Nature (London) **112** 281–282 (1923)

The scattering of light by liquid and solid surfaces

It is a well-known fact of observation that most reflecting surfaces usually also scatter a little light and are thus rendered visible. The effect is usually dismissed, however, as due to dust or imperfect polish of the surface, and little attention has been given to the problem of determining whether, when these disturbing factors are eliminated, any scattering by the surface persists. Experiments carried out by the writer in collaboration with Mr L A Ramdas to test this matter have led to some interesting results.

Freshly split cleavage faces of crystals show extraordinarily little scattering. In fact, it is found that a clean good piece of mica has surfaces which are invisible even when placed at the focus of a lens illuminated by sunlight against a dark background. This is what one would expect theoretically. Cleavage surfaces of rock-salt and Iceland spar are also good, though not so perfect. The conchoidal fracture-surfaces of quartz are relatively very imperfect optically. Blocks of thick plate glass when freshly broken open exhibit surfaces which apparently are quite smooth, but when illuminated by sunlight they show a blue superficial opalescence. Freshly-blown bulbs of glass when held in a strong light also show this surface opalescence very well.

Coming to liquids, the most interesting case is that of metallic mercury. After carrying out a series of chemical purifications, washing and drying the mercury and then distilling it in vacuum from one bulb to another and transferring it back again repeatedly, Mr Ramdas succeeded in obtaining surfaces which were dust-free and chemically clean. When sunlight is concentrated on such a mercury surface in a vacuum, the focal spot shows a bluish-white opalescence, the scattered light when observed in a direction nearly parallel to the surface being very strongly polarised with the electric vector perpendicular to the surface and of nearly similar intensity in all azimuths. The opalescent spot when examined under a microscope appears perfectly structureless, showing that it is a true molecular phenomenon.

To test whether the surface-opalescence exhibited by mercury is due to the mobility of the dispersion-electrons usually assumed to exist in metals, or whether it is due to the rugosities of the surface caused by molecular bombardment, observations were also made with transparent liquids in enclosed bulbs made dust-free by repeated distillation. Various liquids tried, e.g. ether, alcohol, benzene, carbon tetrachloride, liquid carbon dioxide, all showed the surface-opalescence conspicuously under strong illumination. The character of the effect in these cases was, however, quite different from that shown by a clean mercury surface.

The surface-scattering by transparent liquids in undoubtedly due to the effect of molecular bombardment of the surface. It is much more intense when observed in directions adjacent to that of regular reflection and refraction than in other directions. It is less blue than the internally-scattered light, and shows remarkable changes in its state of polarisation with varying angles of incidence and observation. There were notable differences in this respect between the cases in which the light is incident respectively within and outside the liquid on the interface. There is a rapid falling off in the intensity of the surface opalescence when the angle of incidence is increased much beyond the critical angle. These facts clearly indicate that the effect shown by transparent liquids is essentially due to the imperfect planeness of the surface. The scattering by a metallic liquid surface, on the other hand, has probably a different origin, as suggested above.

The interface between two non-miscible dust-free liquids also shows strong opalescence under illumination. For the particular case in which the interfacial tension is very small or negligible, the opalescence becomes greatly exaggerated. Some observations by Mandelstamm (*Ann. d. Phys.* vol. 41, 1913) on the critical state of liquid mixtures are of interest in this connexion.

The experimental observation of the surface-opalescence of *water* presents special difficulties owing to the great ease with which this liquid catches dust and grease. The difficulties have, however, been successfully overcome and the effect satisfactorily demonstrated, both with water rendered dust-free in sealed bulbs and with the water-film on a clean block of melting ice kept free of dust by a gentle stream of gas blowing upon it.

C V RAMAN

210 Bowbazaar Street, Calcutta
28 June