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Compressibility of Liquid He^4 as a Function of Pressure*

low P

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The compressibility, $\beta=-(1/V)(\partial V/\partial P)_T$, of liquid He^4 was measured from 1 atm to the melting pressure and between 1.6 and 2.5°K. ΔV and ΔP were determined from deflections of the cell walls. The normal decrease of β with increasing P was observed except in an area below the λ line. For an isotherm crossing the λ line, β showed a minimum at $P<P_\lambda$ and a peak at P_λ. The minimum also occurred between the lowest T_λ (1.76°K) and 1.70°K. The variation of β with P near P_λ, relative to β at 2.20°K, followed an equation of the form $\beta_T-\beta_{2.2}=a-b\log|P-P_\lambda|$, where a and b for $P<P_\lambda$ are greater than a and b for $P>P_\lambda$. Between the T limits of the λ line, $(\partial\beta/\partial T)_P$ was definitely negative for P just above P_λ, but it approached zero for $P\gg P_\lambda$.

I. INTRODUCTION

IN general, the isothermal compressibility coefficient, $\beta\equiv-(1/V)(\partial V/\partial P)_T$, of a liquid decreases with decreasing temperature and with increasing pressure. The anomalous increase of β with increasing pressure in liquid He^4 near the λ transition was first indicated by the density measurements of Keesom and Keesom.[1] Their Fig. 3 seems to show $(\partial\rho/\partial P)_T$ at 30 atm rising above the values at 25 and 20 atm in a narrow temperature interval 1.80–1.85°K. However, the authors left the point without comment while they noted "as a remarkable fact that the He II parts of the curves seem to approach at decreasing temperatures to a production of the He I parts. It looks as if there is an intermediary region of increased compressibility, which abruptly ends at the λ curve." On the other hand, no pressure anomaly was shown by the adiabatic compressibility derived from sound-velocity data of Atkins and Stasior.[2] Direct measurements of β, i.e., through small ΔP and ΔV at constant temperature, were made by Grilly and Mills[3] over a short range of pressure and at several temperatures. The values of β peaked at P_λ, but the continuity of β was indefinite. However, it was clear that β had an anomalous variation with temperature near the λ transition for $P>P_\lambda$. Then, Lounasmaa[4] measured β with very high resolution in the immediate vicinity (within 10^{-3} to 10^{-2} atm) of one λ point (2.023°K and 13.04 atm). He obtained a linear variation of β with pressure on each side of P_λ and a discontinuity of 10% in β at P_λ.

All these measurements left unanswered some questions. What is the nature of the expected minimum in the β versus P curve? Does the abnormal variation of β with temperature near the λ transition revert to normalcy at (P,T) far above (P_λ,T_λ)? To answer them, β was measured directly as a function of pressure at several constant temperatures.

II. EXPERIMENTAL

A. Method

The present measurements of compressibility in liquid He^4 were done in a cell designed for general P-V-T work in liquid and solid He^4 and He^3. Essentially, each ΔP and ΔV was measured by the deflection of diaphragms. The cell, shown in Fig. 1, consisted of three diaphragms joined circumferentially and left separated by two gaps, each of which was connected to a capillary tube leading to room temperature. The upper gap acted as the sample chamber, whose volume V_U could be changed at will by the pressure of the liquid in the lower gap. The sample under study was confined to V_U by a valve near the cell. The upper chamber pressure P_U was determined from the deflection of the top diaphragm, while the lower chamber pressure P_L was measured at room temperature through the capillary. At any time, V_U could be determined from P_U and P_L through the formula

$$V_U=V_{U_0}+(S_U+S_L)P_U-S_LP_L\,,$$

where V_{U_0} is the volume of the upper chamber for no deflection of the diaphragms, S_U is the sensitivity of the upper diaphragm in terms of volume change per unit pressure difference, and S_L is the sensitivity of the middle diaphragm. Therefore, the compressibility of

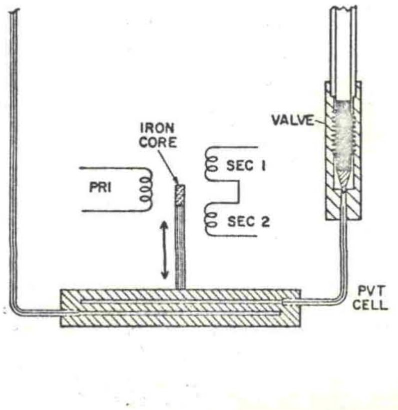

FIG. 1. The P-V-T cell.

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