

Furthermore, since the change in density or specific volume with temperature is comparatively small, i.e., of the order of a few per cent, we will use ANDRADE'S *first formula*, which is sufficiently accurate for our purposes.

TABLE 1.—VISCOSITY CONSTANTS,  $H_\eta$  AND  $a$ , OF ANDRADE'S VISCOSITY EQUATION,  $\eta_T = a \exp(H_\eta/RT)$  (poise) AND THE MELTING POINT OF METALS,  $T_M$ .

Metal	$T_M$ (°K)	Constant $a$ (poise)	$H_\eta$ (cal/gm atom)
Hg	234	$5.634 \cdot 10^{-3}$	600
Cs	301.7	$1.135 \cdot 10^{-3}$	1060
Ga	303	$4.359 \cdot 10^{-3}$	955
Rb	312.2	$0.911 \cdot 10^{-3}$	1230
K	337	$0.659 \cdot 10^{-3}$	1433
Na	371	$0.787 \cdot 10^{-3}$	1625
In	430	$3.020 \cdot 10^{-3}$	1590
Li	452	$1.590 \cdot 10^{-3}$	1220
Sn	505	$3.843 \cdot 10^{-3}$	1740
Bi	544	$3.594 \cdot 10^{-3}$	1770
Cd	576	$4.850 \cdot 10^{-3}$	2040
Pb	601	$4.222 \cdot 10^{-3}$	2295
Zn	693	$4.085 \cdot 10^{-3}$	2950
Sb	903	$2.797 \cdot 10^{-3}$	2970
Ag	1234	$5.750 \cdot 10^{-3}$	4690
Cu	1357	$8.676 \cdot 10^{-3}$	3680
Fe	1812	$16.060 \cdot 10^{-3}$	5070
W (est.)	3650	$36.5 \cdot 10^{-3}$	$\approx 7400$

*Empirical relationship between the activation energy of viscosity and the melting point of the metal*

From the standpoint of inorganic chemistry we are interested in estimating, in a general way, the viscosity of any metal over a wide temperature range and finding any kind of relationship between viscosity and other physical properties of the element.

The theory of the viscosity of liquids has been developed, among many others, by EYRING.<sup>(7)</sup> EYRING'S viscosity theory is based on his theory of absolute reaction rates; his expression for  $\eta$  is:

$$\eta = \left(\frac{\delta}{d}\right)^2 \cdot n \cdot h \cdot \exp(H_\eta/RT)$$

where  $\delta$  is the distance between molecular layers and for simplicity is assumed to equal  $d$ , the distance between crystal lattice points, (thus  $(\frac{\delta}{d})^2 \approx 1$ ),  $n$ , the number of atoms/cm<sup>3</sup>,  $h$  = Planck's constant and  $H_\eta$  is the free energy of activation for viscous flow, obtained from the slope of the logarithm of experimental viscosity data against  $1/T$ .

According to EYRING'S views  $H_\eta$  is proportional to the energy of vaporization,  $\Delta U_{\text{vap.}} = \Delta H_{\text{vap.}} - RT$ , since the processes are very similar. In many cases,<sup>(8)</sup> that is,

<sup>(7)</sup> H. EYRING, *J. Chem. Phys.* 4, 283 (1936); see discussion of EYRING'S theory in book by J. O. HIRSCHFELDER, C. F. CURTISS and R. B. BIRD, *Molecular Theory of Gases and Liquids*, pp. 624-630. J. Wiley, New York (1954).

<sup>(8)</sup> J. F. KINCAID, H. EYRING and A. E. STEARN, *Chem. Rev.* 28, 301 (1941).