The Viscosity of Liquids.

AMONG the properties of liquids the viscosity is probably the one the investigation of which has suffered most from lack of any accepted theory, however crude and approximate, to guide it. A great body of more or less careful observations exist, but it has furnished remarkably little information as to the nature of the liquid state. The new technique of X-rays, the Raman effect, and the depolarisation of light may do much to elucidate the structure of liquids, but the older and grosser property of viscosity must be at least as pertinent. Recently, a letter of mine published in NATURE of Mar. 1 upon the subject of liquid viscosity called forth a number of letters, and seemed to make it advisable to say a little more of a theory which, little elaborated as it is, offers a picture which may prove helpful. The conception of a transitory and fluctuating ' crystallisation ' of a liquid seems to fit in with other observations. I am far from being satisfied with the theory as it stands: my hopes go no further than that the facts cited in my present letter may suggest to some that there is a germ of truth in the point of view put forward. At any rate, I intend to make some measurements myself of the temperature coefficient of liquid viscosity, in the hope that they may throw some light on the old problem as to the force exerted on a single molecule by the molecules in its immediate neighbourhood, within the Lorentz sphere.

THE letter of Prof. Andrade in NATURE of Mar. 1 raises the interesting question as to the reason for the decrease in viscosity of a liquid with rise of temperature. This seems to be closely connected with the similar decrease in the frictional resistance due to the motion of solid bodies through liquids. I have been lately carrying out some experiments on this latter subject as follows.

Two rings of thin sheet-brass were cut off a drawn brass telescope tube about 2 inches in diameter. One ring was 1 inch deep and the other 0·25 inch deep. These rings could be suspended one at a time by four very fine wires with their axes vertical from the bottom of a cylindric inertia mass, which last was hung by a single steel torsion wire. The arrangement was such that the thin rings could be set oscillating in a liquid successively, with the rings totally immersed in it, but the inertia mass not immersed. The object of using rings of different depths was to eliminate any energy loss due to wave or eddy current making due to the fine suspending wires or edges of the rings. The measurement consisted in displacing the suspended mass through a certain angle, say 120°, and then noting the time required for this angle of maximum displacement to be reduced to 60° for the two rings. This gives by difference a measure of the frictional resistance per unit of surface. If the frictional resistance were exactly proportional to the velocity then the differential equation for the motion would be

$$I\frac{d^2\theta}{dt^2} + R\frac{d\theta}{dt} + C\theta = 0,$$

where I is the moment of inertia of the oscillating mass and C the coefficient of restoration and θ the angle of displacement. If t' is the time required to decrease the initial amplitude of displacement to half its value, then it is easy to show that $R = 1.38 I / t'$.

On making the measurements in tap water at various temperatures the following results were found :

15° C.	$R = 19.75$	60° C.	$R' = 10.1$
30°	15.2	70°	10.7
50°	12.1	80°	10.6

It is seen that a rise of temperature of the water from 15° C. to 80° C. reduces the frictional coefficient R to about half its value.

This method is sufficiently sensitive to show the difference between fresh water and sea water at the same temperature.

If we ask the reasons for it the following suggest themselves. The cause of friction between a solid and a liquid may be regarded as of the same nature as the reason for the coherence of molecules together to form either a solid or a liquid. In view of the assumed electric structure of atoms, this coherence must be regarded as due to electrical attractions between atoms or molecules. Rise of temperature ionises or dissociates molecules into ions or atoms and promotes mobility of these with respect to the mass of the liquid. Hence follows a reduction of the force required to shear a liquid surface along a solid.

Experiments made with paraffin oil (Royal Daylight) showed that, although this liquid seems more limpid than water, the coefficient of frictional resistance with the brass rings was considerably greater. The oil is, however, a good dielectric and therefore not ionised so much as tap water at the same temperature. The practical result is that if the sea had an average temperature of 80° C. instead of about 15° C., ships would require less power to drive them through the water than at present. I am continuing these experiments as time permits.

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 Mar. 1.

I HAVE read with great interest Prof. Andrade's letter in NATURE of Mar. 1, dealing with the temperature variation of the viscosity of liquids. The theoretical side of this question has admittedly been curiously neglected with perhaps one or two exceptions, of which one of the earliest was Maxwell. Considering, however, how generally the idea of a time of relaxation has entered into modern molecular theory, particularly in relation to liquids, it is more than probable that Maxwell's original conception of the viscosity process will receive an elaborated physical interpretation.

In view of this fact I should like to mention a formula connecting the viscosity and temperature in liquids which I have had occasion to examine in a paper which has been communicated elsewhere, and which may be built up from Maxwell's fundamental definition of liquid viscosity. This formula

$$\eta = \frac{A e^{\beta T}}{T - b}$$

holds for a number of liquids over a wide temperature range, which liquids include both normal and associating liquids. The accompanying table shows two examples. The formula has admittedly three constants but is similar to that of Prof. Andrade in that it contains an exponential function. From general molecular theory and in view of the direct relation between viscosity and vapour pressure, it is probable that an exponential form of equation