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The Effect of Surface ^{4}He on Superfluid ^{3}He in Aerogel

J. V. Porto and J. M. Parpia

Department of Physics, Cornell University
Ithaca, N.Y. 14853, U.S.A.

We present results from a torsional oscillator experiment designed to measure the superfluid fraction and transition temperature of ^{3}He in aerogel when the surface ^{3}He is replaced with ^{4}He. The cell has an LCMN susceptibility thermometer mounted directly in the liquid outside of the aerogel to establish thermometry in the presence of ^{4}He on the heat exchanger surface. A capacitor is embedded within the aerogel which is sensitive to the presence of ^{4}He, and allows us to determine that the ^{4}He goes into the aerogel cell. Preliminary results indicate that at 8 bar, the addition of ^{4}He does not significantly alter the superfluid behavior. *

1. INTRODUCTION

After initial experiments on pure ^{3}He in aerogel[1, 2] which showed that the superfluid transition was suppressed but still sharp, one naturally asks what is the effect of ^{4}He on the sytem? In other "confined" geometries, coating the surfaces with superfluid ^{4}He has a dramatic effect because of the change in boundary conditions imposed by the ^{4}He. Aerogels have extremely large surface to volume ratios, ($\sim 20\text{m}^2/\text{cm}^3$ for the sample in our experiment), and the addition of ^{4}He should provide us with information about the nature of the influence of aerogel on superfluid ^{3}He.

2. EXPERIMENTAL CONSIDERATIONS

We have taken measurements on two different cells. The first cell is the same cell used previously to measure the superfluidity in pure ^{3}He[1]. It had no bulk signal, which made determining the aerogel superfluid T_c unambiguous, but there was not an internal thermometer in the cell and we had no direct way to determine the amount of ^{4}He in the cell. For measurements of pure ^{3}He, the thermal boundary resistance between the cell and the stage is sufficiently low that the absence of an internal thermometer was not a problem. The addition of surface ^{4}He, however, is expected to increase the boundary resistance by more than an order of magnitude at $\sim$ 1 mK, and unmeasured thermal gradients could be a problem. Based on experiments we have conducted with the new cell, however, we expect thermal lags to be less than 80μK for our typical warming rates of $\sim 30\mu$K/hour (see the following paragraph).

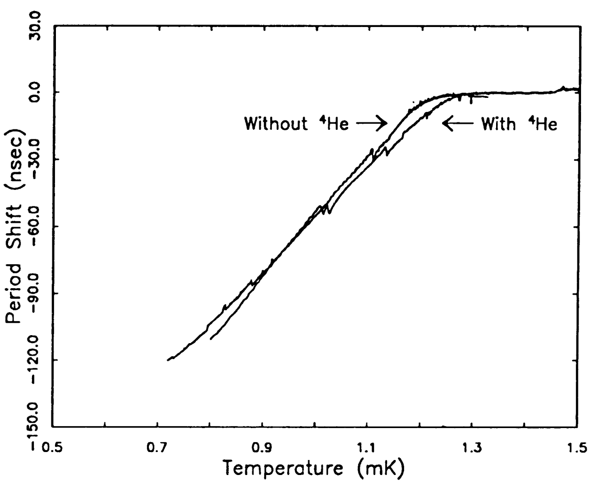

Figure 1: Superfluid period shift at 8 bar for pure ^{3}He and 7% ^{4}He added to the cell. This data is uncorrected for any thermal gradients between the thermometer and cell.

The new cell is identical to the old cell, with three exceptions: the new cell has an lcmn thermometer internal to the liquid volume, the new cell has a capacitor to measure the concentration in the cell, and there is a gap in the cell which gives rise to a bulk superfluid signal. The bulk superfluid transition and the melting curve were both used as a primary thermometer to callibrate the lcmn thermometer. The capacitor is made of two coaxial cylinders of stainless steel with macor spacers, and the aero-

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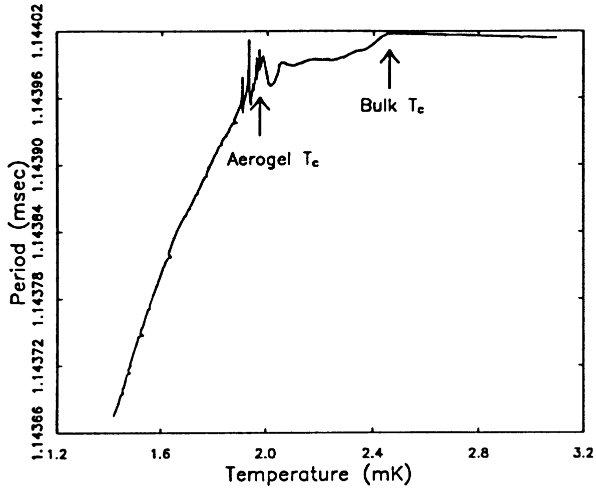

Figure 2: Superfluid period shift for pure ^3He at 28.6 bar, while warming the cell at $40\mu K$/hour.

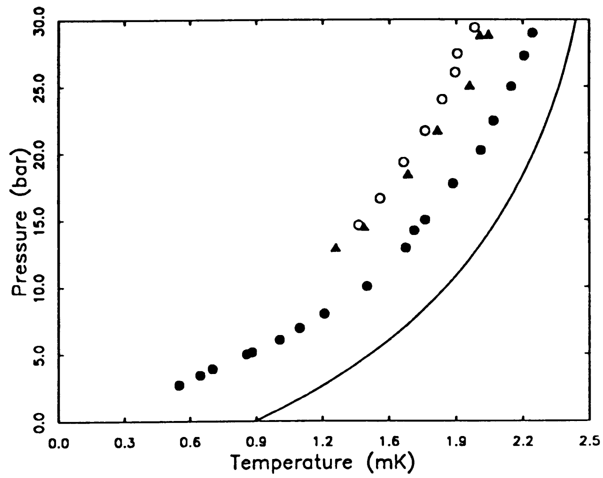

Figure 3: Superfluid transtion temperatures for three different cells. The closed triangles refer to data from reference [2]. The closed circles are data from the first cell, [1], and the open circles are for this cell.

gel was grown so that the capacitor was completely embedded in the aerogel.[4] We found that when the heat exchanger was coated with ~2 layers of ^4He and the entire stage was warmed at a constant rate of $10\mu K$/hour, the cell lagged behind the melting curve by $\sim 3\mu K$ at 2mK. Since the heat exchangers for both cells were of identical construction, this helped increase our confidence in the measurements taken with the first cell. Even if one pessimistically assumes that the boundary resistance increases as T^{-3}, then at 1mK for warming rates of $30\mu K$/hour, the lag would be less than $80\mu K$.

3. RESULTS

In figure we plot the period shift as a function of temperature for two runs in the first cell. The first was taken for the cell filled with pure ^3He, and the second was taken when 7% of the ^3He atoms in the entire cell were replaced with ^4He. The exact distribution of the ^4He between the heat exchanger and the cell isn't known, but if the ^4He were distributed evenly over both surfaces, this would correspond to ~ 8 atomic layers. A ^4He superfluid signal was seen at higher temperatures, and the normal fluid period shift increased when the ^4He was added to the cell, indicating that there was a significant amount of ^4He in the cell. Given the considerations of the preceding section, we would expect the ^4He run to lag by perhaps as much as $\sim 70\mu K$, but this lag would bring the ^4He T_c closer to or lower than the pure T_c. This is clearly not a conclusive measurement, but given the fact that coating surfaces with ^4He in other "confined" geometries has the dramatic effect of increasing T_c to near the bulk value, we argue that the addition of ^4He does not significantly alter the superfluid transition in aerogel, and that this behavior argues against a strictly surface scattering mechanism for T_c suppression.

As of the writing of this paper, we have not yet taken extensive measurements below the transition temperature in aerogel with ^4He in the system. We have made measurements for pure ^3He at several pressures, one of which is shown figure 2. The bulk signal and several sound resonances make it difficult to definitively pick the aerogel T_c, but we can pick out the approximate value as shown with arrows. A comparison to transition temperatures with pure ^3He in other cells is shown in figure 3.

4. ACKNOWLEDGEMENTS

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[3] The aerogel sample had a porosity of 98.2%. It was kindly grown for us at Penn. State by N. Mulders in M.H.W. Chan's research group.