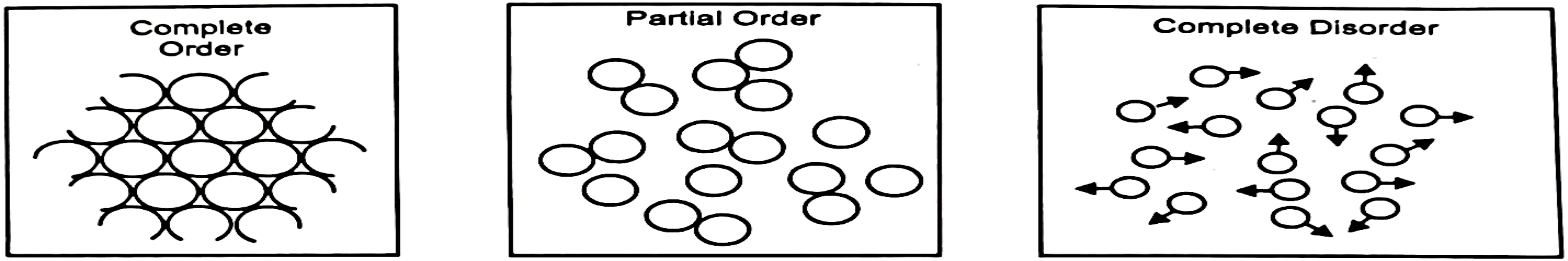
Liquid State

Liquid State

- ➢ **Intermediate state between Gaseous state & Liquid State**



(a) Solid (b) Liquid (c) Gas

- ➢ **Intermolecular forces are strong**
- ➢ **Have definite volume & shape**
- ➢ **Closely packed particles**
- ➢ **Particles can not move**
- ➢ **Incompressible**

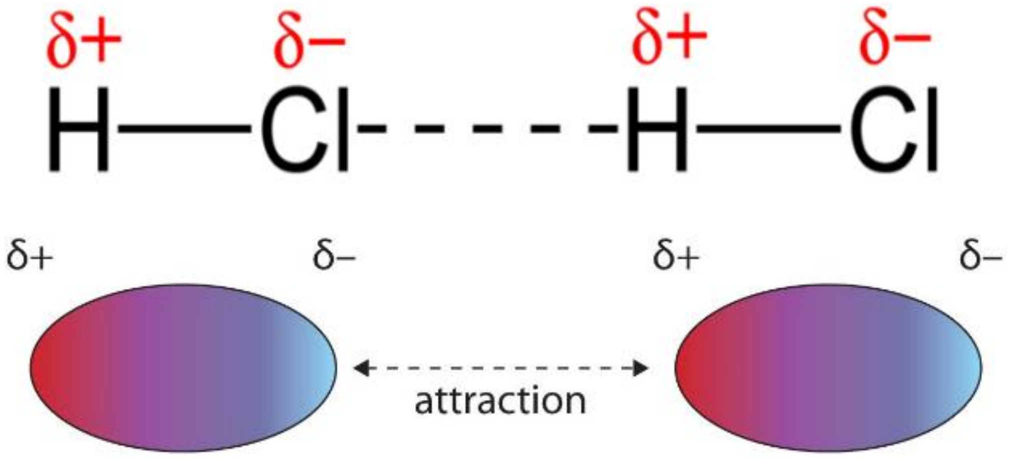
- ➢ **Intermolecular forces nether very strong nor very weak**
- ➢ **Definite volume but not definite shape**
- ➢ **Intermolecular distances are very small**
- ➢ **Molecules can move past one another but movement is restricted**
- ➢ **Very less compressible**

- ➢ **Intermolecular forces are very weak**
- ➢ **Neither definite volume nor definite shape**
- ➢ **Large intermolecular distances**
- ➢ **Molecules are in constant rapid motion**
- ➢ **Highly compressible**

Inter molecular forces in Liquid State

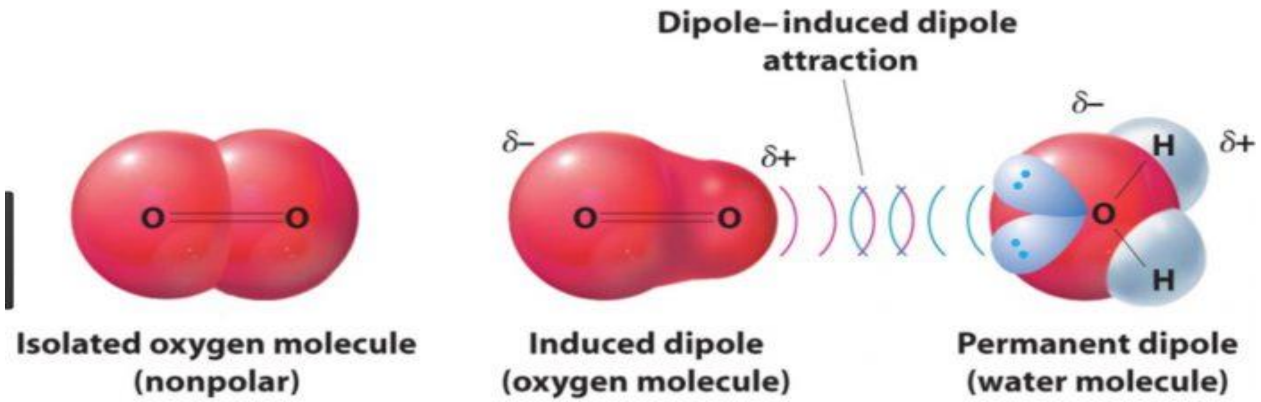
Dipole-dipole interaction

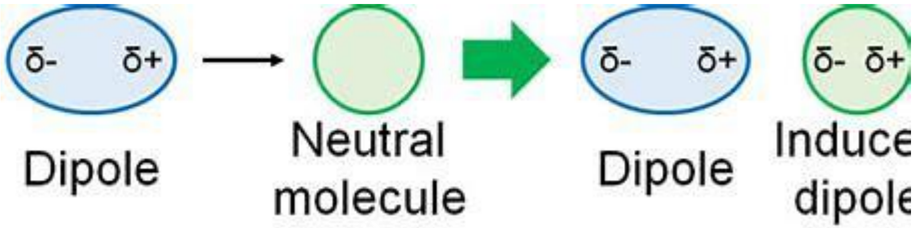
- In polar molecules
- Magnitude depends upon dipole moment
- e.g. NH_3, HCl etc.



Dipole-induced dipole interaction

- Between polar and nonpolar molecules
- Magnitude depends upon dipole moment of polar molecule and polarizability of nonpolar molecule
- e.g. O_2 & H_2O

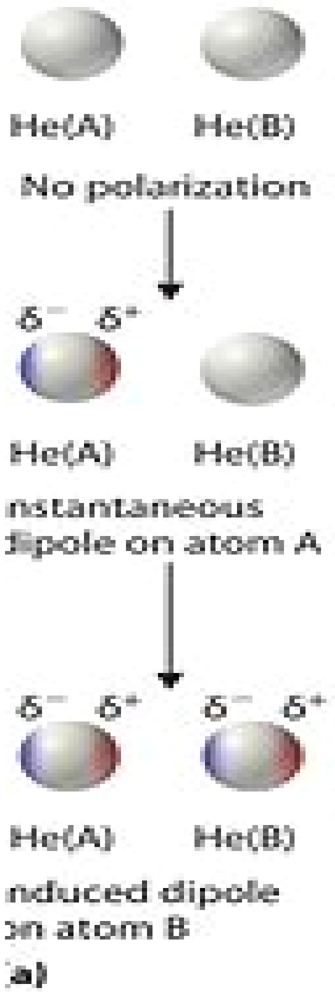




Inter molecular forces in Liquid State

❑ **Induced dipole-induced dipole interaction(London dispersive forces)**

- In nonpolar molecules or atoms of monoatomic substances
- Magnitude depends on size, surface area of the molecules or atoms
- e.g. O_2, Helium etc.



❑ **H-Bonding**

❑ **Repulsive forces**

- At very low distances

Physical properties of liquids

- Depend upon the strength of intermolecular forces
- Physical property can be

1. Additive property

   Sum of the corresponding properties of the constituent atoms e.g. Molecular mass

2. Constitutive property

   Depends upon the structural arrangement of the atoms within the molecule e.g. softness of graphite and hardness of diamond

3. Additive as well as constitutive

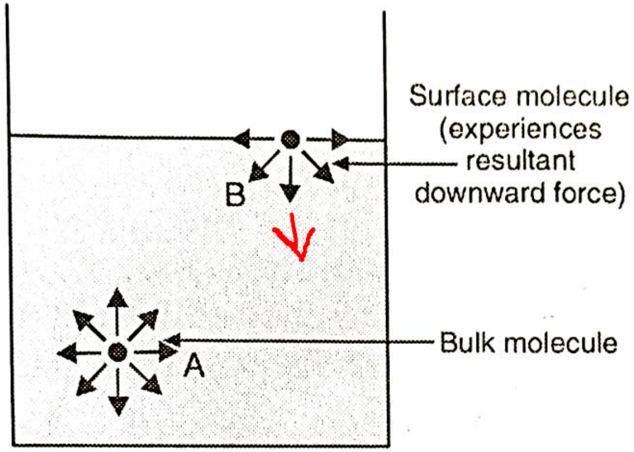
   Which is additive as well as constitutive e.g parachor, molar refraction etc.

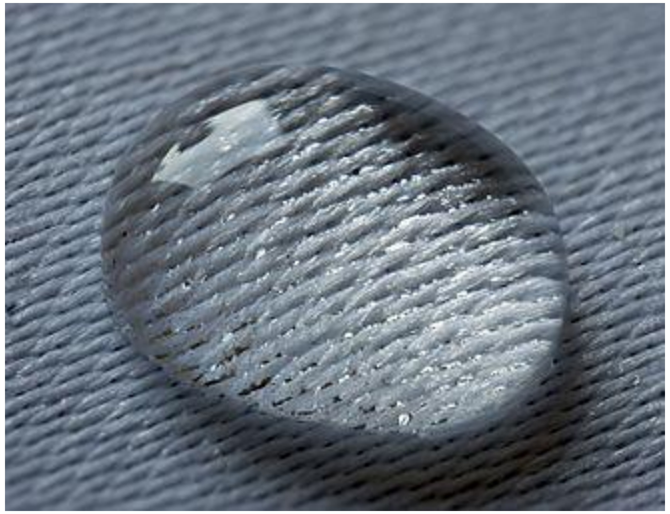
Surface Tension

- Liquid surface is under tension due to unbalanced forces
- Defined as the force acting at right angle to the surface along 1 cm length of the surface

Units

- Dynes/cm or Newton /meter





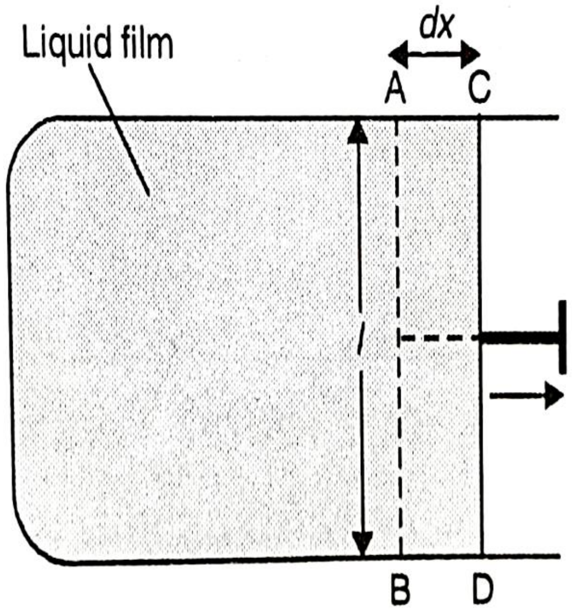
Surface Energy

- It is the work in ergs required to done to increase the surface area by 1 square centimetre
- It is because some work is to be done against force of surface tension

Units

- ergs/cm^2 or J/m^2
- Dimensionally surface energy and surface tension are equivalent

- Surface Energy=$\frac{Amount\ of\ work\ done}{Amount\ of\ area\ increased} = \frac{F\ x\ l}{Area}$
- Surface Energy=$\frac{Dyne\ x\ cm}{cm2} = \frac{Dyne}{cm}$ = Surface Tension
- in SI units Surface Energy=$\frac{N\ x\ m}{m2} = \frac{N}{m}$ = Surface Tension



Surface active agents(Surfactants)

- The substance which on dissolution in liquid lower its surface tension
- Soap in water

Interfacial Tension

- Surface tension acting along the surface of separation or interface
- $\gamma_{AB} = \gamma_A - \gamma_B$ if liquids donot interact strongly
- Surfactants lower interfacial tension between liquid and oil

Consequences of Surface Tension

❖ **Spherical shape of drops**

➢ Inward pull of surface tension makes the drop spherical

➢ Due to Surface tension liquids tend to have minimum surface area

❖ **Capillary action**

➢ In ward pull on the surface of liquid pushes the liquid in to a capillary tube

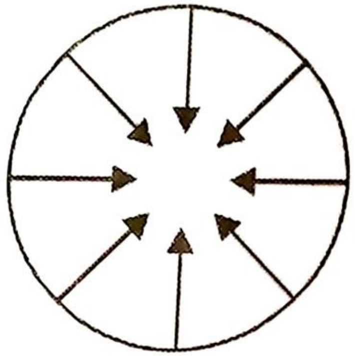
✓ Oil rises in the wick of an oil lamp

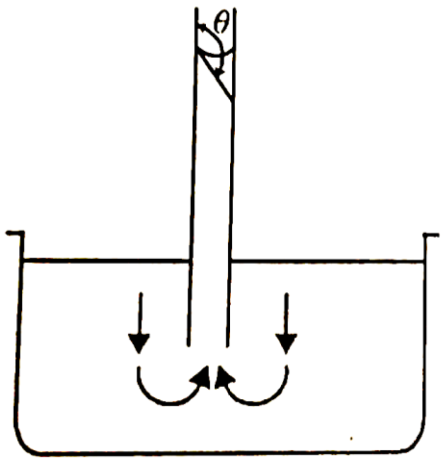
✓ Ink rises in blotting paper

✓ Water in earth rises to plants through roots

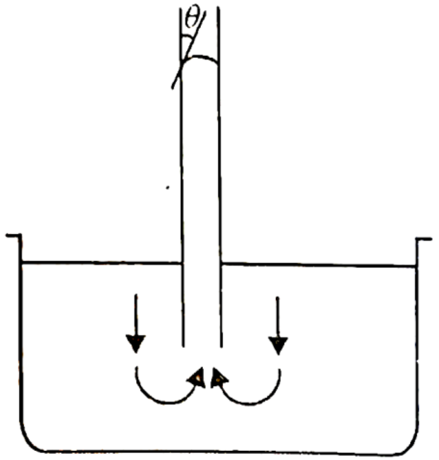
❖ **Angle of contact**

✓ The angle made by the curved surface of liquid with the wall of the capillary





(b) Liquids which wet the glass



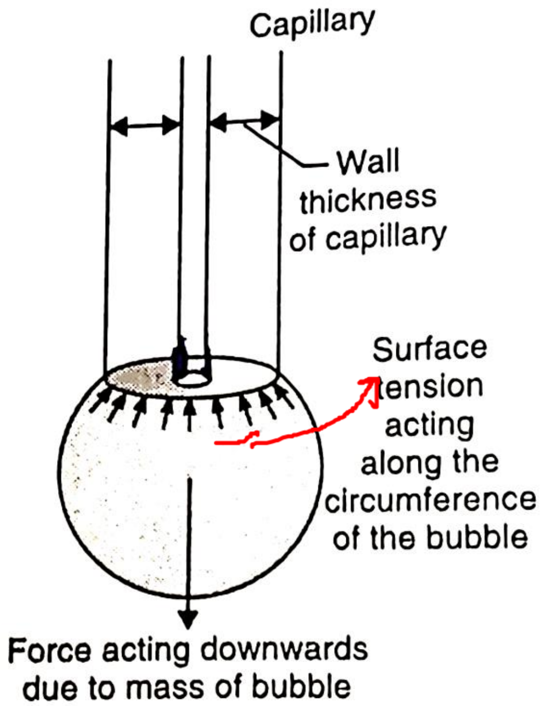
(c) Liquid which do not wet the glass

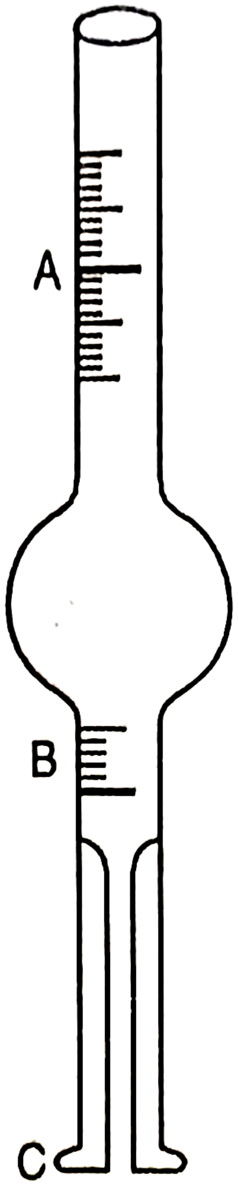
Measurement of Surface Tension Using stalagmometer

- **Two methods**

1. Drop weight method

- **Based upon determination of weight of a drop of liquid which just falls down under its own weight**
- **Two forces act on the drop**
- **Force of surface tension acting upwards**
- **Gravitational force acting downward**
- **The drop falls when its weight is equal to the force of surface tension acting along the circumference of capillary tube**
- **$w = mg = 2\pi r \gamma$**





Measurement of Surface Tension Using stalagmometer

1. Drop weight method

- Relative method is used to avoid measurement of r and water is chosen as reference liquid
- $w_l = m_l g = 2\pi r \gamma_l$
- $w_w = m_w g = 2\pi r \gamma_w$
- $\frac{m_l g}{m_w g} = \frac{2\pi r \gamma_l}{2\pi r \gamma_w}$
- $\frac{m_l}{m_w} = \frac{\gamma_l}{\gamma_w}$
- $\frac{m_l}{m_w} = \frac{\gamma_l}{\gamma_w}$
- $\gamma_l = \frac{m_l}{m_w} \gamma_w$

☐ Determine mass of 30 drops of each liquid
☐ From this determine mass of single drop
☐ Put the values of m_l , m_w and γ_w to calculate γ_l

OR

☐ Let weight of empty weighing bottle = w_1 g
☐ Weight of weighing bottle with 30 drops of liquid = w_2 g
☐ Weight of weighing bottle with 30 drops of water = w_3 g
☐ So $m_l = (w_2 - w_1)$ g
☐ and $m_w = (w_3 - w_1)$ g

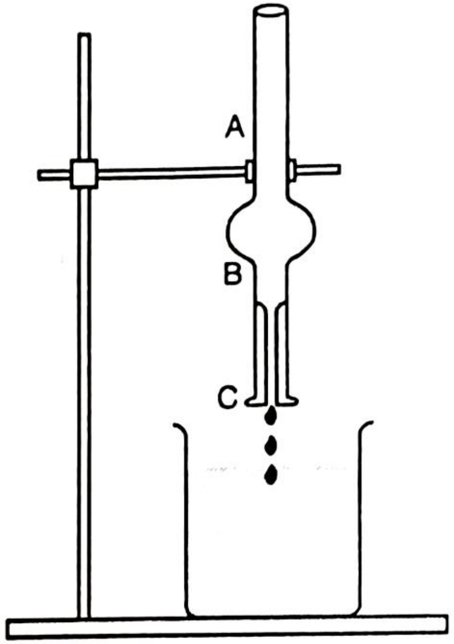
Measurement of Surface Tension Using stalagmometer

2. Drop number method

- Based upon counting of number of falling drops of a liquid from the stalagmometer
- More convenient as it is easy to count rather than weigh
- Count number of drops for equal volumes of two liquids
- The volume of single drop of liquid $v_l = V/n_l$
- The volume of single drop of water $v_w = V/n_w$
- Now mass of one drop of liquid ie $m_l = v_l \times d_l = V\frac{d_l}{n_l}$

Since Density = Mass / Volume

- And mass of one drop of water ie $m_w = v_w \times d_w = V\frac{d_w}{n_w}$
- $\frac{\gamma_l}{\gamma_w} = \frac{m_l}{m_w} = \frac{V\frac{d_l}{n_l}}{V\frac{d_w}{n_w}} = \frac{d_l}{n_l} \times \frac{n_w}{d_w}$
- $\gamma_l = \frac{d_l}{n_l} \times \frac{n_w}{d_w}\gamma_w$



Effect of temperature on Surface Tension

- ☐ **Surface tension decreases with increase in temperature**
- Because intermolecular forces of attraction decrease with increase in temperature
- At Tc the critical temperature S.T. is zero
- According to EOTVAS
- $\gamma\left(\frac{M}{D}\right)^{2/3} = k\,(tc - t)$ here M/d is molar volume & tc is critical temperature
- $\gamma\left(\frac{M}{D}\right)^{2/3}$ is molar surface energy if volume is a sphere
- Molar surface energy varies linearly with temperature and becomes zero at critical temperature
- According to Katayama
- $\gamma\left(\frac{M}{D - d}\right)^{2/3} = k(t_c - t)$ here d is density of the vapours

Viscosity

- **The internal resistance to the flow of a liquid**
- Consider liquid flowing in a tube. The liquid flows in the form of a large number of thin cylindrical coaxial layers
- The layer in contact with wall is stationary
- As we move towards the centre the velocity of layers increase ~~and~~ becomes maximum in the centre
- Every layer offers some resistance to the layer flowing below it
- The force of friction which one layer offers on the other is called as viscosity

Viscosity

- ❑ **Coefficient of viscosity**
- ➢ The tangential force F is required to maintain the constant speed of different layers

  $F \propto A \frac{dv}{dx}$ or $F = \eta\ A \frac{dv}{dx}$ or $\frac{F}{A} = \eta \frac{dv}{dx}$ Now if dv = $1cm^2$ & dx = 1 cm then $\frac{F}{A} = \eta$

- ➢ So Coefficient of viscosity may be defined as the tangential force per unit area required to maintain velocity difference of 1 cm/s between two layers at a distance of one cm.

- ➢ Units of **Coefficient of viscosity**
- ➢ $\eta = \frac{F}{A}\frac{dx}{dv}$ **CGS system** $\eta = \frac{dyne}{cm^2}\frac{cm}{cm/sec}$ = **dyne-sec cm^{-2}**
- ➢ CGS unit is also called as Poise(P)

- ❑ **Fluidity**
- ➢ It is the reciprocal of coefficient of viscosity

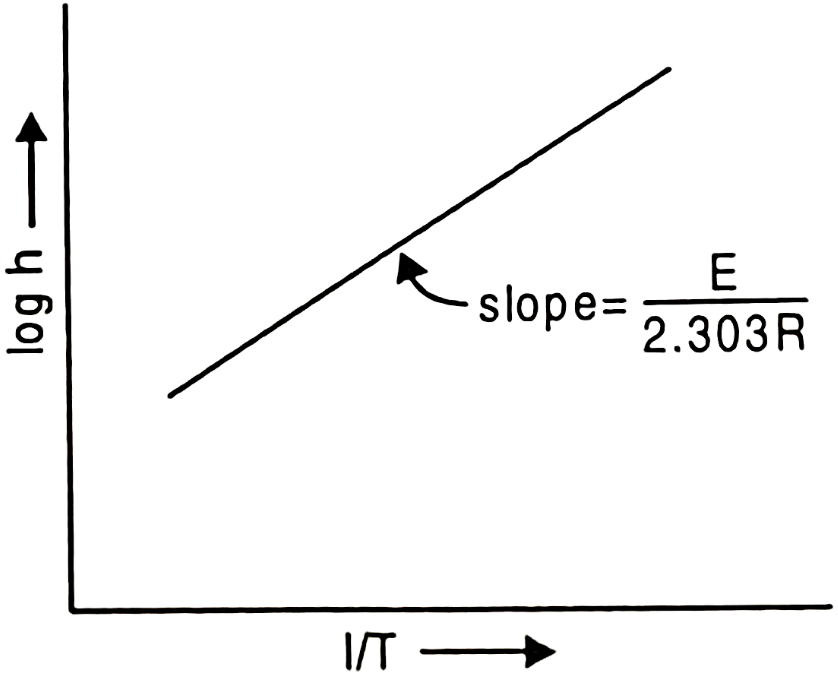
Effect of temperature on viscosity

- ❑ **Viscosity decreases with rise in temperature**
- ➢ **Because with increase in temperature intermolecular forces decrease and kinetic energy of liquid molecules increases.**

$$\eta = Ae^{E/RT}$$

$$\log \eta = \log A + \frac{E}{2.303\,RT}$$

A & R are constants and E is activation energy for viscous flow



Measurement of coefficient of viscosity

- **Can be measured by observing the rate of flow through some capillary**
- **When viscous liquid flows through a capillary, then according to Poiseuille formula**

$$\eta = \frac{\pi p r^4 t}{8.Vl}$$

- **For a given capillary, r and l are constant. If fixed volume of a ;iquid is taken then**
- **η = kpt**
- **For two different liquids, we can write**
- **$\eta_1 = kp_1t_1$…………………………1**
- **$\eta_2 = kp_2t_2$…………………………..2**
- **Also the hydrostatic pressure on the liquid p = hdg**
- **On liquid 1 , p1 = hd1g……………..3**
- **On second liquid p2 = hd2g………………4**

Measurement of coefficient of viscosity

- ☐ From equation 1 2,3 & 4
- ➢ $\eta_1 = khd_1gt_1$………………………5
- ➢ $\eta_2 = khd_2gt_2$………………………6
- ➢ Dividing we get
- ➢ $\frac{\eta_1}{\eta_2} = \frac{khd_1gt_1}{khd_2gt_2}$
- ➢ $\frac{\eta_1}{\eta_2} = \frac{d_1t_1}{d_2t_2}$
- ➢ **If we put the values of η_2, d_2, t_1 and t_2, then η_1 can be calculated.**
- ➢ **Ostwald's viscometer is used for determining the time of flow.**