

is shown in Fig. 2. Within the limits of the measurement accuracy¹⁾ (on the order of 3×10^{-5}), the positions of these lines are described by the formulas for the transmission frequencies of a linear molecule in different vibrational states of a certain low-frequency vibration, although the dependence of the effective rotational constant on the proposed vibrational quantum number n is rather complicated. We note that the large value of the effective rotational constant (on the order of 11.2 GHz) is in contrast with the obtained low vibrational frequency (on the order of 57 cm^{-1}). It was difficult to observe these ordered groups in the spectrum either by methods of ordinary microwave spectroscopy (only one group falls in the centimeter band, and large sections of the complex spectra were not observed in the millimeter and submillimeter bands), or by infrared-spectroscopy methods (in view of the low sensitivity and resolution, since the lines in the groups are weaker by an approximate factor of 25 than the typical HCOOH lines, and lie close to the latter).

The development of the described procedure for gas spectroscopy in the submillimeter band, the capabilities of which are far from exhausted, makes it possible, in our opinion, to increase appreciably the importance of submillimeter spectroscopy in the research on molecular spectra.

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¹⁾The measurements were performed with the aid of the known SO_2 spectrum. The authors thank Dr. J. Bellet and G. Steenbeckeliers for suggesting this spectrum as a reference and for supplying the tables.

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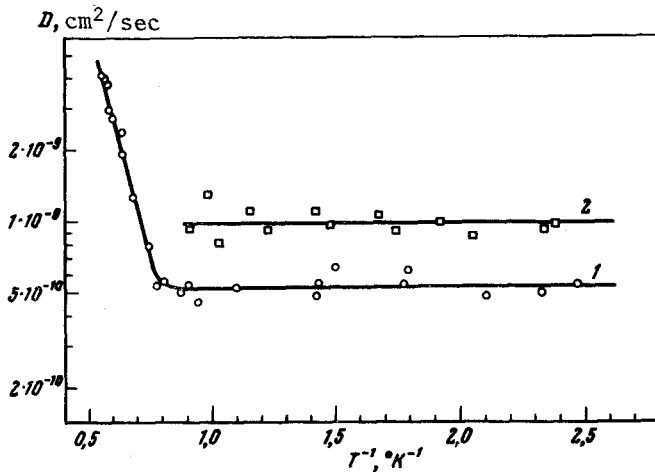
NEW SINGULARITIES IN QUANTUM DIFFUSION OF He^3 IN SOLID HELIUM

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We measured the diffusion coefficient of an He^3 impurity in the HCP phase of solid helium at increased density. The transition from vacancy diffusion to quantum diffusion of the impurities was observed for the first time. A strong dependence of the volume integral J_{34} on the density of the solid helium was observed.

Singularities were recently observed in the temperature [1] and concentration [1, 2] dependences of the diffusion coefficient of He^3 in weak $\text{He}^3 - \text{He}^4$ solid solutions. These singularities are connected with the quantum character of the impurity motion in the solid helium. The obtained experimental data confirmed the theoretical premises [3 - 6] according to which the impurities and defects in quantum crystals behave like quasiparticles and move through the crystal almost freely.

In view of the measurement difficulties, the cited experiments [1, 2] were confined to the region of maximal molar volumes, which is directly adjacent to the melting curve of the HCP phase of the solution. Since further comprehensive investigations of the quantum-diffusion phenomenon are of considerable interest, we undertook to perform new experiments, using an



Diffusion coefficient of He^3 vs the reciprocal temperature in $\text{Hd}^3 - \text{He}^4$ solid solution containing 0.75% He^3 : 1) $V = 20.7 \pm 0.05 \text{ cm}^3/\text{mole}$, 2) $V = 21.0 \pm 0.05 \text{ cm}^3/\text{mole}$.

the earlier procedure. The measurements were made with the NMR spectrometer used in earlier investigations [1, 9]. By introducing several additional blocks, we were able to perform measurements both in the usual echo and in the stimulated-echo modes. The cryogenic part of the apparatus and the measurement procedure were in the main the same as in [1, 9].

We investigated solutions containing 0.25% and 0.75% He^3 at molar volumes $V_1 = 20.7$ and $V_2 = 21.0 \text{ cm}^3/\text{mole}$ in a wide temperature range. As seen from the figure, which shows the results for the second of the indicated solutions, two temperature regions are clearly seen on curve 1, a high-temperature region corresponding to vacancy diffusion, and a low-temperature region in which impurity diffusion takes place. (There is no vacancy diffusion section on curve 2, since the HCP phase does not exist at $V = 21.0 \text{ cm}^3/\text{mole}$ and $T > 1.3^\circ\text{K}$.)

At low temperatures in the quantum diffusion region, where D does not depend on the temperature, the first striking feature is the appreciable decrease of the diffusion coefficient at a relatively small change of the molar volume. This is evidence of weakening of the exchange interaction of the He^3 and He^4 atoms with increasing density. Using the obtained experimental data and the relation [5, 6]

$$D \sim J_{34} a^2 / \hbar x,$$

where J_{34} is the exchange integral characterizing the $\text{He}^3 - \text{He}^4$ exchange frequency, a is the interatomic distance and x is the He^3 concentration, we obtain $J_{34}(V_2)/J_{34}(V_1) \approx 1.9$.

The result offers evidence of an extremely strong dependence of J_{34} on the density of solution, greatly exceeding the analogous dependence for pure He^3 [10], where the exchange integral changes by approximately 25% following a similar variation of the molar volume. This interesting circumstance can probably be explained in the microscopic theory of the behavior of He^3 impurities in solid helium.

At high temperatures, an exponential relation $D = D_0 \exp(-\Delta/T)$ is observed with an activation energy $\Delta = (8.9 \pm 1)^\circ\text{K}$ and $D_0 = (6 \pm 2) \times 10^{-7} \text{ cm}^2/\text{sec}$ (curve 1). It should be noted that the obtained value of Δ is much smaller than in the BCC phase of He^3 [11] at the same molar volume (there is no HCP phase of He^3 at $V = 20.7 \text{ cm}^3/\text{mole}$, an extrapolation from higher densities leads to even higher values of Δ). This circumstance may be connected, on the one hand, with the different contributions made to the vacancy formation energy by terms that take into account the crystal-expansion work (owing to the difference in the pressures corresponding to identical molar volumes), and on the other hand with the fact that in the solution the distance between the He^3 and the nearest neighbors is somewhat larger than the mean value, owing

improved measurement procedure. The main results are reported here.

The main task was to determine the influence of the molar volume on the magnitude and character of the quantum diffusion. To this end, the diffusion coefficient D of He^3 was measured in a number of solutions at different values of the molar volume. Owing to the sharp decrease of the transverse-relaxation time with increasing pressures, it was practically impossible to measure D by the usual spin echo method under these conditions, and we used the method of so-called stimulated echo [7, 8], in which, owing to the use of three 90° pulses, it is possible to decrease appreciably the relaxation damping and to increase greatly the range of measured values of D . We note that the use of this procedure yields much more accurate data, thanks to the better signal/noise ratio. The results differ somewhat from those given in [1], where the measurements were performed at the limit of the capability of

to the larger amplitude of the zero-point oscillations, and this likewise leads to a decrease of Δ .

For the 0.25% solution, the temperature dependence of D has a similar character, but the region of vacancy diffusion is much narrower, so that it is impossible to determine reliably the characteristic parameters Δ and D_0 .

We note further that the inverse proportionality of D and x, which is characteristic of impuriton diffusion and has been observed earlier near the melting curve [1, 2], takes place at low temperatures, according to our experiments also for $V = 20.7 \text{ cm}^3/\text{mole}$.

It should be noted in conclusion that curve 1 of the figure makes it possible, for the first time, to trace the continuous transition from vacancy diffusion to impuriton diffusion.

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COHERENT MOTION OF VORTICES IN SUPERCONDUCTING BRIDGES OF LARGE DIMENSIONS

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Experimental proof is presented that coherent vortex motion can be realized in superconducting film bridges "of variable thickness" in the absence of the ordering action of magnetic and microwave fields even if the bridge dimensions greatly exceed the coherence length.

1. It is known that coherent motion of vortices in superconducting film bridges (constellations) having dimensions much greater than the coherence length $\xi(T)$ can be realized by synchronizing their motion with an external microwave field [1]. This synchronization is facilitated by imposing a constant magnetic field normal to the plane of the bridge [2].

Coherent motion of vortices in an autonomous bridge is revealed by the appearance of Josephson current steps on its current-voltage characteristic following of application of a weak (probing) microwave signal. The signal is regarded as small if no changes occur in the other sections of the current-voltage characteristic, say the critical current I_c . We have observed this effect in tin bridges of "variable" thickness, in which the thickness d of the film making up the bridge is much less than the thickness d_0 of the "shore" films.

2. The bridges were rectangular in shape and their characteristic dimensions were the dimension along the transport current, $l \approx 6 - 7 \mu$, and the width, $w \approx 30 \mu$. The bridges were produced in two stages. Thick films ($d_0 \approx 2000 \text{ \AA}$, square resistance $(R_{\square})_{4.2^\circ\text{K}} \approx 10^{-1} \text{ ohm}$) were first evaporated on a substrate of optically polished crystalline quartz. A quartz thread