The Liquid State: General Properties

Liquids and Gases both are termed as fluids - the reason being their property to flow. 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.

Characteristics:

All liquids show following characteristics:

- **Strong intermolecular forces:** The intermolecular forces of attraction in a liquid are stronger than a gas and weaker than a solid. The strong force of interaction between the molecules is due to the less space shared by them at the molecular level.
- **Definite volume and density:** Liquids have a definite volume. Unlike gases, liquids occupy a limited space, the reason being their low space between the molecules. Under normal physical conditions, the molecules of a liquid seldom separate from one another. Not only are liquids denser than gases but are also less compressible than them.
- **Free flowing and shapeless:** Liquids take the shape of the container in which they are stored. Due to the free-flowing molecules that move past each other liquids assume the flowing characteristic as well.

At normal conditions of temperature, pressure, and volume liquids generally, show the above-mentioned features. When the physical conditions change the basic characters of liquids also undergo a drastic change.

Apart from the above characteristics, liquids also show the following properties:

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 vapor pressure or saturated vapor pressure. The whole phenomenon of vapor formation solely depends on the temperature and hence tends to increase with the increasing temperature.

Boiling Point

Liquids when heated, evaporate. In closed vessels, the heating produces vapors which exert pressure on the container of the walls while when heated in open vessels, the vapors evaporate to the surroundings from the surface. When bulk vapors evaporate to the surroundings at a specific temperature, then that temperature is called the boiling point.

Thus, **Boiling point is the temperature at which vapour pressure of the liquid becomes equal to atmospheric pressure.**

The boiling temperature at 1 atm pressure is called as the normal boiling point while the boiling point at 1 bar is called the standard boiling point. The normal boiling point of water is 100° C and the standard boiling point in 99.6° C.

The pressure directly affects the boiling point. In hilly areas liquids boil at the lower temperature as compared to plains. The reason for this is that at higher altitudes the pressure is very low, hence the boiling point is also comparatively low.

The boiling point is not a result of heating, rather it is the outcome of the increasing vapor pressure. Initially, we can see a line between the liquid phase and vapor phase but as the temperature increases, the speed of vaporization also increases leading to more and more molecules entering the vapor phase. With the rising density of vapors, the density of liquids decreases making the molecules move apart from each other.

Surface Tension

Liquids do not have a shape of their own, they take the shape of the container. Despite its undefined shape, the drop of any liquid looks likes a sphere. This is due to surface tension of liquids. Surface tension is the property specific to liquids.

The molecules in a liquid experience an equal intermolecular force from all the sides. **The intermolecular force between the molecules on the surface is exerted perpendicularly downwards and this is called the 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.**

As compared to other molecules in the container, the surface molecules are the most active and energetic. Despite being less in number than the other molecules their pressure and energy are high and hence exert a downward force towards the liquid. Now if the surface is distorted and the surface of the liquid pulls another molecule from the bulk, then it takes energy to rebuild the surface area. The energy required to build the surface tension is called the surface energy. The unit for surface tension is Jm^{-2} and it is denoted by γ.

The surface tension depends on the surface area. The lower the surface area the lower shall be the surface tension of the surface molecules towards downwards. Surface tension is also inversely proportional to the temperature. The kinetic energy between the molecules tends to increase with the increasing temperature but decreases the force of attraction between the molecules. This decreases the surface tension of the liquid.

Viscosity

The viscosity of a liquid substance is a measure of resistance to flow. The intermolecular forces and internal friction between the moving molecules in the liquids make them viscous to flow. When a liquid flows, the molecules in contact with the surface are stationary, while the upper layer tends to move, the velocity of this moving layer increases with the distance of layers from the stationary layer.

This implies that the farther the moving layer, the faster it moves. This kind of increasing velocity is termed as Laminar flow. The lower layer nearest to the surface retards the movement of the layer above it, this result in viscosity in liquids.

Coefficient of Viscosity

Viscosity of liquids is the resistance to flow shown by molecules. The flow of layers requires force to get away with the resistance between layers. This force helps to maintain the flow of molecular layers and is directly proportional to the area of contact of layers and velocity gradient. The ratio of changed velocity (du) and original velocity (dx) is termed as the velocity gradient.

Now, $F \propto A$

$F \propto du/dx$ (velocity gradient)

$F \propto A(du/dx)$

$\Rightarrow F= \eta A(du/dx)$

Here, η is the proportionality constant and is called as the coefficient of viscosity. The unit of η in SI system is 1 Newton second per sq.metre (1 N sm^{-2}) or Pascal-second (Pa s), while in the CGS system the unit of η is Poise.

The viscosity of the aqueous substance decreases with the increasing temperature. At high temperature, the force of attraction between the molecules decreases and due to the high kinetic energy in the molecules the intermolecular forces slip past each other in the layer. This results in decreased viscosity.

Structural differences between solids liquids and gases

Solids are characterized by definite volume and shape, liquids by their ability to adapt the shape of the container in which it is kept and gases by their ability to expand and adapt the shape as well as volume of the container.

The table below points out the major differences between solid, liquids and gas phase for better comparison of the three phases:

Basis	Solid	Liquid	Gas
Rigidity	Solids are rigid.	Liquids are not rigid.	Gases are not rigid.
Fluidity	Solids lack the ability to flow.	Liquids can flow from higher level (concentration) to lower level.	Gases can flow in all directions.
Volume and shape	Solids have definite shape and volume due to their rigid structure.	Liquids have definite volume but it lacks definite shape and can take the shape of the container in which it is stored.	Gases neither have a definite shape nor a definite volume.
Intermolecular interaction	Particles in a solid are packed closely together, so they are only able to vibrate but not move.	Intermolecular interaction is comparatively less than that of solids, so the molecules or particles have enough energy to move around.	Here, the intermolecular interaction is least, so the gas molecules or particles can move freely and quickly.
Compressibility	One cannot compress solid appreciably.	Can be compressed.	Can be compressed significantly.
Storage	It can easily be stored without a container or vessel.	Liquids cannot be stored without a vessel or container.	Gases can be stored in vessels only.
Examples	Cup, brick, chair, wood, etc.	Water, milk, honey, oil, etc.	Air, ozone, natural gas, etc.