At very low momenta, $p < 10^8$ *ev./c.*, mesons are distinguished from electrons by heavy ionization in the cloud chamber rather than by behaviour traversing a metal plate. The technique of random expansions in a large chamber with a low magnetic field, adopted by Williams[4], is of particular value in this region, and a measurement by Williams is included in the table and in the diagram.

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Viscosity of Associated Liquids

EXISTING theories of the viscosity of liquids fail to give a satisfactory account of the temperature variation of the viscosity of certain associated liquids. The X-ray diffraction patterns of liquids show that the inter-atomic distances vary about a mean; the variability increasing with increasing temperature. In addition, for the silicate glasses and for water, it is concluded that the structure is a random three-dimensional network of atomic bonds. This network is continuous throughout the liquid and in this sense glasses and water are associated liquids. In glasses the network is built up of Si—O bonds and in water of O—H bonds, the silicon atoms being surrounded by four oxygen atoms, and in water, the oxygen atoms by four hydrogen atoms.

Owing to the variability of the inter-atomic distances, some of the Si—O—Si or O—H—O links are so long that the position of equilibrium of the central atom ceases to be midway between the two outer atoms. Two positions of equilibrium for the central atom now appear, one to each side of the midpoint, with a potential barrier between them. When a shear force is applied the barriers will be lowered in the direction of the force, and there will be a drift of atoms in that direction. If it be assumed: (1) that thermal motion ensures that, at constant temperature, the number of atoms having such alternative positions available to them remains constant, and (2) that the four co-ordinated atoms have always only one position of minimum potential energy available which moves with the flow; then an expression can be set up for the viscosity of the liquid.

As the variability of the inter-atomic distances increases the number of atoms having alternative positions available to them will increase. To obtain a simple expression for the viscosity as a function of temperature the assumption may now be made that the two-bonded atoms fall into two classes, (*a*) no alternative position available, (*b*) two equilibrium positions available separated by a potential barrier of height E at a distance apart a; E and a are taken to have the same values for all atoms in class (*b*). The expression for the coefficient of viscosity then becomes

$$\eta = \frac{1}{\omega} QT\, e^{E/kT}, \quad . \quad . \quad . \quad (1)$$

where η is coefficient of viscosity, T is absolute temperature, ω is fraction of total number of two bonded atoms in class (*b*), Q is a constant and k is Boltzmann's constant.

Having made the assumptions of the previous paragraph it appears that the variation of the number of atoms in class (*b*) with temperature might be found by a process similar to that used in the cases of Frenkel and Schottky defects in ionic lattices. An expression for the variation of ω with temperature found in this way and substituted in (1) gives

$$\eta = T\,(Ae^{E/T} + Ce^{DT}), \quad . \quad . \quad (2)$$

where A, B, C, D are constants which in a more accurate expression would be slowly varying functions of temperature (that is, of the order of volume changes with temperature).

This equation has been fitted to the experimental results for a lime-soda-silica glass and for water. Comparison is made between the calculated and experimental values in the table.

Lime soda glass

Equation found

$$\eta = T\,(2{\cdot}86 \times 10^{-19}\, e^{50,980/T} + 2{\cdot}11 \times 10^{-9}\, e^{27,6\text{[illegible]}0/T})$$

Temperature ° C.	1127	1027	827	627
$\log_{10}\eta$ Exp.	3·06	3·620	5·37	9·05
Calc.	3·154	3·680	5·366	9·048

Water

Equation found

$$\eta = T\,(3{\cdot}1 \times 10^{-11}\, e^{3,763/T} + 8{\cdot}78 \times 10^{-8}\, e^{1,620/T})$$

Temperature ° C.	100	80	60	40	20	0
η Exp.[1]	0·2838	0·3565	0·4688	0·6560	1·0050	1·7921
Calc.	0·2838	0·3569	0·4692	0·6570	1·0047	1·7460

Equation (2) may also be written

$$\eta = T\, A^1\, e^{B^1/kT}\,[1 + C^1\, e^{D^1/kT}]. \quad . \quad (4)$$

Here the expression in the square bracket gives the value of $\frac{1}{\omega}$ and the remaining terms are concerned with the flow.

In the case of water the equation becomes

$$\eta = T.e^{2\cdot 24 \times 10^{-13}/kT}.\ 8{\cdot}78 \times 10^{-8}\,[1 + 3{\cdot}54 \times 10^{-4}\, e^{2\cdot 94 \times 10^{-13}/kT}]. \quad (5)$$

Ubbelohde and Woodward[2] estimate the height of the potential barrier separating the two equilibrium positions of a hydrogen atom between two oxygen atoms 2·8 A. apart as $2{\cdot}2 \times 10^{-13}$ erg. and $1{\cdot}33 \times 10^{-13}$ erg. when the oxygen atoms are 2·75 A. apart. This compares favourably with $2{\cdot}24 \times 10^{-13}$ obtained from equation (5).

For the case of Schottky defects in rock-salt Mott and Gurney[3] estimate $C^1 \sim 10^{-3}$–10^{-4} and $D^1 \sim 30 \times 10^{-13}$; the values obtained thus appear to be reasonable.

The constant A^1 corresponds with Q in the equation (1) and the theoretical value agrees with the value from the viscosity data to within a factor of 10. Bearing in mind the nature of the approximations made, the rough numerical agreement of the constants in the equation fitted to the viscosity data with their estimates by other means is at least suggestive that the theory is on correct lines.

A full account of this work is being prepared for publication.

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Mechanism of Creep in Metals

IT is thought that the experimental observation described in the present note leads to new and useful information on the mechanism of creep in metals, a problem which was the subject of a recent conference at the Royal Society[1].

The observation will be better appreciated if reference may first be made to the following relevant results from previous work at the National Physical Laboratory on the structural changes revealed by X-ray diffraction when a metal is plastically deformed.

(*a*) Under normal static loading of a *polycrystalline* metal, the grains break down into crystallites characterized by widely differing orientations, and for a given metal, a particular lower limiting size. This has been termed the random crystallite formation[2].

(*b*) Under similar loading of a *single metal crystal*, a dislocation of the mosaic structure occurs, but the mosaic elements in general remain approximately parallel. This condition has been termed the 'parallel crystallite formation', to distinguish it from the case of the polycrystalline metal, and to emphasize the point, not generally realized, that the behaviour of the isolated single crystal in this respect is quite different from that of the metal crystal in the aggregate[3].

It was considered that a difference in this fundamental process of breakdown of the grains might be a factor distinguishing the normal short-time deformation of a polycrystalline metal in a tensile test with increasing stress from continuous deformation at the much slower rate known as 'creep'. This has proved to be the case. A specimen of aluminium, initially annealed, was stretched at 300° C. in a normal tensile test to an extension of 0·9 per cent, the extension being completed in about two minutes; it was then unloaded, cooled and examined by X-rays. A similar specimen was allowed to creep under a load of ½ ton/sq. in. at the same temperature until the same extension was reached, but the extension took fifty minutes. X-ray examination then showed that the tensile specimen showed the random crystallite formation referred to in (*a*) above, but the creep specimen had the

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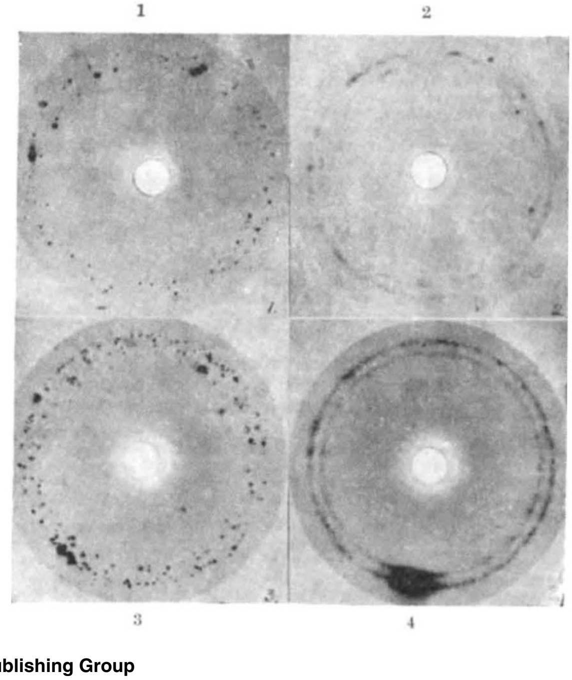

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