

Surface Tension [For D-1(H) & D-1(Sub)]

Molecular forces. Since surface tension is essentially a molecular phenomenon we should first have a clear idea as to what forces operate between molecules. There are two types of molecular

(i) forces of adhesion, or adhesive forces, (ii) forces of cohesion or cohesive forces

(i) Adhesion is the force of attraction between molecules of different substances, and is different for different substances. For example, gum has a greater adhesive force than water or alcohol.

(ii) Cohesion is the force of attraction between molecules of the same substance. This force is different from the ordinary gravitational force and does not obey the ordinary inverse square law, the force varying inversely probably as the eighth power of the distance between two molecules and thus decreases rapidly with distance - in fact it is appreciable when the distance between two molecules is inappreciable and becomes inappreciable when the distance is appreciable. It is greatest, in case of solids, less in the case of the liquids and the least in case of gases, almost negligible at ordinary temperature & pressure. This explains at once why a solid has a definite shape, a liquid has a free surface and gas neither.

Molecular range - Sphere of Influence. The maximum distance upto which the force of cohesion between two molecules can act is called molecular range. A sphere drawn around a molecule as a centre, with a radius equal to its molecular range is called the sphere of influence. Obviously the molecule is affected only by the molecules inside this sphere i.e., it attracts and is, in turn, attracted by them, remaining unaffected by the molecules outside it. Laplace and Gauss evolved this theory of cohesive force between two molecules to explain the satisfactorily the effects of surface tension.

Surface Tension: It is a general experience that a liquid in small quantity, free from any external force, like due to gravity, will always assume the form of a spherical drop - e.g. rain drops. Small quantity quantities of mercury placed on a clean glass plate

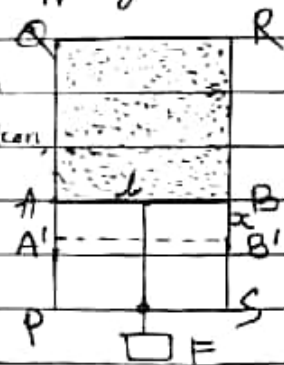
Now for a given volume, a sphere has the least surface area. Thus, a liquid has always tends to have the least surface area on account of the cohesive forces between the molecules of a liquid, the free surface of a liquid always behaves like stretched membrane or sheet and tends to contract to the smallest possible area. The tension or pull in the surface of a liquid is called surface tension, and may be defined as the force per unit length of a line drawn in the liquid surface, acting perpendicularly to it at every point and tending to pull the surface apart along the line.

Surface Energy: Let us consider a rectangular frame of wire PQRS with a horizontal wire AB placed across it, free to move up or down and form a soap-film across AQRB, by dipping it in soap solution. The wire AB is

pulled upwards by the surface-tension of the film. To keep the wire in position, therefore, a force has to be applied downwards, equal and opposite to the upwards force due to surface tension.

Let this downward force be F equal to F including the weight of the wire AB, which is also acting downwards. Then if T be the surface tension of the film and l , the length of the wire AB, we have upward force acting on the wire $AB = 2lT$, because the film has two surfaces. Since the film is in equilibrium, it is clear that

$$2l.T = F$$



Now, if the wire AB be pulled through a distance x into the position A'B', ^{keeping temp. constant} the film is extended by an area $2x$ on each side, we have

$$\text{Work done} = 2T \times 2L \times x$$

$$\text{Increase in area} = 2L \times x$$

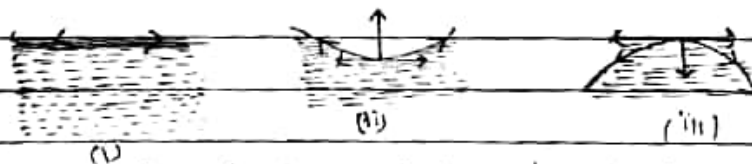
$$\therefore \text{Energy per unit area} = \frac{2TLx}{2Lx} = T$$

= work done in increasing
unit area of the film

Thus, the Surface tension of a liquid may be defined as the amount of work done in increasing the surface area of the liquid film by unit area as the mechanical part of the surface energy of a liquid film. This mechanical part of the surface energy of the liquid film is a free energy; so that, the surface tension of a liquid is equal to the surface energy of the liquid film or surface.

Pressure difference across a liquid surface - Drops & Bubbles

(i) Let us suppose the free surface of a liquid is plane as shown in fig (i), then, the resultant force due to surface tension on a molecule on the surface is zero, and cohesion pressure is therefore, negligible just nominal.



(ii) If the free surface of the liquid be concave, fig (ii) the resultant force on a molecule on the surface would be upwards and the cohesion pressure is therefore decreased.

(iii) If the free surface of a liquid is convex, fig (iii) resultant force due to surface tension on a molecule on the surface will be directed downwards, so that the cohesion pressure is, in this case increased.

Excess Pressure inside a liquid drop

It is clear from the above that the molecules near the surface of the a drop (which is a convex surface) experiences resultant a resultant pull down wards. The pressure inside of must therefore, be greater than the pressure outside of

Let the ^{excess} pressure inside over the pressure outside of the drop be P .

Then if r be the radius of the drop, and T its surface tension,



Considering the equilibrium of one-half of the drop. Say the upper half, or the upper hemisphere. The upward thrust on plane ABCD, due to the excess pressure is equal to $P \pi r^2$

And, force due to surface tension, acting downwards on it and ~~and~~ round its edge, is equal to $T \cdot 2\pi r$. Since the hemisphere is in equilibrium, we have

$$P \pi r^2 = 2\pi r T$$

$$\text{When } P = \frac{2\pi r T}{\pi r^2} = \frac{2T}{r}$$

Excess Pressure inside a soap bubble.

If instead of a drop of liquid, we consider a bubble, there are two surfaces to be considered, and not one, because it is like a spherical shell or a hollow sphere; so that, the force due to surface tension, in this case, is $2 \times 2\pi r T$. (i.e. $2\pi r T$ due to each surface).

Therefore for equilibrium of the hemisphere, we have

$$P \cdot \pi r^2 = 2 \times 2\pi r T = 4\pi r T$$

$$\text{When } P = \frac{4\pi r T}{\pi r^2} = \frac{4T}{r}$$

It is thus seen that the excess pressure inside a drop or a bubble is inversely proportional to its radius (i.e. $P \propto \frac{1}{r}$); so that smaller the bubble the greater the excess pressure inside it.