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COMPRESSIBILITY OF LIQUID He⁴ [1]

M. H. EDWARDS AND W. C. WOODBURY

ABSTRACT

The refractive index n, density ρ, and isothermal compressibility $k_T = (1/\rho)\times(\partial\rho/\partial P)_T$ of liquid He^4 have been measured along isotherms between the saturated vapor pressure and 4.5 atmospheres at 3.0°, 3.5°, 4.0°, 4.5°, and 5.0° K. The liquid was compressed in an optical cell 9.58 cm long in a Jamin interferometer. Changes in density were inferred through the Lorenz–Lorentz equation from refractive index changes measured with a photomultiplier fringe recorder. One fringe corresponds to a change in refractive index of $(5.699\pm0.003)\times10^{-6}$ in this apparatus. Densities range between 0.0995 g cm^{-3} at 5.0° K at the saturated vapor pressure and 0.1501 g cm^{-3} at 3.0° K and 4.5 atmospheres pressure. Compressibilities range between 65×10^{-8} cm^2 dyne^{-1} at 5.0° K at the saturated vapor pressure and 1.16×10^{-8} cm^2 dyne^{-1} at 3.0° K and 4.5 atmospheres pressure. The limiting liquid structure factors for zero-angle X-ray scattering and for coherent scattering of slow neutrons have been calculated from these density and compressibility measurements. In addition, the ratio of heat capacities has been calculated at 3.0°, 3.5°, and 4.0° K where other measurements of the velocity of first sound are available.

INTRODUCTION

A study of the refractive index of He^4 (Edwards 1956, 1957, 1958) has been extended to give further information on the liquid density. The refractive index n, the density ρ, and the isothermal compressibility $k_T = (1/\rho)(\partial\rho/\partial P)_T$ of liquid He^4 have now been measured along isotherms between the saturated vapor pressure (SVP) and 4.5 atmospheres at 3.0°, 3.5°, 4.0°, 4.5°, and 5.0° K. The complete absence of "dead space" corrections makes this optical method particularly attractive at temperatures and pressures where the gas in the connecting tubing is a large correction for direct pycnometric methods. The liquid density has not previously been measured above 4.2° K at any pressure above the SVP, nor has the liquid compressibility been determined directly at any temperature or pressure.

A knowledge of the isothermal compressibility of the liquid is needed for the interpretation of the scattering of X rays through small angles, and the coherent scattering of slow neutrons, since such scattering is attributable to liquid density fluctuations. Furthermore, the liquid compressibility is a most important factor in the electrostriction calculations involved in the analysis of the movement of ions in liquid helium (Atkins 1959; de Boer and 't Hooft 1961).

2. INSTRUMENTATION

The liquid was contained and compressed in an optical cell 9.58 cm long in a special optical cryostat mounted on a Jamin interferometer (Edwards 1956, 1957, 1958). A shift of one fringe in this apparatus implies a refractive index

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