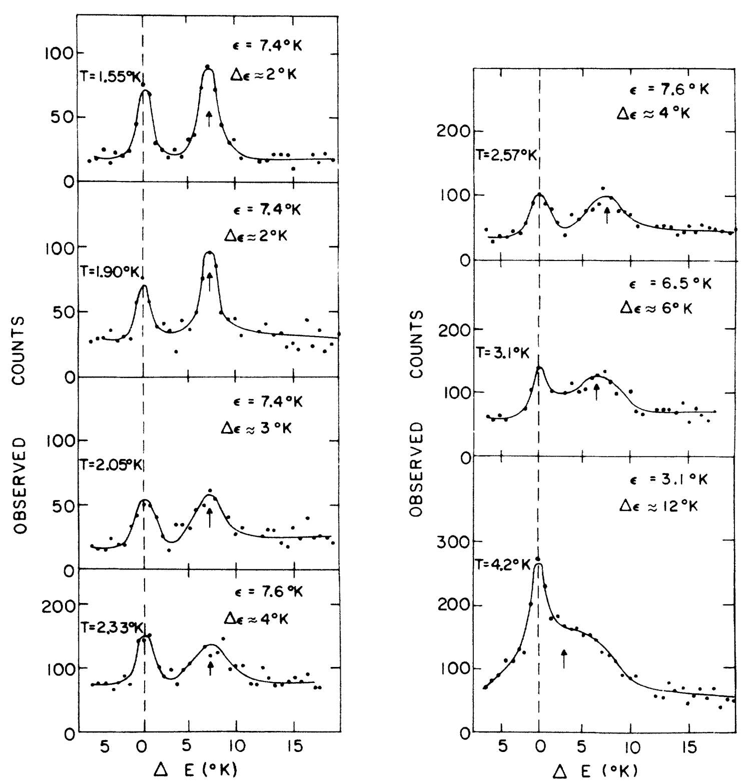

FIG. 1. Distributions of scattered neutrons from liquid helium shown as a function of the energy change, ΔE, in degrees Kelvin. Neutrons to the right (left) of the dashed line are those which have lost (gained) energy in the scattering process.

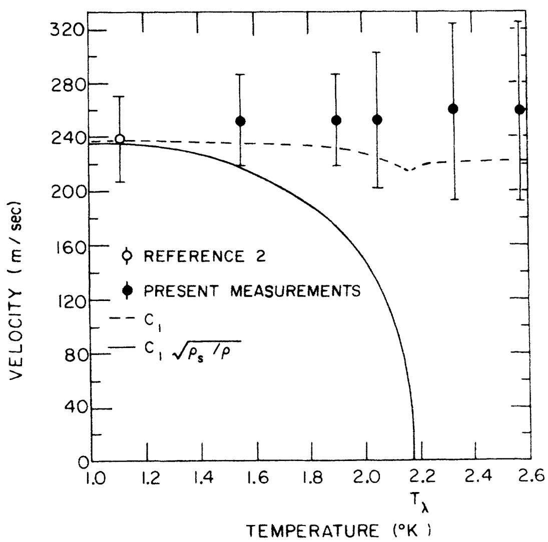

FIG. 2. Phonon velocity calculated from the observed neutron groups compared with the measured velocity of sound and the predictions of reference 1. The vertical bars on the points correspond to the full width at half-maximum of the neutron groups. The instrument resolution is ~ 2°K and is the width observed at temperatures below 1.9°K.

temperature, until temperatures considerably above the lambda point are reached. The width of the neutron group does increase slightly with temperature, however; at 4.2°K the peak is no longer well defined but has become very broad and the maximum in the scattered intensity is at an energy considerably below that corresponding to the velocity of sound. Figure 2 compares the observed phonon velocity as a function of temperature with the measured velocity of sound, c_1, and with $c_1(\rho_S/\rho)^{1/2}$.

The results show clearly that at temperatures up to 2.57°K neutrons scattered with momentum transfer $(p/\hbar)$ of 0.38 Å^{-1} occur in groups whose width increases slowly with temperature and whose energy corresponds to that of a phonon with the velocity of ordinary sound in liquid helium. In the helium-II region there is no apparent dependence on density of the superfluid component. Neither the observed energy change nor the observed width shows any significant change at the λ point such as was observed[2] for neutron scattering from liquid helium at values of $p/\hbar$ near the "roton" region of the dispersion curve. Thus, this region of $\epsilon(p)$ does not depend for its existence upon the fact that the liquid is in its superfluid state.

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[2]D. G. Henshaw and A. D. B. Woods, Phys. Rev. 121, 1266 (1961).

[3]B. N. Brockhouse, in Inelastic Scattering of Neutrons in Solids and Liquids (International Atomic Energy Agency, Vienna, 1961), p. 113.

EXTERNALLY EXCITED WAVES IN LOW-PRESSURE PLASMA COLUMNS

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This Letter reports measurements on low-frequency waves in hydrogen, neon, argon, and mercury arcs ($f = 4$-400 kc/sec, $p = 0.3$-30 mTorr, longitudinal magnetic field $= 0$ or 10-45 gauss, column diameter = 5 or 3 cm). Currents of several amperes were obtained in these gases with a mercury-pool cathode, using a liquid-nitrogen trap in the discharge path.[1] Waves were excited in the positive column by a coil placed 80 cm from the anode and detected by a photomultiplier on the anode side of the coil, as in earlier experiments here on compressional waves in a low-pressure mercury arc.[2-4]

The dispersion curves obtained fall into two groups, those having negative slope (backward waves, Fig. 1) and those having positive slope (forward waves, Fig. 2). Curves obtained by other observers for backward waves in mercury[5] and forward waves in argon[6] and hydrogen[7] are included, together with some of the measurements in mercury reported previously[2]. The symbols specifying the various conditions are explained in Tables I and II.

The backward waves may be described approximately by the empirical relation

$$\omega k = \text{constant}. \quad (1)$$