$$\mu_e + \mu_p = \hbar\omega_1 - R_0/[A - B(\hbar\omega_1 - \Delta)^{1/2} J\partial f_e/\partial\varepsilon_e], \quad (3)$$

where J is the flux of quanta at frequency ω_1, and R_0 is the recombination rate. Then

$$\mu_e + \mu_p = \hbar\omega_1, \quad A = \left(\frac{\partial R_0}{\partial n} + \frac{\partial R_0}{\partial p}\right)\left[\left(\frac{\partial n}{\partial \mu_e}\right)^{-1} + \left(\frac{\partial p}{\partial \mu_p}\right)^{-1}\right]^{-1}.$$

From (3) we can determine the minimum intensity which will give rise to the threshold value of $\mu_e + \mu_p$;

$$J_{min} = R_0/k(\omega_1) \approx R_0/B(\hbar\omega_1 - \Delta)^{1/2} \times (\hbar\omega_1 - \mu_e - \mu_p)(\partial f_e/\partial\varepsilon_e), \quad (4)$$

where $k(\omega_1)$ is the absorption coefficient.

If the intensity of the external radiation J exceeds the threshold intensity given by (4) laser action will occur in the semiconductor, so that, independent of the excitation, (2) is always satisfied. This has the result that the quantity $\mu_e + \mu_p$ remains constant and equal to its value at threshold even up to extremely large intensities, at which point significant heating of the electron-hole gas begins. In this case the thickness of the active region is given by

$$l = [k(\omega_1) + \varkappa]^{-1} \ln(J/J_{min}) \quad (5)$$

and the efficiency η is given by

$$\eta = \{J - J_{min}(J/J_{min})\varkappa/(k + \varkappa) - R_0 \ln(J/J_{min})/(k + \varkappa)\}/(J\omega_1/\omega_0).$$

If the conditions $J \gg J_{min}$ and $k \gg \kappa$ are satisfied, the value of η will be approximately unity, indicating the possibility of efficient transformation of incoherent monochromatic radiation into coherent radiation.

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SUPERFLUIDITY OF He^3

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THE question of whether He^3 can be superfluid was raised immediately after studies of its properties were started. However, no superfluidity could be observed down to the lowest attainable temperatures. After the formulation of the theory of superconductivity, it appeared quite probable [1-3] that He^3 would become superfluid at sufficiently low temperatures, since its atoms, in analogy with the electrons in superconductors, have a tendency towards noticeable pair interaction, owing to the presence of nuclear spins. These considerations have served as an impetus for complicated experimental investigations, brief results of which are presented here.

To attain the very lowest temperatures in He^3, an instrument was developed with three-stage demagnetization of paramagnetic salts. The first stage constituted iron-ammonium alum, the second consisted of large crystals of cerium-magnesium nitrate (CMN), while the third is shown in Fig. 1. The bath with He^3 was connected by means of a superconducting tin heat switch to a pellet of iron-ammonium alum, while the third was connected by the tin switch to the second stage, the method of connecting the second stage to the first being shown in Fig. 1. For more rapid cooling, 640 copper wires 2 cm long and 50 microns in diameter, silver-soldered to a copper frame, were placed in the third capsule. The capsule was pressed in the form of a sphere made of CMN powder with average grain dimension $\sim 10\,\mu$ in such a way that the total volume of the pores was ~ 1 cm^3, with a sphere volume 8 cm^3. The sphere was coated with epoxy resin mixed with crushed quartz (the composition was prepared at the Institute of Physics

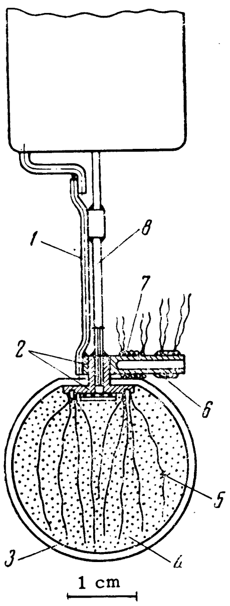

FIG. 1. Third stage of instrument for adiabatic demagnetization. 1—Thermal switch (Sn), 2—copper frame, 3—epoxy resin with quartz filler, 4—cerium-magnesium nitrate, 5—copper wires 0.05 mm in diameter, 640 pieces, 6—thermometer, 7—heater, 8—German silver capillary with inside diameter 0.125 mm.

Problems under the guidance of N. N. Mikhaĭlov). After drying the coating, surface polymerization was produced to ensure that the capsule remains hermetically sealed down to the lowest temperatures.

It was possible to cool 1.12 cm^3 liquid He^3 with this system to a (magnetic) temperature 0.0033°. The lowest magnetic temperature corresponding to the largest deflection of the ballistic galvanometer was taken to be 0.0032°, in accordance with the measurements of Daniels and Robinson[4]. Since one cannot hope to obtain rapid establishment of thermal equilibrium in the entire volume of the sphere after local overheating, the capsule was heated rather uniformly over the entire volume by radiation from two gamma sources (Cs^{137}) on two sides. The sources were brought close to the capsule every minute or two minutes (accurate to 0.1″) and were moved apart automatically; the energy released in the capsule amounted in this case to 70 or 140 erg. The parasitic heat influx was ~ 1—4 erg/min. The temperature of the capsule was determined every minute by measuring the deflection of the ballistic galvanometer as the sphere magnetization was reversed. The heating curves showed distinct steps without any "tails," making it possible to determine the specific heat of the capsule and indicating that more effective heat transfer occurred between the CMN and the He^3 than between the metal and the He^3. This may be connected with the magnetic interaction of the He^3 atoms and the CMN on the interface.

Figure 2 shows the variation of the specific heat with temperature for five experiments. The dependence of the specific heat of the empty capsule coincides with the specific heat of the capsule filled with liquid He^4. On the other hand, if only 0.058 cm^3 of He^3 is condensed on the capsule, that is, an amount sufficient to cover with film all the CMN crystals, then for $T > 0.005°$ the specific heats of the empty and filled capsules almost coincide, and for $T < 0.005°$ the capsule with He^3 has as it were a lower specific heat, that is, it receives a much larger quantity of heat than a capsule which is empty or filled with He^4. This can be attributed to the fact that the epoxy resin, the copper frame, and the copper wires are heated

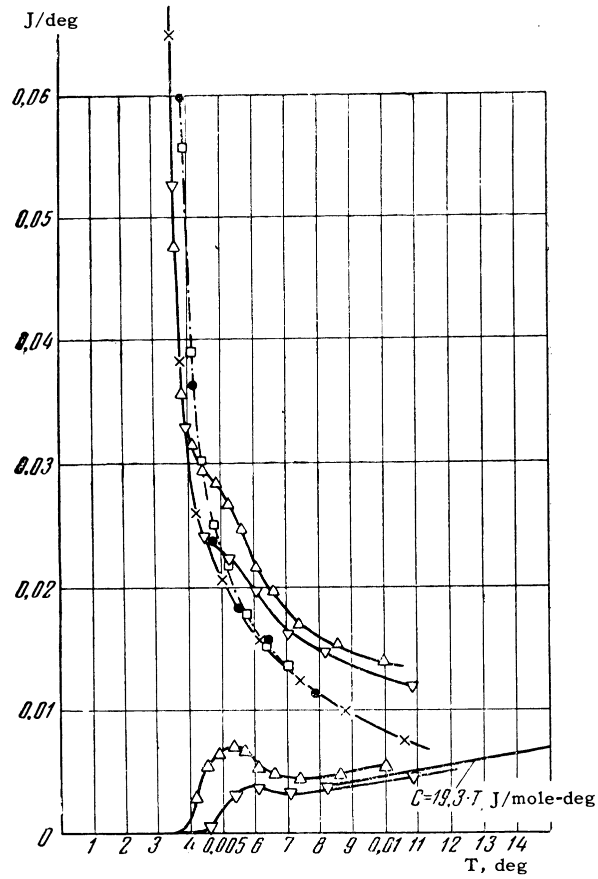

FIG. 2. Dependence of specific heat of the capsule on the temperature (upper curves): ●—empty capsule, □—1 cc of liquid He^4 in capsule, ×—0.058 cc of liquid He^3 in capsule, ▽—1.12 cc of liquid He^3, irradiation with two gamma sources each releasing 140 erg in the capsule in 120 seconds, △—1.12 cc liquid He^3, with 68 erg released in the heater in 60 seconds. Lower curves: ▽ and △—difference in specific heats determined respectively from the points × and △ of the upper curves and the curves drawn through the points ×. The lower straight line corresponds to the specific heat C = 19.3 T J/mole-deg, determined for liquid He^3 by Anderson et al.[5]

by the gamma rays to several hundredths of a degree and if the capsule is empty or filled with He^4 they give up the heat principally through the superconducting switch to the upper salt, while in the presence of He^3 the heat transfer from the copper through the He^3 to the CMN greatly increases. The symbol ∇ denotes the experimental points for a capsule completely filled with He^3 and heated with gamma rays, while the symbol Δ corresponds to the experiment with capsule filled completely with He^3, but with the heat $\Delta Q = 68$ erg released in heater 7 wound on the copper frame. Here, as in the case of gamma irradiation, distinct steps were observed, but with "tails" shorter than 3 minutes. In the calculation of the specific heat it was assumed that only 66 ergs enter into the capsule; in this case the value of the specific heat at $T = 0.0035°$ coincided with the specific heat obtained in experiments with gamma radiation for a capsule completely filled with He^3, and a capsule filled with 0.058 cm^3 of He^3, if it is assumed that in the latter case the heat release is not 140 but 126 erg.

On the bottom of Fig. 2 are shown the values of the specific heat of He^3 obtained from the plot as the difference between the specific heat of the capsule filled with 1.12 cm^3 of liquid He^3 and filled with 0.058 cm^3 He^3. On the right is shown a straight line corresponding to $C = 19.3\,T$ J/deg-mole—the specific heat of He^3 measured in the interval from 0.008 to 0.04° by Anderson, Salinger, Steyert, and Wheltey [5]. It is clear that when the heat is released from a heater one cannot hope for thermal equilibrium to be established within a few minutes in the entire volume of the capsule, but the character of the specific heat curves obtained in such a manner, and also the sharp increase in the heat transfer through the He^3 to the CMN at temperatures below 0.0055° can hardly be interpreted in any other way except as the transition of He^3 at $T \approx 0.0055°$ into a superfluid state.

It must be noted that the existence of a superfluid phase in He^3, its possible properties, and the transition temperature were considered theoretically by several workers [6-12]. According to the calculations of Gor'kov and Pitaevskiĭ [11] the transition temperature T_{cr} should lie between 0.008 and 0.0002°K, and in accordance with the calculations of Soda and Vasudevan [12] $C = \alpha T$ (above T_{cr}) and the heat capacity increases jumpwise by 2.08 times at the transition point, beyond which it decreases rapidly with decreasing temperature. We see that our results agree with those theoretical estimates. A more detailed description of the experiments will be published later.

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