

concentric cylinder viscometer, an extrapolation of the curve in Fig. 1 over an interval of merely 27°C is quite easy and reliable. From an enlargement of this figure we thus estimate  $\eta = 10^{13.2}$  poises at 240°.

In the case of glucose glass the transition region centers around 25°C and the viscosity study<sup>3</sup> previously referred to yielded a value of  $10^{13.1}$  poises at this temperature. A more recent, unpublished investigation in this laboratory also gives values ranging from  $10^{13.2}$  to  $10^{14.1}$  poises at 25°, depending on the extent of the annealing and previous working of some glassy glucose fibers. Moreover, some viscosity studies on com-

mercial inorganic glasses<sup>5</sup> have yielded values in the neighborhood of  $10^{13.7}$  poises for this transition region.

It thus appears that the *transition region* in glass-forming materials, whether these be inorganic or organic in character, or composed of only one component or of several components, can be in general identified with a viscosity of the order of  $10^{13}$  to  $10^{14}$  poises. This rule, while purely empirical at present, should be very useful in the study of amorphous solids.

<sup>5</sup> W. E. S. Turner, *The Constitution of Glass*, The Society of Glass Technology, Sheffield, England (1927), pp. 73 and 160. See also Samsoen, *Comptes rendus* **182**, 517 (1926).

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## The Viscosity of Mixtures of Liquids at High Pressures<sup>1</sup>

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The effects of pressure and temperature change on the viscosity of organic, binary mixtures have been investigated by methods developed and used by P. W. Bridgman. Six mixtures have been examined over the entire concentration range at two temperatures, 30° and 75°C, and at pressures extending to 12,000 kg/cm<sup>2</sup>. The isobaric, log viscosity-concentration curves for *n*-hexane carbon disulphide, and *n*-hexane *n*-decane are linear at both temperatures, indicating that these mixtures obey Arrhenius' empirical equation for the viscosity of a binary mixture. It is believed that a comparatively simple type of interlocking among molecules occurs in these mixtures due to the effectively linear structure of the molecules and the

absence of non-uniform molecular fields such as would cause some sort of association. For the remaining mixtures: *n*-hexane diethyl ether, *n*-hexane chlorobenzene, *n*-pentane benzene, and eugenol carbon disulphide, the corresponding viscosity isobars are more complex; irregularities occur in certain regions of concentration which vary with temperature and pressure. In these latter mixtures, the interlocking at high pressures is complicated by the structural differences of the component molecules and their effects. The viscosity of *n*-decane as a function of pressure and temperature has also been investigated. Density data at atmospheric pressure and 30° are included in the paper.

TO study the effect of hydrostatic pressure on the viscosity of pure liquids, P. W. Bridgman<sup>2</sup> investigated forty-three pure liquids through a pressure range of 12,000 kg/cm<sup>2</sup> at 30° and 75°C. His data indicate that viscosity at high pressures is entirely different from that at ordinary conditions and that the "free-space" between molecules is largely decreased, crowding the molecules together in such a way that some sort of interlocking takes place. This conception

gives a possible reason for the great increase in viscosity at high pressures.

It becomes interesting to extend such measurements of viscosity at high pressures to include mixtures of liquids for it is obvious that with different kinds of molecules in mixture the interlocking can be studied more completely than for pure liquids, since it is believed that the degree of interlocking depends on the size and shape of molecules. Consequently, this paper is devoted to the effects of various pressures and temperatures on the viscosity of six liquid, organic mixtures. With the exception of *n*-decane, the pure liquids used for the mixtures have been

<sup>1</sup> This paper is a summary of a thesis presented to the Graduate School of Arts and Sciences, Harvard University in partial fulfilment of the requirements for the Ph.D. in physics (1933).

<sup>2</sup> P. W. Bridgman, *Proc. Am. Acad.* **61**, 57 (1926).

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