curves. Measurements of the Hall coefficient of the same p-type InSb samples, with hole densities $p \sim 10^{14} - 10^{13}$ cm^{-3} at temperatures 4.2 - 50°K, revealed an impurity band due to shallow acceptors. Their ionization energy fluctuates in the range $(5 - 8) \times 10^{-3}$ eV. The separately determined acceptor and donor densities, for example in a sample with hole density $p \sim 3 \times 10^{13}$ cm^{-3}, were respectively $N_a = 2.653 \times 10^{16}$ cm^{-3} and $N_d = 2.650 \times 10^{16}$ cm^{-3} (N_d/N_a = 99.95%). It must be noted that the maxima on the $R = f(10^2/T)$ curves shift towards higher temperatures with decrease of carrier density. Thus, in p-InSb samples with hole densities (at T = 77°K) 2.6×10^{13}, 9.85×10^{13}, and 1.47×10^{14} cm^{-3}, the maxima of $R = f(10^2/T)$ are observed at 18, 11.8, and 6.2°K respectively. In samples with uncompensated hole densities $\sim 6 \times 10^{11} - 6 \times 10^{12}$ cm^{-3}, no impurity zone was observed at temperatures lower than 50°K.

The new experimental facts reported in this paper cannot be convincingly explained as yet. We can propose the following preliminary suggestions: 1. It is possible that the maxima on the $R = f(T)$ curves, for samples with densities $6 \times 10^{11} - 6 \times 10^{12}$ cm^{-3}, are the results of the simultaneous action of the shallow-acceptor band and the deep defect level. 2. It can also be assumed that the appearance of the maxima is connected with the presence in the InSb of two kinds of holes, the density ratio of which changes under the influence of a number of factors[6].

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ATTEMPTS TO OBSERVE EXPERIMENTALLY THE PENETRATION OF SUPERFLUIDITY INTO NARROW PORES

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It is well known that superfluidity should vanish in narrow gaps at temperatures T_c whose positions below the λ-point (T_λ = 2.173°K) are the lower, the smaller the gap width [1]. However, Mamaladze and Cheishvili have shown [2] that if a sufficiently large volume of superfluid liquid flows around a microporous body, then the helium filling the pores of this body retains its superfluidity in the temperature interval $T_\lambda > T > T_c$.

We report here the results of a preliminary set of experiments undertaken by E. L. Andronikashvili and the authors for the purpose of investigating these phenomena.

Figure 1 shows the setup employed by us. Zeolite powder NaX (1), with large and small cavity diameters 6.6 and 11.6 Å respectively, was placed in a cylindrical vessel (6) made of Plexiglas and immersed in liquid helium.

Zeolite is usually employed in the form of granules, tablets, or small spheres. The granules are secondary formations, consisting of contacting crystallites with dimensions from 1 to 4 μ, the gaps between which form the secondary porous structure of the granules. The pore dimensions in the granules may fluctuate in a very wide range, and depend on both the dimensions of the crystals themselves and on the character of their packing. According to data by M. M. Dubinin [5], the equivalent radii of the secondary pores (cavities) range from several tenths to hundreds of thousands of Angstroms.

In our experiment, the zeolite NaX was first conditioned for 3-4 hours at 350-400°C in a vacuum of 10^{-4} mm Hg to remove the moisture vapor from it. Before each experiment, the zeolite was lightly compacted by hand pressure and evacuated anew. To prevent its being drawn into the vacuum line, a glass filter (3) was installed in the lower part of the tube (2). A carbon thermometer (4) was placed in the vessel (6).

The experimental procedure was as follows: The dewar was filled with helium and evacuated to a pressure corresponding to a temperature 1.4°K. The valve (5) was then opened and the superfluid helium filled the vessel (6). This was revealed, first, by the appearance of liquid above the filter (3) after some time, and second, by the thermometer reading. The vacuum valve was then closed, causing the helium to be heated. The temperature rise, which is first recorded by the carbon thermometer (4), is then registered by an automatic potentiometer (EPP-09). The helium was then again cooled and heated by opening and closing the vacuum valve. This yielded a series of thermogram showing the heating and cooling of the vessel with the zeolite.

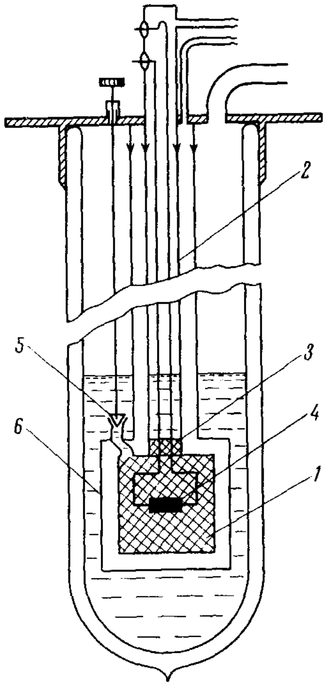

Fig.1. Diagram of instrument

These thermograms show a number of singularities at different temperatures. This is seen most clearly in Fig. 2, which shows the singularities at the λ-point and at 2.085°K. Unlike the λ-point, the remaining kinks of the thermograms do not reproduce consistently. Furthermore, even in the series of measurements in which the singularity at T = 2.085°K was clearly pronounced on the heating thermograms, it was frequently missing from the cooling thermograms. This becomes perfectly clear if one considers in detail the process of heating and cooling with the aid of the convection heat-transfer mechanism in narrow gaps. The insufficient reproducibility of the results indicates apparently that the dimensions of the pores responsible for the change in the thermal properties of the liquid helium at $T \neq T_\lambda$ are not identical and can depend on the preparation of the samples prior to the measurements.

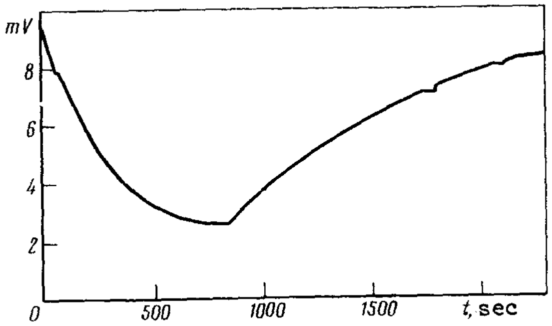

Fig. 2. Time dependence of voltage drop on carbon resistance thermometer placed in the zeolite

The character of the observed singularity on the thermograms is governed also by the rate of heating and cooling, and possibly by the number of pores of any one size.

The singularity observed by us at $T = 2.085°K$ is not a displaced λ-point for the main zeolite pores with width $d < 12$ Å. Actually the point $T = 2.085°K$ corresponds to the following dimension: according to the experimental data of [3] (curve on Fig. 2) $d = 30$ Å, according to the formula $\Delta T = -2 \times 10^{-14}/d^2$ of Ginzburg and Pitaevskii [1] $d = 48$ Å, and according to the formula $\Delta T = -2.5 \times 10^{-11}/d^{3/2}$ of Mamaladze [4] $d = 43$ Å. Obviously the singularity observed by us at 2.085°K can be attributed to a shift of the λ-point in pores of width $d \approx 30 - 50$ Å. Pores on the order of several hundred Å produce no noticeable λ-point shift. It is thus natural to assume that the singularities observed at $T_c = 2.085°K$ and at T_λ are due to the presence of the secondary porous structure.

It seems to us that the phenomena predicted by Mamaladze and Cheishvili are revealed in our experiments by the difference observed between the thermograms taken in the vessel with the zeolite (Fig. 2) and the thermograms taken with the same thermometer in the helium bath (Fig. 3). The kink at $T = T_\lambda$ observed in the helium bath gives way in the case of zeolite, for both singularities (at T_c and at T_λ), to a small plateau parallel to the time axis.

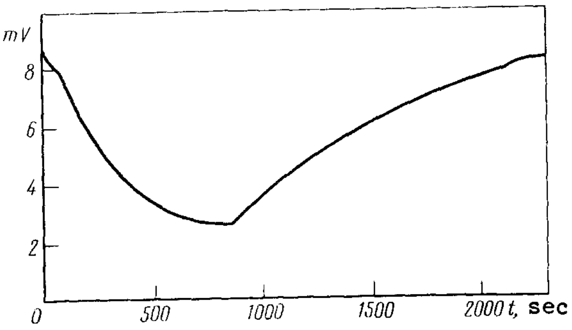

Fig. 2. Time dependence of voltage drop on carbon resistance thermometer in helium bath.

According to Mamaladze and Cheishvili [2], the amount of liquid going over from the s- to the n-state is, for a given change in temperature, extremally large in a narrow temperature interval near T_c, where the depth of penetration of the superfluid into the narrow pores has a sharp maximum. In this connection, a definite amount of liquid in the pores should remain superfluid at $T = T_c$ and go over rapidly to the normal state in a very narrow temperature interval immediately after rising above T_c.

Obviously, the "plateaus" observed by us on the heating thermograms are actually plots of the slow rise in temperature from the value T_c to a value very close to it, at which the "crowding-out" of the superfluid from the pores is in fact completed. The slower change in temperature in this interval can be attributed to the increased amount of heat needed to provide the increment of the free energy of the liquid on going from the superfluid to the normal state.

Since the experiments are being continued, the authors wish to emphasize once more that the results described here should be regarded as preliminary.

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