Letters to the Editor.

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Viscosity of Liquids.

I was extremely interested to read, in NATURE for Oct. 24, Prof. G. W. Stewart's letter, in which he states that his X-ray diffraction experiments strongly support my theory of viscosity, and I look forward with eagerness to reading the full account of his results. We are both in agreement that the liquid state is more akin to the crystalline than to the gaseous state, and it is in this connexion that I wish to direct attention to another result of my theory which bears on this point, more especially as fuller publication has, by various mischances, been delayed.

I postulate that liquid viscosity is due to an interchange of momentum between adjacent layers, effected not, as in a gas, by a passage of molecules from one layer to the other, but by a temporary union of molecules, which does not endure for longer than the very brief time required for the molecule to acquire a common velocity of translation—a temporary holding of hands between individuals of two parallel rows moving past one another rather than a stepping bodily from one row to the other. The nature of the union need not be discussed here ; all that is demanded of it is that it should produce momentarily a common velocity of the molecules. This leads to the expression

$$\eta = \frac{2m\nu}{\sigma}$$

where m is the mass of a molecule, σ the average distance between the centres of molecules, and ν the frequency of junction per second, which is also, of course, the frequency of disjunction, since the union is of negligible duration. The variation of ν with temperature is an essential feature of the theory, but I am not at the moment concerned with that, but rather with the value of ν at the melting point of the liquid.

Suppose that we make the assumption, which may appear startling, that when a solid is melted it still retains in the liquid form sufficient of its crystalline character for the molecules to possess a frequency of vibration which is practically the same as that of the solid form at the melting point. This is not so remote from Lindemann's theory, in which he derives the frequency of vibration of the solid state of elementary substances at the melting-point from the assumption that melting takes place when the amplitude of the atomic vibration becomes about equal to the average distance apart of the atoms. There is fairly good agreement between the values derived from other methods and those found from Lindemann's formula, which is

$$\nu = C \sqrt{\frac{T_m}{A V_A^{2/3}}}$$

where T_m is the melting point, A the atomic weight, and V_A the volume of a gram-atom at temperature T_m. Suppose that we substitute the frequency ν so found in the viscosity formula. Since $\sigma = \left(\frac{V_A}{N}\right)^{1/3}$, and $m = \frac{A}{N}$, where N is Avogadro's number, we obtain for the viscosity η_m at the melting point

$$\eta_m = 2C \frac{(A T_m)^{1/2}}{(N V_A)^{2/3}}.$$

Lindemann gives for the constant C the value

$2\cdot 8 \times 10^{12}$. Substituting this, and the value $6\cdot 06 \times 10^{23}$ for N, we have

$$\eta_m = 7\cdot 82 \times 10^{-4} \frac{(A T_m)^{1/2}}{V_A^{2/3}}. \qquad . \qquad . \quad (1)$$

The following table shows the calculated and experimental results for elementary substances, of which the viscosity of the liquid form in the neighbourhood of the melting point can be found from published experimental data. For many liquid metals the viscosities, as found by different workers, show such large discrepancies that they have not been used.

Element.	Melting Point.	Viscosity of Liquid in the Neighbourhood of the Melting Point.	
		Calculated.	Experimental.
Mercury .	234·2° Abs.	0·0283	0·021
Bromine .	265·7	0·0132	0·0147
Iodine .	386	0·0198	0·0235
Chlorine .	171	0·0104	0·0143
Oxygen .	54	0·0038	>0·0019
Hydrogen .	14	0·00051	>0·00013

As regards the viscosities of liquid oxygen and hydrogen, only one determination, that of J. E. Verschaffelt, exists, namely, at 90° abs. for oxygen ($\eta = 0\cdot 0019$), and at 21° abs. for hydrogen ($\eta = 0\cdot 00013$), temperatures which are respectively 67 per cent and 50 per cent above the melting point. It is certain that the viscosities at the melting point must be considerably higher than those shown in the table.

It should be emphasised that the constant in formula (1) is not arbitrary, but taken from Lindemann's formula. When this is remembered the agreement between experiment and calculation must be considered as very satisfactory, and furnishing a strong confirmation of the conception of the liquid state put forward, namely, that liquids at the melting point behave as crystals which have, so to speak, lost their general rigidity, while retaining local memory of their former state. I have sketched the argument leading to formula (1) as briefly as possible : I hope to make it a little more convincing when I have more space at my disposal.　　　　E. N. DA C. ANDRADE.

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Anomalous Variation of the Electrical Conductivity of Quartz with Temperature at the Transformation Point.

For many years the variation of electrical conductivity of crystalline dielectrics with temperature has been studied by different physicists ; for example, A. Joffé [1] has studied this problem with quartz, calcite, ammonium-alum, and copper sulphate, and found that their conductivity σ is expressed by $\log \sigma = \frac{A}{T} + B$, where T is the absolute temperature, A, B the material constants. More recently, W. Seith [2] has also studied this problem with lead chloride and iodide crystals and deduced the expressions $\sigma = A e^{-Q/RP}$ for the chloride, and $\sigma = A_1 e^{-Q_1/RP} + A_2 e^{-Q_2/RP}$ for the iodide, where A, A_1, A_2 and Q, Q_1, Q_2 are material constants, T the absolute temperature, and R the gas constant. But no one has noticed that there exists any anomalous change of the electrical conductivity of quartz at the temperature 573° C.

It is well known that the index of refraction, specific heat, Young's modulus, and other physical properties of quartz, except its electrical conductivity, show anomalous changes at its $\alpha \rightleftarrows \beta$ transformation.