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Transparency of liquids and colour of the sea

In an earlier note in *Nature* (Nov. 24, 1921, vol. 108, p. 402) I pointed out that the scattering of light in its passage through a liquid resulting from the local fluctuations of density, the magnitude of which is given by the Einstein–Smoluchowski relation, should enable its transparency to be determined for the parts of the spectrum in which it does not exercise selective absorption. It should be mentioned that in making an experimental test of this point, account has also to be taken of the scattering resulting from the anisotropy of the molecules and that there is an important difference between this and the scattering due to density-fluctuations. The orientation-scattering is almost completely unpolarised and is therefore distributed symmetrically in all directions. The density-scattering is polarised and is twice as intense longitudinally as in a transverse direction.

The coefficient of extinction resulting from the joint effect of both types of scattering can be calculated theoretically if the compressibility, refractive index, and the ratio of the components of polarisation in the transversely-scattered light are known. Taking the case of benzene as an example, the coefficients of extinction calculated for the 5461 and 4358 lines of the mercury spectrum, which fall in regions in which there is no selective absorption, are respectively 0·00022 and 0·00060. These values agree very closely with the recent experimental determinations of Martin, and form a striking confirmation of the theory. There is little doubt that the observed transparency of many other liquids will similarly be found to be in agreement with theory when accurate data are available.

The case of water is of special interest. Of all ordinary liquids it is the one for which the coefficient of scattering is smallest, and is therefore most affected by traces of selective absorption. There is an absorption band which is clearly marked up to 0·5 μ, and it is possible that traces of it extend into the blue region of the spectrum. For the 4358 line, the coefficient of extinction calculated theoretically is 0·00006 and Martin's observed value is 0·00012. It seems probable that a little farther out in the violet, the transparency may agree more closely with that derived from the theory of scattering.

The newer data now available enables a quantitative test to be made of the theory put forward by me in a recent paper (*Proc. R. Soc.*, April 1922) that the blue colour of the deep sea arises from the molecular scattering of sunlight in water, the thickness of the effective layer being determined by the attenuation of the sun's rays as they penetrate into the liquid. The tentative calculations made in that paper have now been revised. The table shows the theoretical albedo of ocean water expressed in terms of the equivalent scattering by dust free air at normal temperature and pressure.

Albedo of ocean water

Wave length in μ	0·658	0·602	0·590	0·578	0·546	0·499	0·436
Equivalent kilometres of air	0·5	0·7	1·8	2·8	5·2	7·0	15

It is evident from these figures that the blue of the sea would be much more saturated than the blue of the sky, which is the standard of comparison. The height of the homogeneous atmosphere being 8 kilometres, the sea would be about half as bright as the zenith sky on a clear day. This agrees well with the photometric determinations made by Luckiesh during aeroplane flights over deep ocean water in the Atlantic (*Astrophys. J.*, **49**, 1919, p. 129). Luckiesh makes it clear that the greater part of the observed luminosity of water viewed perpendicularly really arises from light diffused upwards from within the water. His determinations thus appear to furnish a quantitative proof of the theory which attributes the colour of the deep sea to molecular scattering of light.

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