LIQUID HELIUM

New Excitation

from our Condensed Matter Correspondent

A NEW type of elementary excitation, christened the ^{3}He roton, may exist in liquid ^{3}He–^{4}He mixtures according to a calculation by Stephen of Rutgers University and Mittag of the University of Miami, published in a recent issue of *Physical Review Letters* (**31**, 923; 1973) and based on a suggestion made by L. P. Pitaevski during the United States–Soviet symposium on condensed matter at Berkeley in May.

Below its superfluid transition temperature T_λ, liquid ^{4}He can be regarded as an inert superfluid background in which exists a gas of elementary excitations carrying all the entropy of the liquid and thus being responsible for its thermodynamic properties. At zero temperature there are no excitations but, as T is increased, the density of the excitations, known as the normal fluid density (ρ_n), increases until at T_λ it is equal to the overall density of the whole liquid. In pure liquid ^{4}He, except very close to T_λ, there are two distinct types of elementary excitation: at small momenta, the energy ϵ of an excitation is directly proportional to its momentum p, and it is thus a phonon, or quantum of sound; at higher momenta there is a minimum in the $\epsilon(p)$ curve, and the excitations, all of energy close to Δ, existing in this region are known as rotons. Their physical nature is not entirely clear, but they may, perhaps, be the microscopic quantum mechanical analogue of classical vortex rings.

The addition of small proportions of ^{3}He profoundly affects the properties of the liquid. The ^{4}He atoms act as additional excitations, and thus increase the normal fluid density and contribute to the thermodynamic properties. Measurements of the heat capacity and wave velocity at very low temperatures have shown that a ^{3}He atom behaves very much like a free particle in that its energy varies as the square of its momentum, but with a modified mass m_3^* to take account of the superfluid background through which it moves.

When Sobolev and Esel'son made direct experimental measurements of ρ_n (*Zh. éksp. teor. Fiz.*, **60**, 240; 1971) they found that ρ_n seemed to increase with ^{3}He concentration much more rapidly than expected. Since the contribution to ρ_n from the ^{3}He atoms is just n_3 m_3^* where n_3 is their number density, and that from phonons at any given temperature depends only on the velocity of sound which does not change much with n_3, it was concluded that the effect must be associated with a decrease in the roton energy Δ. Recent experimental measurements of Δ by Surko and Slusher of Bell Laboratories, and independently by Woerner, Rockwell and Greytak of MIT, both using light scattering techniques and reported in the same issue of *Physical Review Letters* (**30**, 1111 and 1114; 1973) have shown, however, that Δ does not change significantly with ^{3}He concentration.

It was this apparent contradiction in the experimental evidence for the value of Δ which led Pitaevski to suggest that the $\epsilon(p)$ curve for ^{3}He excitations in liquid ^{4}He might also display a minimum, much like the roton minimum. If the value of ϵ at the minimum were less than Δ, then there would clearly be a possibility of resolving the conflict.

Stephen and Mittag have now carried out a detailed calculation, using the same theoretical approach as in the original Feynman-Cohen derivation of the $\epsilon(p)$ spectrum for pure ^{4}He. As Pitaevski had surmised, they find that the ^{3}He excitation spectrum does indeed display a minimum, that this occurs at an energy lower than Δ, and that it is thus possible to reconcile quantitatively, within experimental error, the measured values of ρ_n with those of Δ. The probable reason that ^{3}He excitations near the minimum, referred to as ^{3}He rotons, were not also observed in the light scattering experiments is, the authors suggest, that the relative intensity of the scattering associated with rotons and ^{3}He rotons is proportional to the square of the ratio of the ^{4}He and ^{3}He number densities, so that, because the proportion of ^{3}He was always less than 30%, the former scattering process would have been strongly dominant.

Convincing confirmation that ^{3}He rotons really do exist, however, must probably await the results of further light scattering experiments.

PHYTOPATHOLOGY

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CRYSTAL GROWTH

Crystallite Coalescence

from our Materials Science Correspondent

MASSON and his colleagues in Marseilles have published a series of beautifully executed electron microscope studies of the early stages of condensation of metallic films on ionic substrates; the strikingly novel finding from this work was that small crystallites can wander about in a two-dimensional walk, and, above a certain temperature, the migrating crystallites will coalesce when they touch by chance in the course of their wanderings. These findings have been summarised before (*Nature phys. Sci.*, **241**, 1; 1973).

Now some theoretical implications of the Marseilles findings have been worked out by Robertson (*J. appl. Phys.*, **44**, 3924; 1973) in a stimulating paper. He starts from the observation (by the Marseilles team and others) that whereas crystallites do in fact coalesce at elevated temperatures (for example, above 150° C in KCl), they do not at lower temperatures, although other evidence indicates that they do migrate at these lower temperatures. Robertson analyses the predicted coalescence kinetics in terms of migration rates and collision probabilities (which themselves depend on crystallite sizes). It turns out that there should be extensive coalescence under conditions when in fact none is experimentally observed.

Robertson speculates on possible reasons why collisions should not result in coalescence. Three ideas are put forward: the crystallites may in various ways pick up electrostatic charges or the substrate surface may be contaminated; either form of disturbance is known to inhibit coalescence of colloids suspended in fluids. The third source of disturbance, examined in more detail, is the buildup of misfit stresses between substrate and crystallites, and Robertson indicates that the possibly sharp dependence of misfit stress on crystallite size could lead to either enhancement or hindrance of coalescence. He concludes by claiming that the very process of crystallite migration is not yet established beyond all doubt, and that this is a research topic deserving of much more attention, since it may force a complete revision of the classical concept of heterogeneous nucleation and growth.