The First Sound Velocity and Attenuation of Supersaturated Superfluid ^{3}He - ^{4}He Solutions under Elevated Pressure

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Abstract

The experimental study of concentration dependencies of the first sound velocity and attenuation coefficient in superfluid ^{3}He - ^{4}He mixtures for saturated and supersaturated regions at constant elevated pressure and constant temperature has been carried out. The metastable long-lived state is reached by original technique of continuous increasing of the ^{3}He concentration *in situ* due to changing of osmotic and fountain pressures. It was shown that the data obtained are in good agreement with the theory of sound propagation in a gas of fermi-excitations. Corresponding values of effective mass and relaxation time of ^{3}He quasi-particles were taken from the analysis of the experimental data available. The excess sound attenuation was not registered in the supersaturated region within the accuracy experiment.

Key words: superfluid ^{3}He-^{4}He solutions, first sound, degenerated regime, attenuation and velocity

1. Introduction.

According to Landau theory superfluid ^{3}He-^{4}He solutions can be described as a set of elementary excitations, namely, phonons, rotons and ^{3}He quasiparticles (impuritons). Below 0,2 K the thermal excitations-phonons and rotons are "frozen out" and impuritons give the main contribution into all processes. In this work the first sound properties of degenerated Fermi-system in stable and metastable state were measured using the original method of continuous variation of concentration ^{3}He in experimental cell. The obtained data was compared with the theory of Baym and Pethick[1] and Adamenko and Tsyganok [2].

2. Sound properties.

The experiments were performed at constant temperature and pressure in the temperature range 80-200 mK using the ^{3}He - ^{4}He dilution refrigerator, the pressure range was 0-20 atm. The attenuation of first sound was measured at a frequency of 30 MHz by a pulsed technique, with error not over 5%. The relative measurements of the first sound velocity $\Delta c/c$ were carried out at frequency of 10 and 30 MHz by the method of echo-pulse superposition with the error of $5 \cdot 10^{-5}$.

The initial state was a homogeneous nonseparated mixture. Then the mixture concentration was continuously increased. The rate of the concentration growth was about 10^{-4}% of ^{3}He per second. The absence of free vapor-liquid interface permitted measurements not only in the stable state but in the supersaturated metastable long-lived state of the solution as well. Figure 1 shows the experimental data on the sound attenuation a in the saturated and supersaturated solutions (the boundary of their coexistence region is indicated by an arrow) and solid lines were calculated according to [1]. Also are shown the experimental results obtained in Ref.[3] at the same experimental conditions.

It follows from the plots that the experimental con-

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centration dependence of the sound attenuation agrees within the total error limits with the predictions of the theory [1], which uses a gas model of the ^{3}He quasiparticles without taking the Fermi-liquid corrections into account. This means that in the investigated regions the main mechanism for the attenuation of first sound is the direct absorption of an acoustic phonon by ^{3}He quasiparticles. Within the experimental error at frequency 30 MHz, the data do not show any anomaly at the transition from the saturated to the supersaturated solution due to growing the droplets of the condensed phase ^{3}He as it was predicted in [4].

The relative variation of the first sound velocity on concentration $\Delta c(x)/c$ is shown in Fig.2 for several pressures. The experimental data were normalized to the ^{3}He concentration of 6%. The arrows correspond to the concentration at the separation line under the corresponding pressure.

According to the theory predictions [1,2] in the first sound velocity in the superfluid ^{3}He-^{4}He solutions two terms should be distinguished: $\Delta c/c = \Delta c(x)/c + \Delta c(x,T)/c$. The temperature-independent term is defined by the probability of scattering of acoustic phonons by ^{3}He quasiparticles in the solution and can be written as $\Delta c(x)/c = k \cdot x$, where $k = 1/2\{\rho_4 \cdot \partial a/\partial \rho_4 + \lambda(\lambda - 1)m^*/m_4\}$ with ρ_4-^{4}He density, $\lambda = \{a + (m^* - m_3)/m_4\}m_4/m^*$, m_4, m_3, m^*-masses of bare ^{4}He, ^{3}He atoms and effective mass of ^{3}He in mixture, a- relative changing of molar volume due to exchange of ^{4}He atom by ^{3}He one,.

As can be seen in Fig.2 for all pressures our data is close to linear.

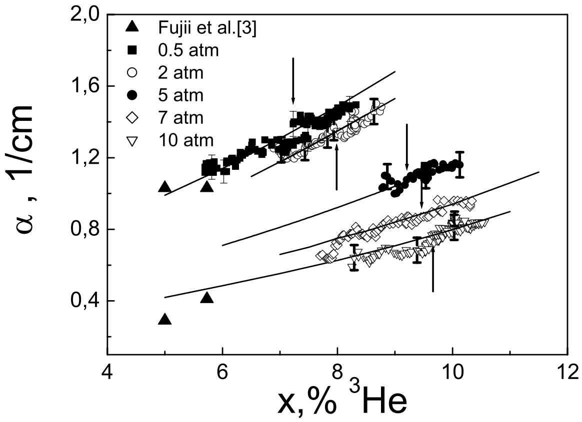

Fig. 1. Concentration dependence of first sound attenuation in superfluid solutions, curves- calculation according to [1].

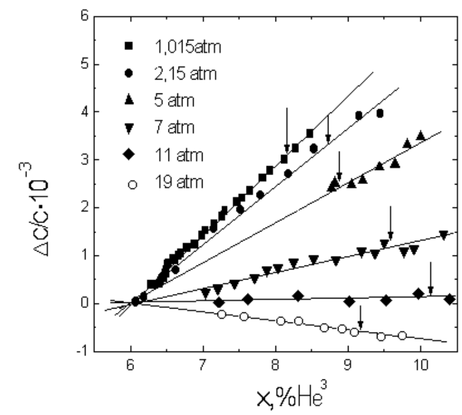

Fig. 2. Concentration dependence of first sound relative velocity shift in superfluid ^{3}He-^{4}He solutions.

3. Conclusion.

The technique of continuous variation of the concentration of superfluid ^{3}He-^{4}He solutions has enabled us to measure for the first time the concentration dependence of the first sound attenuation and velocity at constant temperature and different pressures. It was found that in the investigated concentration region, which also includes metastable supersaturated solutions, the sound attenuation and velocity are described well by the theory of impurity–impurity absorption for the degenerate temperature region in the framework of a gas model of the Fermi excitations. Under the experimental conditions the excess sound attenuation due to the appearance of suspended droplets of the concentrated phase in the region of supersaturated solutions was not manifested. It seems advisable to continue the measurements into a higher frequency range.

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