Surface Tension

(Questions & Answers) PART-A

e-content for B.Sc Physics (Honours)

B.Sc Part-I

Paper-I

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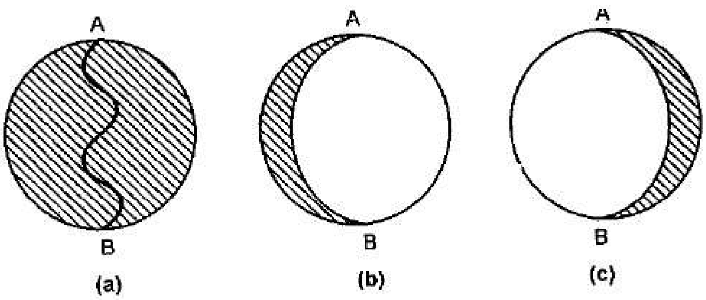
Surface Tension

Free surface of the liquid tends to minimize the surface area.

e.g.(1)If the small quantity of mercury is allowed to fall on the floor, it converted in to small spherical shaped droplets, which has least surface area.

(2) If the ring of thin wire tie a thread loosely between any two points A&B .Dip the ring in the soap solution Free surface of the liquid behaves like stretched elastic membrane under surface a soap film is produced within the ring as shown in fig.a If the film to the right is broken, the thread is pulled in the opposite direction, forming the circular arc as shown in fig.b If the film to the left of AB is broken the thread is pulled to the right & forming the circular arc as shown in fig.c .



The circular shape of the thread is due to contraction of the surface area of the film above experiment shows that that the free surface of liquid tends to minimize surface area as it is under tension called as **surface tension.**

Que.1:Explain the term Intermolecular force of attraction.

Ans : Intermolecular force of attraction:-The force of attraction between two molecules of liquid is called intermolecular force of attraction.

It is a short range force I.e. It is effective over short distance (about 10^{-9} m). Beyond this distance, this force is negligible.

Intermolecular forces of two types

(a) Cohesive force

(b) Adhesive force

Que.2: Define

1. Cohesive force

2. Adhesive force

3. Range of molecular attraction

4. **Sphere of influence**

Ans:

1. Cohesive force

The force of attraction between two molecules of same substance is called as **cohesive force.**

2. Adhesive force

The force of attraction between two molecules of different substances is called as **adhesive force.**

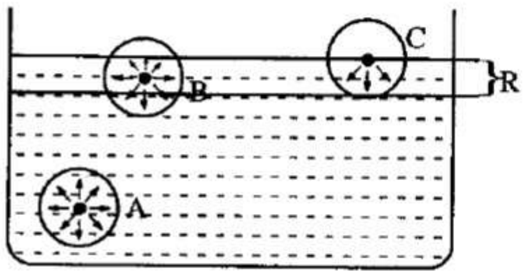
These intermolecular forces, cohesive & adhesive both are short rang forces i.e. effective over very short distance, beyond which they are negligible

3. **Range of molecular attraction:** - The maximum distance between two molecules unto which the intermolecular forces are effective is called as range of molecular attraction.

it is denoted by R.

4. **Sphere of influence:-** An imaginary sphere drawn round a molecule as the centre, with a radius equal to the range of molecular attraction is called as sphere of influence.

Que.3 Explain the phenomenon of surface tension on the basis of molecular theory



i. The molecules are attracted if other molecules are inside the sphere. Three molecules A, B,& C of liquid with their spheres of influence are shown in fig .

ii. The sphere of influence of molecule A is well inside the liquid. Other molecules of the liquid are symmetrically distributed around the molecules A. the molecule **A** is equally attracted in all direction by the cohesive forces so that resultant cohesive force acting on it is zero.

iii. The molecule **B** is just inside the liquid surface, the part of sphere of influence lies outside the liquid containing air molecules, but there is very small so that adhesive force exerted by the air molecules is neglected as compared to the cohesive force exerted by the molecules of the water inside the sphere of influence. The resultant down ward force acts on the molecule B & try to pull it inside the liquid.

iv. The molecule C is on the surface of the water, half sphere of influence is in water & half is in air. Molecules of liquidate extremely large than molecules air in the upper part of the sphere of influence therefore molecule C experiences maximum downward force, try to full it into the liquid.

v. Thus all the molecules in the layer of thickness R , below the free surface of the liquid, experiences the maximum inward pull. The pull is greater, if the molecules on the surface of the liquid.

vi. In order to increased surface area of the liquid surface, molecules from inside the liquid is brought to the surface. The work must be down against the inward pull exerted by the liquid. This work done is stored in the form of potential energy.

vii. But the nature tendency of a body is to attain the minimum potential energy. Thus the free surface of the liquid has a tendency to minimize the surface area which has the tendency to minimize the potential energy, which give raise the phenomenon of surface tension. In order to minimize the surface area the force due to surface tension must be acts tangentially to the liquid surface.

Que.4: Define, Surface energy and Give its S.I. unit and dimension

Ans:- In order to increased the surface area of the liquid, the number of molecules must be increased. The motion of the molecules towards the surfaces opposed by the inward pull exerted the molecules of the liquid. The work is down against the inward pull, which is stored in the form of potential energy.

The potential energy per unit surface area of the liquid is called as surface energy.

S.I. unit is $\mathbf{J/m^2}$ & C.G.S. unit is $\mathbf{erg/cm^2}$ the dimensions of the surface energy is

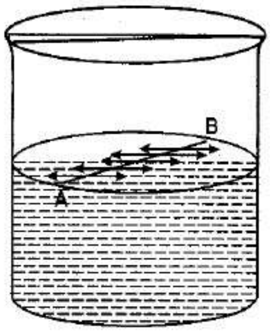
$$[\textbf{surface energy}] = \frac{[\text{work}]}{[\text{area}]}$$

$$= \frac{[M^1 l^2 T^{-2}]}{[M^0 L^2 T^0]}$$

$$= [M^1 L^0 T^{-2}]$$

Que.5: Define surface Tension and give its S.I. unit and dimension. Also five application of surface tension.

Surface tensions: - ***surface tension of the liquid is defined as the force per unit length, acting at right angles to an imaginary line drawn in the free surface of the liquid.***



If $\boldsymbol{l} = \boldsymbol{length\ of\ the\ line}$ &

$\boldsymbol{F} = \boldsymbol{force\ acting\ on\ it}$.

Then surface tension acting on the liquid (T) is

$$\mathbf{T} = \frac{\mathbf{F}}{\boldsymbol{l}}$$

S.I. unit is $\frac{N}{m}$ & C.G.S. unit is dyne /cm

[Surface tension]$= \frac{[force]}{[length]}$

$$= \frac{[M^1 L^1 T^{-2}]}{[L^1]}$$

$$= [M^1 L^0 T^{-2}] .$$

As shown in the fig. the force due to surface tension is acting on the both side of the line drawn on the surface of the liquid

Application of surface tension:

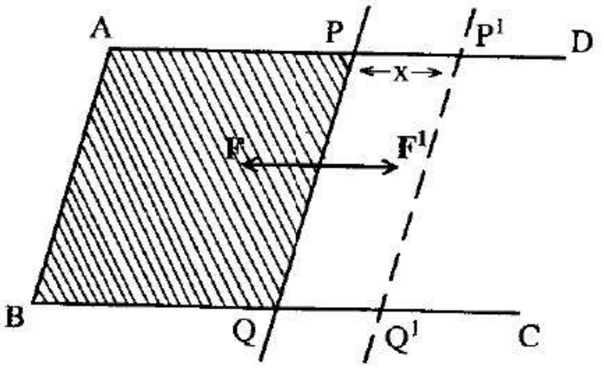
i) Tooth paste spreads more freely in the mouth while clearing the mouth because it contains soap which reduces surface tension

ii) If detergent is added in water, the surface tension of resulting detergent solution becomes less than water. This increases area of contact and cleaning

iii) Mosquito eggs float on the surface of water due to surface tension of water. when Kerosene is sprayed on the surface of water , the surface tension is lowered and eggs go down inside the water and breeding of mosquitoes stops.

Que.6: **Obtain the relation between** surface **tension & surface energy**.

Ans:-



i. ABCD is the open rectangular frame of the wire on which a wire PQ can side with friction. The frame is held in the horizontal position as shown in the fig.

ii. The frame is dipped into soap solution & taken out so that soap film APQB is form. Due to surface tension of soap, a force F will act on the wire PQ tends to pull towards AB.

iii. If T is S.T. Of soap solution & PQ= I then total force acting on PQ is $\boldsymbol{F = 2Tl}$ the factor 2 is appears because the soap film has two surfaces, both are contact with wire.

iv. If the wire PQ is pulled outwards through a small distance x to the position $P'Q'$ by the application of external force F , the work done against the inward pull of surface tension is given by $\boldsymbol{work = applied\ force \times displacement}$

$$\boldsymbol{W = Fx = 2Tlx}$$

The increased in surface area is $dA = 2lx$ hence the mechanical work done per unit surface area

$$\frac{W}{dA} = surface\ energy = \frac{2Tlx}{2lx} = T$$

This shows that surface tension is equal to work done per unit surface area of the liquid **ie. Surface tension is equal to surface energy per unit area of the liquid since surface tension**

$$(T) = \frac{work}{area} = \frac{W}{A}$$

$S.I. of\ surface\ tension\ is\ J/m^2$

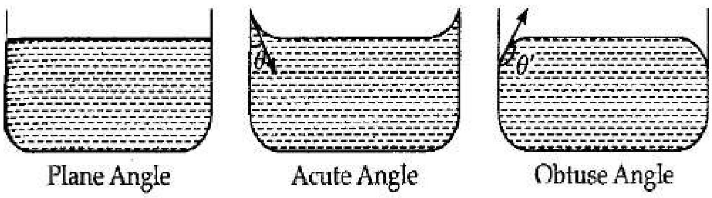
$work\ done\ (w) = T \times increase\ in\ area$

$$\therefore \quad W = T \times dA$$

Que.7: What is angle of contact? State its Characteristics.

Ans: Angle of contact:- when liquid is contact with solid, the angle between the surface of solid & tangent drawn to the surface of the liquid, at a point of contact, measured on the side of the liquid is called as angle of contact.

Characteristics of angle of contact: -



(1) The angle of contact is constant for the given solid –liquid pair.

(2) For the liquid which partially wets the solid, the angle of contact is acute. e.g. kerosene in contact with glass.

(3)For the liquid which does not wets the solid, the angle of contact is obtuse. e.g. mercury in contact with glass.

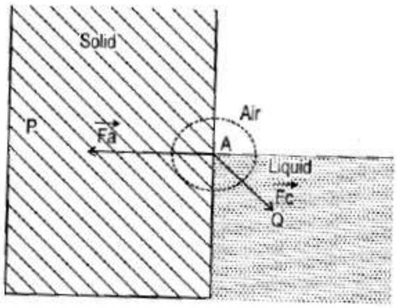
(4) For the liquid which completely wets the solid, the angle of contact is zero e.g. water in the contact with glass.

(5) For the given solid–liquid pair, even a small contamination of the surface causes a large change in the angle of contact.

(6) The angle of contact changes due to temperature.

Que.8: Explain the phenomenon of angle of contact on the basis of intermolecular forces.

Ans: Explanation of angle of contact:-The phenomenon of angle of contact can be explained by considering the intermolecular forces of attraction, acting on the molecules 'A' in contact solid. As shown in fig its sphere of influence is partly in solid, party in liquid & party in air. The molecule **A** is acted upon by following forces



(1) Adhesive force exerted by the molecules of the solid, such that resultant adhesive force is perpendicular to the surface of the solid, APrepresented by P .

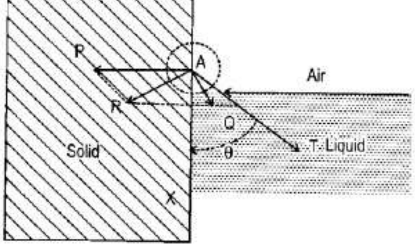
(2) Cohesive force exerted by the molecules of the liquid, by the symmetry, the resultant cohesive force is inclined at 45^0 with the surface of the solid, represented by AQ .

(3) Adhesive forces exerted by the molecules of air. Since the number of molecules of air in the sphere of influence A is very small, the resultant adhesive force due to the air molecules can be neglected.

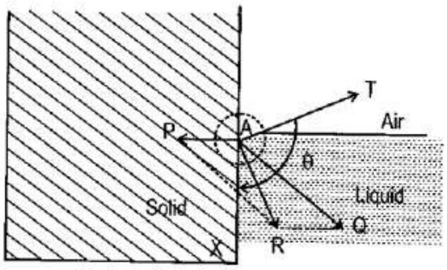
(4) The molecule A i.e. also exerted by the gravitation force, equal to its weight acting vertically downward which very small as compared to strong adhesive & cohesive force s hence can be neglected.

In the state of the equilibrium, the free surface of a liquid is always perpendicular to the resultant force on it.

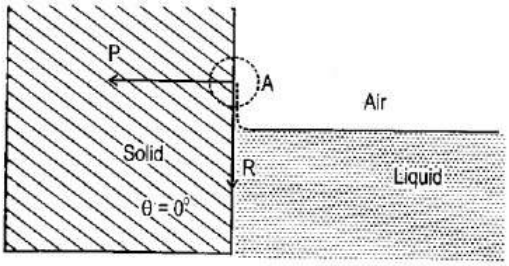
(1) For the liquid partially wets solid: - For the liquid which partially wets the solid, the resultant adhesive force AP is quit large than the resultant cohesive force AQ . Therefore their resultant AR lies outside the liquid. As shown in fig. In order to be perpendicular to this resultant AR, the molecule **A** moves upwards & surface of the liquid becomes concave. If tangent AT is drawn to the surface of the liquid, forming a acute angle of contact



(2) Liquid does not wets the solid:- For the liquid which does not wets the solid, the resultant cohesive force AQ is quite large than resultant adhesive force AP .Therefore their resultant force AR lies inside the liquid as shown in fig. In order to be perpendicular to AR, a liquid molecule moves downwards & liquid surface becomes convex, forming an obtuse angle of contact, by drawing a tangent to the surface of liquid.



(3) For liquid completely wets the solid:- In case of the liquid which completely wets the solid, the resultant adhesive force AP is so large that the resultant cohesive force AQ can be neglected. In such a case the resultant force AR is almost coinciding with AP. Therefore the liquid surface in contact is almost tangent to the surface of solid & the angle of contact is zero.



Que.9 : Explain why angle of contact is acute for water glass pair and is obtuse for mercury glass pair. Shape of the liquid drop: - Consider the equilibrium of a liquid drop on a flat solid surface.

Let T_1 be the surface tension for solid-liquid interface

T_2 be the surface tension for air-solid interface

T_3 be the surface tension for air-liquid interface, as shown in fig.

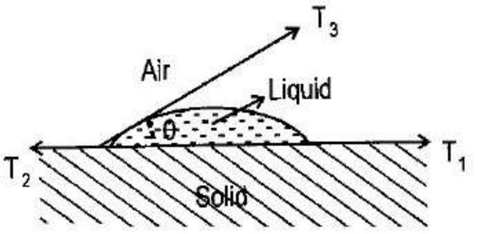
For the equilibrium position of the drop.

$$T_2 = T_1 + T_3 \cos\theta$$

$$\therefore \quad \cos\theta = \frac{T_2 - T_1}{T_3}$$

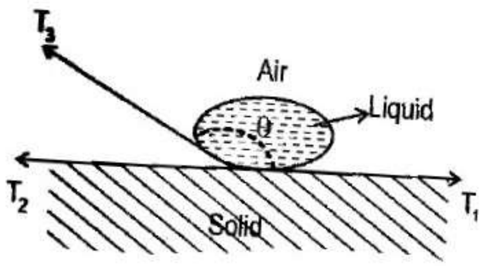
This expression leads the following conclusion

(1) If $T_2 > T_1, \cos\theta$ is +ve & θ is acute



(b) (drop of water)

(2) If $T_2 < T_1$. $cos\theta$ is –ve , & θ is obtuse



(a) (drop of mercury)

(3) $T_2 - T_1 = T_3 cos\theta$,

$cos\theta = 1$ & θ *is nearly equal to one*

(4) If $T_2 - T_1 > T_3 cos\theta$, $cos\theta > 1$ which is impossible, equilibrium is not possible, liquid is spread on the ground & drop shall not be formed on the solid.