MAGNETIC PROPERTIES OF He^3 AT PRESSURES NEAR THE MINIMUM IN THE MELTING CURVE[*]

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Recent measurements of the specific heat[1] and the velocity of sound[2] of He^3 at pressures slightly above the minimum of the melting curve, P_{min}, and temperatures below 0.1°K have shown departures from the behavior of both the liquid at pressures less than P_{min} and the solid. The purpose of this Letter is to report measurements of magnetic properties of He^3 in this region of the phase diagram which also indicate anomalous behavior.

In these measurements the self-diffusion coefficient, D, the transverse relaxation time, T_2, and the magnetic susceptibility, χ, were measured by the use of the method of spin echoes using the apparatus and techniques described elsewhere.[3,4] The longitudinal relaxation time, T_1, was estimated by observing the time necessary for the magnetization to recover after having been destroyed. The thermometer used was the same magnetic thermometer described in reference 3, and was calibrated by measuring the self-diffusion coefficient at temperatures less than 0.1°K and a pressure of 13 cm Hg and comparing with the results of reference 3.

When working at pressures greater than P_{min}, a plug of solid He^3 was formed in the tube through which the pressure was applied to the sample so that the pressures quoted refer to the pressures at which the plug formed and not necessarily to those of the sample at the temperatures at which the measurements were being made. Although the exact region of the phase diagram in which these measurements were carried out is not known with certainty, it is probable that the present measurements were made in the same region of the phase diagram as the measurements of specific heat and velocity of sound since a similar technique was employed in each case.

The principal results of these measurements are as follows. At a pressure of 28.9 atm, below P_{min}, the liquid behaved in a manner similar to that of the liquid at lower pressures; the diffusion coefficient increasing with decreasing temperature, being 2.6×10^{-4} cm^2/sec at 0.033°K, T_2 being greater than 0.75 sec, T_1 being of the order of 10 sec, and the susceptibility being nearly constant with temperature. At 29.5 atm, a pressure slightly greater than P_{min}, this behavior changed greatly. The diffusion coefficient became too small to be

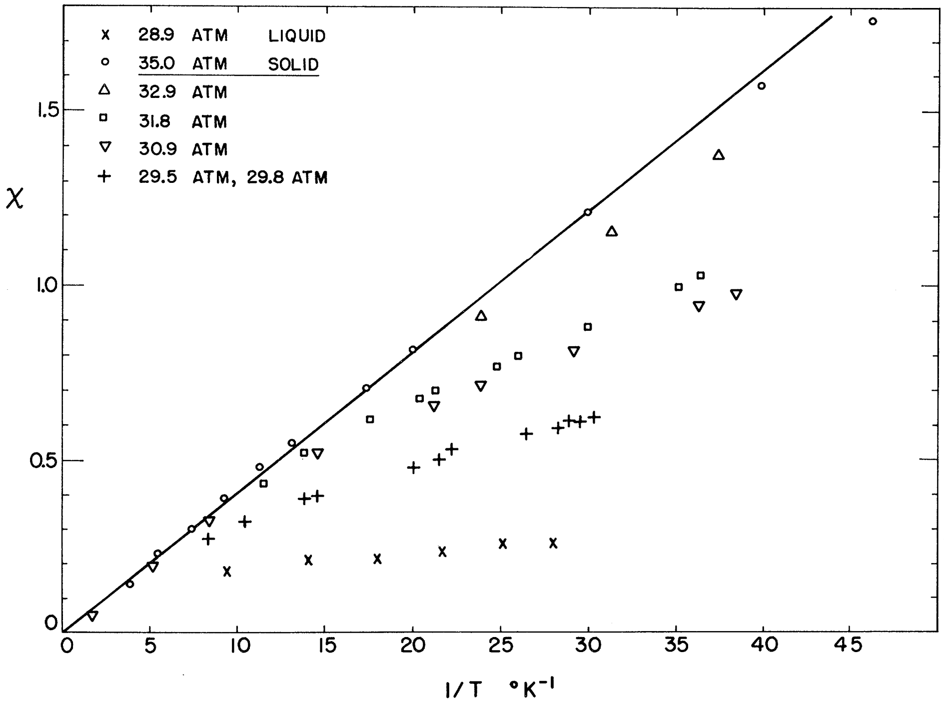

FIG. 1. Susceptibility of He^3, χ, in arbitrary units vs $1/T$. The points are averages of the raw data at each temperature. The solid line represents the best Curie law fit to the 35.0-atm solid data. The pressures for all but the 28.9-atm liquid data are the pressures at which the plug of solid He^3 was initially formed. The data for 29.5 atm and 29.8 atm are shown with the same symbol since no difference could be distinguished between them. Quite possibly this is the result of irreproducibility in the process of forming the plug.

measured with the present apparatus, being less than 5×10^{-7} cm^2/sec, while T_2 decreased to 0.34 ± 0.02 sec and T_1 decreased to be of the same order as T_2. At 0.033°K the susceptibility was a factor of 2 larger at 29.5 atm than at 28.9 atm and displayed a considerably different temperature dependence at the higher pressures from that of the liquid below P_{min}. No difference in T_2, T_1, or D could be observed either upon further increasing the pressure or by heating the He^3 to temperatures where the solid phase should exist.

A portion of the susceptibility data is shown in Fig. 1. It should be noted that in addition to the change in behavior of the susceptibility between 28.9 and 29.5 atm, the susceptibility obeyed Curie's law much better at pressures of 32.9 atm and above than at lower pressures. It is interesting to note that in the region between 29.5 atm and 31.8 atm the susceptibility seems to break away from Curie's law near the temperatures where the melting curve of Edwards et al.[5] would predict the solid-liquid phase boundary to occur if the pressure of the sample were that at which the plug was formed.

In view of the measurements of specific heat, sound velocity, susceptibility, T_1, T_2, and D, it appears that the nature of He^3 in the region of the phase diagram of pressures greater than P_{min} and temperature less than about 0.1°K is not understood. It is possible that a new phase of solid, rather than liquid, exists in this region, although further experimentation will be necessary to establish such a fact.

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BEHAVIOR OF STRONGLY SHOCKED CARBON*

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This Letter gives evidence for the conversion of graphite to the diamond phase when it is subjected to strong, explosively generated shocks. Furthermore, the data lend support to a further conversion at still higher pressures to a new, higher density phase of carbon, presumably the close-packed metallic liquid.

The initial material was, in the majority of the experiments, natural graphite from Ceylon of very high purity which was pressed into suitable uniform-density pellets of about 95% of theoretical density. Some work was done with commercial graphite, which has a density of 75% of theoretical.

The samples were mounted on an aluminum plate, and by optical means[1] both the shock and free surface velocity of carbon and aluminum were determined. The measurements on the aluminum standard could then be used to determine the pressure-volume point of carbon from its measured shock velocity. This is a more reliable procedure than the use of the free surface velocity when the material does not have a simple behavior. The data are presented in Fig. 1, where the specific volume has been used to avoid artificial corrections due to varying initial densities. However, a correction to the pressure or volume still needs to be made for the increased energy content resulting from a greater change in volume of an initially low-density sample. This correction is insignificant except for samples of $\frac{3}{4}$ theoretical density.

The shock data at low pressures agree with the x-ray determination of crystal densities under pressure[2] as shown by the triangles in Fig. 1. At somewhat higher pressures the static data of Bridgman[3] are indicated by squares in Fig. 1. Again the agreement is good if those data are corrected for the alleged error in the pressure