LIQUID STATE

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CLASSIFICATION OF STATE OF MATTER

Matter can be classified on the basis of two states:

1) Physical state
2) Chemical state

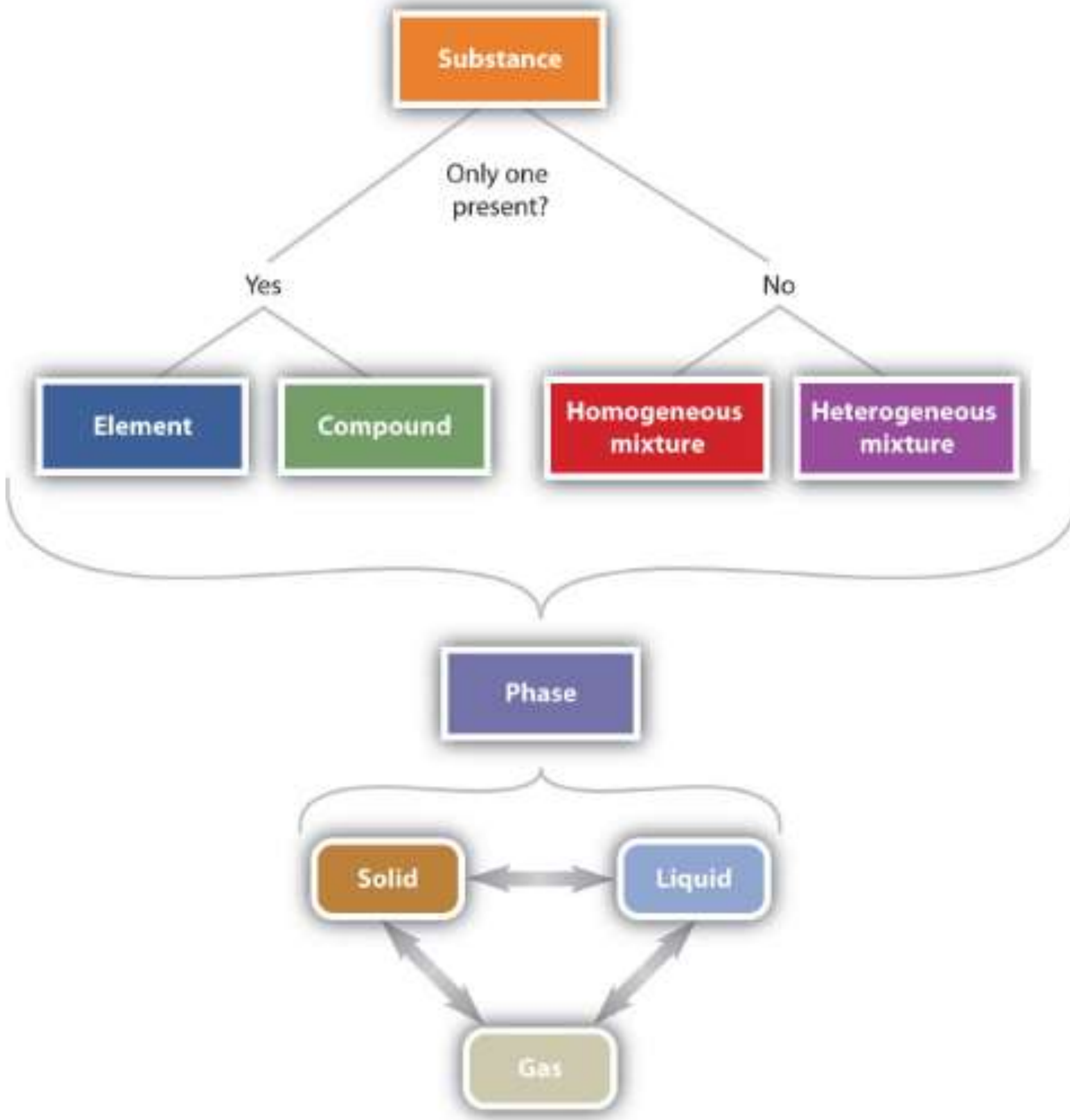
On the basis of Physical state, matter can be classified into three groups:

a) Solids
b) Liquids
c) Gases

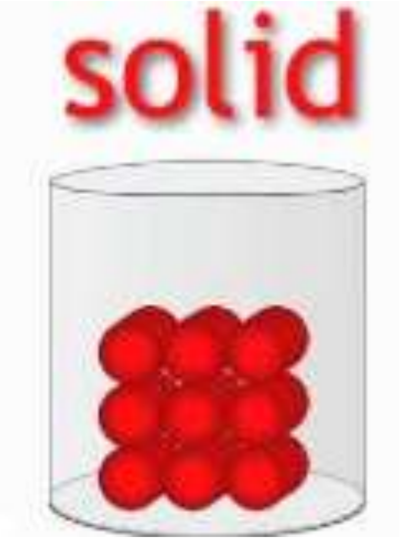
On the basis of Chemical state, matter can be classified into three groups:

a) Elements
b) Compounds
c) Mixtures

CLASSIFICATION OF STATE OF MATTER



PHYSICAL PROPERTIES OF SOLID



- **IN SOLIDS,** the particles are closely packed. There is a strong force of attraction between the particles of a solid so that particles cannot move freely but can only vibrates. As a result, a solid has a stable, definite shape, and a definite volume. The particles of a solid have the minimum kinetic energy. due to this, solids have the most orderly arrangement of particles. Solids can be transformed into liquids by melting, and liquids can be transformed into solids by freezing. Solids can also change directly into gases through the process of sublimation, and gases can likewise change directly into solids through deposition.

PHYSICAL PROPERTIES OF LIQUID

- **IN LIQUID,** the particles are close together, but they are not as close as in solids. In fact, the particles are somewhat loosely packed in liquids. The inter particular space in liquids is more than in solids but still very small. The force of attraction between the particles of a liquid is strong. It can keep the particles together but the force is not strong enough to keep the particles in fixed positions. The particles of a liquid can move from one position to another within the liquid. the particles of a liquid have more kinetic energy than the particles of a solid. due to this, the liquids have a more disorderly arrangement of particles than solids.

PHYSICAL PROPERTIES OF GASES

- **IN GASES,** the particles are much farther apart from one another as compared to solids and liquids. There are no force of attractions between the molecules due to the large distance between the molecules. The particles of a gas move with high speeds in all directions. The positions and spaces between the particles of a gas are not fixed. When the fast moving gas particles hit the walls of the container, they exert pressure by a gas is due to the collisions of the fast moving gas particles against the walls of the container. When a gas is put in an empty container, it quickly spreads throughout container and fills it completely. Ifa gas is heated, the particles of gas start moving faster and faster.

LIQUID STATES

Liquids and Gases both are termed as fluids. But at the molecular level, a liquid is different from a gas. From forces of attraction to the effects of physical properties, liquids show different properties and behavior. Here we learn the microscopic and macroscopic behavior of a liquid state.

- **Volume & Shape:** The particles in a liquid are attracted to each other. This keeps the particles close together and take the shape of container in which they are kept. That is why liquids have a definite volume.

- **Compressibility:** Liquids are largely incompressible. It is because there is very little empty space between the molecules. In contrast, the gases are highly compressible because of large empty spaces between their molecules.

- **Diffusion:** Diffusion is the process of spreading of a substance from a region of higher concentration to a region of lower concentration. Diffusion is more in liquid.

- **Evaporation:** Evaporation is the process by which a liquid changes into vapour. In a liquid, at any temperature, a small fraction of the molecules is moving with relatively high velocity. Such molecules have high kinetic energy. These can overcome the intermolecular attractive forces and escape through the surface of the liquid

- **Vapour pressure:** When a liquid is filled in a container, its walls are occupied by the vapors from that liquid. Liquids show the unique property of turning into vapors, as soon as the temperature rises. Generally, vapors from the aqueous substance occupy the walls of the unfilled part of the container and exert a pressure on the walls of that container, this pressure is called the vapor pressure. Initially, the vapor pressure increases but after some time it becomes constant. Gradually, an equilibrium between the liquid phase and the vapor phase is established.

The vapor pressure at the point of equilibrium is known as the equilibrium vapour pressure or saturated vapour pressure. The whole phenomenon of vapour formation depends on the temperature and hence tends to increase with the increasing temperature.

Vapour pressure ∞ temperature

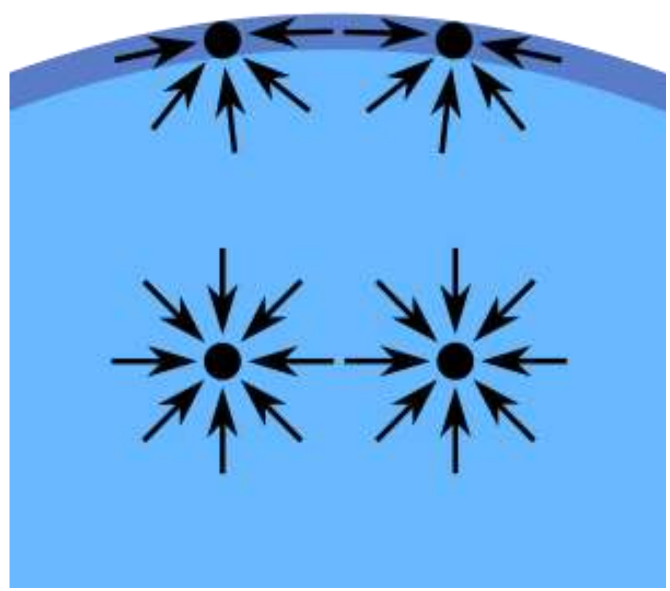
➢ **Heat of vapourization:** The quantity of heat which has to supplied to a liquid at its boiling point so as to change it into vapour state at same temperature is heat of vapourization.

➢ Trouton's Rule

- ❖ This rule is used to estimate the Heat of vapourization of liquids whose boiling points are known.
- ❖ Rule is given by the name of Frederick Thomas Trouton.
- ❖ The ratio of molar heat of vapourization of liquid and the normal boiling point of liquid is Trouton's rule.
- ❖ The molar heat of vapourization is expressed in Joules per mole (J/mol).
- ❖ The boiling point is expressed in Kelvin (K).
- ❖ Mathematically, it can be expressed as:- H_{vap} / T_b ~ 88 J/mol/K

➢ **SURFACE TENSION:** The intermolecular force between the molecules on the surface is exerted perpendicularly downwards is surface tension of the liquid. The surface tension of a liquid depends on the intermolecular forces directly, greater the force higher is the surface tension.

Water has a higher surface tension (72.8 milli newtons per meter at 20 °C) compared to that of most other liquids due to high attraction of water molecules for each other through a web of hydrogen bonds.



- The molecules at the surface do not have any neighbor molecules (compared to interior molecules) on all sides of them and therefore have higher energy and are pulled inward.
- The minimized number of boundary molecules results in a minimal surface area. As a result of surface area minimization, a surface will assume the smoothest shape.
- The molecules in the interior have many neighbor molecules and therefore have lower energy.
- The energy supplied (or work done) for increasing the surface area of a liquid by a unit amount is known as its surface energy.
- The unit for surface tension is joule per square metre ($J\ m^{-2}$ or $N\ m^{-1}$) and it is denoted by γ.

Effect of Adding Solutes on Surface Tension

- The concentration of solutes is more on the surface of the liquid than in the bulk. Their addition to a liquid lowers the surface tension.

Surface Tension ∞ 1/Solute

Effect of Temperature on Surface Tension

- On heating, the liquids expand. This increases the intermolecular distances.
- On heating, the average kinetic energy of molecules and hence their chaotic motion increases.

Due to both of these factors, the intermolecular forces become weak and the surface tension decreases.

Surface Tension $\propto$ 1/temperature

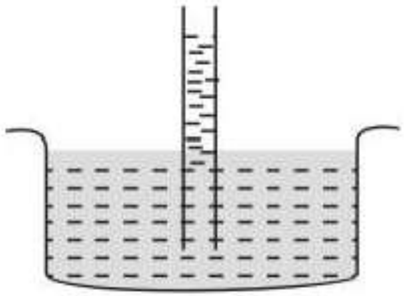
Effects of Surface Tension on:

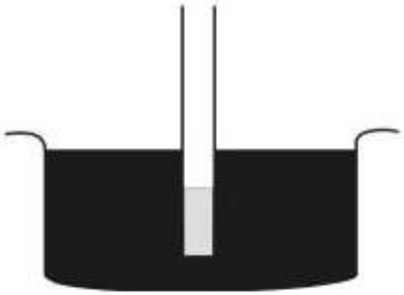
(i) Spherical Shape of liquid drops

- Due to the surface tension, liquids have a natural tendency to acquire the least surface area and form spherical drops, when no external force acts on them.
- Droplets of water tend to be pulled into a spherical shape by the cohesive force of the surface layer.

(ii) Capillary Action

- When one end of a capillary tube is dipped in water, it rises in the capillary (a). On the other hand when one end of a capillary tube is dipped in mercury, its level falls in the capillary (b). The phenomenon of rise or fall of a liquid in a capillary is known as capillary action.
- Capillary action occurs when the adhesion to the walls is stronger than the cohesive forces between the liquid molecules.
- The rise of water in the glass capillary (a) is due to more adhesive forces than cohesive forces. Water tends to increase the area of contact with glass wall of the capillary by rising in it. The fall of mercury in the glass capillary (b) is due to more cohesive forces than adhesive forces . Mercury tends to minimise the area of contact by depressing inside the capillary.


(a)


(b)

(iii) Wetting and Non-wetting properties

- When a drop of liquid is placed on a solid surface, the force of gravity should cause it to spread out and form a thin layer . Such a liquid is called a **wetting liquid**.
- When a drop of mercury is placed on the surface of glass, it does not spread out. Such liquids are called **non-wetting liquids**.
- If adhesive forces are stronger than cohesive forces, the liquid would be **wetting** in nature and when cohesive forces are stronger than adhesive forces it would be **non-wetting** in nature on the surface of a particular solid. The intermolecular attractive forces between molecules of a liquid are called **cohesive force** while those between the molecules of the liquid and the solid (whose surface is in contact with the liquid) are called **adhesive forces.**

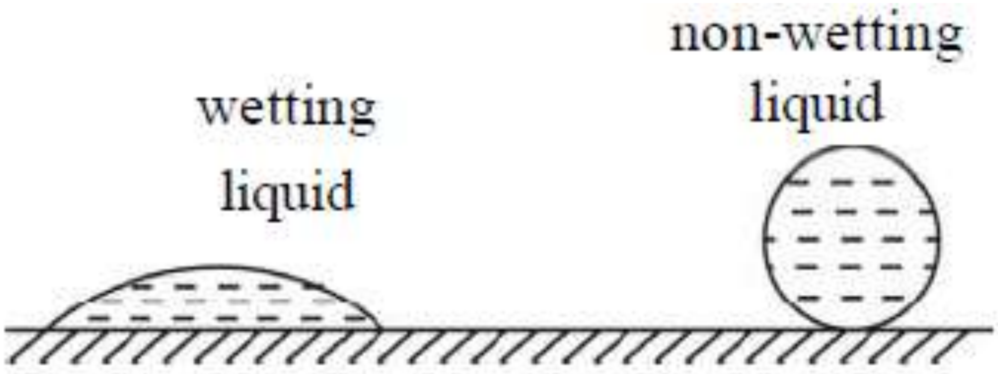


Fig: Wetting and non-wetting liquids on the surface of a solid.

➢ VISCOSITY:

- Every liquid has the ability to flow. It is due to the fact that molecules in a liquid move freely within a limited space. Water flows down a hill under gravitational force or through pipes when forced by a pump. Some external force is always required for a liquid to flow. Some liquids like glycerol or honey flow slowly while others like water and alcohol flow rapidly. This difference is due to the *internal resistance of liquid to flow which is* called **viscosity.**
- The liquids with higher viscosity flow slowly and are more viscous in nature like glycerol or honey. Water and alcohol have lower viscosity and are less viscous in nature. They flow more rapidly.
- The viscosity is related to the intermolecular forces. Stronger the intermolecular forces more viscous are the liquids.

Let us understand this with the help of Figure. When a liquid flows steadily, it flows in different layers with one layer sliding over the other. Such a flow is known as **laminar flow.**

Consider a liquid flowing steadily on a plane surface. The layer closest to it is almost stationary due to adhesive forces. As the distance of the layer from the surface increases, is velocity increases. Thus different layers move with different velocities. Due to intermolecular forces (cohesive forces) each layer experiences a force of friction from its adjacent layers. This force of friction, *f between two layers* depends upon:

(i) area of contact between them (A).

(ii) distance between the layers, dx.

(iii) difference in velocity between the layers, du.

These quantities are related as : $f = \eta A. du/dx$

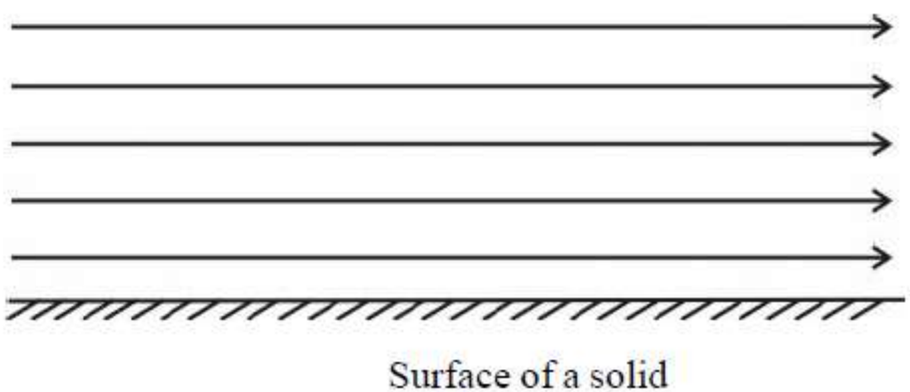


Fig. : Flow of different layers of a liquid

Here η *(Greek letter 'eeta')* is called the coefficient of viscosity and du/dx is the velocity gradient between the layers.

If A = 1 cm^2, du = 1 cm s^{-1} and dx = 1 cm, then

$$f = \eta$$

Thus, coefficient of viscosity is the force of friction between two parallel layer of the liquid which have 1cm^2 area of contact, are separated by 1cm and have a velocity difference of 1cm s^{-1}. It may be noted that *f is also equal to the* ***external force which is required to*** overcome the force of friction and maintain the steady flow between two parallel layers having (A) area of contact, and which are (dx) distance apart and moving with a velocity difference of du.

UNIT

CGS unit of viscosity is dyne cm^{-2} s. This unit is also known as poise (P). The SI unit of viscosity is N m^{-2}s or Pas. The two units are related as :

$$1 \text{ Pas} = 10 \text{ P}$$

Effect of Temperature on Viscosity

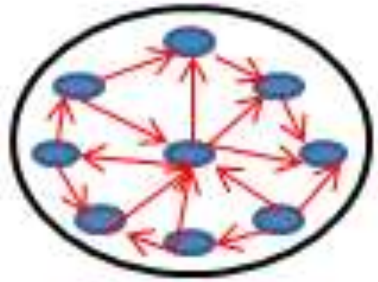
- On heating, viscosity of liquid decreases. This is due to decrease in intermolecular forces (increases the intermolecular distances).
- Due to this factors, the intermolecular forces become weak and the viscosity of liquid decreases.

$$\text{viscosity} \propto 1/\text{temperature}$$

TEMPERATURE VARIATION OF VISCOSITY OF LIQUIDS AND COMPARISON WITH THAT OF GASES.

In case of Liquid

As we know that liquid molecules are bonded with each other due to more cohesive forces between the molecules. Increase of temperature breaks this cohesive forces. This implies that the forces of attraction between the molecules get reduced. Thus viscosity of liquid decreases with increase of temperature.

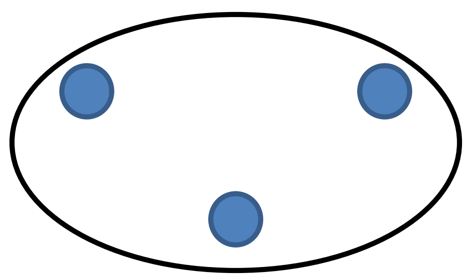


viscosity ∞ 1/temperature

Fig.: Cohesive force bind the liquid molecules together

In case of Gas

With increase of temperature, average kinetic energy increases between the gaseous molecules. As a result, they start colliding with each other. As the collision become more frequent then the molecular momentum transfer increases. This implies that the forces of attraction between the molecules get increased. Thus viscosity of gas increases with increase of temperature.

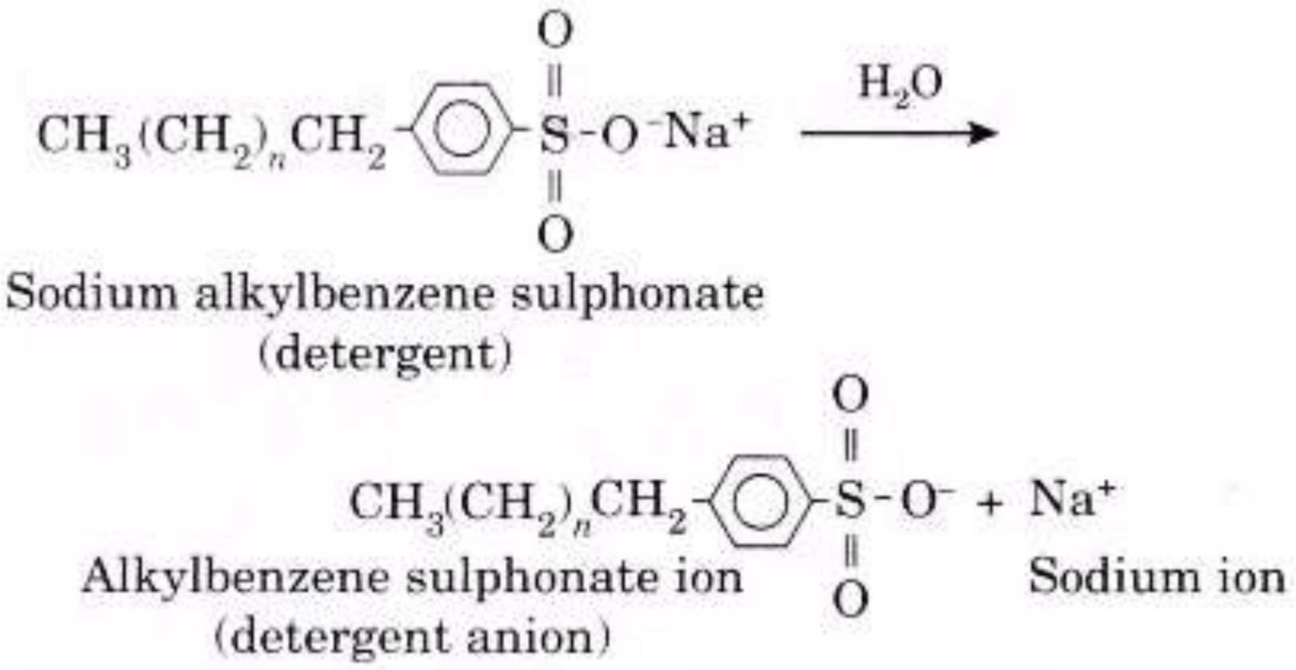


viscosity ∞ temperature

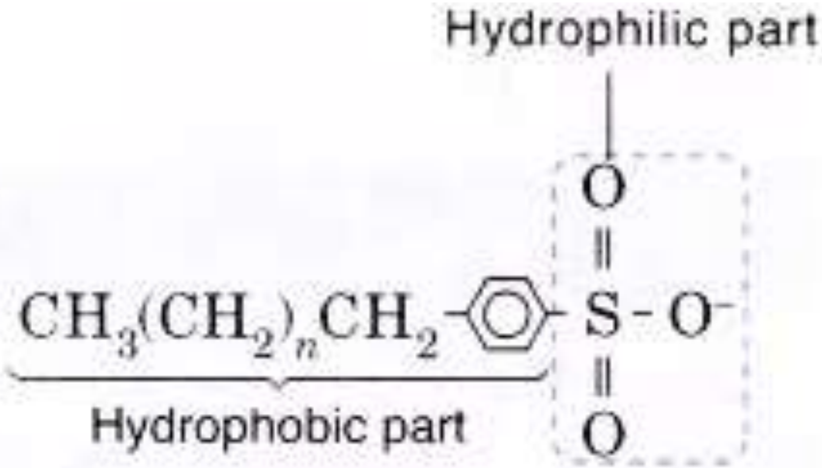
Fig.: Arrangement of gaseous molecules

CLEANSING ACTION OF DETERGENTS

Most of the dirt is oily in nature and oil does not dissolve in water. The molecule of detergent constitutes of a hydrophilic sulfonate head-group and a hydrophobic alkyl benzene tail-group.



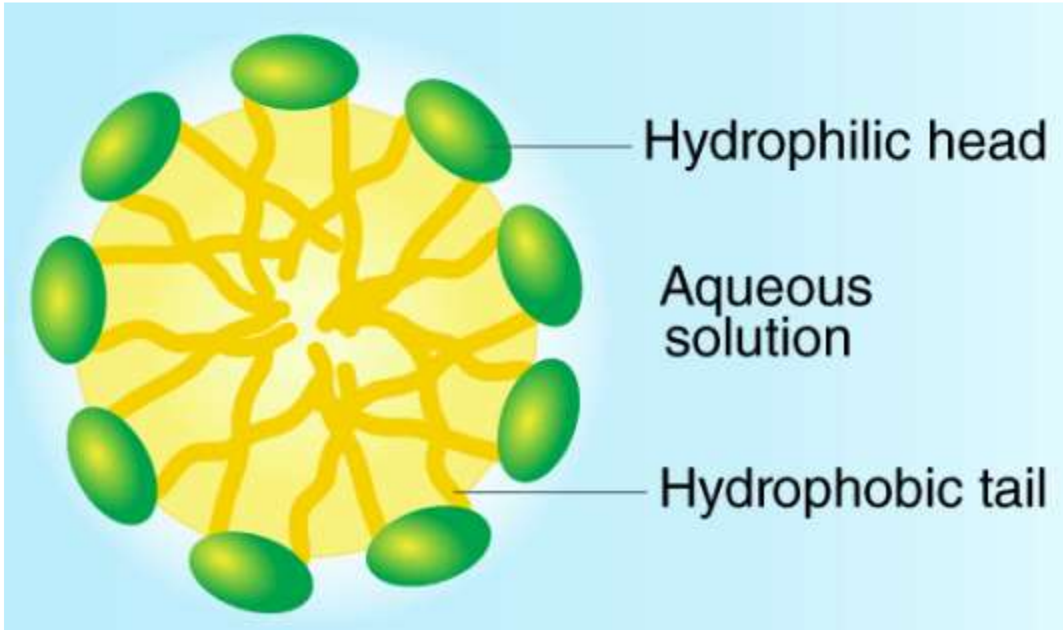
In the case of detergent, the alkyl benzene is hydrophobic which dissolves in oil and the ionic sulfonate is hydrophilic which dissolves in water.



Alkylbenzene sulphonate ion

Thus the detergent molecules form structures called micelles. In micelles, one end i.e. alkyl benzene is towards the oil droplet and the other end i.e. sulfonate which is the ionic faces outside. Therefore, ionic part forms an emulsion in water and helps in dissolving the dirt when we wash our clothes.

Micelle formation



In water, the detergent molecule is uniquely oriented which helps to keep the hydrocarbon part outside the water. When the clusters of molecules are formed then hydrophobic tail comes at the interior of the cluster and the ionic end comes at the surface of the cluster and this formation is called a **micelle**. When the detergent is in the form of micelles then it has the ability to clean the oily dirt which gets accumulated at the center. Therefore the dirt from the cloth is easily washed away.