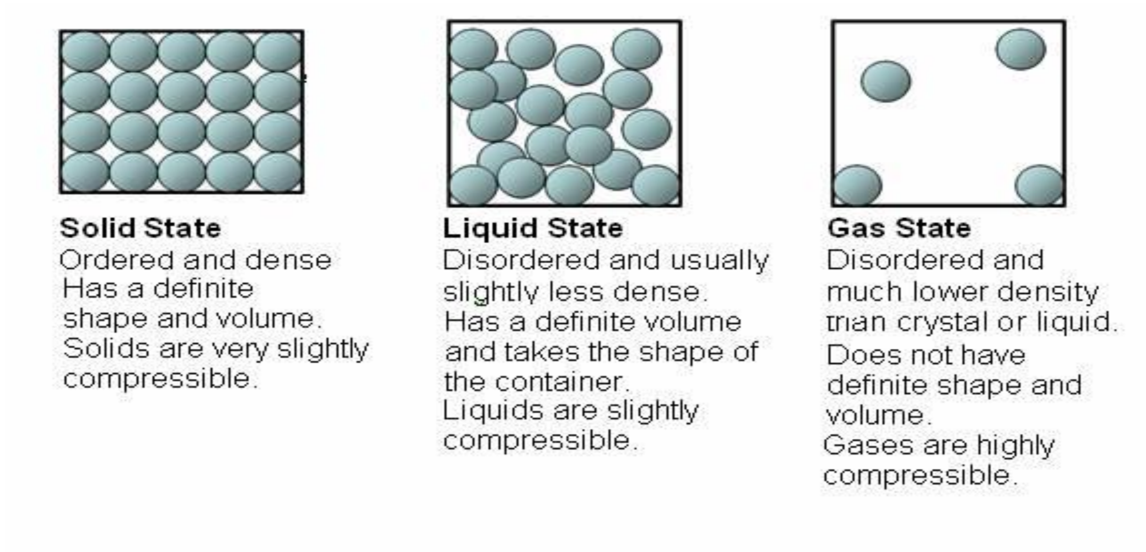
Shri R. L. T. College of Science,

Chapter 6 (Physical chemistry)

A. Liquid State (Surface tension)

A] Liquid State:



Introduction:

- Matter exists in five states but at this level we will deal with three states namely solid, liquid and gas.
- The smallest structural unit of all chemical substances in these three states may be atoms, ions or molecules.
- The solid state exhibits a complete ordered arrangement of atoms, ions or molecules.
- While the gaseous state exhibits complete disorder or randomness.
- And the liquid state exhibit only a short range order arrangement.
- A liquid may be regarded as a condensed gas or a molten solid. In a liquid, the molecules are not rigidly fixed as in solids.
- They have some freedom of motion which is much more restricted than that in the gases. A liquid, therefore, has a definite volume although not a definite shape.

- It is much less compressible and far denser than a gas. Since, the molecules in a liquid are not far apart from one another.
- The intermolecular forces are fairly strong. The characteristic properties of liquids arise from the nature and the magnitude of these intermolecular forces.

6.1 Surface tension:

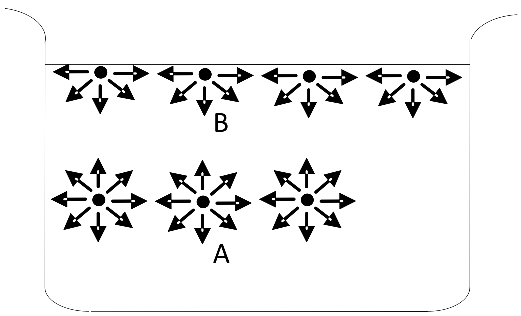


Fig. Molecular attraction

- Consider the molecule 'A' in the interior of liquid, which is surrounded from all sides by other molecules. Hence, it is attracted equally in all directions. Therefore molecule 'A' will behave as if no force is acting on it. However, molecule 'B' which is at the surface of liquid will experience inward pull because it is attracted sideways and towards the interior. Thus, the surface of liquid tends to contract to the smallest possible area and behaves as if it is under tension. This tension which acts along the surface of liquid is called as surface tension. It is the reason that drops of a liquid has spherical shape because for a given volume of sphere has minimum surface area due to surface tension

- Surface tension is the characteristic property of liquid. This property is caused due to the strong intermolecular forces of attraction between the liquid molecule

- Surface tension is denoted by Greek letter 'γ '

- The surface tension (γ) is defined as, *the downward force in Newton acting along the surface of a liquid at right angle to any line 1 meter in length*.

Or

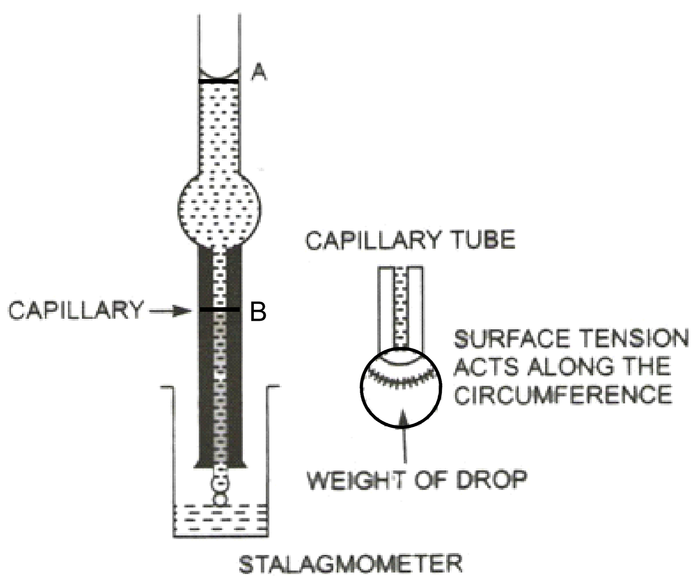
- *Surface tension may be defined as the force acting per unit length perpendicular to the line drawn on the surface of liquid.*
- S. I. Unit = Newton per meter ($N\ m^{-1}$)
- C. G. S unit = dyne cm^{-1} Both these units are related as:
- 1 dyne cm^{-1} = 10^{-3} $N\ m^{-1}$

6.2 Determination of surface tension by drop number method:

In drop number method, the number of drops formed for a fixed volume of liquid is determined by using drop pipette or stalagmometer. The liquid under examination is sucked up in capillary, say up to upper mark A. then a definite number of drops say 20, are received in weighing bottle and weighed. From this, weight of single drop is calculated.

Let 'r' is the radius of capillary tube and γ is surface tension of liquid. When drop falls off at that time the weight of drop is equal to the force due to the surface tension.

$$W = 2\pi r\gamma \qquad \text{------------------------------------(1)}$$



For relative determinations, instead of determining the weight of the single drop, number of drops falling between two fixed marks (one above the bulb and other below the bulb) are counted for water (reference). The stalagmometer is dried and filled with another liquid of which surface tension is to be determined. Number of drops for the experimental liquid falling between same two fixed marks is counted.

If n_1 and n_2 are the number of drops falling between two fixed marks for water and experimental liquid having densities d_1 and d_2 and surface tensions γ_1 & γ_2 then,

When drop falls, wt. of the drop = force due to surface tension

$$W = mg = vdg = 2\pi r \gamma \quad \text{------------------------------------(2)}$$

$\therefore$ For water, we can write

$$2 \pi r \gamma_1 = v_1 d_1 g \quad \text{------------------------------------(3)}$$

For experimental liquid

$$2 \pi r \gamma_2 = v_2 d_2 g \quad \text{------------------------------------(4)}$$

Multiplying equation (3) and (4) by n_1 and n_2 respectively then,

$$2 \pi r \gamma_1 n_1 = n_1 v_1 d_1 g \quad \text{------------------------------------(5)}$$

$$2 \pi r \gamma_2 n_2 = n_2 v_2 d_2 g \quad \text{------------------------------------(6)}$$

But, $n_1 v_1 = n_2 v_2 = V$, the volume of liquid falling between two fixed marks. Equations (5) and (6) become

$$2 \pi r \gamma_1 n_1 = V d_1 g \quad \text{------------------------------------(7)}$$

$$2 \pi r \gamma_2 n_2 = V d_2 g \quad \text{------------------------------------(8)}$$

Dividing equation (8) by (7), we get

$$\frac{\gamma_2}{\gamma_1} = \frac{n_1 d_2}{n_2 d_1} \quad \text{------------------------------------(9)}$$

Where, $\frac{\gamma_2}{\gamma_1} =$ Relative surface tension.

Hence, by counting number of drops and determining densities, surface tension of any liquid relative to reference (water) can be calculated.

6.3 Effect of temperature on surface tension:

- Surface tension is directly proportional to Nature of liquid.
- Surface tension is inversely proportional to Temperature.
- For all liquids, surface tension (γ), decreases with increasing temperature. This is because; with the rise in temperature the kinetic energy of the liquid molecules increases.
- These tend to decrease the effect of intermolecular cohesive forces.
- At or near the critical temperature, the surface tension becomes zero.
- Surface tension decreases with increase in temp.
- Surface tension values of some common liquids at various temperature.

Table: Surface tension values of some common liquids at various temperatures.

Liquids	**Surface tension Nm^{-1} x 10^2**		
	273 K	**293 K**	**313 K**
Water	7.56	7.28	6.96
Benzene	3.16	2.89	2.63
Toulene	3.07	2.84	2.61
Acetone	2.62	2.37	2.12
Ethyl alcohol	2.40	2.23	2.06

6.4 Applications of surface tension:

i) It is important in the study of emulsion and colloid chemistry.

ii) It is an essential factor in the concentration of ores by froth flotation process.

iii) Surface tension measurements are of much importance in biological science, particularly in bacteriology.

iv) The movement of moisture of soil and passage of sap in plants involve the surface tension.

v) It is used to determine parachor $[P] = \frac{M}{d}\gamma^{1/4}$, a additive and constitutive property used to investigate molecular structures of compounds.

vi) In everyday life, soaps and detergents are used for cleaning purposes. Synthetic surfactants have property of lowering the surface tension of water. Hence, they are used in preparations like tooth paste, cream, toilet soaps, washing powders, medical emulsions, etc.

vii) Surface tension measurements are useful in knowing the presence of air bubble in blood stream and identifying the presence of bile salts in urine (Hay's test for bile salts).