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Shear Viscosity of Superfluid ^{3}He using Collision Integral Model Kinetic Equation

Dr. Sushil Kumar,
Sunil Bhawan, Rd No.11, Ashok Nagar, Kankarbagh, Bihar, India

ABSTRACT

Helium is an inert gas and it has two isotopes ^{4}He and ^{3}He. ^{4}He is abundant in nature where as ^{3}He is rarely found. ^{4}He is a Bose particle and it follows Bose Einstein Statistics. Whereas ^{3}He is a Fermi particles and it follows Fermi Dirac Statistics and also Pauli Exclusion Principal. Both these particles are well separated out and at low temperature they are in liquid form. Liquid ^{4}He is a normal Bose liquid whereas liquid ^{3}He is a Fermi liquid. These two liquids are also called Quantum liquids. At T = 2.17 K liquid ^{4}He goes into famous phase transition called λ-transition. Above λ Temperature i.e. T_λ = 2.17 K ^{4}He is a normal liquid also called He-I and below λ Temperature it is a superfluid also called He-II. In liquid ^{3}He, phase transition occurs at very low temperature, about 2.7 mK. Between 3 mK to 100 mK liquid ^{3}He is a normal liquid and below 3mK they are in a superfluid phase and these phases are also mesophase called ^{3}He-A phase and ^{3}He-B phase. These phases are observed through NMR experiments. These phases are also spin polarised phase. It is generally belief that superfluidity is a flow of liquid without viscosity. In case of superfluid He-II the value of viscosity is almost negligible. Where in two phase of superfluid ^{3}He, He – A phase is almost negligible viscosity whereas He-B phase has finite value of viscosity which is in Tensor form having first order (shear) and second order viscosity. We have evaluated the shear viscosity of ^{3}He-B normalized to the value at T_c versus reduced temperature $(1-\frac{T}{T_c})$ at melting pressure and a parameter λ. The evaluation is done through equation

$$\frac{\eta(T)}{\eta(T_c)} = 1 - a(\lambda_2)\left[1 - \frac{T}{T_c}\right]^{\frac{1}{2}}$$

Where $a(\lambda_2) = \frac{\pi^2}{4}\left(\frac{2\Delta C}{3\Delta N}\right)^{\frac{1}{2}} \frac{\left[\frac{1+\frac{3}{4}\lambda_2}{(1-\lambda_2)^2}\right]}{f_n(\lambda_2)}$ And $f_n(\lambda_2) = \frac{1}{2}\pi^2 + \frac{3}{4}\left(\frac{\lambda_2}{1-\lambda_2}\right)$

λ is strong function of viscosity and since result have performed through collision integral therefore value of λ is confined from 0.5 to 0.8. Here the values of λ_2 taken is 0.65. We have taken the values of specific heat discontinuity $\frac{\Delta C}{\Delta N} = 2$ appropriate at melting pressure. The result is compared with the vibrating wire data of the Helsinki group. The agreement with the experimental data is not very satisfactory. If one takes the strong coupling enhancement of the zero temperature gap then one can make a correction for the deviation at low temperature which is presumably due to finite mean free path effects. A comparison of theory is made with the high precision data of Cornwell group. Here we have evaluated the square of the relative change of the viscosity near T_c as a function of (T/T_c). The evaluated result is seen to be quite satisfactory, apart from a systematic deviation of viscosity data toward lower value at lower temperature.

Keywords: Superfluid, Quantum Liquid, Bose Particle, Fermi Particles, Shear Viscosity.

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