Thixotropy of Liquid Helium?

THE object of this note is to compare the properties of liquid helium with those of a colloidal substance exhibiting the phenomena of thixotropy, with a view to point out that the transition from helium I to helium II at the λ point may be thixotropic.

The well-known phenomena of isothermal reversible sol-gel transformation is known as thixotropy. The formation of the gel can be attributed[1,2] to the constituent particles becoming locked into place in equilibrium positions, wherein the Van der Waals force of attraction is just balanced by the force of repulsion due to the mutual repulsion of the double layer. The presence or absence of electrolyte regulates the effective spheres of action of the repulsive forces by regulating the value of the ζ-potential, and hence determines whether there is completely stable suspension, coagulation or the intermediate stage of thixotropy.

This change of structure is accompanied by a change, of viscosity, elasticity, density and double refraction. Kistler[3] finds that the dielectric constant does not change appreciably and Freundlich[4] finds that the velocity of electrically charged bodies, remains unaltered even when the sol is changed into a gel. Freundlich suggests that this may be due to a local softening of the gel, under the action of the electric current and thus providing a channel for the passage of the particle.

According to Freundlich[1] 'Loose-packing' and the formation of structures caused by an equilibrium between attracting and repelling forces are common to all thixotropic systems. But the nature of these forces—whether they are due to the particles or molecules—may be very different when passing from one system to another. Hauser and Reed[5] point out that the thermal transition from sol to gel is continuous and the only difference between sol and gel appears to be mechanical, hence they conclude that during the period of gelation some type of structure with mechanical resistance to shear is being built up out of the constituent particles of the sol. This picture postulates a two-phase system.

PROPERTIES OF LIQUID HELIUM[6,7]

In the case of liquid helium McLennan[8] finds that when the pressure above the liquid is lowered slowly, there is a sudden change in the appearance of the liquid as the λ point is passed, rapid ebullition giving way to a perfectly clear and tranquil liquid. The latent heat of transformation is less than 0·002 cal./gm., and Ehrenfest[9] calls it a phase-change of the second order.

The properties of liquid helium that change at the λ point are the thermal conductivity, viscosity, and the specific heat, whereas the specific resistance and the optical properties are not appreciably changed. Keesom and Macwood[10] are not in a position to say whether the viscosity at λ point changes discontinuously.

Keesom and Taconis[11] took the Debye-Scherrer diagram of liquid helium. Liquid helium I gave rings similar to those of other liquids. The rings for helium II suggested a face centred cubic lattice, in which half the number of atoms have been removed in such a way that every atom and every hole is surrounded by six atoms and six holes. They point out that such an open structure explains the great heat conductivity. Keesom and Taconis[12] have also taken X-ray pictures of solid helium, and suggest an hexagonal close-packed structure. In connection with the structure of liquid helium II Keesom and Taconis[11] discuss the diamond lattice hypothesis of London[13] and Fröhlich[14] and find that this hypothesis is not in harmony with their X-ray data.

It appears that the λ point may be explained in the same way as thixotropy by assuming that during the transition some helium molecules become locked in place in their equilibrium positions in a loose-packed structure, whereas the holes may change their places; the position and arrangement of the molecules change during the transition, but the electronic configuration of the molecules remains appreciably unaltered. This picture would lead us to expect that at the λ point, the viscosity, elasticity, thermal conductivity and specific heat are primarily affected, while the changes in the electrical and optical properties should be of the second order. It may be remarked that this picture is in agreement with the experimental observations carried out at the λ point.

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