

USE OF THE POMERANCHUK EFFECT TO OBTAIN INFRALOW TEMPERATURES

Yu. D. Anufriyev

Vavilov Institute of Physics Problems, USSR Academy of Sciences

Submitted 4 May 1965

It is known that the melting curve of He^3 has a minimum at a temperature $T_{\min} \approx 0.3^\circ \text{K}$ and a pressure $P_{\min} \approx 30 \text{ atm}$. At temperatures below T_{\min} , an increase in pressure is accompanied by a decrease in the temperature of the two-phase liquid-solid He^3 system. If the pressure is applied adiabatically, then this method makes it possible to obtain a temperature T^* on the order of the energy of interaction of the nuclei of the solid He^3 , which amounts to 10^{-6} K in the absence of exchange interaction. This effect, predicted as early as 1950 by Pomeranchuk [1], should be a convenient method of obtaining infralow temperatures [2]. The Pomeranchuk effect has many remarkable advantages over the standard adiabatic demagnetization of paramagnetic salts. First, adiabatic crystallization of He^3 will apparently yield lower temperatures (lower than 0.001°K). In addition, by virtue of the high spin concentration, in the Pomeranchuk effect the cooling produced by one cubic centimeter of He^3 is approximately 10 times larger than the corresponding cooling produced by adiabatically demagnetized paramagnetic salts.

The most interesting, however, is the fact that the Pomeranchuk effect makes it possible to cool liquid He^3 to the temperature T^* . Indeed, by using the experimental data on the entropy of liquid He^3 and by assuming that when $T < T_{\min}$ the entropy of solid He^3 is $R \ln 2$, we can easily construct the curves shown in Fig. 1. These curves illustrate the variation of the composition of the two-phase liquid-solid He^3 system during adiabatic compression. We see that if the process is started at $T = 0.1^\circ \text{K}$, then more than 50% of He^3 remains liquid down to the lowest temperatures. When liquid He^3 is cooled in this manner, the usual difficulties connected with the Kapitza jump on the interface between the He^3 and the solid do not arise, so that this cooling can be effected within a reasonable time.

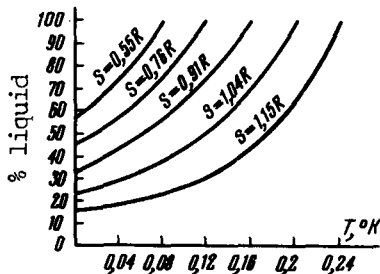


Fig. 1. Change in composition of a two-phase liquid-solid He^3 system following adiabatic compression

The main difficulty which arises in this case is the problem of adiabatic transfer of pressure to the He^3 . The point is that owing to the anomalous behavior of the melting curve of He^3 when $T < T_{\min}$ and $T > T_{\min}$, all the capillaries leading to the higher-temperature region must be plugged with solid He^3 . To observe the Pomeranchuk effect it is therefore necessary, if possible, to reduce the volume in which the He^3 is contained without releasing any heat. We developed for this purpose the apparatus shown in Fig. 2.

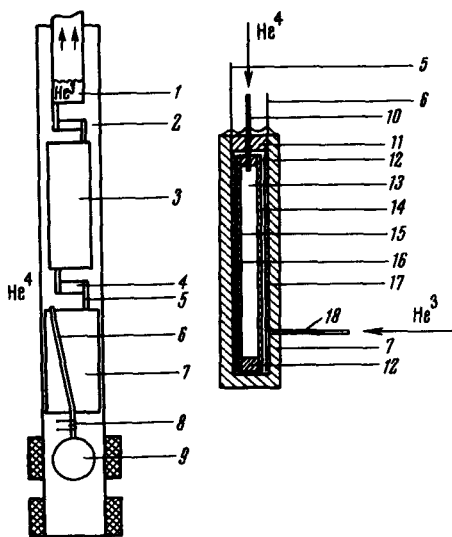


Fig. 2. Schematic diagram of the apparatus.

The chamber 13, bounded by frame 12 and membranes 14 and 15 of special stainless steel, is contained inside a bronze chamber 7 with inside dimensions 40 x 20 x 3.5 mm. Between the membranes and the walls of chamber 7 there were left gaps of 0.5 mm, in which sheets of metal foil 16 and 17 (heat exchange area 30 cm²) were placed to serve as cold leads from the chamber. The chamber 7 was covered on the top with a lid 11 and sealed with tin solder. A tin superconducting switch leading to the paramagnetic salt 3 (iron-ammonium alum) was connected to cold finger 5. In addition, cold finger 6 was in thermal contact with a carbon thermometer 8 and thermometric salt 9 (5 g of cerium-magnesium nitrate). Block 3 consisted of 60 g iron-ammonium alum and was connected through tin switch 2 to a bath of He³ (1). Capillaries 18 and 10, leading

to chambers 7 and 13, passed through the He³ bath and through block 3.

To observe the effect, He³ was condensed inside chamber 7 at a pressure of 30 atm, causing membranes 15 and 14 to deform. He⁴ was then condensed in chamber 14 at low pressure, and the entire system was cooled to a temperature $T < T_{\min}$ by adiabatic demagnetization of the iron-ammonium alum block. The pressure of the He⁴ was then raised gradually (in 30 to 90 min). This pressure was partially transmitted through membranes 14 and 15 to the He³, which was already compressed to 30 atm. The pressure of He³ could thus be adiabatically raised above P_{\min} .

Adiabaticity was ensured by the fact that at such low temperatures (lower than 0.3° K) the normal part of He⁴ has practically disappeared, so that both the thermal conductivity and the specific heat of He⁴ are due essentially to the phonons. It is obvious that the heat content of He⁴ entering chamber 13 is negligible compared with the cold produced by the Pomeranchuk effect, and the heat transferred along the capillary with the He⁴ can be made as small as possible by using a small capillary diameter (capillary 10 had a diameter of 0.1 mm). The thermometers installed in the apparatus made it possible to measure the He³ temperature only down to 0.015 - 0.02° K. It was impossible to measure a lower temperature by using the magnetic susceptibility of the cerium-magnesium nitrate, since the time necessary to equalize the thermometer and the He³ temperatures was approximately 10 minutes even at $T \sim 0.02^\circ$ K. Since this time varies with temperature like $1/T^5$, many hours would be necessary to measure lower temperatures.

Experiments on the adiabatic crystallization of He³ have shown that the Pomeranchuk effect can yield with assurance temperatures of 0.02° K (actually, the temperature was in all probability lower). The time schedule of one of the experiments is shown in Fig. 3. The pressure was measured at the entrance of the capillary with the He⁴ into the apparatus, and the He³

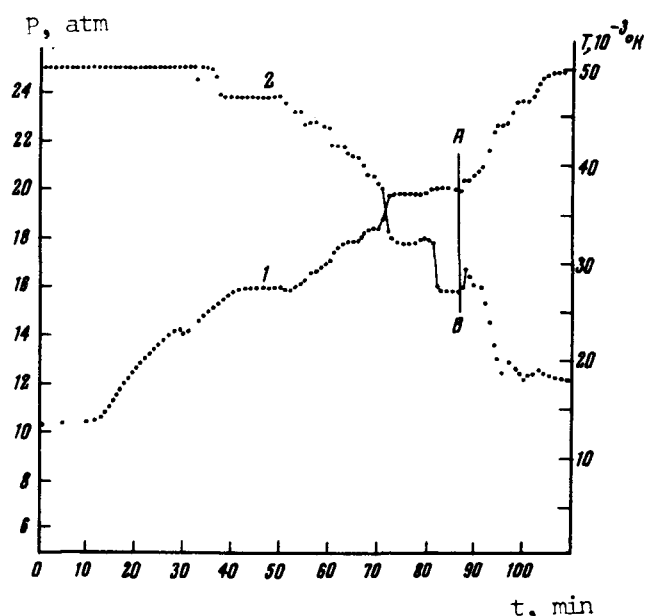


Fig. 3. Time schedule of the experiment with adiabatic recrystallization of He³. 1 - He⁴ pressure, 2 - He³ temperature.

followed immediately by a rise of approximately 0.005° in the temperature of the He³ (point B on curve 2).

A more detailed study of the Pomeranchuk effect, using nuclear thermometry, is presently under way.

The author is grateful to P. L. Kapitza for interest in the work and V. P. Peshkov for guidance and continuous help.

[1] I. Pomeranchuk, JETP 20, 919 (1950).

[2] V. P. Peshkov and K. N. Zinov'eva, UFN 67, 193 (1959), Soviet Phys. Uspekhi 2, 82 (1959).

TIME PARITY NONCONSERVATION IN STRONG INTERACTIONS

G. A. Lobov

Submitted 4 May 1965

Henley and Jacobsohn [1] (see also [2]) calculated the correlation of the pulses of two cascade gamma quanta emitted by an excited polarized nucleus. The correlation calculation took account of the nonconservation of time parity in strong interactions for the particular case when the first γ transition is mixed and the second pure.

temperature was determined from the susceptibility of the cerium-magnesium nitrate. The reason why abrupt cooling does not set in immediately, but only after the pressure of the He⁴ has risen to 15 - 16 atm, is that at large pressure drops, when $P_{\text{He}^3} \sim 30$ atm and $P_{\text{He}^4} \sim 1$ atm, the membranes 14 and 15 (Fig. 2) become strongly deformed and come in contact with each other. Consequently a noticeable change in the volume of the He³ occurs only when $P_{\text{He}^4} > 15$ atm. It is very important to vary the pressure smoothly. A sharp increase in pressure can lead not to cooling but, to the contrary, to an increase in the temperature of the He³. By accident, the pressure rose on curve 1 (Fig. 3), at the point A, by several tenths of an atmosphere within 2 - 3 seconds. (No such pressure jumps are noted on curve 1, since the readings of the instruments were recorded not oftener than once a minute.) This was