STATE OF MATTER II: LIQUIDS

Chapter 5

Teaching Periods	Assessment	Weightage
12	1	7

Students will be able to:

- **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.
- **Explain** applications of dipole-dipole forces, hydrogen bonding and London forces.
- **Explain** physical properties of liquids such as evaporation, vapour pressure, boiling point, viscosity and surface tension.
- **Use** the concept of Hydrogen bonding to explain the following properties of water: high surface tension, high specific heat, low vapor pressure, high heat of vaporization and high boiling point. and anomalous behavior of water when its density shows maximum at 4 degrees centigrade.
- **Define** molar heat of fusion and molar heat of vaporization.
- **Describe** how heat of fusion and heat of vaporization affect the particles that make up matter.
- **Relate** energy changes with changes in intermolecular forces.
- **Define** dynamic equilibrium between two physical states.
- **Describe** liquid crystals and give their uses in daily life.
- **Differentiate** liquid crystals from pure liquids and crystalline solids.

INTRODUCTION

Liquid state is the state of matter having definite volume, but no definite shape. This phase of matter is formed when particles come closer together due to the presence of short range attractive forces operating among them. However, the magnitudes of these forces vary from liquid to liquid. This is due to the great variations in their physical properties like boiling point, evaporation, viscosity etc.

A pure liquid is said to be a single phase substance composed of identical molecules. In the liquid state, though atoms and molecules remain close together in the form of clusters but acquire enough energy for moving around and can slip over each other. This freedom of liquid molecules to move easily makes them flow and to pour.

Water is the most abundant liquid compound present on the earth's crust. Water is used by human beings in many necessary processes for example agriculture, drinking, washing etc. It is a fact that almost 70% of our body consists of water. Oils are also liquids and play important roles in our daily life. We use oils for lubricating engines of automobiles, in the hydraulic machines, and also for cooking food (edible oils). Many fuels for example Gasoline, Kerosene oil and Diesel oil are liquids. Some elements are liquid at room temperature such as Mercury (a metal) and Bromine (a non-metal).

5.1 KINETIC MOLECULAR INTERPRETATION OF LIQUIDS

The behavior of liquid in term of kinetic molecular theory is summarized below.

(i) Liquid molecules are close together having small spaces among them.

(ii) Liquid molecules are in constant motion but their movement is restricted.

(iii) There are weak attractive forces present among liquid molecules.

(iv) The collisions among liquid molecules are more frequent. Brownian motion is the result of unequal number of collision of liquid molecules with each other from different sides.

(v) Unlike gases, liquids do not show appreciable increase in their volumes by heating.

5.1.1 Simple properties of Liquids

Diffusion: Two miscible liquids diffuse into each other; however the process of diffusion in liquids is slower than gases due to small intermolecular gaps which cause difficulties in molecular movement. For example a drop of ink spreads in a glass full of water slowly.

Compression: Liquids are very less compressible as compared to the gases. In term of kinetic molecular theory liquid molecules are in constant random motion in small intermolecular spaces hence if we put a pressure on liquid its volume does not appreciably change.

An example of compression of liquid is hydraulic brakes system in automobile.

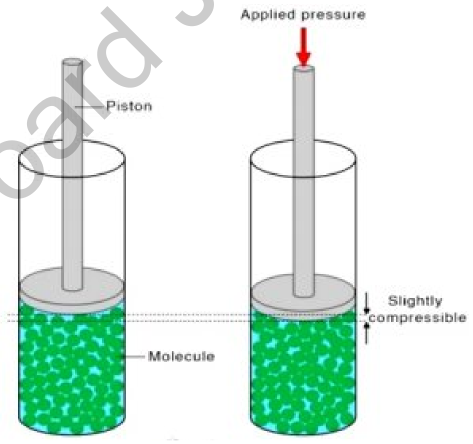


Fig. 5.1: Compression of liquid

Expansion and contraction: Liquids expand on heating. However they do not show appreciable increase in their volumes by heating like gases do. Expansion is due to high kinetic energy of molecules at the higher temperatures which result in the separation of molecules and creation of molecular gaps.

Contraction is opposite of expansion and it takes place by lowering the temperature. Molecules of liquid at low temperatures lose kinetic energies and come close together.

Molecular motion: Liquid molecules move randomly in all possible directions however due to small gaps and attractive forces speed of molecules is slower as compared to gas.

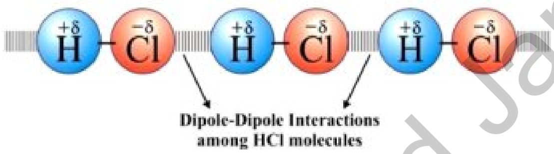
Kinetic energy: Molecules in liquid state are quite nearer to each other due to attractive forces hence collision among them is not as fast as in gases. Therefore kinetic energy of liquid molecules is relatively low. However, a rise in temperature breakdown the attractive forces and increases the molecular collision which results in increasing the kinetic energy.

5.2 INTER-MOLECULAR FORCES IN LIQUIDS (Van der Waal forces)

The forces of attraction among liquid molecules are collectively called intermolecular forces or secondary forces or more famously as Van der Waal forces. These attractive forces are actually physical bonds and are electro-static in nature.

5.2.1 Dipole-Dipole Interaction

Liquid molecules are either polar or non-polar. Polar molecules bear partial positive and partial negative charges due to electronegativity differences on their opposite ends (dipoles). For example, HCl is a polar molecule and there is a partial positive charge on hydrogen atom at one end and partial negative charge on chlorine atom at the other end. These opposite poles attract each other in the liquid states. **"The electrostatic force of attraction between the positive end of one polar molecule and the negative end of other polar molecule are called dipole-dipole interaction"**. The strength of these forces depends upon difference of electronegativities of the two atoms in the polar molecule. As a rough comparison their strength is about 1% of a normal covalent bond.



An example of liquid in which dipole-dipole forces exists is iodine mono chloride (reddish brown oily liquid). The more electronegative chlorine atom possesses partially negative charge (-δ) where as less electronegative iodine atom bear partially positive charge (+δ). Thus partially negative chlorine terminal of one molecule is attracted to the partially positive terminal of iodine of another molecule.

5.2.2 Hydrogen Bonding

In certain molecules like H_2O, HF, NH_3 etc hydrogen atom is bonded to a electronegative smaller size atom. They are referred as highly polar molecules in which hydrogen bear a positive charge and other atom (N, O, F) bear negative charge. Molecules of these substances attract each other through a special type of dipole – dipole interaction known as hydrogen bond. **"The force of attraction between partially positive charged hydrogen atom of one molecule and lone pair of electron of highly electronegative atom of another molecule is called Hydrogen bonding"**.

Hydrogen bond is represented by the dotted lines (……). It is strongest among all inter-molecular forces however much weaker than ordinary covalent bond. The strength of hydrogen bond is about 5 to 10% of the strength of covalent bond.

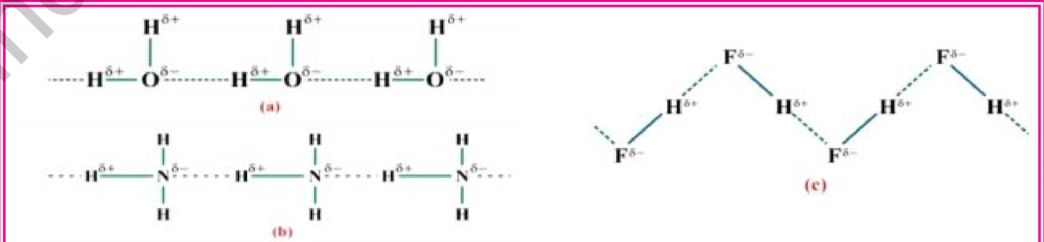


Fig. 5.2: Hydrogen bonding in (a) Water molecules (b) Ammonia molecules (c) Hydrogen fluoride

Application of Hydrogen bonding

In many aspects, hydrogen bonds are important for life on earth and have a wide range of applications in many essential chemical and biochemical processes for example.

(i) Water is an essential need of human being. It is not only use for drinking but various other purposes. It exists in liquid state at ordinary temperature rather than gas due to the presence of hydrogen bonding. Hydrogen sulphide (H_2S) on the other hand is a hydride of same group but exist in gaseous state at room temperature since it does not have hydrogen bond.

(ii) Macro biomolecules such as protein, Deoxyribonucleic acid (DNA) etc play vital function for life. Hydrogen bonds hold their chain in particular sequence.

(iii) Cleaning action of soap and detergent is based on hydrogen bond formation between the polar part of detergent and soap with water molecules.

(iv) Paints are viscous material; they easily form a smooth layer on surface. The adhesive action of paints is developed due to hydrogen bonding.

(v) Fabric of cloths is made up of fibers such as silk, polyester, Nylon etc. The rigidity and tensile effect in threads is developed by hydrogen bonding.

Concept of hydrogen bonding to explain the properties of water

Water possesses some unique properties due to the presence of hydrogen bonding among its molecules.

High specific heat

Specific heat is the amount of heat energy required to raise the temperature of one gram of any substance by 1°C. Water does not warm or cool rapidly, this is due to high specific heat of water which is due to hydrogen bonding.

High specific heat of water has marked effect on the weather. It plays important role in moderating the temperature of earth's surface. Heat is absorbed and stored at day times while sun shines but released at nights. This is why the temperature of coastal areas usually remains moderate throughout day. On the other hand the temperature in desert areas usually shoots up at day time and falls steeply at nights because rocks and sand have lower specific heat.

High boiling point of water

Each water molecule consists of two polar hydrogen atoms and one oxygen atom with two non bonded pairs of electrons. Thus a water molecule can form a maximum four hydrogen bonds in three dimensional spaces hence extra energy is required for breaking hydrogen bonds that is why water boils at high temperature (100°C) as compared to most of other liquids. Hydrogen bonding among HF molecules is stronger due to high electronegative fluorine atom but boiling point of HF is quite lower than water because fluorine can make less number of hydrogen bond with electro positive hydrogen of neighboring molecule.

High density of water

Due to the presence of hydrogen bonds water molecules are strongly attracted and occupy less volume. Since density is inversely proportion to volume, the density of water is relatively high. At 20°C the density of water is 1 g/cm^3. Marine life survives under water due to high density of water.

High viscosity of water

Hydrogen bond is the strongest attractive force among other intermolecular attractions. Since water possess multiple hydrogen bonds in three dimensional space, its molecules are quite closer together. This led to its high viscosity as compared to other molecules of comparative size.

High surface tension of water

High surface tension of water molecules is due to the strong cohesive forces. These cohesive forces are conceptually hydrogen bonds.

Anomalous behavior of water:

Hydrogen bondings in water lead to some unusual and unique behavior which is seen in daily life. It shows highest density at 4°C and below this temperature its volume increases instead of decreasing. This anomalous behavior of water can be attributed by arrangement of hydrogen bonding among H_2O molecules.

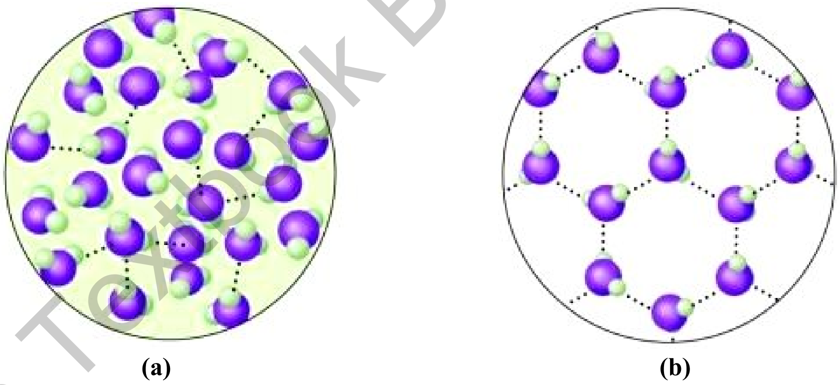


Fig. 5.3: Hydrogen bonding in (a) Ice (b) liquid water

Hydrogen bonding in water above 4°C is temporary due to the high thermal energies. Thus water molecules can easily break their hydrogen bond and quickly re-form new hydrogen bonding with some other molecules in the neighborhood.

When the temperature falls below 4°C, water molecules start arranging themselves by lining up in such a manner that each water molecule can form up to maximum number of four hydrogen bonds. The increased number of

Do You Know?

In the cold regions water supply pipelines burst if not properly insulated. The reason behind this is the anamolous expansion of H_2O below zero degree centigrade.

hydrogen bonding results in the freezing of water into ice. In the form of ice water molecules are arranged in the more regular hexagonal patterns in the manner that empty spaces are created in the structure of ice and its volume expands up to 10%. The low density of ice can be seen when ice float on water.

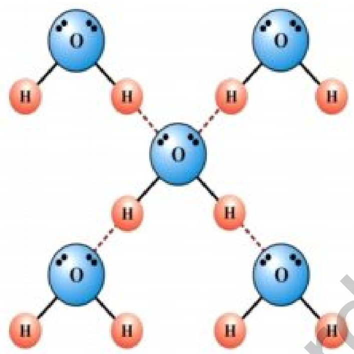


Fig. 5.4: Each water molecule form maximum four hydrogen bonds

Self Assessment

(i) Correlate the following behavior of water with hydrogen bonding among its molecules? ▪ High B.P ▪ High density

(ii) How the high specific heat of water effects on moderating the temperature of atmosphere?

5.2.3 London Dispersion Forces

These forces were first reported by German physicist Fritz London. These attractive forces exist among non- polar molecules which becomes polar temporarily. Never the less gasoline and benzene, are non-polar molecules but exist in liquid state at room temperature due to the presence of London dispersion forces.


Fritz London (1930)

When non polar substance such as H_2, Cl_2, F_2, CH_4, He, Ne, Ar etc are allowed to liquefy by lowering the temperature, a temporary interaction is developed among their molecules due to the distortion of electrons cloud of one atom by the electronic influence of other atom. This makes a short-lived polarization of molecule and it is said to be **instantaneous dipole**. This instantaneous dipole then distort the electron density of nearer atom and hence produce an **induce dipole** in the nearby atom. **"The attractive force which develop between an instantaneous dipole and an induce dipole is known as London dispersion force".**

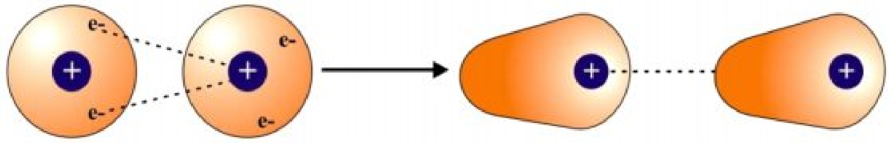


Fig. 5.5: London dispersion forces in two helium atoms

The strength of London dispersion forces depends mainly upon following two factors.

(i) Size of atom or molecule Large size atom or molecule possess greater number of electrons therefore more distortion of electrons is possible which increases the strength of London forces.

(ii) Atoms in the molecules The greater the number of atoms in a non polar molecule the more is the number of electrons hence the stronger the electronic distortion which results in enhancing the strength of London forces.

Self Assessment

Identify the intermolecular forces present in the given molecules.
(i) Hydrochloric acid (ii) Liquid helium (iii) Ice

5.3 PHYSICAL PROPERTIES OF LIQUIDS

`Depending upon the nature and strength of attractive forces among the molecules, liquids have following essential properties.

Evaporation:

We observe that moist clothes become dry while hanging outside in the sunshine, this is due to evaporation. **"At any given temperature, a certain number of the molecules in a liquid possess sufficient kinetic energy to escape from the surface. This process is called evaporation".** It is a surface phenomenon where change of state only takes place at the surface of liquids. Molecules at the surface start getting energy from surroundings and breaking away into gaseous phase.

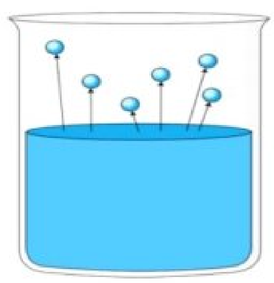


Fig. 5.6: Evaporation in a container

On the basis of the rates of evaporation, liquids can be divided into two types (i) volatile liquids and (ii) non-volatile liquids. The liquids which have higher vapor pressures and evaporate readily are called volatile liquids such as, ethanol, acetone and gasoline etc. and those which have low vapor pressures do not readily evaporate are called non-volatile liquids such as, mobil oil and mercury etc.

Evaporation is an endothermic process. When it starts, the high energy molecules leave the liquid surface. Therefore the average kinetic energy of remaining molecules decreases. As a consequence the temperature of the liquid falls. For example, when we pour some ethanol on our palm, we feel coolness. This is because volatile liquids rapidly absorb heat from our skin and evaporate.
The rate of evaporation is affected by following three factors.

Surface Area

The larger the area of exposed surface the more is the tendency of molecule to transfer from liquid to air. This is due to the fact that greater surface area allows more molecules getting energy from surroundings and escape into air that is why water spilled on floor evaporates more readily as compared to the same amount of water in a container.

Do You Know?

Some water droplets are quickly formed at the outer surface of a cold bottle when it is taken out from refrigerator. This process is called condensation, which is exactly opposite to evaporation. Since it is exothermic process, it happens when gas molecules start losing kinetic energy by striking at cooler surfaces and change into liquid state.

Intermolecular Forces

Evaporation also depends upon the nature of intermolecular forces present among liquid molecules. For example, acetone evaporates quicker than water at the same temperature. This is because stronger intermolecular forces (Hydrogen bonds) are present among water molecules but weaker intermolecular forces (London dispersion forces) present among acetone molecules.

Temperature

Although, evaporation takes place at all temperature but a rise in temperature increases the rate of evaporation. It is in our observation that cloths dry more faster in summer, this is due to the fact that water molecules on wet cloths absorbs heat from atmosphere and becomes more energetic to overcome intermolecular forces and escape more readily.

Vapor pressure

When a liquid is enclose in a tightly covered container, and the air present above the surface of liquid is evacuated, the liquid starts to evaporate and enter into the enclosed space. Some of them will collide with the liquid surface and rejoin it. This process of rejoining the molecules from vapours phase back into liquid phase is known as condensation.

In the beginning the rate of evaporation is faster than the rate of condensation but when more liquid molecules escape out from the surface into the enclose space the rate of condensation increases

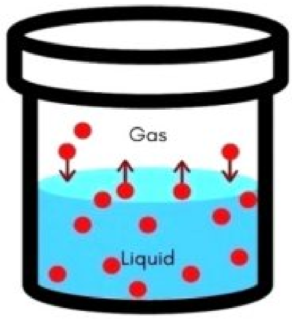


Fig. 5.7: Equilibrium between rate of evaporation and condensation

gradually and a state of dynamic equilibrium is finally established when rate of evaporation and condensation becomes equal.

$$\text{Evaporation} \rightleftharpoons \text{Condensation}$$

The pressure of vapours at this stage becomes constant and known as vapours pressure of that liquid. **"The pressure exerted by the vapours when they are in equilibrium with liquid phase at that temperature is called as vapours pressure".**

Vapours pressure is independent upon the amount of liquid but depend upon temperature and intermolecular forces. Vapours pressure increase with increase in temperature due to increase in kinetic energy of molecules. For example vapours pressure of water at 20°C is 17.5 torr but at 100°C it is 760torr.

Another factor which affect on vapour pressure of liquid is the strength of existing intermolecular forces. The stronger the intermolecular forces the lesser the rate of evaporation and hence the lower the vapours pressure. For example the vapours pressure of diethyl ether at 20°C is 170 torr which is much higher than water (17.5 torr) at the same temperature. This is due to weak London dispersion forces among the molecules of ether.

Boiling point

When a liquid is heated, more molecules acquire high kinetic energy to escape into the air and the evaporation becomes more rapid. As a consequence, the vapour pressure of the liquid increases until it becomes equal to atmospheric pressure, the liquid is said to boil. **"Boiling point is the temperature at which the vapor pressure of liquid becomes equal to its atmosphere pressure"** when atmosphere pressure is one atmosphere; the boiling point is referred to as normal boiling point.

Boiling points of liquids depend upon the atmospheric pressure and it varies at the different regions on earth. At the sea level, where the atmospheric pressure is usually close to 760 torr, water boils at 100°C, whereas at mountainous regions such as Muree hills, atmospheric pressure is usually low (may be 700 torr), thus water boils at below 100°C.

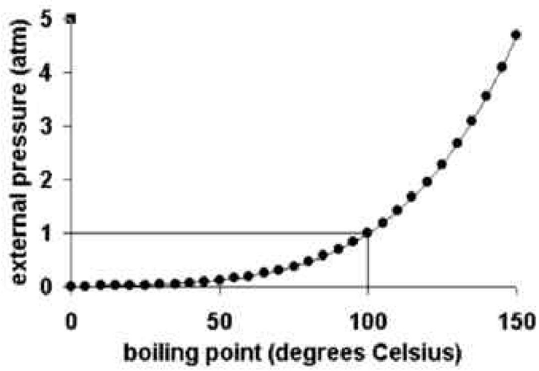


Fig. 5.8: Boiling point of water as a function of external pressure

At normal boiling point (100°C) of water, the food will be cooked easily. However at higher altitudes such as Gorakh Hills, Sindh, where air pressure is usually low, water boils at lower temperatures thus food will take longer time.

In pressure cooker which does not allow the steam to escape. Pressure cookers help to build greater pressures over the water surfaces inside the pot, and as a consequence boiling point of water rises that leads to the decrease in cooking time.

For example glycerin boils at 290°C at 760 torr but it decomposes at this temperature. If it is heated under reduced pressure (50 torr), it boils at 210°C without decomposition.

Viscosity:

The decrease in flow of liquids is due to the internal resistance among the layers of molecules. Every layer offers some friction to the neighbouring layer which tends to flow over it. **"Viscosity is the measure of internal resistance of a liquid to flow"**.

Viscosity of a liquid is affected by following three factors.

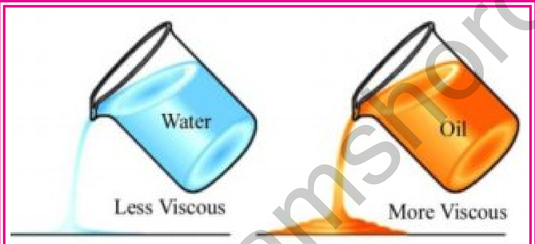


Fig. 5.9: Oil is more viscous than water

(i) Intermolecular forces:

Liquids like benzene, gasolines etc which consist of non polar molecules posses weak intermolecular forces and have relatively low viscosities. Contrarily, more polar liquid such as glycerol and methanol etc experience stronger intermolecular forces and possess high viscosity.

Water is more viscous than acetone because of stronger hydrogen bonding present in water molecules and weaker London dispersion forces present in acetone molecules.

(ii) Temperature:

It is our everyday experience that viscosity of liquids decreases with the rise of temperature due to increase in kinetic energy of molelcules. Honey is viscous at room temperature but can be made thin on heating, vegetable oil becomes less viscous while cooking.

Table 5.1: Viscosities of some liquids at different temperatures.

Liquid	Viscosity (centipoise)		
	0°C	20°C	50°C
Acetone	0.395	0.322	0.246
Water	1.789	1.005	0.55
Ethyl alcohol	1.78	1.19	0.701
Glycerin	12100	1499	--

(iii) Molecular Size:

Liquid of large molecular size are highly viscous because their molecular chains get tangled up in each other and create more friction to flow. For example paraffin oil and motor oil are viscous due to their large hydrocarbon chain. The high viscosity of honey is due to large molecular size as well as presence of hydrogen bond among the molecules.

Units of Viscosity:

The unit of viscosity is Poise and centi poise. The S.I unit of viscosity is $N.s.m^{-2}$.

Surface Tension:

We have already discussed that liquid molecule attract each other but intermolecular forces are not uniform throughout the liquid body. Consider two molecules of liquid "A and B". Molecule" B" is nearly in the middle and molecule "A" is just on its surface. Molecule "B" is equally pulled from all sides by the neighboring molecules, however molecule "A" does not experience any pull from the above, as there is no any liquid layer above it due to surface position. Hence, there is net downward pull at the right angles which tends to contract the surface of a liquid. This shows that attractive forces on molecules at surface and inside liquid are unbalanced. Molecules at the surface of a liquid experience more attraction which works like a stretched membrane and it tends to compress the molecules below to the smallest possible area and create surface tension **"Surface tension is the force acting at right angle on the unit length of surface of liquid"**. Since work has to be done to lift the inner molecules to the surface of liquid, some energy is required to expand the surface area thus surface tension may also define as **"The amount of energy that cause to increase the unit area of liquid"**. The unit of surface tension is dyne/cm or erg/cm^2.

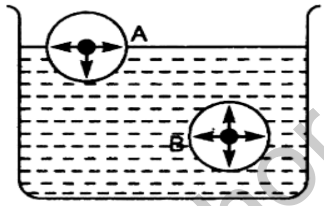


Fig. 5.10: Cohesive forces in the liquid molecules at surface and inner side


Fig. 5.11: Falling drop of a liquid is spherical in shape.

Liquids tend to minimize their surface area as much as possible to attain a spherical shape. You might have noticed spherical droplets of water coming out of tap for a while just after closing it. The reason behind is the presence of cohesive forces between the surface molecules and the molecules toward the interior side. Since the surface molecules are being pulled by the interior ones, as a consequence, the surface area is reduced as much as possible to acquire a spherical geometry since sphere has the least surface area for a given volume.

Do You Know?

Attractive forces between the molecules of same type are known as cohesive forces whereas the attractive forces between the molecules of different type are known as adhesive forces. For example Mercury when confined in a glass tube does not wet the wall due to its stronger cohesive forces as compared to adhesive forces that is why it is used in thermometer.

Table 5.2: Surface tensions of some common liquids at 20°C

Liquid	Surface tension (dynes/cm)	Liquid	Surface tension (dynes/cm)
Ethanol	22.03	Benzene	28.88
Acetone	23.7	Water	72.583
Chloroform	27.1	Mercury	471.6

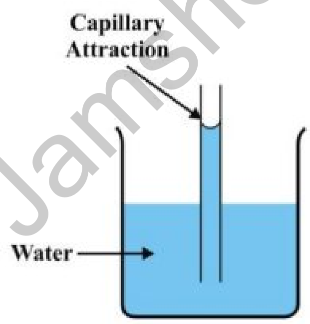
An essential factor which affect on surface tension of liquids is the strength of intermolecular forces. The stronger the intermolecular forces the higher the surface tension.

For example surface tension of water is stronger than many other liquids, due to the presence of stronger intermolecular forces (Hydrogen bonds). Mercury has much higher surface tension than water because its atoms are held together by strong metallic bond.

Surface tension is markedly affected by temperature. High temperature weakens the cohesive forces among the molecules which results in decreasing the surface tension.

Capillary action:

When you dip one end of a clean capillary tube in a liquid, you will observe the liquid rising to a certain height. **"The flow of liquid in a capillary tube is called as capillary action"**.

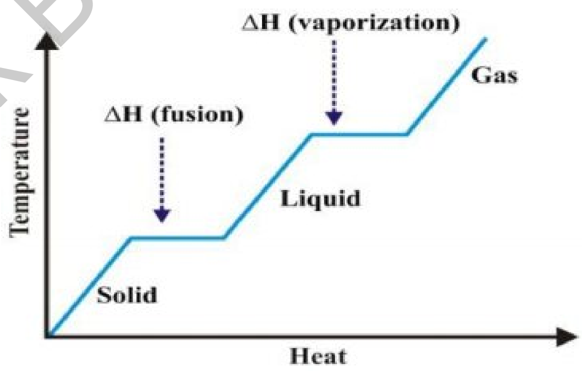


The flow of liquid in a capillary tube is due to a combine effect of cohesive forces among liquid molecules and adhesive forces between liquid molecules and the wall of tube. Water rises in the capillary tube because its adhesive forces become stronger in a tube of small diameter.

Other examples of capillary rise action are spreading of ink into blotting paper and rise of oil in the wicks of lamp.

5.4 ENERGETIC OF PHASE CHANGE

Transformation of substance from one physical state to another is accompanied by absorbtion or evolution of heat. This heat energy refers the strength of intermolecular forces and are of three types.



Molar heat of fusion (ΔH_{fusion}) It is the amount heat required to convert one mole of a solid completely into liquid at its melting point. The molar heat of fusion when ice is converted into water is given as.

$$Ice_{(s)} \longrightarrow Water_{(l)} \ (\Delta H_{fusion} = +6.02 KJ/mol)$$

Even though heat is being supplied during melting but temperature remains constant because all of the energy is consumed by the molecules to over come the intermolecular forces.

Molar heat of vaporization (ΔH_v) The amount of heat required to convert one mole of a liquid into its vapours at boiling point is referred as molar heat of vaporization.

$$Water_{(l)} \longrightarrow Vapours_{(g)} \ (\Delta H_v = +40.7 KJ/mol)$$

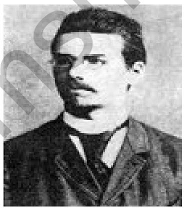
Heat of vaporization is much greater than the heat of fusion because while converting liquid into vapour, notable change in the intermolecular distance and potential energy of particles occur.

Molar heat of sublimation (ΔH_s) the amount of heat absorbs when one mole of a solid is directly convert into vapours without going through a liquid state is known as molar heat of sublimation. For example dry ice (solid CO_2) changes directly from solid to gas at atmospheric pressure.

$$CO_{2(solid)} \longrightarrow CO_{2(gas)} \ (\Delta H \text{ sublimation}) = +25.2 \text{ KJ/mol}$$

5.5 LIQUID CRYSTALS

A liquid crystal is a state of matter between liquid and solid. It was first discovered by Fredrich Reintzer (1888), while he was examining physico-chemical properties of different derivatives of cholesterol. He observed that cholesteryl –Benzoate did not melt the same way as other compounds, and it has two melting points. At 145.5°C it first melted into a cloudy liquid and then at 178.5°C it melted again and cloudy liquid became clear and this phenomenon was reversible. Liquid crystals are usually organic in nature or may be sometimes mixture of both organic and inorganic materials. Liquid crystals exist both naturally or they can be synthetically developed.



Fredrich Reintzer

Liquid crystals can be differentiating from a pure liquid and crystalline solid with its certain characteristics. They have ability to flow like liquid but the molecular arrangement is similar to crystalline solids. Liquid crystal have optical properties as found in crystalline solid but exhibit anisotropy.

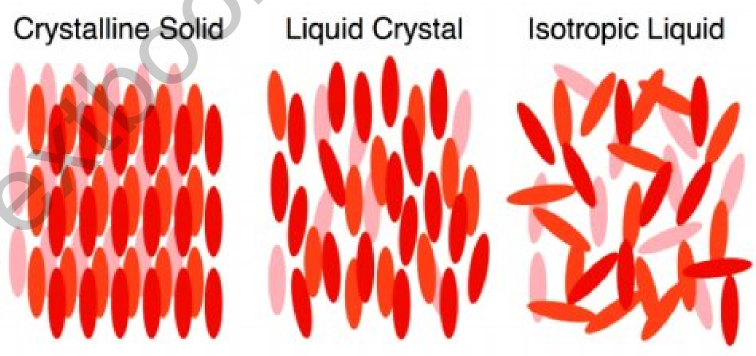


Fig. 5.12: Liquid Crystal

Uses of liquid crystals

- Liquid crystals are commonly used in our daily life. For example, liquid crystal displays (LCDs) are used in the screens of various devices like wrist watches, mobile phones, tablet computers, screens of computers, televisions, pH meters, ATM machine displays etc.
- Liquid crystals are used as temperature sensors in thermometers and other devices to measure the body temperatures.

- Liquid crystals are used in many fields of science and engineering to detect faulty connections in microelectronic circuit boards.
- In the medical science liquid crystals help to detect blockage of veins, arteries and tumors etc.
- Liquid crystals are used in the chromatographic techniques as solvents for the separation of many components.
- Some of liquid crystals are also used in the hydraulic machines due to their high viscosities.

Society, Technology and Science

Use of liquid crystals in digital instruments

LCD is a great invention in modern technology due to its flat compact screen and excellent quality of picture.

Liquid crystal is sealed between the two glass sheets having a transparent conducting surface. When backlight is activated, the molecules of liquid crystal rearrange their direction to produce display.

Activity

This activity motivates you to study the effect of temperature on the viscosity of liquid. Just take one table spoon of honey at room temperature and pour it in an empty cup. You will observe that the honey will flow slowly due to dominant viscous forces between its different layers. Now take another table spoon of honey and heat it on a low flame for 1 minute. Then pour it in the same cup. Now you will observe a quick flow of honey into the cup. The reason is that heating honey increases its temperature, thereby causing its viscosity to decrease which in turn results in a faster flow.

SUMMARY with Key Terms

- **Dipole-Dipole interactions** is the electrostatic force of attraction between the positive end of one polar molecule and the negative end of other polar molecule.
- **London dispersion forces** are weak intermolecular forces which develop among non polar molecules such as H_2, He, Ne, Ar, CH_4 etc. It is a short-lived polarization of molecule due to the distortion of electron of one atom by the electronic influence of other atom.
- **Hydrogen bonds** is the force of attraction between partially positive charged hydrogen atom in one molecule and lone pair of electron of highly electronegative atom in another molecule. It exist in the molecules which possess electro positive hydrogen atom and high electronegative atom.
- **Evaporation** is a surface phenomenon in which molecules from liquid surface starts escaping into gaseous state. It depends upon surface area of liquid and the forces which hold the molecules in liquid state.
- **Condensation** is the reverse process of evaporation in which gas molecules after losing their kinetic energy transform into liquid state.
- **Vapours pressure** is the pressure exerted by vapours when they are in equilibrium with liquid phase. It is dependent upon temperature and intermolecular forces.
- **Dynamic equilibrium** is established in a closed vessel when the rate of evaporation and rate of condensation of liquid becomes equal.
- **Boiling point** is the temperature at which vapours pressure of liquid becomes equal to the atmospheric pressure. The greater the atmospheric pressure, the higher the boiling point.
- **Viscosity** is the internal resistance to flow of a liquid. It is mainly depends upon intermolecular forces. The unit of viscosity in SI measurement in Nsm^{-2}.
- **Surface tension** is the force responsible for the tension at the surface of a liquid. It is the energy required to stretch the surface by unit area.
- **Capillary action** is the rise of water in a capillary tube. It occurs due to small surface area of capillary tube which causes weak surface tension.
- **Abnormal behavior of water** is found below 4°C when its volume increases due to the arrangement of hydrogen bonding. Ice has low density than liquid water that is why float on water.
- **Molar heat of fusion** is the heat required to convert one mole of solid completely into liquid at its melting point. Molar heat of fusion of water is + 6.02 KJ/mol.
- **Molar heat of vapourization** is the heat required to convert one mole of a liquid into its vapours at its boiling point. The molar heat of vapourization of water is 40.7KJ/mol.
- **Molar heat of sublimation** is the heat absorbs when one mole of a solid directly change into vapours without going through liquid state. It is the sum of molar heat of fusion and molar heat of vapourization.
- **Liquid crystals** is state between liquid and crystalline solids. They are used in making LCDs, ATM machines, computers etc.

EXERCISE

Multiple Choice Questions

1. Choose the correct answer

(i) The boiling point of water (H_2O) is 100°C where as that of hydrogen sulphide (H_2S) is 42°C, This can be attributed to:
(a) Smaller bond angle of H_2S than H_2O
(b) Smaller radii of oxygen than sulphur
(c) High I.P of oxygen than sulphur
(d) Tendency of water to form hydrogen bond

(ii) Liquids can form convex meniscus in a narrow glass tube when:
(a) Cohesive forces are stronger than adhesive forces
(b) Adhesive forces are stronger than cohesive forces
(c) Cohesive and adhesive forces are equal in strength
(d) None of these

(iii) Which of the following statement is incorrect?
(a) Viscosity is the resistance against flow of liquid
(b) Liquid possess definite volume
(c) One feels sense of cooling after bath due to condensation
(d) Sublimation is endothermic process.

(iv) Which of the following possesses weakest London dispersion forces:
(a) Cl_2 (b) F_2 (c) Br_2 (d) I_2

(v) Hydrogen bond is not found in:
(a) H_2O (b) CH_4 (c) NH_3 (d) HF

(vi) The boiling points of different liquids may be different at the same external pressure due to:
(a) Amounts of liquids (b) Intermolecular forces
(c) Surface area (d) Viscosities

(vii) Which statement is incorrect about evaporation?
(a) It is an exothermic process
(b) It is a reverse process of condensation
(c) It occurs at all temperature and pressure
(d) It causes cooling effect

(viii) Which of the following liquids show maximum surface tension?
(a) Water (b) Mercury (c) Ethyl alcohol (d) Gasoline

(ix) (ix) A non-polar molecule with bigger size will experience:
(a) London forces (b) dipole-dipole interaction
(c) Hydrogen bonding (d) All of these

(x) Cooking time is reduced in a pressure cooker because:
(a) Boiling point of water increases (b) Boiling point of water decreases
(c) Vapor pressure of liquid is reduced (d) Heat is uniformly distributed

Short Questions

1. Explain the following in terms of kinetic molecular interpretation of liquids:
   (a) Diffusion (b) Compression (c) Expansion (d)Molecular motion
2. Name three major kinds of intermolecular forces in liquids. Explain intermolecular forces in HCl.
3. Define the following:
   (a) Molar heat of fusion (b) Molar heat of vapourization (c) Molar heat of Sublimation
4. Describe hydrogen bonding in water and explain the anomalous behavior of water due to hydrogen bonding.
5. Water is more volatile than glycerin but petrol is more volatile than water at the same temperature. Explain in term of intermolecular force.
6. Give reasons for the following:
   i. Water spilled on floor evaporate faster than the same amount of water in a container.
   ii. A falling drop of a liquid is spherical.
   iii. Evaporation is a cooling process.
   iv. Boiling point of liquid remains constant although heat is continuously supplied to the liquid.
   v. Mercury has its meniscus upward.
   vi. Liquids cannot be compressed as gases do.
   vii. Density of water is highest at 4°C.
   viii. Honey is more viscous than water.

Descriptive Questions

1. What is Surface tension? Explain it with example. Give its unit and describe the factors that affect on surface tension of liquids?
2. Explain the factors why honey is more viscous than water?
3. What is hydrogen bond? How is it established? Give its application in industrial and biochemical process.
4. What is meant by liquid crystals? How is it differing from liquids and crystalline solids?