VISCOSITY OF NORMAL AND SUPERFLUID HELIUM THREE

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Résumé.- Nous avons mesuré la viscosité de la composante normale de l'^{3}He dans les phases A et B, et dans le liquide de Fermi normal. Près de T_c, nous pouvons décrire la viscosité réduite avec l'équation $(1 - \eta/\eta_c) = A(1 - T/T_c)^{1/2} - B(1 - T/T_c)$. A l'aide des résultats applicables au liquide normal, nous avons calculé le temps de relaxation $\tau(0)T^2$ d'une quasi-particule dans l'état normal.

Abstract.- The normal fluid viscosity has been measured in the A and B phases of ^{3}He, as well as in the normal Fermi liquid. Near T_c we find that the reduced viscosity can be written in the form $(1 - \eta/\eta_c) = A(1 - T/T_c)^{1/2} - B(1 - T/T_c)$. Using the normal liquid results we have calculated the normal state quasiparticle relaxation time $\tau(0)T^2$.

We have employed a torsional oscillator to measure the viscosity of the normal fluid in both the phases of superfluid ^{3}He in close proximity to the transition temperature T_c. In addition we have measured the viscosity of the liquid in the Fermi liquid region. These results have been used to calculate the normal state quasiparticle relaxation time, $\tau(0)T^2$, and the collision probability parameter α_η. The details of the analysis and a portion of the results have been discussed elsewhere /1,2/.

The liquid ^{3}He sample is contained in a disc shaped region of 0.42 cm diameter and 95×10^{-4} cm height. This fluid is connected to the thermometer and refrigerant via a hollow beryllium-copper torsion rod. The viscometer is driven at its resonant frequency of approximately 909 Hz.

Between 20 mK and about 4mK, we find that the viscosity, η, accurately follows the expected T^{-2} behavior of a normal Fermi liquid. Below 4mK, we observe a small pressure dependent deviation whose origin is thought to be the finite quasiparticle mean free path.

The coefficients of ηT^2 have been determined at several pressures between 0 and 29 bar. At low pressures, these values deviate appreciably from those tabulated by Wheatley /3/. This data has been used to determine values of the effective relaxation time, τ_η, from the relation $\eta = (1/5) nm^* \tau_\eta V_F^2$. These values for $\tau_\eta T^2$ are plotted in Figure 1 and listed in Table I.

At T_c, the viscosity drops sharply. Bhattacharyya et al. /4,5/ have calculated that near T_c, the drop in viscosity should be proportional to the gap.

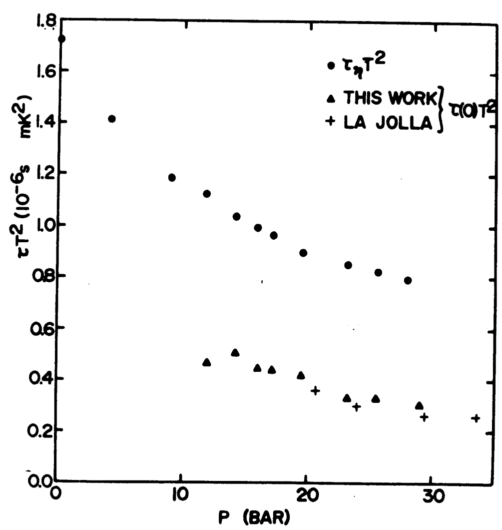

Fig. 1 : Pressure dependence of the effective rexation time $\tau_\eta T^2$ and the quasiparticle relaxation time $\tau(0)T^2$.

We find that the reduced viscosity can be fitted to an expression of the form $(1 - \eta/\eta_c) = A(1 - T/T_c)^{1/2} - B(1 - T/T_c)$ over the temperature interval $1>T/T_c>0.99$, where values of A and B are listed in Table I. There is little pressure dependence to the term linear in the gap in the B phase. However, in the A phase, the data show that the viscosity drops more sharply at the higher pressures. The η_{zx} component of the viscosity tensor is measured in the A phase, corresponding to the uniform texture.

Bhattacharyya et al. /4,5/ have used the s-p approximation to estimate the size of the decrease in reduced viscosity in the superfluid as well as the absolute value fo the normal state viscosity. Neither estimates are quantitatively accurate. However, the pressure dependence of the reduced viscosity in the A and B phases is in agreement with our measurements. It is possible to circumvent the s-p approximation by relating the viscosity decrease in the superfluid directly to the normal fluid results, through the expression $(1 - \eta/\eta_c) = (\pi/4)(1 - \pi^2/12 + \tau_\eta/\tau(0))^2$ $(\tau(0)/\tau_\eta)\Delta/k_BT_c$.

In order to determine the relaxation time $\tau(0)$, we need detailed knowledge of the pressure dependence of the gap parameter, Δ. We have estimated the size of the gap from the magnitude of the heat capacity discontinuity as measured by Webb et al. /3/. In the B phase, we have used the BCS value for the gap. The values of $\tau(0)T^2$ are plotted in Figure 1, and listed in the Table.

Pressure bar	$\tau_\eta T^2$ (10^{-6}s	$\tau(0)T^2$ mK^2)	A	B	α_η
0	1.72				
4.14	1.41				
9.01	1.18				
11.90	1.12	.47	6.79	22.9	1.37
14.20	1.03	.50	6.01	18.0	1.27
15.93	0.99	.45	6.87	20.9	1.32
17.12	0.96	.44	6.25	20.0	1.35
19.64	0.89	.42	6.14	18.4	1.28
23.18	0.85	.33	6.28	21.0	1.41
25.51	0.82	.34	6.43	21.8	1.38
29.00	0.79	.30	6.98	25.0	1.42

Table : Reduced viscosity and normal liquid parameters.

We find good agreement with the values of $\tau(0)T^2$ determined by Webb et al. /6/ and Paulson et al. /7/. Further, the B phase results extend our knowledge of the quasiparticle relaxation time to lower pressures.

The normal state collision probability parameter α_η has been calculated from the coefficient A in the expression for the reduced viscosity. Details of the expansion used may be found in the review by Bhattacharyya et al. /4,5/. Values of α_η are listed in table I.

Once again, the s-p approximation values for α_η are seen to be smaller than the experimental values. However the pressure dependence is replicated. We hope that these measurements of the transport properties will provide the incentive for new calculations of the collision probability.

One of us (J.M.P.) would like to thank Professor John Wilkins for his comments.

This work has been supported by the National Science Foundation through Grant No. DMR 75-08624 and No. DMR 76-21669 and by the National Science Foundation through the Cornell Materials Science Center Grant No. DMR 76-81083.

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