Shri R. L. T. College of Science,

Chapter 6 (Physical chemistry)

A. Liquid State (Viscosity)

Viscosity:

- Every liquid exhibits some resistance to flow. This resistance to flow is called *viscosity*. It is developed in liquids because of the shearing effect of moving one layer of liquid past another.

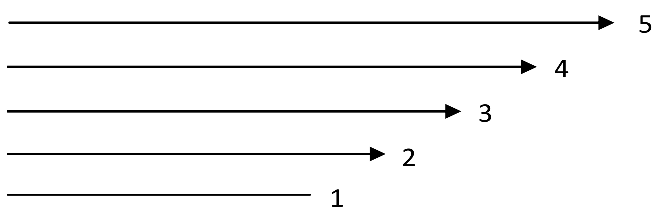
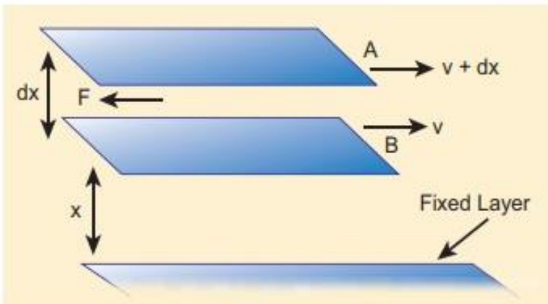


Fig. Motion of liquid

- A motion of liquid can be visualized as movement of one layer over another. A layer in contact with stationary surface remains stationary. The second layer moves slowly, third faster than second and so on. This type of flow is called as *laminar flow* or *streamlines flow*.
- *Laminar Flow*: The liquid is considered to be consisting of molecular layers arranged one over the other. When the liquid flows over a glass surface then the layer of molecules immediately in contact with the glass surface are stationary with zero velocity. But the layer immediately above it is not stationary but flows with some velocity. The next layer above it still moves more faster, and the topmost layer of molecules flow with maximum velocity. This type of flow in

which there is gradual gradation in the velocities on passing from one layer to another is called laminar flow.

- ❖ In laminar flow, the force ‘f’ required to maintain a steady difference of velocity dv between two parallel layers separated by distance dx is proportional to the area of contact (A) and velocity gradient $\left(\frac{dv}{dx}\right)$.



- ❖ If any molecular layer say B (shown in above figure) we take, then the layer above it say A accelerates its flow because the molecules from the above layer A with higher velocity speeds the lower layer B molecules also. But the layer below B is stationary layer it retards its flowcbecause the molecules in the lower layer are with lower velocity. This whole results in the friction between the two layers which gives rise to viscosity.
- ❖ So, viscosity is defined as the internal resistance to flow in liquids which arises due to the internal friction between the layers of liquid as they slip past one another while liquid flows.

$$f \propto A \cdot \frac{dv}{dx} \qquad \text{-----------------------------------(1)}$$

$$f = \eta A \cdot \frac{dv}{dx} \qquad \text{-----------------------------------(2)}$$

Where, f = Retarding force or viscous drag (acting in opposite direction of flow)

η = coefficient of viscosity of the liquid.

$$\therefore \quad \eta = \frac{f}{A \cdot \frac{dv}{dx}} \qquad \text{-----------------------------------(3)}$$

- f = Retarding force or viscous drag (acting in opposite direction of flow)
- η = coefficient of viscosity of the liquid.
- A=Area of Contact
- dv=Velocity difference
- dx= Distance between two layers
- dv/dx=velocity gradient which is change of velocity with distance

When, A = 1 sqm, dv = 1 m sec^{-1} and dx =1 m, then

$\eta = f$

- The coefficient of viscosity (η) may be defined as, *the force that must be exerted between two parallel layers 1 m^2 in area and 1 meter apart in order to maintain velocity difference of 1 m sec^{-1}.*

Units of Viscosity:

- The SI unit of viscosity is kg m^{-1} s^{-1}.
- The CGS unit of viscosity is g cm^{-1} s^{-1}. It is called Poise (P). In practice similar units centipoises (10^{-2} poise) and millipoise (10^{-3} poise) are used.

The units are related as

1 poise = 1 g cm^{-1} s^{-1} = 0.1 kg m^{-1} s^{-1} = 10^{-1}kg m^{-1} s^{-1}

6.6 Measurement of viscosity by Ostwald's viscometer method:

The direct measurement of absolute viscosity of a liquid is very difficult, the relative viscosity of liquid with respect to reference liquid (water) can be conveniently determined with the help of apparatus called Ostwald's Viscometer.

A definite quantity of the liquid under examination is put into the wider limb. The quantity of liquid should be so taken that bigger bulb is filled more than half of its volume (This generally requires 10 to 15 cm^3 of liquid). It is then sucked up into the other limb through a capillary tube. The liquid is allowed to flow through the capillary attached to the smaller bulb and the time of flow from mark A to mark B is noted.

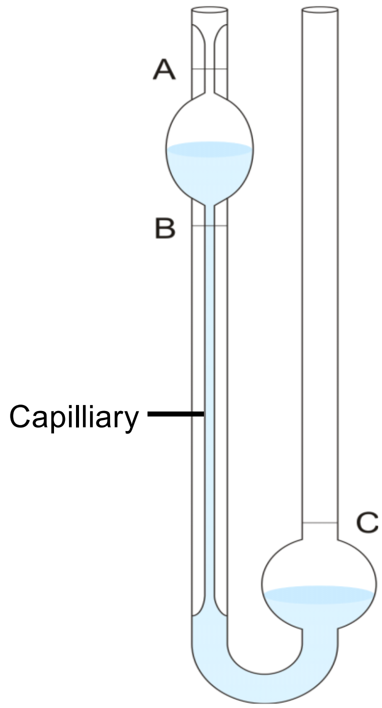


Fig. Ostwald's Viscometer

When liquid flows through the capillary, the time of flow 't' is directly proportional to the viscosity coefficient and inversely to the density 'd' of the liquid,

$t \propto \frac{\eta}{d}$ or $\eta \propto td$ or $\eta = ktd$ ------------------------------------(1)

The whole process is then repeated for the same volume of water, exactly under similar conditions then we have,

$\eta_w = kt_w d_w$ ------------------------------------(2)

When η_w, t_w and d_w are the coefficient of viscosity, time of flow and density of water respectively.

Equation (1) divides by (2), we get,

$\frac{\eta}{\eta_w} = \frac{t\,.\,d}{t_w\,d_w}$ ------------------------------------(3)

$$\frac{\eta}{\eta_w} = \eta_r \text{ (i.e. the relative viscosity of liquid)}$$

Ostwald's viscometer is a very convenient apparatus for determination of viscosity at higher temperatures as it can be easily suspended in thermostat.

6.7 Effect of temperature on viscosity:

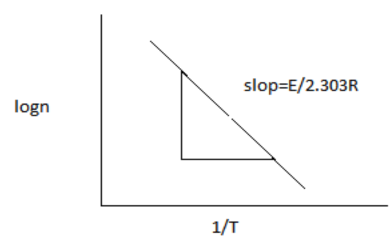
It has been found that the viscosity of liquid decreases with rise in temperature. The variation of viscosity with temperature is best expressed by the equation.

$$\eta = A.e^{+E/RT} \qquad \text{-----------------------------------(1)}$$

Where, A and E (activation energy for viscous flow) are constants for a given liquid. Taking logarithms.

$$ln\,\eta = ln\,\text{A} + \frac{E}{RT} \qquad \text{-----------------------------------(2)}$$

$$log_{10}\,\eta = log_{10}\,\text{A} + \frac{E}{2.303RT} \qquad \text{-----------------------------------(3)}$$



Hence a plot of $log_{10}\,\eta$ versus $1/T$ should be a straight line. The reason why viscosity decreases with temperature is that, as the temperature increases, the molecular agitations increase and hence the resistance to flow (i.e. viscosity) may be expected to decrease.

6.8 Applications of viscosity measurements:

i) In lubrication, oil viscosity is the most important characteristic. It must be right. The correct viscosity gives you the ability to lubricate that means ability to protect against wear (by separating surfaces) and to reduce friction.

ii) Viscosity measurements help in gradation of lubricant oils. In precision instruments such as watches special kinds of lubricants are needed, which should not change their viscosities very much with temperature. Therefore, all weather lubricants are manufactured by mixing long chain coiling polymers with oil.

iii) The viscosity measurements yield information regarding the movement of liquid through pipes.

iv) In determination of molecular weight of polymers by viscosity measurements.

v) The study of viscosity has been used by chemist for knowing the constitution of molecules through Rheochor $R = \left(\frac{dv}{dx}\right)\eta^{1/8}$ which is both additive as well as constitutive property.

vi) When carbon dioxide gets accumulated in blood, breathing becomes difficult. Due to absorption of CO_2, blood corpuscles swells which in turn, raise the viscosity of blood. This process quickly lead to heart attack.

vii) To the heart patients, doctors prescribe medicines to lower the viscosity of blood in order to lower the pressure on heart.