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MEASUREMENTS OF THE MELTING CURVE OF PURE He^3 BELOW THE MINIMUM*

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We have measured the melting curve of pure He^3 in the temperature range 0.12°K to 0.7°K by observing the pressure and temperature of a constant volume containing the liquid and solid phases in equilibrium. The constant volume vessel was filled at 1.2°K with liquid He^3 under pressure[1] through a 0.3-mm i.d. capillary. On cooling this system by means of a paramagnetic salt thermally attached to it,[2] a solid block was created in the capillary thereby sealing the vessel from effects of pressure change above the block and maintaining a constant volume below the block. During further cooling, two phases existed in the vessel. By appropriate adjustment of the initial conditions, the two-phase equilibrium could be maintained over the whole region of observation.

The temperature of the vessel was observed by use of a spherical cerium magnesium nitrate magnetic thermometer thermally attached to the vessel, as has been used and described by us previously.[2] Temperatures could be measured to better than ±0.004°K. The pressure inside the vessel was observed by a strain gauge (Baldwin *SR*4) which was cemented to the cylindrical thin outside wall of the vessel.[3] To minimize possible effects of temperature changes on the strain gauge readings, an identical gauge was used as a compensator, this "dummy" being mounted on a thick unstrained portion of the vessel. The gauge was calibrated when the vessel was filled with liquid He^3 against a calibrated Bourdon gauge, accurate to ±0.1 atmos, located in the He^3 line at room temperature. The strain gauge permitted pressure differences to be read to ±0.02 atmos. Details concerning the use of these strain gauges as pressure transducers at these low temperatures and concerning the high-sensitivity ac resistance bridge for use with them will be given elsewhere. The vessel itself had a volume of 0.3 cm^3 and was constructed to have a large copper internal surface, so as to effect optimum contact between it and the He^3 it contained.

The results obtained during repeated coolings and warmings of the vessel on five different runs are shown in Fig. 1. The scatter in the results of each run is rather small, but systematic

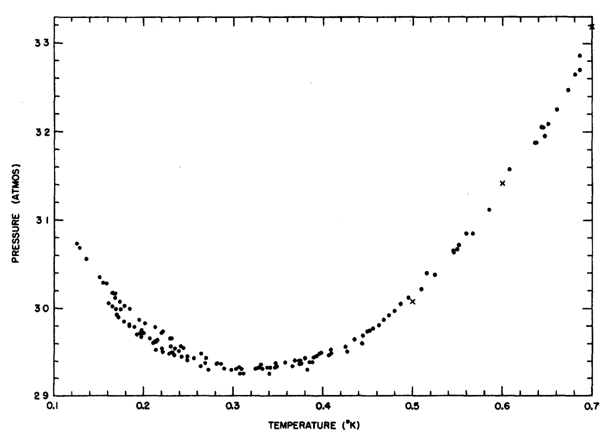

FIG. 1. The melting curve of pure He^3. The circles give the experimental results reported in this Letter. The crosses are obtained from previous work by Weinstock, Abraham, and Osborne (see text) and represent a few of their results of measurement above 0.32°K.

Table I. The melting pressure of He^3 as a function of temperature. Smoothed values taken from Fig. 1.

T (°K)	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.40	0.50	0.60	0.70.
P (atmos)	30.8	30.5	30.2	30.0	29.8	29.5	29.3	29.4_5	30.15	31.4	33.1

errors appear between runs, due to inaccuracies in the Bourdon gauge, which increase the overall error to about ±0.1 atmos. Table I gives smoothed values of the melting pressure taken from Fig. 1.

The measurements above 0.32°K agree within the estimated error with the measurements of Weinstock, Abraham, and Osborne.[4] For comparison we include in Fig. 1 some of these previous results, shown by the crosses, calculated from the equation given by Weinstock et al. At lower temperatures the curve shows an upward trend, the minimum occurring at about 0.32°K and 29.3 atmos, thus confirming directly the conclusions concerning the existence of a minimum arrived at by Fairbank and Walters.[5] Our evaluation of T_{min} agrees closely with that obtained by Lee, Fairbank, and Walker.[6]

These results may be compared with the theories of Pomeranchuk,[7] Sanikidze,[8] and Bernardes and Primakoff.[9] All of these theories predict a minimum, but with subsequent rises in pressure at temperatures below the minimum which exceed our experimental observations. A revised form[10] of the paper by Bernardes and Primakoff shows close agreement with our experimental data, giving a minimum at 0.37°K and rising to 31.3 atmos at 0.12°K. The latter figure is to be compared with our observed value of 30.8 atmos at the same temperature.

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[1]The He^3 was kindly lent to us by the Stable Isotopes Division of the U. S. Atomic Energy Commission.

[2]Brewer, Sreedhar, Kramers, and Daunt, Phys. Rev. 110, 282 (1958); Brewer, Daunt, and Sreedhar, Phys. Rev. (to be published).

[3]We are indebted to Dr. R. M. McClintock for informing us of his experimental work on the use of strain gauges at liquid helium temperatures and for a preprint from the Cryogenic Engineering Laboratory, National Bureau of Standards, Boulder, Colorado, by him describing this work.

[4]Weinstock, Abraham, and Osborne, Phys. Rev. 85, 158 (1952).

[5]W. M. Fairbank and G. K. Walters, Symposium on Liquid and Solid He^3 (Ohio State University Press, Columbus, 1957), p. 220; and Bull. Am. Phys. Soc. 2, 183 (1957).

[6]Lee, Fairbank, and Walker, Bull. Am. Phys. Soc. 4, 239 (1959).

[7]I. Pomeranchuk, J. Exptl. Theoret. Phys. U.S.S.R. 20, 919 (1950).

[8]D. G. Sanikidze, J. Exptl. Theoret. Phys. U.S.S.R. 35, 279 (1958) [translation: Soviet Phys. JETP 8, 192 (1959)].

[9]N. Bernardes and H. Primakoff, Phys. Rev. Letters 2, 502 (1959).

[10]N. Bernardes and H. Primakoff, this issue [Phys. Rev. Letters 3, 144(1959)]. We are grateful to Dr. Bernardes for communicating his results to us before publication.