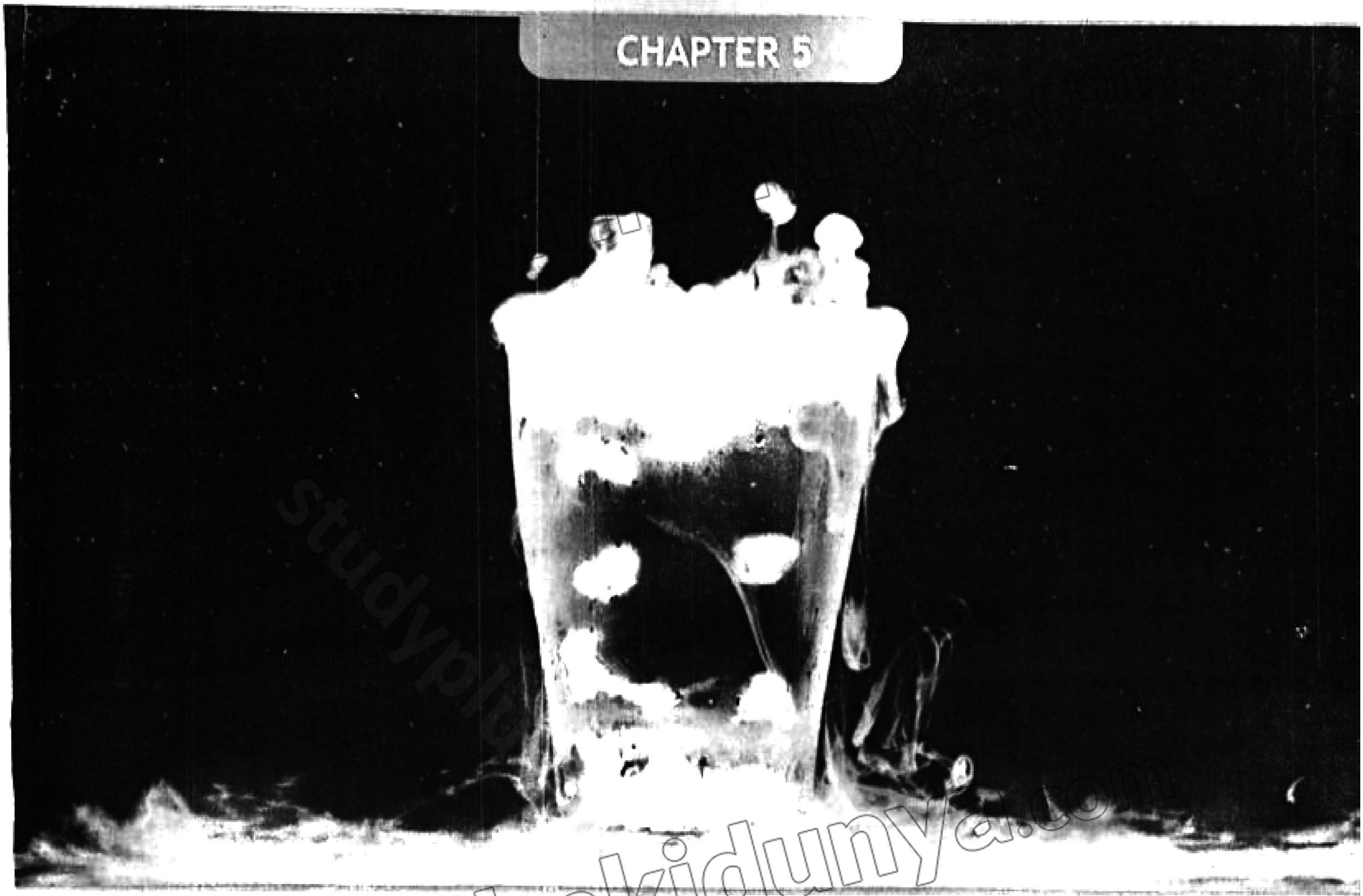
CHAPTER 5



STATES AND PHASES OF MATTER

SLOs: After completing this lesson, the student will be able to:

1. Describe simple properties of liquids e.g., diffusion, compression, expansion, motion of molecules, spaces between them, intermolecular forces and kinetic energy based on kinetic molecular theory.
2. Describe types of intermolecular forces.
3. Explain the strength and applications of dipole-dipole forces, hydrogen bonding and London forces.
4. Describe physical properties of liquids such as evaporation, vapor pressure, boiling point, viscosity and surface tension.
5. Apply the concept of hydrogen bonding to explain the properties of water (specifically high surface tension, high specific heat, low vapor pressure, high heat of vaporization, and high boiling point).
6. Define molar heat of fusion and molar heat of vaporization.
7. Describe how heat of fusion and heat of vaporization affect the particles that make up matter.
8. Outline the importance of heat of fusion in the study of glaciers and ice sheets (particularly while studying polar ice caps).
9. Describe the physical properties of gases (including compressibility, expandability, and pressure exerted by gases).
10. Describe liquid crystals and give their uses in daily life.
11. Dfferentiate liquid crystals from pure liquids and crystalline solids.
12. Describe simple properties of solids e.g., compression, expansion, motion of molecules inter particle space, intermolecular forces and kinetic energy based on kinetic molecular theory.
13. Differentiate between amorphous and crystalline solids.
14. Describe properties of crystalline solids like geometrical shape, melting point, habit of a crystal, cleavage, and crystal growth.

Phases within a system exist as gas, liquid or solid. The matter within a system contains only a single phase of gaseous phase, but it may have one or more liquid or solid phases. All the phases of matter are made up of microscopic particles which differ in their behaviour in the three phases.

5.1 KINETIC MOLECULAR INTERPRETATION OF LIQUIDS

The postulates of the kinetic molecular theory of liquids are given below:

a) A liquid consists of molecules in contact with each other.

b) Molecules within a liquid are in constant motion, but the motion of the molecules is limited by their close packing.

c) The attractive forces of liquid molecules are greater than the attractive forces of gas molecules. However, these attractive forces are not sufficient to hold the molecules in a fixed position. Liquid molecules can slide past each other.

d) The average kinetic energy of liquid molecules is directly proportional to the absolute temperature.

e) At constant temperature, the average KE of the molecules is equal to the K.E of the vapours of the liquids.

5.1.1 Properties of Liquids

There are some common properties of liquids, which can be explained by the Kinetic Molecular Theory.

1. Diffusion

Diffusion in liquids occurs because molecules move from one place to another. Restricted movement of a molecule reduces the rate of diffusion, e.g. an ink drop added to water slowly spreads due to the relatively small spaces between the molecules. Diffusion between molecules in densely packed liquids is slow because there are fewer collisions between them.

2. Compression (effect of pressure)

By raising the pressure, the liquid cannot be significantly compressed, because the molecules are already in close contact with each other, e.g., an increase in pressure from one to two atmospheres reduces the volume of water to 0.0045 per cent, which is negligible. However, the same pressure reduces the gas volume by up to 50 percent.

3. Expansion (effect of temperature)

Liquids expand when heated because the intermolecular forces between them decrease. In addition, an increase in temperature increases effective collisions between molecules. As the temperature drops, the volume decreases.

4. Motion of molecules

The molecules move with lesser speed due to larger forces of attraction among them, as a result they have lesser kinetic energy. However, the kinetic energy increases with the increase in temperature.

5. Spaces between them

The molecules that make up liquid states are quite close to each other. There is very little spaces between them. As a result, the rate of intermolecular collisions is moderate. Therefore, the average kinetic energy is also moderate.

6. Intermolecular forces

The forces of attraction between individual particles of matter are called intermolecular forces. The physical properties of liquids, such as boiling point, vapor pressure, surface tension, viscosity, and heat of vaporization, depend on the strength of attractive forces between molecules.

7. Kinetic Energy based on Kinetic Molecular Theory

According to kinetic molecular theory, molecular movements and collisions caused by strong intermolecular attraction are minimal. Let's look at the example of water, because the molecules are closer together and have a strong attraction due to hydrogen bonding, so they have low kinetic energy

5.2 PHYSICAL PROPERTIES OF LIQUIDS

5.2.1 Vapour Pressure and Boiling Point

When a liquid is heated, its vapour pressure increases with increasing temperature due to the decrease of intermolecular forces. As a result, more and more vapor are released into the air. A stage is reached where the liquid begins to boil. So the temperature at which the vapour pressure of a liquid is equal to the atmospheric pressure or some external pressure is called the boiling point of the liquid.

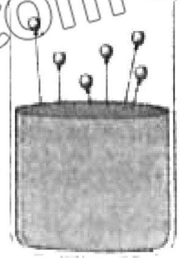
e.g. Boiling Point of water at 760mmHg = 100 °C

Boiling Point of water at 23.7mmHg = 25 °C

5.2.2 Evaporation

The molecules in liquids are in motion and move within the liquid volume. The energy of molecules is not equally distributed. The molecules having high kinetic energy move faster while other molecules having low kinetic energy move slowly. When the high speed molecules reach the surface of the liquid it may escape the attraction of its side or neighbouring molecules and leave the surface of the liquid.

The spontaneous change of a liquid into its vapour at the surface of liquid at given temperature is called evaporation. Evaporation takes place at all temperatures. Evaporation causes cooling. When the high energy molecules leave the liquid during evaporation, low energy molecules are left behind, the average kinetic energy of molecules of liquid decreases and temperature of the liquid falls so heat moves from surrounding to the liquid and temperature of surrounding falls.



Evaporation is controlled by different factors. When surface area of a liquid increases, evaporation increases because evaporation takes place from liquid surface. When liquid surface increases then more molecules can escape and rate of evaporation increases. Intermolecular forces is another factor which affect evaporation. When intermolecular forces are strong molecules of liquid cannot leave the liquid surface easily and evaporation decreases. Rate of evaporation is slow when intermolecular forces are strong and when intermolecular forces are weak, the rate of evaporation is faster. At high temperature molecules have greater energy and rate of evaporation increases. Gasoline and ethyl alcohol whose molecules have weaker intermolecular forces (London forces of attraction) evaporation is much faster than water. Where molecules of water have strong intermolecular forces (Hydrogen bonding).

Do You Know?

Why Does High Air Humidity Make it Feel Hotter?

The natural mechanism of our body to cool itself down is sweating. Evaporation of sweat from our skin takes up energy from our bodies, cooling ourselves down. The more water there is already in the air (higher humidity), the more difficult this evaporation process take place. Therefore, higher concentration of water on air, makes us feel hotter because we cannot cool down efficiently.

5.2.3 Vapour pressure:

The liquid molecules having high kinetic energy leave the liquid surface and escape out of liquid and this process is called evaporation. When the surface of liquid is open the liquid molecules mixed up with air above the liquid and the molecules leave the surface and go away. If the surface of liquid is covered and the system is closed the molecules of liquid evaporate and start gathering above the surface of liquid. These evaporated molecules collide with surface of liquid and also with walls of the container. These molecules are captured by surface of the liquid. This coming back of vapours to liquid and captured by liquid surface is called condensation. Both the processes evaporation and condensation continue till a time reaches when the rate of evaporation is equal to the rate of condensation. This state is called the state of dynamic equilibrium.

$$\text{Liquid} \rightleftharpoons \text{Vapours}$$

Vapour pressure of a liquid is the pressure exerted by vapour of the liquid in equilibrium with the liquid at a given temperature. At a constant temperature the number of molecules leaving the surface of liquid is equal to the number of molecules coming back into liquid. At one moment the molecules of liquid are in liquid state may be in vapour state in next moment during evaporation. The vapour pressure is independent of the amount of liquid or volume of container. The surface area has no effect on vapour pressure. Larger surface area has larger target for evaporation and for returning the molecules.

The vapour pressure of liquid depends on nature of the given liquid (intermolecular forces between its molecules, size of molecules whether small or large molecules) and the other important factor is temperature. Increasing temperature increases the kinetic energy of molecules. At high temperature molecules of liquid have high kinetic energy and capacity of molecules to break the intermolecular forces and escape to leave the liquid surface also increases and as a result the rate of evaporation increases this causes the increase of vapour pressure. Water shows increase of vapour pressure from 4.579 torr at 0^0C to 9.209 torr at 10^0C, 527.8 torr at 90^0C and 760 torr at 100^0C.

Intermolecular forces are also a factor which decides increase or decrease in vapour pressure of a liquid. At a particular temperature stronger the intermolecular forces lower the vapour pressure and weaker the intermolecular forces higher the vapour pressure. At the same temperature different liquids have different vapour pressure. At 20^0C Glycerol has 0.00016 torr and Isopentane 580 torr vapour pressure.

Table 5.1: Vapour pressure of some liquids at 20^0C.

Name of compound	Vapour pressure at 20^0C (torr)
Glycerol	0.00016
Mercury	0.012
Water	43.9
Carbon Tetrachloride	87
Chloroform	170
Ethyl ether	442.2
Isopentane	580

Water boils at 100^0C at 760 torr pressure at sea level and boils at 120^0C at 1489 torr pressure. While boils at 25^0C at 23.7 torr pressure. At Murree hills where external pressure is 700 torr water boils at 98^0C while water boils at 69^0C at the top of Mount Everest where external pressure at 323 torr.

When the external pressure increases artificially the boiling temperature increases as in pressure cooker. A pressure cooker is a closed container from which water vapor cannot escape and pressure is created and the boiling temperature rises, therefore food is cooked quickly.

In vacuum distillation liquid boils at low temperature which requires less amount of heat. Under this process boiling point of liquid is decreased and liquids like glycerine having boiling point 290^0C at 760 torr pressure can decompose at this temperature and cannot be distilled at this temperature. By vacuum the boiling point of glycerine decreases to 210^0C at 50 torr and is distilled without decomposition.

The liquid reach to their boiling point when their vapour pressure become equal to atmospheric pressure at sea level 760 torr. When different liquids are heated, due to the difference in their intermolecular forces they show different vapour pressure and so their boiling point is different.

5.2.4 Boiling point

By heating the liquid, its vapour pressure increases. When heating is continued a stage will reach when the vapour pressure of the liquid becomes equal to external pressure or atmosphere pressure. The temperature at which the vapour pressure of a liquid becomes equal to external pressure or atmospheric pressure is called boiling point or boiling temperature. At this temperature boiling starts. The kinetic energy of molecules increases by heating and temperature of the liquid also increases. When the kinetic energy of the liquid molecules become maximum then further heat supplied will not increase the temperature (temperate remains constant at boiling point) because the further heating will break the intermolecular forces and the liquid is converted into vapours. The amount of heat required to convert one mole of liquid into vapours at its boiling point is called, its molar heat of vaporization. For water the molar heat of vaporization is 40.6kJ/mole.

5.2.5 Boiling point and atmospheric pressure

Boiling point of liquid depends on intermolecular forces. Greater the intermolecular forces high is the boiling temperature and vice versa. Boiling point depends on external pressure or atmospheric pressure. Boiling point is the temperature at which vapour pressure of a liquid becomes equal to external pressure or atmospheric pressure. When external pressure is high then larger amount of heat is required to produce vapour pressure equal to external pressure and liquid boils at high temperature hence boiling point is high. Likewise, at lower external pressure liquid boils at lower temperature as liquid requires less amount of heat to boil and boiling point is low.

5.2.6 Viscosity

A common observation is that water can be poured from one container to another very quickly compared to honey and glycerine. The resistance to flow of a liquid is called viscosity. The higher the viscosity, the slower the liquid flows. Viscosity measures how easily molecules slide past each other. To understand viscosity, think of a fluid flowing in a pipe as consisting of a series of concentric circular layers. Resistance is caused by internal friction between layers of molecules. The layer next to the walls have the lowest speed. Each layer attracts the other and thus causes resistance to flow.

Units:

SI units of viscosity is Pascal Second (Pa.s). Non-SI unit of viscosity is poise.

1 poise = 0.1 kg $m^{-1}s^{-1}$ or $gcm^{-1}s^{-1}$

1Pa.s= 1 $kgm^{-1}s^{-1}$ = 10 poise

The size and shape of the molecule strongly influence viscosity. Liquids such as water, acetone, benzene and methanol, whose molecules are small and compact, have a low viscosity. In liquids with large and irregular molecules, such as honey, glycerine tends to tangle with each other. This hinders the flow of molecules and leads to high viscosity. The stronger the intermolecular force, the higher the viscosity. Liquids whose molecules form hydrogen bonds are more viscous than others without hydrogen bonds. For example, water is more viscous than methanol mainly due to extensive hydrogen bonding. Molecules move faster when the temperature rises. This is because; an increase in temperature decreases intermolecular forces. This dependence is quite visible for very viscous liquids such as honey and syrup. These liquids are easier to pour when hot than cold.

5.2.7 Surface Tension

Surface tension is the property of the surface of liquids to behave as if a membrane were stretched over it. All molecules below the surface of a liquid are surrounded by other molecules in all directions. Thus, the force exerted by such molecules is balanced in all directions, while at the surface of a liquid there are molecules beside and below but none above it. This results in an unbalanced force that pulls the surface molecules inward. Molecules on the surface therefore feel an inward pull, creating surface tension. "A force in dynes acting at right angles to a unit length of liquid surface is called surface tension." For a molecule to reach the surface, it must overcome the downward force of attraction. This means that work must be done to bring it to the surface. Therefore, increasing the surface area of the liquid requires input energy. Surface tension can also be defined as the amount of energy required to expand the surface of a liquid per unit area. Molecules on the surface of a liquid are less stable than inside it, so a liquid is stable if it has the fewest molecules on its surface. This happens when the surface of the liquid is the smallest. Spheres have less surface area per unit volume than anything else. Therefore, small liquid droplets are usually spherical.

The surface tension of a liquid directly depends on the strength of the intermolecular forces. The stronger the intermolecular forces between the liquid molecules, the higher the surface tension and vice versa. For example, water has a higher surface tension than many other liquids, such as alcohols, ethers, benzene, etc. This is due to the strong hydrogen bonding between water molecules. The surface tension of a liquid decreases with increasing temperature. This is because the increased kinetic energy of the molecules reduces the strength of the intermolecular forces. It is different for different liquids because of different types of intermolecular forces

Units

SI unit of surface tension is joule per square meter, Jm^{-2}or Newton per meter, Nm^{-1}.

5.2.8 Concept of Hydrogen Bonding to Explain the Properties of Water

Hydrogen bonding in water contributes to its unique properties, which are as follows.

i. Surface tension is affected by strong intermolecular attractive forces. Water has hydrogen bonding which is strong intermolecular force. This creates a high surface tension.

Solvent	Surface tension ($\gamma \times 10^{-2}$) (Nm^{-1})
Water	7.275
Methanol	2.26
Ethanol	2.28
Benzene	2.888

Hexane	1.84
CCl_4	2.70

ii. Vapour pressure: vapour pressure of a liquid is affected by intermolecular attractive forces. Strong forces of attraction make the evaporation slow. Due to hydrogen bonding in water which is strong intermolecular attractive force decreases evaporation and so water has low vapour pressure.

iii. High heat of vaporization of water: Heat of vaporization of water compared to other liquids is high because of strong intermolecular forces of hydrogen bonding in water. More heat is required to overcome these attractive forces to vaporize water and as a result water show high heat of vaporization than other liquids.

iv. High heat of vaporization of water results in high boiling point. Due to strong hydrogen bonding water has low vapor pressure. So, more heat is required to enhance evaporation and produce vapour pressure equal to external pressure. As a result water has high B.P.

5.3 ENERGETIC OF PHASE CHANGES

Physical and chemical changes are accompanied by a change in energy in the form of heat. Physical energy change is a quantitative measurement of the strength of intermolecular forces. The change in energy at constant pressure is called the change in enthalpy, denoted by ΔH. It is expressed in $kJ\ mol^{-1}$. When a substance undergoes a phase change (change of state), its temperature remains constant even when heat is added.

5.3.1 Molar Heat of Fusion and Molar Heat of Vaporization

Molar heat of fusion (ΔH_f) is the amount of heat required to convert one mole of a solid into its liquid state at its melting point is called molar heat of fusion (ΔH_f)

e.g. Molar heat of fusion for ice is +6.02 kJ $mole^{-1}$

$$H_2O_{(S)} \longrightarrow H_2O_{(l)} \quad , \quad \Delta H_f = +\ 6.02\ kJ\ mole^{-1}$$

Molar heat of vaporization (ΔH_v)

The amount of heat required to convert one mole of a liquid into its vapours at its boiling point is called molar heat of vaporization.

e.g. $$H_2O_{(l)} \longrightarrow H_2O_{(g)} \qquad \Delta H_v = +40.7\ kJ\ mole^{-1}$$

5.3.2 Energy Changes and Intermolecular Forces:

As a result of melting of a solid, a small change in intermolecular distance and potential energy takes place in atoms, molecules or ions. On the other hand on evaporation of a liquid atoms, molecules or ions undergo large changes in their intermolecular distance and potential energy. Therefore, heat of vaporisation is much greater than that heat of fusion.

5.3.3 Liquid Crystals and Their uses in Daily Life

Pure liquids have sharp melting points and at its melting point the temperature remains constant. Generally, when solids are heated, they are converted into liquids. In 1888 Fredesick Reimitaz discovered a universal property during study of cholesteryl benzoate an organic compound. When this compound is heated it turns milky liquid at 145^{0}C and turns into clear liquid at 179^{0}C. When cooled the reverse occurs. The turbid liquid state is called liquid crystals.

There are many crystalline solids which melt to turbid liquid and then clear liquid phase. Turbid liquid phase can flow and have properties of liquids like viscosity. Surface tension etc. It is to be noted that molecules of this turbid liquids have some degree of order and resemble crystals in properties like optical properties.

The liquid crystalline state between melting temperature and clearing temperature is called liquid crystals. Liquids crystals are always isotropic while crystalline solid may be isotropic or anisotropic.

$$\text{Solid crystal} \rightleftharpoons \text{liquid crystal} \leftrightharpoons \text{clear liquid}$$

Long rod like molecular substance make these type of liquid crystals. These molecules oriented in random direction in normal liquid phase and in liquid crystal form they are in order. On basis of order of molecules the liquid crystals are nemtic, smectic and choloestrinic.

The liquid crystal is intermediate between solid crystal and clear liquid its properties are also between crystals properties and those of isotropic liquids. Liquid crystals have property of crystals like optical property and have fluidity of liquids.

Uses of liquid crystals

1. Liquid crystals are used in the display of electrical devices like digital watches, laptops computers, calculators etc.
2. Due to electromagnetic optic characteristic and photoelectric properties of nematic and cholesteric types liquid crystals were used in different laboratories, universities and industries began to focus on their applications.
3. Cholesteric liquid crystals applied to skin are used to locate veins, arteries, infections, tumours etc. which are warmer than other tissue.
4. Nematic liquid crystals are used in magnetic resonance. Molecules dissolved in nematic crystal liquid solvents show resolved NMR spectrum. Intermolecular Dipole-Dipole fine structures are obtained.
5. Liquid crystals are used in chromatographic separation to study molecular arrangements, kinetics and as anisotropic fluid for visible, UV and IR spectroscopy.
6. Liquid crystals are used in Oscillography system, television displays, liquid crystal screens have also been developed.
7. Liquid crystals polymers are used in industries. Polyester liquid crystals *were developed* for fire resistant and used as coating for multifibre, optical cables etc.

5.3.5 Differentiation of liquid crystals from pure liquid and crystalline solids

In liquid crystals, the molecules are arranged as in a crystal, but with certain degrees of freedom, so that they can flow like liquids. They have both fluidity and some long-range molecular order. They have the ability to change their molecular structure in response to external factors such as temperature, electric field or pressure.

Pure liquids have a random arrangement of molecules with no long-range order. They can flow freely and take the form of a vessel. Pure liquids show no significant changes in molecular arrangement in response to external stimuli, other than changes in temperature or pressure.

In solids molecules or atoms have a well-ordered and repeating three-dimensional arrangement. A solid maintains a certain shape and volume. Some crystalline solids can change phase under the influence of temperature.

5.3.6 Glaciers and ice caps

- The study of glaciers, particularly polar ice sheets, heavily relies on understanding the significant role that heat of fusion plays in their behaviour.
- The melting and freezing of ice are closely tied to the heat of fusion. Hence, it holds great significance to anticipate the response of glaciers and ice sheets to fluctuations in temperature.
- The increasing global temperatures caused by global warming will necessitate the consideration of heat of fusion as a crucial element in evaluating the susceptibility of polar ice sheets. By utilizing this information, scientists are able to make predictions regarding the extent of ice melting and its impact on sea levels as well as other environmental transformations.
- The quantity of water released during the melting of ice is directly proportional to the heat of fusion. Through the analysis of the heat absorbed during the melting process of ice cores, researchers are able to obtain valuable information about previous climatic conditions.

5.4 GENERAL PROPERTIES OF GASES

1. Gases do not have definite shape and volume. Gas molecules are free to move. Molecules of gas are in random motion. Volume of the gas is the volume of its container. Similarly, the gases have no definite shape and acquire the shape of the container.
2. Intermolecular space in gas molecules is more due to which gases show low densities. Gases bubble and rise up through liquid due to its low densities than liquids and solids.
3. Intermolecular spaces in gases are more enough to accommodate other gases molecules and show properties of diffusion and effusion.
4. When gases are heated the velocity of molecules increases and volume of gases increases. Similarly, if volume is available then gases can expand and occupy the available volume.

5. Gas molecules are in random motion and collide with each other and with the walls of the container. Gases exert pressure due to the number of collisions.
6. Gases have some common physical properties. According to kinetic molecular theory the space between gas molecules is more than solids and molecules of gas are free to move. The kinetic energy of molecules of a gas depends on temperature. Gases are free to flow and fill the available volume or container.

1. Compressibility:

Gases are highly compressible because the particles in gases are far apart and large spaces exists between them. So gases can be compressed into small volume by applying pressure. Due to this property of gases large volume of a gas can be placed in small cylinder by compression. For example oxygen gas in cylinders are supplied to hospitals. Compressed Natural gas (CNG) is used in vehicles liquid petroleum Gas (LPG) is used for cooking in kitchen.

The state of a substance is determined by the balance between kinetic energy of individual particles atoms or molecules and the intermolecular forces between them. The kinetic energy keep the particles apart and moving around and determine the temperature of the substance while intermolecular forces draw molecules together.

In gases average kinetic energy of molecules is larger than average energy of attraction between particles or molecules of the gas.

2. Expandability:

Gases expand to fill its container. Expandability of gases is spontaneous and gases occupy the available volume. The gas molecules are in random motion having kinetic energy and there is empty space between gas molecules. The air contained in a balloon fills up the whole balloon. If the gas in balloon is let into the room it will spread in the room. In balloon gas has high pressure and, in the room, gas has low pressure. Compressed gas can also expand if volume is available. Compression and expansion of gases is also used in liquefaction of gases.

3. Pressure exerted by the Gases:

Molecules of a gas are in constant random motion and collide against walls of the container. Due the collisions with the walls of the container the walls experiences a continuous force. Due to this force gases exert pressure. Pressure is force per unit area.

5.5 GENERAL PROPERTIES OF SOLIDS:

- Solid have definite mass, volume and shape. It has a compact arrangement of constituent particles. There is short distance between molecules and forces of attraction between its particles is very strong. Due to this reason solid are non-compressible and they cannot diffuse into each other. Solid particle only has vibrational motion.
- Solids is a collection of atoms or molecules held together in a definite shape under constant conditions. Substances which are rigid hard, cannot flow and have definite volume under constant conditions.
- They have definite size under constant conditions, because of strong forces of attraction

between its atoms or molecules.Its constituent particles (atoms, molecules or ions) cannot move randomly. Particles only show vibrational motion.

- Solid particles are held together by strong cohesive forces.
- Its constituent particles (atoms, molecules or ions) are closely packed with each other. There exists a well ordered arrangement in solids.

5.5.1 Kinetic molecular interpretation of solids:

Solids show maximum attractive forces among their particles (atoms, molecules or ions) due to very close packing of arrangement.

The particles of solids are closely packed as a result they occupy minimum volume and show high density.

Solid particles do not show translational motion therefore there is no collision between the molecules.

- The particles of solid can only vibrate and possess only vibrational kinetic energy.
- Crystalline solids have definite, distinctive geometric shape due to orderly arrangement of particles (atoms, molecules or ions) in three dimensional shape.

5.5.2 Properties of solids based on kinetic molecular theory

1. Diffusion:

Diffusion depends on velocity of molecules. Movement of molecules in solids is vibration only and show negligible diffusion.

2. Motion of molecules:

Particles of solids (atoms, molecules or ions) are closely packed with each other and show only vibrational motion. Particles can only vibrate about their mean position.

3. Inter molecular forces:

Intermolecular forces are maximum in solids. Molecules of solids are held together in fixed position by strong forces of attraction and can vibrate about their fixed position.

4. Compression:

The particles of solids are closely packed and have no space between them. There is minimum or no effect of pressure on solids.

5. Expansion:

Solids expand when heated (volume increases). This is due to the fact that increase in temperature decreases intermolecular attractive forces and space is created between the molecules and volume increases.

5.5.3 Types of solids

Solids are classified on the basis of regular arrangements of its particles (atoms, ions or molecules). There are two types of solids accordingly.

1. Crystalline solids:

The solids which have definite regular and three-dimensional geometric shapes are called crystalline solids e.g., NaCl, diamond, ice, glucose $ZnSo_4$ etc. In these solids the arrangement of atoms ions or molecules are in a definite three-dimensional pattern. this recurring geometrical pattern of structure extends in three dimensions.

2. Amorphous solids:

Amorphous solids are those who's constituent particles (atoms, ions or molecules) do not possess arrangement in regular orderly manner. These solids have no definite Geometric shapes are called amorphous solids for example glass, plastic, rubber, etc. These solids have solids state properties but do not have in ordered crystalline state. The crystalline solids can be converted into amorphous solids by melting and cooling the molten mass rapidly. So, the particles do not find time to arrange themselves. The amorphous solids can have some small regions of orderly arrangement. These crystalline parts of amorphous solids are known as crystallites. Amorphous solids have no sharp melting points. The particles of glass soften over high temperature and can be molded.

5.5.4 Properties of crystalline solids

1. Geometrical shape:

Crystals have a geometric shape. The particles of solids (ions, atoms or molecules) are arranged in three-dimensional space. The internal angles of a crystal (where surfaces intersect) are always the same, no matter in what form they are grown.

2. Melting point:

Crystalline solids have sharp melting points. When a solid is heated, its particles start vibrating at higher temperature and transfer their kinetic energy throughout the solid. At the melting point, their vibration energies become so high that they start leaving fixed positions simultaneously and the solid turn into a liquid.

3. Cleavage planes:

Crystalline solids break up along certain planes called cleavage planes. When pressure is applied to it along the cleavage plane, it changes into small crystals of the same size and shape as that of the original crystal. For a given crystalline solid, the cleavage planes are bent towards each other. The angles between them vary from one crystalline solid to another.

4. Habits of a crystal

Crystals slowly form when a saturated solution is cooled. With slow cooling, liquid crystals are formed. Crystals form by growing in different directions. If the growth conditions remain the same, crystals of the same shape will form. The shape of a crystal in which it usually grows is called habit of a crystal. For example, cubic crystals of sodium chloride are obtained from its aqueous solution. But if the conditions are changed, the shape of crystals also changes. For example, if 10% urea is present in aqueous solution of sodium chloride, octahedral crystals of sodium chloride are obtained.

Key Points

- Forces of attraction between molecules of a substance in any phase are called intermolecular forces.
- The forces of attraction between positive end of one molecule and the negative end of other molecule are called Dipole-Dipole forces.
- The attractive forces between dipoles and induced dipole are called Dipole induced dipole forces or as Debye forces
- The momentary forces of attraction created between instantaneous dipole and induced dipole called instantaneous dipole induced Dipole forces or London Forces.
- The spontaneous change of a liquid into its vapour at the surface of liquid at given temperature is called evaporation.
- Vapour pressure of a liquid is the pressure exerted by vapour of the liquid in equilibrium with the liquid at a given temperature.
- The temperature at which the vapour pressure of a liquid becomes equal to external pressure or atmospheric pressure is called boiling point or boiling temperature.
- The resistance to flow of a liquid is called viscosity.
- A dyne force acting at right angles to a unit length of liquid surface is called surface tension
- Molar heat of fusion (ΔH_f) is the amount of heat required to convert one mole of a solid into its liquid state at its melting point is called molar heat of fusion
- The amount of heat required to convert one mole of a liquid into its vapours at its boiling point is called molar heat of vaporization
- The liquid crystalline state between melting temperature and clearing temperature is called liquid crystals.
- Crystalline solids have definite, distinctive geometric shape due to orderly arrangement of particles (atoms, molecules or ions) in three-dimensional shape.
- The breaking of crystalline solids takes place along definite planes which are called cleavage planes.

References for Further information:

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- John Olmsted III and Gregory M. Williams, Chemistry, The Molecular Science.
- Osei Yaw Ababio, New School Chemistry.
- George M. Bodner and Harry L. Pardue, Chemistry, an experimental Science.

Exercise

1. Choose the Correct Answer

i. Van Der Waal's forces are effective;

(a) At long distance (b) Both at long as well as short distance

(c) Only at short distance (d) Independent of distance

ii. Which one of the following forces are also called London forces?

(a) Ion-dipole forces (b) Dipole-induced dipole forces

(c) Dipole-dipole forces (d) Dispersion forces

iii. Which of the following two halogens are gases at room temperature?

(a) Fluorine and Iodine (b) Chlorine and Bromine

(c) Fluorine and Chlorine (d) Iodine and Bromine

iv. The intermolecular forces are of;

(a) Two types (b) Three types

(c) Four types (d) Five types

v. Thermostat is an instrument which;

(a) Increases the temperature (b) Decreases the temperature

(c) Maintains the temperature (d) Fluctuate the temperature

vi. The scientist who discussed the phenomenon of viscosity are;

(a) Poisuelle (b) Newton

(c) Fritz (d) Vander Wall

vii. The distillation under reduced pressure is called;

(a) Fractional distillation (b) Vacuum distillation

(c) Steam distillation (d) Pressure distillation

viii. The unit of surface tension is;

(a) Newton per metre (b) Newton per metre square

(c) 760mmHg (d) Newton square per metre

ix. The intermediate phase lying between the solid phase and the normal liquid phase is called,

(a) Crystalline solid (b) liquid crystals

(c) Mesogens (d) Crystal lattice

x. In which of the following are the particles the most disordered?

(a) Water at 100 °C (b) Steam at 100 °C

(c) Impure water at 102 °C (d) Water at 10 °C

xi. Which of these statement best supports the idea that matter is made up of particles?

(a) Liquids always fill the space available to them

(b) Liquids are easily compressible

(c) 1 cm^3 of water produces nearly 1700 cm^3 of steam

(d) If a bottle of perfume is opened, the smell spread quickly

xii. Which of these processes involve a weakening of the attraction between particles?

(a) Condensation (b) Freezing

(c) Crystallization (d) Evaporation

xiii. A liquid is thought to be pure ethanoic acid (acetic acid), which of the following is the best way to test its purity?

(a) Measure its B.P

(b) React it with ethanol

(c) Burn it completely in oxygen

(d) Dehydrate it with concentrated H_2SO_4

2 Give short answer.

i. Give the general properties of liquids as to

(a) Diffusion (b) Compression

ii. What are the types of intermolecular forces, give examples?

iii. What is hydrogen bonding, give particular examples?

iv. What are the applications of H-bonding?

v. What are the different types of physical properties of liquids?

vi. Define vapour pressure. What are the factors affecting the V.P?

vii. What is

(a) Viscosity.

(b) Surface tension.

viii. Define molar heat of fusion and molar heat of vaporization.

ix. How will you differentiate liquid crystals from pure liquids?

x. Why distillation under reduced pressure is often used in the purification of chemicals?

3 (a) Give the simple properties of liquids with special reference to the following:

- Diffusion
- Compression
- Expansion
- Inter molecular forces
- Kinetic energy

(b) Explain on the basis of kinetic molecular theory. Why the boiling point of a liquid remains constant although heat is continuously supplied to the liquid?

4 (a) Define and explain evaporation.

(b) What are the factors affecting evaporation?

(c) Different liquids have different rates of evaporation. Explain with reference to ether and alcohol?

5 (a) Define and explain vapour pressure. How equilibrium is established between evaporation and condensation?

(b) What are the factors affecting vapour pressure of a liquid?

(c) Kinetically how will you explain the effect of temperature on vapour pressure?

6 (a) Define and explain boiling point of a liquid?

(b) How will you explain the effect of pressure on the boiling point of a liquid?

(c) Practically how will you explain the

(i) Effect of increase of pressure on boiling point.

(ii) Effect of decrease of pressure on boiling point.

7 (a) Define and explain the term viscosity of a liquid? How does the resistance to the layers causes viscosity?

(b) What are the factors affecting the viscosity of a liquid?

(c) Use the concept of hydrogen bonding to explain the following properties of water?

(i) High surface tension

(ii) High heat of vaporization

(iii) High boiling point

8 (a) Define and explain the phenomenon of surface tension?

(b) What are the factors affecting surface tension?

(c) Define dynamic equilibrium between two physical states?

(d) Define?

(i) Molar heat of fusion

(ii) Molar heat of vapourization

9 (a) Define a liquid crystal?

(b) What are the uses of liquid crystals in daily life?

(c) How will you differentiate liquid crystals from pure liquids and crystalline solids?

10 What are the energetics of phase changes?

11 (a) Define and explain the boiling point of a liquid?

(b) How will you explain the two practical applications regarding the effect of pressure on the boiling point of a liquid?

12 How can you interpret the anomalous behaviour of water?

13 Evaluate the impact of temperature on surface tension of liquids.

14 Interpret the influence of intermolecular forces on the following properties of liquids.

(a) Vapour pressure

(b) boiling point

15 Evaluate the importance of H-bounding in understanding physical properties of water.

16 Differentiate between molar heat of fusion and molar heat of vaporization.

Project:

Explore the science behind LCDs and prepare a report about it.