energy is lower when drift oscillations are excited). It is of interest to carry out similar experiments not only in a plasma-beam discharge. Direct measurement of the effective collision frequencies is also of importance.

The authors are grateful to A.S. Bakai for a discussion of the results and to L.I. Bolotin for interest in the work.

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INVESTIGATION OF MASS TRANSPORT OF He^3 IN LIQUID HeI BY THE THERMAL-NEUTRON METHOD

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Submitted 13 March 1972
ZhETF Pis. Red. 15, No. 9, 504 - 508 (5 May 1972)

An investigation of transport phenomena in liquid helium near T_λ is of undoubted interest for a wide circle of problems connected with phase-transition physics. However, the available experimental data are insufficient for an unambiguous clarification of the physical picture of the phenomenon [1 - 5]. At the same time, the large cross section for the absorption of thermal neutrons by He^3 nuclei makes it possible to obtain direct data on the mass transport of the isotope in relatively weak solutions (∿1%) [6].

The measurement principle consists of the following: a capillary filled with liquid He^4 is connected at a definite instant of time to a ∿1% solution of an He^3-HeI mixture with a volume 200 - 300 times the volume of the capillary. The entire system is at a specified temperature, and the amount of He^3 passing through the capillary during the mass-transport process is determined from the change of the intensity of the neutron beam penetrating through it:

$$I/I_0 = \exp(-\sigma N), \tag{1}$$

where I_0 and I are the intensities at the initial instant of time (t = 0) and at the instant of time t, respectively, N is the total number of He^3 atoms that have entered the investigated volume by the time t, and σ is the cross section for the thermal-neutron absorption by the He^3 nuclei. High sensitivity of the method is ensured by the very large value of σ, which is directly proportional to the wavelength λ of the neutron radiation and in our concrete case (λ = 4 Å) reaches 1.2×10^4 b. The remaining effects of scattering and absorption in the investigated mixture amounted to ∿5 b.

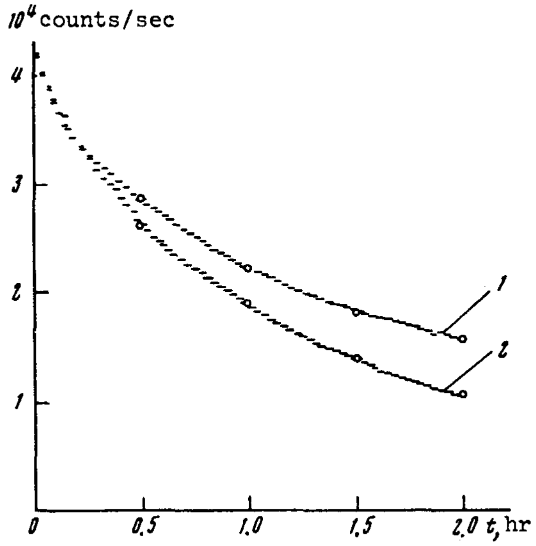

Fig. 1. Intensity variation of the neutron beam passing through the capillary: 1) T = 2.24°K; 2) T = 2.31°K.

Special investigations have verified that the neutron-absorption cross section is independent of the temperature.

The temperature was determined by measuring the vapor tension of the helium with a KM-6 cathetometer, with the mercury levels in the manometer determined accurate to ±0.02 mm. The stability of the temperature during the diffusion process was monitored by continuously recording the readings of a resistance thermometer. The drift and instability of the temperature during the course of one experiment did not exceed several thousandths of a degree.

The intensity change was determined at intervals up to 100 sec for two hours. Typical plots obtained by such a measurement for different temperatures are shown in Fig. 1.

An examination of this figure shows readily that the relative change of the neutron-beam intensity within a certain control time on the counting curve can serve as a qualitative characteristic of the mass-transport rate. On the basis of optimality considerations discussed in [6], we chose this control time to be 2 hours.

Thus, the temperature dependence of the relative change of intensity I_0/I_{2h} (I_0 and I_{2h} are the neutron-beam intensities at the initial instant and after 2 hours) represents fully the temperature dependence of the mass transport rate.

It can be verified that if the capillary in which the mass is transported is horizontal, the equations of hydrodynamics have no stationary solutions corresponding to the pure diffusion mechanism, i.e., to a vertical disposition of the equal-concentration lines¹⁾. In other words, such an experimental geometry is inevitably accompanied by macroscopic flows that also transport mass. It is therefore natural to raise the question of the relative contribution of these two competing mass-transport mechanisms²⁾.

This question was considered theoretically by Gurevich and Laikhtman, who used the results of [7, 8]³⁾. Compared with the experimental situation, the theoretical problem was greatly idealized, since a capillary of round cross section and of diameter d was replaced by plane-parallel plates spaced at a

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1)The authors consider it their pleasant duty to thank Professor V.P. Peshkov and his co-workers for calling our attention to the gist of the problem discussed below and for numerous discussions of this question.

2)Using an analysis similar to that in [7, 8], it is easy to verify that static convective vortices are produced at sufficiently large Grashof numbers (for a capillary diameter d = 2 mm). In principle, they could cause a non-monotonic temperature dependence of the mass-transport rate. Similar estimates show, however, that no such vortices occur at d = 0.2 mm.

3)The authors are exceedingly grateful to Gurevich and Laikhtman for kindly agreeing to perform these calculations.

distance d apart. Numerical estimates were made of the contributions of each of the indicated mechanisms for two values of d, 2 and 0.2 mm. It turns out that in the former case the convective transport cannot be neglected. At the same time, at d = 0.2 mm its relative contribution is negligibly small. It can therefore be assumed that such a neglect is certainly justified for a capillary of round cross section.

Our experimental results of the study of the temperature dependence of mass transport for the two indicated diameters are shown in Fig. 2.

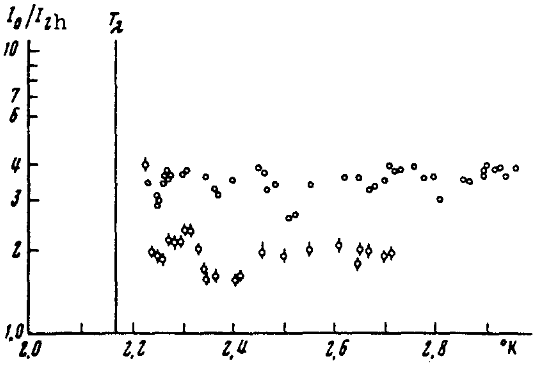

Fig. 2. Temperature dependence of the rate of mass transport of He^3 in HeI: o - d = 2 mm, ϕ - d = 0.2 mm.

From a comparison of the results shown in Fig. 2 (and also of the data of [6]) we can draw the following conclusions:

1. The rate of mass transport of the isotope He^3 in liquid HeI has a nonmonotonic temperature dependence, and the result does not depend on the neutron wavelength and on the intensity of the neutron flux.

2. The mass-transport rates obtained experimentally under the most favorable conditions (capillary diameter d = 0.2 mm) are estimated to lie at the lower limit of the experimentally determined values of the diffusion coefficient [9]. We note that the investigations of [9] were performed with a vertical capillary, thus automatically excluding the influence of convective transport.

3. The observed temperature nonmonotonicity of the rate of mass transport cannot be explained by means of a trivial convection mechanism. It is most likely that this mechanism contributes to the background part of the effect without changing significantly the qualitative character of the nonmonotonicity.

In conclusion, the authors are deeply grateful to Prof. D.M. Kaminker for constant interest in the work and to E.G. Tarovik for help with the experiments.

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