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Low-Temperature Negative-Ion Mobility in Liquid ^{3}He†

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The negative-ion mobility in liquid ^{3}He has been determined in the range 17–300 mK. The pressure dependence of the mobility up to 2 atm was also studied.

The transport properties of ^{3}He below 50 mK (thermal conductivity, viscosity, and spin diffusion) can all be characterized by a relaxation time τ varying as T^{-2} in accord with Landau's theory of a Fermi liquid.[1] In contrast, the negative-ion mobility is observed to be temperature independent in the range 30–800 mK.[2] The explanation of this differing behavior lies in the form of the collision integral entering the mobility problem. If the recoil of the ion is neglected, the problem becomes identical to the force exerted by a current of conduction electrons on an impurity in a solid (where statistics turn out to be unimportant).[3] The resulting expression for the mobility is $\mu = e/\sigma n \hbar k_F$, where n is the number of ^{3}He atoms per cm^3, $\hbar k_F$ is the Fermi momentum, and σ is the conductivity-scattering cross section. Essentially identical results have been obtained by a number of authors using a variety of techniques.[4–7] Satisfactory agreement with experiment is achieved using a hard-sphere model (valid when $k_F a \gg 1$), in which case we have $\sigma = \pi a^2$, where a is the ion radius. At temperatures such that $T \ll (m/M)T_F$, where m and M are the mass of the ^{3}He atom and ion, respectively, the recoil of the ion may not be neglected and several authors have predicted that $\mu \propto T^{-2}$ in this limit.[8–10]

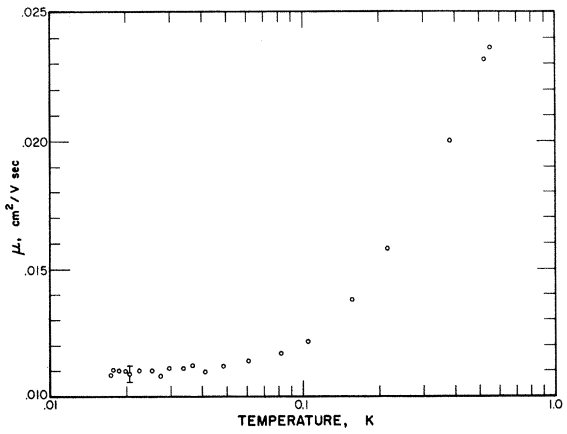

FIG. 1. Negative-ion mobility as a function of temperature in pure ^{3}He at the vapor pressure.

In an effort to observe a departure from a constant value for the mobility of negative ions in ^{3}He, we have extended the measurements down to 17.5 mK. Figure 1 shows the temperature dependence of the negative-ion mobility. Our data are in agreement, within experimental error, with the earlier data of Anderson *et al.*[2] in the temperature range where they overlap. It will be observed that the mobility does not deviate from a constant value at low temperature and, thus, a transition into a $\mu \propto T^{-2}$ region must be at still lower temperatures (if indeed such a transition occurs at all). Figure 2 shows the pressure dependence of the ion mobility (at low temperatures) at pressures to 2 atm. A sizable shift is observed for such a small pressure change thus offering convincing evidence supporting the "bubble" model of the negative ion.

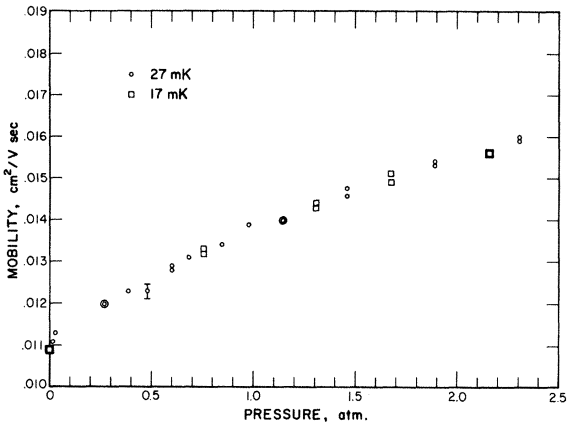

FIG. 2. Pressure dependence of the negative-ion mobility in pure ^{3}He at low temperature.

The low temperatures used in these experiments were produced by a ^{3}He-^{4}He dilution refrigerator with a copper mixing chamber. The mobility was measured with a double-gate velocity spectrometer with a 2.1-cm path length which was housed in a copper cell containing ~2000 cm^2 of sintered Cu for heat contact. Ions were produced by a tritiated titanium source of 3.5-mCi nominal intensity which introduced a heat input of 1.2 erg/sec. The temperature differential between the liquid and the chamber (calculated from the known Kapitza resistance) should thus be of the order of our temperature scale error. The temperature of the mixing chamber-ion cell combination was measured by a cerium-magnesium-nitrate magnetic thermometer made up of single crystals and coil foil in a roughly spherical shape. The magnetic thermometer was calibrated against the vapor pressure of ^{3}He between 0.6 and 1.5 K, and the error in the temperature scale is estimated to be 5%.

†Based on work performed under the auspices of the U.S. Atomic Energy Commission.

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Multiple-Quantum Transitions in a Rotating Magnetic Field*

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The multiple-quantum and rotating-field descriptions of resonant transitions requiring two frequencies are compared. Transitions combining features of both descriptions have been observed.

I. INTRODUCTION

Happer[1] has discussed two-frequency resonant transitions in which one may consider the field of one applied frequency ν_1 as establishing the stationary states and the field of the other frequency ν_2 as causing transitions between them. This description appears to differ somewhat from the idea of multiple-quantum transitions,[2] in which a transition between stationary states (established in the absence of applied frequencies) is produced by the absorption of several photons. In fact, Happer's treatment assumes that photons of frequency ν_1 are plentiful and those of frequency ν_2 are rare. All the transition frequencies he predicts can be written $\nu_2 = |(\Delta E_{ij}/h) + n\nu_1|$, where ΔE_{ij} is the energy difference between two levels and n is an integer; clearly such transitions involve one photon