Letters to the Editor.

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Crystal Structure of Basic Beryllium Acetate.

PROF. G. T. MORGAN recently sent me some well-formed crystals of basic beryllium acetate $Be_4O(C_2H_3O_2)_6$, suggesting that their analysis by X-ray methods would, in all probability, be of considerable interest. The results show, I think, that the anticipation was well founded.

The molecule is a perfect tetrahedron. The crystal structure is that of diamond, a molecule replacing each atom of carbon. The carbon atom is itself tetrahedral, but is very nearly a sphere. The slight departure from sphericity is shown by the presence of a very small second order in the reflection by the tetrahedral plane of diamond. In the acetate this effect is large, because the tetrahedral character is so much more pronounced than in the carbon atom.

The oxygen atom must be at the centre of the tetrahedron. The beryllium atoms lie on the lines from the centre to the corners ; and each $(C_2H_3O_2)$ group must be associated in a very symmetrical manner with one of the tetrahedron edges.

Prof. Morgan and I hope to give, at a later date, a fuller description of the analysis, and to discuss the inferences that may be drawn from it.

W. H. BRAGG.

A Theory of the Viscosity of Liquids.

As is well known, the viscosity of gases and its variation with temperature has received a satisfactory explanation on the basis of molecular theory. Little progress has, however, been made towards explaining the phenomena of the viscosity of *condensed* media—that is, of liquids and solids from a molecular point of view. What is evidently required is a working hypothesis which will indicate why, when a substance passes from the state of vapour to that of liquid, its absolute viscosity is greatly increased but *diminishes* with rising temperature, while that of the vapour *increases* in the same circumstances. I propose in this note to put forward briefly the outline of a theory which appears to have claims to serious consideration, as it indicates a quantitative relation between the viscosity of a liquid and of the corresponding vapour which is supported by the experimental data.

The manner in which transverse stress is propagated through a material medium is known in the cases in which the substance is in the state of vapour and in that of a crystalline solid. In the former case, momentum is transferred through the diffusion of the molecules between parts of the medium in relative motion, and this is a relatively slow process. In the crystal, on the other hand, the stress is transmitted in the form of transverse elastic waves, and the latter process, at least for ordinary displacements, is extremely rapid. We may conceive that in a liquid, momentum is transported partly by the first process and partly by the second, and that the effective viscosity depends on their relative importance. The ratio in which the two modes of propagation are operative may be determined from thermodynamical considerations, combined with certain simple suppositions regarding the constitution of a liquid.

We shall assume that the state of aggregation of the molecules in a liquid is of a composite character : some of the molecules are quite free to move, and may be termed " vapour " molecules ; the others are attached to each other somewhat as in a crystal, and may be termed " crystalline " molecules. In determining the proportion of the two types, we shall consider only binary encounters between molecules. Let E_1 be the work required to separate a pair of molecules of the first type, and E_2 those of the second type. Then applying Boltzmann's distribution law, we may, as a first approximation, take the relative proportion of the two types of aggregation in the dissociation equilibrium to be as $e^{E_1/RT}$ to $e^{E_2/RT}$, where R is the gas-constant and T the absolute temperature. The next step is to determine the rate of transport of momentum through the medium. In the " vapour " part of the aggregation, the transport occurs by bodily movements. In the " crystalline " part, the rate of transport may be considered to be practically infinite. The effective rate of transport in the liquid is therefore greater than in the vapour at the same temperature and pressure in the ratio $e^{E_2/RT}/e^{E_1/RT}$. The viscosity of the liquid is therefore given by the formula $\eta_{liquid} = \eta_{vapour}\, e^{(E_2 - E_1)/RT}$. Since $E_2 > E_1$ it follows that the viscosity of the liquid will *diminish* with rising temperature.

The next step is to determine the absolute magnitudes of the energy constants E_1 and E_2. As was first pointed out by Sutherland, in the cases of gases and vapours the attractive forces between the molecules tend to *increase* the frequency of collisions and thus *diminish* the viscosity. The matter has been further examined by Chapman, who has shown that Sutherland's constant is one-sixth of the mutual potential energy of the molecules when in contact. It is convenient to use an amended form of Sutherland's formula and write

$$\eta_{vapour} \propto T^{\frac{1}{2}}\, e^{-E_3/RT},$$

where E_3 is another energy-constant. From Chapman's work it would appear that $E_2 = 6E_3$, and we may also take $E_1 = E_3$. Hence, finally, we have

$$\eta_{liquid} = \eta_{vapour}\, e^{5E_3/RT}.$$

E_3 may be found from the data for the viscosity of vapour at different temperatures, and the formula thus enables the viscosity of the liquid to be calculated *a priori*.

To illustrate the matter, it will suffice to take the case of benzene as an example. The table shows the viscosity of liquid benzene at different temperatures as determined by Thorpe and Rodgers, and also as calculated from an empirical equation of the type $\eta = Ae^{B/T}$.

VISCOSITY OF BENZENE LIQUID.

A = 0·0000951.   B = 1237.

Temperature.	Calculated Viscosity.	Observed Viscosity.	Difference.
7·67°	0·00781	0·00789	+8
13·46	0·00714	0·00717	+3
19·39	0·00654	0·00654	0
25·96	0·00595	0·00595	0
32·07	0·00549	0·00547	−2
38·47	0·00504	0·00502	−2
45·35	0·00464	0·00461	−3
51·66	0·00429	0·00429	0
57·37	0·00403	0·00402	−1
63·29	0·00377	0·00377	0
69·41	0·00353	0·00354	+1
73·36	0·00332	0·00333	+1

Viscosity of benzene vapour at 100° C. = 0·0000930.
$5E_3$ calculated from the value at 212·5° C. is 1300.