PHYSICAL CHEMISTRY

CHAPTER- THE LIQUID STATE

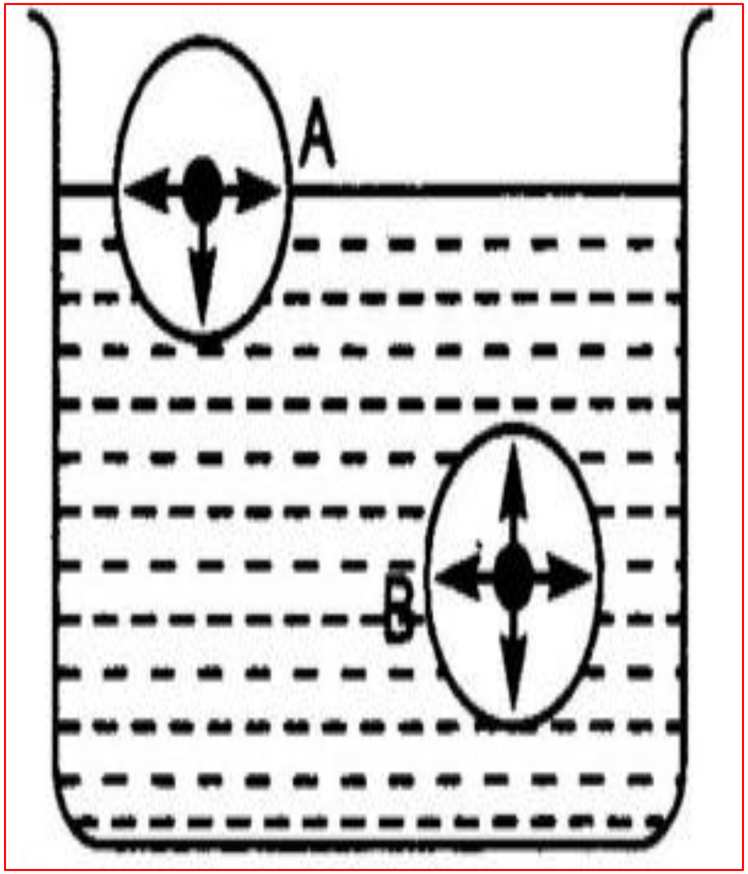
LECTURE NO. 1

DATE:- 8, MAY, 2021

TIME: (9.00A.M.)

The liquid state

Introduction: - Consider a liquid in a container. Let a molecule 'B' is in the interior of a liquid. It is surrounded by other molecules from all sides. Therefore, molecule 'B' is attracted equally from all directions by other molecules and the forces are balanced.



Now, consider a molecule ‘A’ on the surface of liquid. There are more molecules below it. Therefore, molecule ‘A’ experiences greater downward force than upward force. This creats an imbalance of forces and the surface molecules are pulled inwards. Therefore, the molecules at the surface of a liquid are under certain tension or strain. This strain is called as the surface tension of liquid. This inward pull tends to give minimum surface area to the liquid. Hence, surface of a liquid contract to a smaller area. E.g. Spherical shape of rain drops. The force responsible for the contraction of liquid surface is called as surface tension.

Definition of Surface tension: - “The force in dynes acting along the surface of a liquid at right angle to any line 1cm in length”.

Unit of Surface tension: - The CGS unit of surface tension is dyne.cm^{-1}. While, the SI unit is N.m^{-1}. Where, 1dyne.cm^{-1} = 1 mN.m^{-1}.

Factors affecting Surface tension: -

i) Nature of liquid: - Surface tension depends on nature of the liquid, because the attractive forces are different in different liquids. Hence, surface tension vary with nature of liquid.

ii) Temperature: - Surface tension decreases with increase in temperature. When temperature increases, the kinetic energy increases, due to which the attractive forces between the molecules decreases. Due to this, there is a decrease in inward pull on surface molecules, and hence surface tension decreases.

Capillary action: -

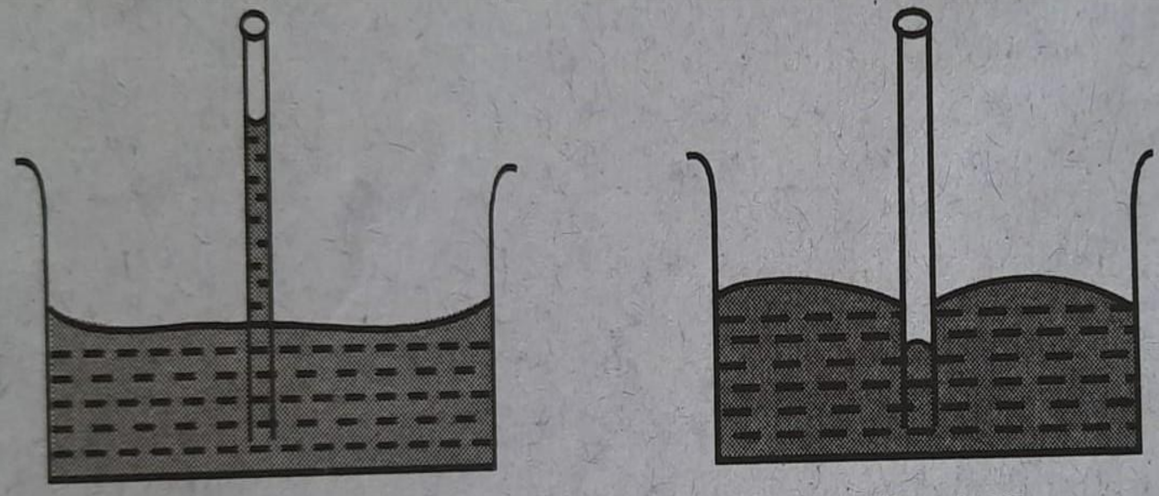


Fig. 2.2 Capillary action

When the end of a capillary tube is placed vertically in a liquid, then the liquid rises above the surface of the liquid. This process continues till the surface tension tends to pull the liquid upwards becomes equal to the weight of the liquid in the capillary. This point is called as equilibrium point. At this equilibrium point, the liquid rises in the capillary to a certain height which is characteristic of the liquid.

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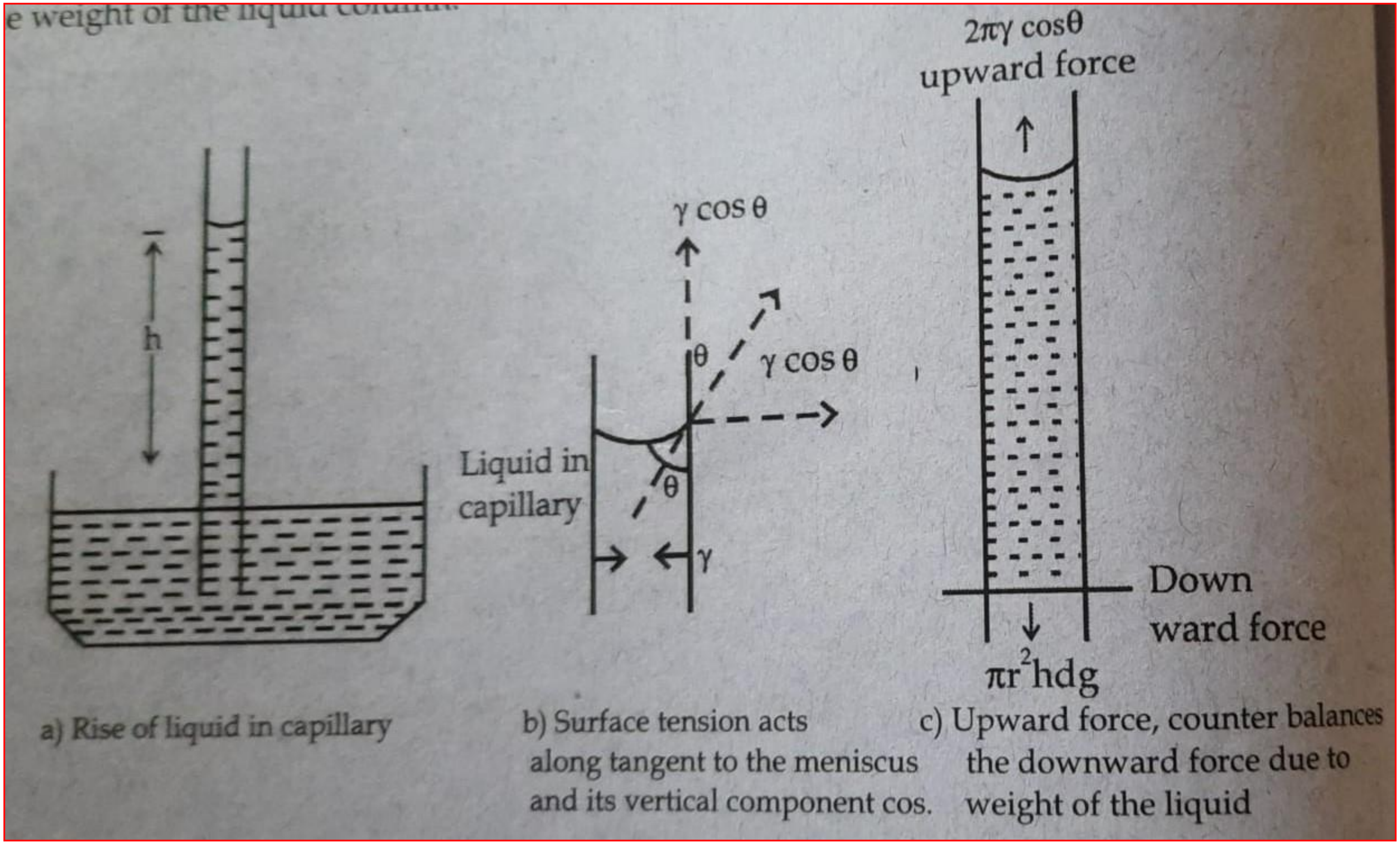
LECTURE NO. 2

DATE:- 14, MAY, 2021

TIME: (3.00P.M.)

Determination of surface tension: - There are two methods: -

•Capillary rise method: - Consider a capillary of radius (r) is inserted vertically into the liquid. Due to capillary action, the liquid rises in the capillary and forms a concave meniscus.



Let ‘h’ be the height of liquid rise in the capillary. The liquid in the capillary is supported by the surface tension ‘γ’ which acts along the tangent to the meniscus. The vertical component of surface tension $\gamma\cos\theta$ pulls the liquid upwards in capillary. This force acts on inner circumference $2\pi r$ of capillary tube. Then total force acting upwards is = $2\pi r \times \gamma\cos\theta$.

For most of the liquids, $\theta \approx 0$, and hence, Cos 0 = 1.

∴ Upward force = $2\pi r \gamma$-------------(1)

The downward force on the liquid is due to its wt. and it is given by = $\pi r^2 hdg$----(2)

Where, d ⟶ Density of liquid, g ⟶ Acceleration due to gravity

πr^2⟶ Volume of cylindrical column h.

But, Upward force = Downward force.

From eq^n.(1) and (2),

$2\pi r \gamma = \pi r^2 hdg$

$$\gamma = \frac{\pi r2hdg}{2\pi r} \qquad \gamma = \frac{hrdg}{2}$$ dyne.cm^{-1}.

2) Drop formation method: -

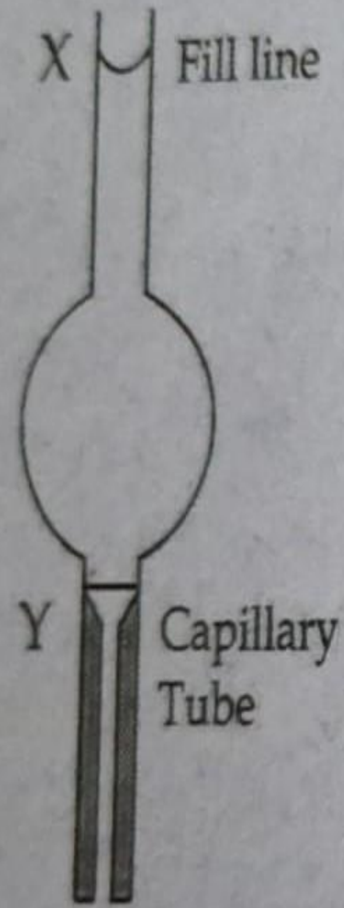


Fig. 2.4 Stalagmometer

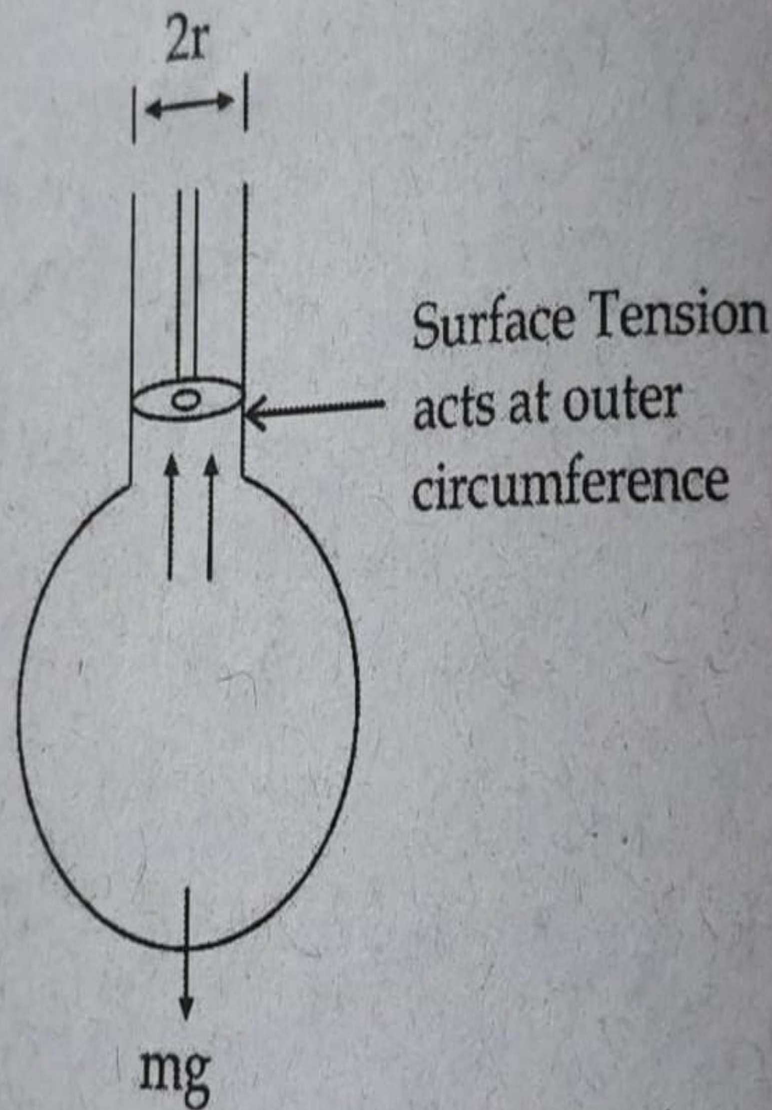


Fig. 2.5 Formation drop of liquid

If the liquid is allowed to flow through capillary tube then, a drop of liquid is formed at the end of the capillary. The size of drop increases and finally the drop breaks from the capillary end. The drop is supported by upward force of surface tension acting at the outer circumference of the tube. The wt. of drop (mg) pulls it in downward direction. When, these two forces are balanced then the drop break from the capillary tube end. Thus, at the point of breaking,

Wt. of drop = Surface tension acting at outer circumference

$mg = 2\pi r \gamma$ ----------(1)

Where, m = mass of drop

g →Acceleration due to gravity

r →Outer radius of capillary

The apparatus used to determine the number of drops in definite volume of the liquid is called as 'Stalagmometer' or 'Drop pipette'. By using Stalagmometer, surface tension is determined by two methods.

•Drop weight method: - The Stalagmometer consists of glass pipette with capillary at the lower part. The glass pipette has upper marking ‘*x*’ and lower marking ‘y’.

The Stalagmometer is cleaned, dried and filled with the liquid whose surface tension is to be determined upto the mark *x*. Then, about 20 drops of liquid are received from the Stalagmometer in the weighing bottle and weighed. From the wt. of liquid, wt. of one drop of liquid is determined. The Stalagmometer is again cleaned and dried.

The same procedure is repeated for any reference liquid (e.g. Water) and wt. of one drop of reference liquid (water) is determined as before.

We know that, at the point of breaking from eq^n. (1),

$mg = 2\pi\, r\, \gamma$

∴ For first liquid, $m_1\, g = 2\pi\, r\, \gamma_1$-------(2)

and for second liquid, $m_2\, g = 2\pi\, r\, \gamma_2$---------(3)

Dividing eq^n. (2) by (3),

$$\frac{m_1}{m_2} = \frac{\gamma_1}{\gamma_2}$$

$$\gamma_1 = \frac{m_1}{m_2} \times \gamma_2$$

Where, m_1 →Mass of a drop of liquid 1,

m_2 →Mass of a drop of liquid 2

γ_2 → Surface tension of reference liquid 2.

Knowing the surface tension of reference liquid from tables, we can determine the surface tension of unknown liquid.

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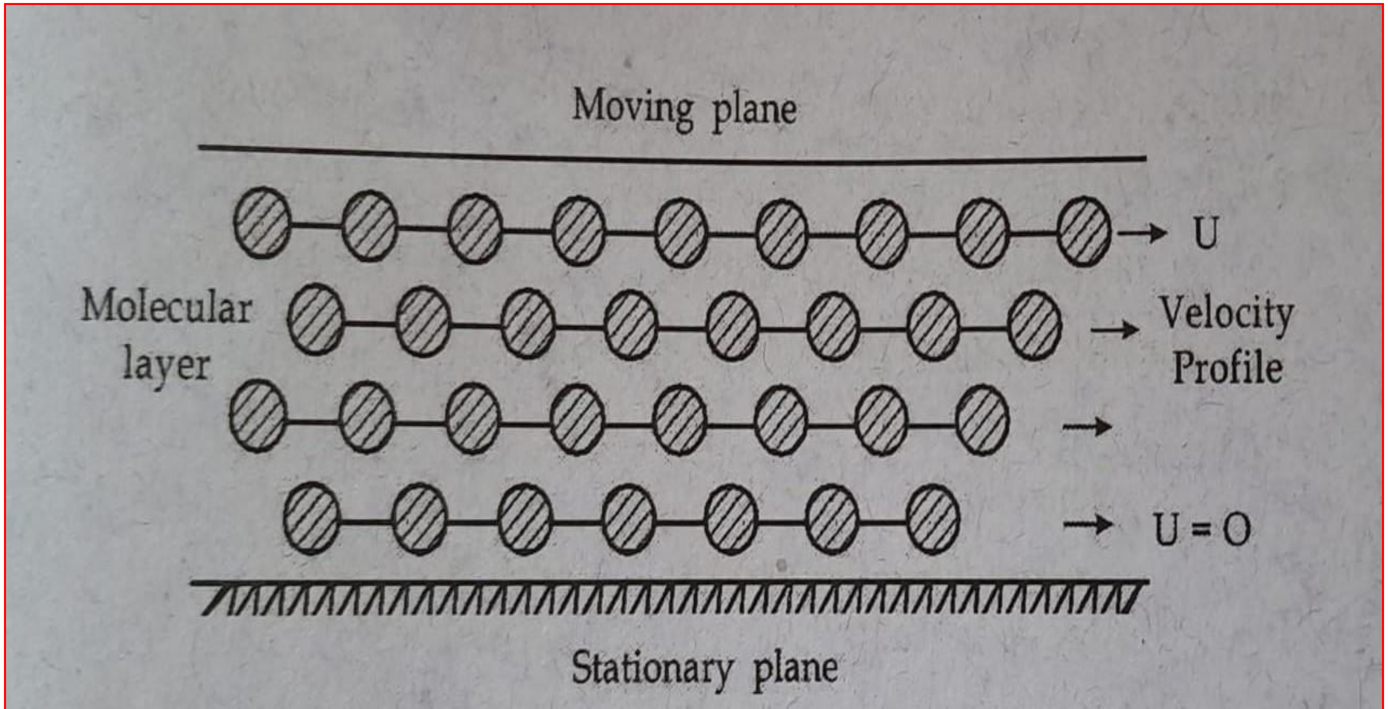
LECTURE NO. 3

DATE:- 21, MAY, 2021

TIME: (3.00P.M.)

Viscosity: - Flow is a characteristic property of liquids. Some liquids, like water, ether, benzene, etc. flows rapidly (fast) are known as mobile liquids. While, some other liquids like glycerine, oils, etc. flows very slowly are known as viscous liquids. This difference in flow rates is due to the property known as viscosity. The rate of flow depends on the nature of liquid and intermolecular forces of attraction in liquids.

If we consider, a motion of liquid in a glass tube, there are number of molecular layers A,B, C, D,……etc. arranged one over another as shown in fig.



The layer A is in contact with the wall of tube, is stationary. The second layer B moves little faster than first layer A and the third layer C moves faster than B layer. The velocity of the layer that moves along the axis is larger.

The slow moving layer exerts a retarding force on the fast moving layer, and this retarding force gives rise to viscosity of liquid. Hence, the displacement of different layers relative to one another is opposed by internal friction of liquid is called as viscosity.

Or Viscosity of a liquid is a measure of resistance of the liquid offers to flow.

The unit of viscosity is "Poise" (i.e. $gm.cm^{-1}. Sec^{-1}$).

When the flow of liquid becomes steady, there will be a constant difference in the velocity between two different layers. The force per unit area required to maintain this constant difference in velocity is directly proportional to the difference of velocity V of two adjacent layers and inversely proportional to their distance '*x*' apart.

Factors affecting Viscosity: - 1) Temperature: - An increase in temperature, decreases the viscosity of liquids. Because, increase in temperature, increases molecular motion which will decrease cohesive forces between the molecules. It is observed that, viscosity decreases by about 2% for each degree rise in temperature.

2) Intermolecular forces: - These forces do not permit a free flow of molecules in liquids. Hence, if strength of intermolecular forces is more then viscosity will be more.

3) Molecular wt.: - Heavier the molecules of a given liquid, the greater will be its viscosity.

4) Structure and shapes of molecules: - Liquids with large, irregularly shaped molecules are generally known to be more viscous than those with small and symmetrical molecules. It is observed that the spherical molecules are less viscous than rod shaped molecules.

5) Pressure: - The increase in pressure, increases the strength of cohesive forces between molecules, and hence viscosity of liquid increases.

Measurement of Viscosity: - It is very difficult, to determine the absolute viscosity (because we must know, P, t, r and *l*). To overcome this, the viscosity is determined with respect to that of reference liquid. This is called as relative viscosity.

Ostwald's Viscometer method: - The apparatus used for the determination of relative viscosity of liquid is known as Ostwald's viscometer.

The viscometer is first cleaned, dried and clamped vertically. Then a definite quantity of liquid under examination is filled in the bulb N. Then the liquid is sucked up above the marking *x*, by rubber tube near to the top of right limb, and then it is allow to flow back (down). The time taken for the meniscus required to fall from *x* and y markings is noted by stop watch. Suppose, it is 't_A

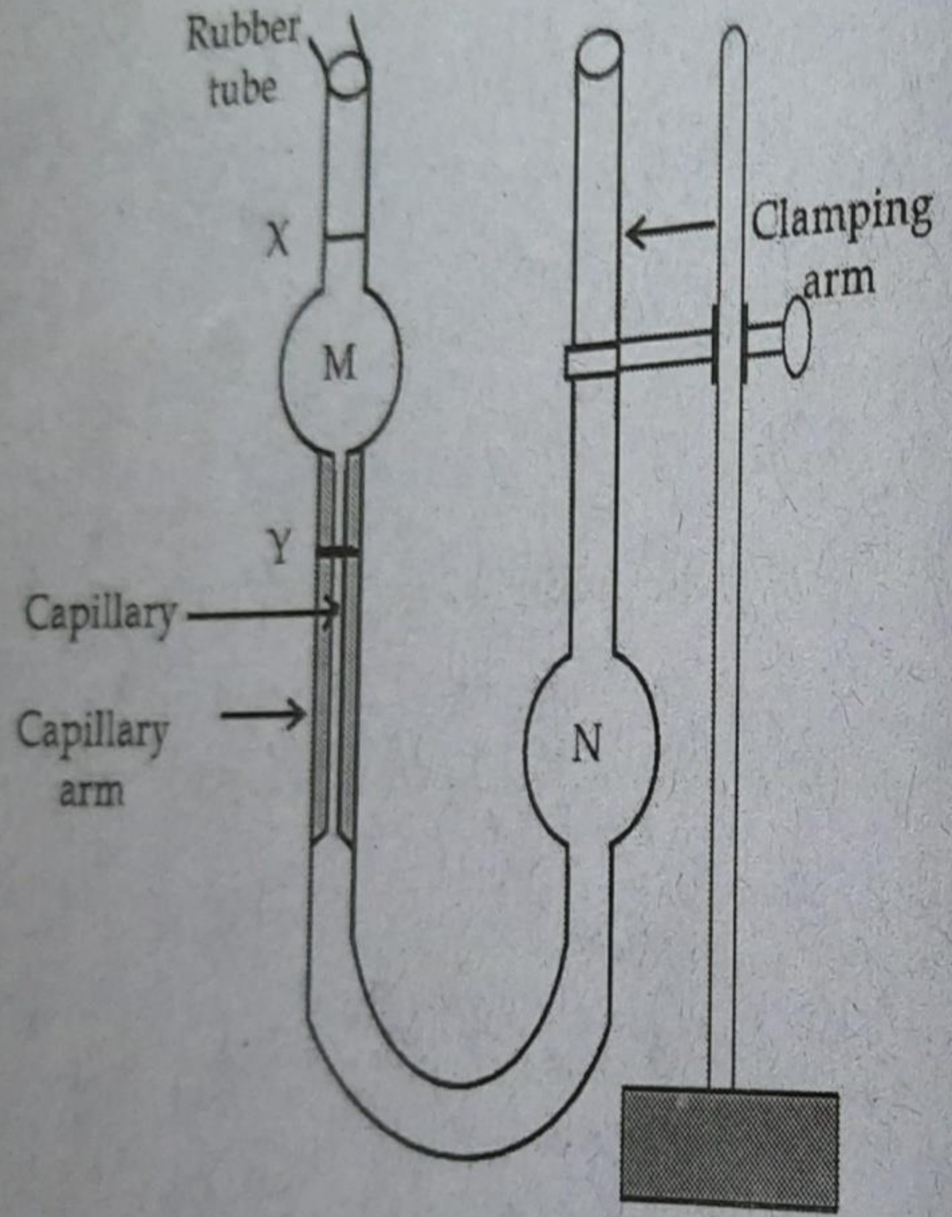


Fig. 2.7 Ostwald viscometer

Thank You.

Stay Home, Stay Safe.