Chapter 5 PHYSICAL STATES OF MATTER

Time Allocation

Teaching periods	= 12
Assessment period	= 3
Weightage	= 12

Major Concepts

5.1 Gaseous State
5.2 Laws Related to Gases
5.3 Liquid State
5.4 Solid State
5.5 Types of Solids
5.6 Allotropy
5.7 Plasma State
5.8 Bose Einstein Condensate

STUDENTS LEARNING OUT COMES (SLO'S)

Students will be able to:

- Understand effect on the pressure of gas by change in the volume and temperature.
- Compare the physical states of matter with reference of intermolecular forces present between them.
- Account for pressure volume changes in a gas using Boyle's Law.
- Account for temperature volume changes in a gas using Charles's Law.
- Summarize the properties of liquids like evaporation, vapor pressure and boiling point.
- Explain the effect of temperature and external pressure on vapor pressure and boiling point.
- Describe physical properties of solids (boiling and melting points).
- Differentiate between amorphous and crystalline solids.
- Explain the allotropic forms of solids.
- Define the plasma with help of examples.
- Define Bose Einstein Condensate with help of example.

Introduction:

As we know that matter is physical material of universe. It is defined as anything which has mass and occupy space. States of matter differ in some observable properties. A gas has no fixed volume or shape it can easily be compressed and expanded. A liquid state has no fixed shape but has fixed volume it cannot be compressed easily. A solid has a definite shape and volume, it cannot be compressed. In addition to the above three states, there are two more states of matter named as plasma state and Bose Einstein condensate. The different physical states of matter are due to arrangement of molecules and intermolecular forces.

Gaseous State:

The gaseous state molecules are lying away from one another, this assumption was proposed by Boltzmann, Maxwell, Kelvin. They explained the behavior of gases according to their kinetic molecular theory. Gaseous state shows following characteristics

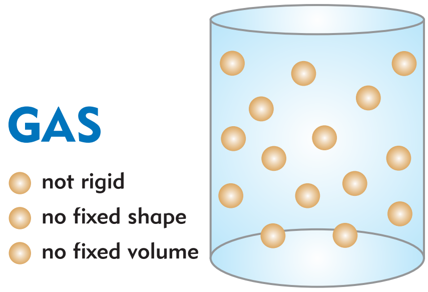


Fig 5.1

- The molecules in gases are widely separated from each other.
- They have negligible volume.
- The gas molecules are in constant random motion.
- The gas molecules moves in straight line until they collide with each other or wall of container.
- On collision molecules do not lose energy because their collision is perfectly elastic.
- Pressure Produced when molecules collide with the wall of container.
- There are no attractive and repulsive forces between molecules.

5.1 PROPERTIES OF GASES

The kinetic molecular theory explains the behavior of gases such as Diffusion, Effusion, Pressure, compressibility, Mobility and Density which are defined below:

5.1.1 Diffusion:

The Diffusion is defined as spontaneous mixing of molecules by random motion and collision to from a homogenous mixture. Gases are rapidly diffusible and rate of diffusion depend upon the molecular mass of the gases. Lighter gases diffuse rapidly than heavier gases as H_2 diffuses four times more than O_2.

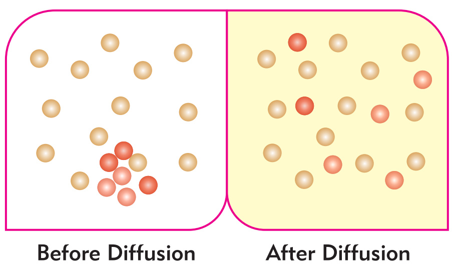


Fig 5.2 Diffusion

Diffusion is movement of particles from an area of higher concentration to lower concentration. The rate of this movement depends upon temperature, viscosity of the medium and the size or mass of the particles. Diffusion results in the gradual mixing of materials, and eventually it forms a homogeneous mixture.

For Examples:

- You can smell perfume because it diffuses into the air and makes its way into your nose.
- Smoke diffuses into the air.
- Flower smell, garbage stink or body odor.

5.1.2 Effusion:

The Effusion is escaping of gas molecules through a tiny hole into a space with lesser pressure. Effusion depends upon molecular masses of gases .Lighter gases effuses rapidly than heavier gases. For process of effusion the diameter of hole must be smaller than the molecule's mean free path.

For Examples:

- Leakage of air through tyre pin hole.
- Leakage of helium through gas balloons.

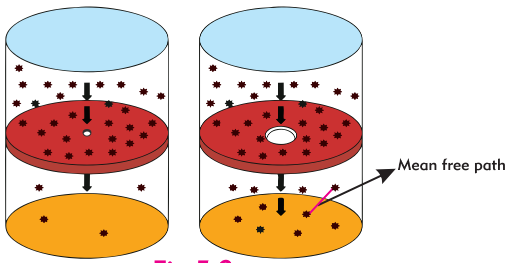


Fig 5.3

Do you know?

Mean free path is the average distance that a gas particle travels between successive collisions with other gas particles.

5.1.3 Pressure

The force exerted by gaseous particles per unit area is called gas pressure. It can be expressed mathematically as.

Pressure = Force / Area or $P = F / A = N/m^2$

The S.I unit of force is Newton (N) and unit of area is m^2, hence pressure has S.I unit of Nm^{-2}. It is also known as Pascal (Pa). 1 Pascal = $1Nm^{-2}$.

The molecules of gases are in continuous motion,

Do you know?

Pressure exerted by the atmosphere at the sea level is called atmospheric pressure. It is defined as the pressure exerted by a mercury column of 760 mm height at sea level.

1atm = 760mm of Hg = 760 torr

1atm = 101325 pascal

But the pressure is developed by the collisions of molecules of gas with the walls of container. Barometer is used to measure the atmospheric pressure and manometer is used to measure the pressure of gases in the laboratory.

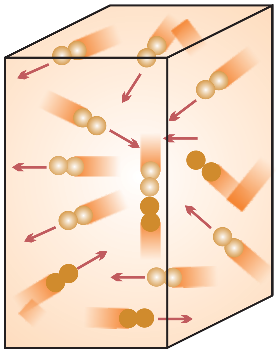


Fig 5.4

5.1.4 Compressibility

The capacity of something to be flattened or reduced in size by pressure is called compressibility. The gases are highly compressible due to larger spaces between their molecules. When gases are compressed, the molecules come closer to one another and occupy less volume as compared to the volume of uncompressed state.

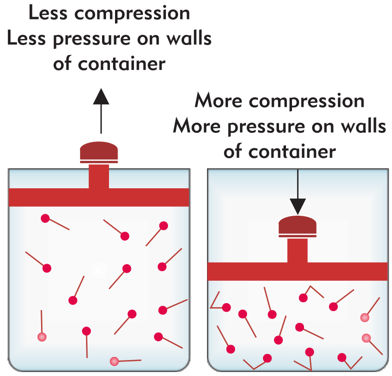


Fig 5.5

5.1.5 Mobility:

The ability to move freely is known as mobility. As the gas molecules are in continuous motion they can move fast due to high kinetic energy. The molecules move freely in the empty space .This mobility is responsible to produce a homogenous mixture of gases.

5.1.6 Density:

The Density is degree of compactness or closeness of a molecules. Gases have low density because of light mass and more volume occupied by the gas molecules. Gas density is expressed in grams per dm^3. Gases are less denser than liquids. The density of gases can be increased by cooling.

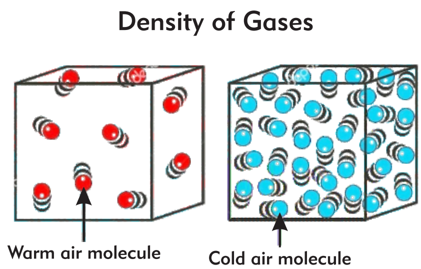


Fig 5.6

Table 5.1 Density of different gases

Gas	Chemical formula	Density Kg/m^3
Oxygen	O_2	1.407
Chlorine	Cl_2	3.120
Carbon dioxide	CO_2	1.935
Hydrogen	H_2	0.088
Nitrogen	N_2	1.232
Helium	He	0.176

Test Yourself

- Why gases diffuse rapidly, Explain?
- Why density of gases increases on cooling?
- Explain that Effusion depends on mean free path.

5.2 LAWS RELATED TO GASES

The properties of gases are governed by the following laws.

5.2.1 Boyle's Law:

In 1662 Robert Boyle proposed gaseous law about the relationship between volume and pressure of gas at constant temperature, Boyles law states that "The volume of a given mass of a gas is inversely proportional to applied pressure, at constant temperature "

Mathematical Representation of Boyle's Law:

According to Boyle's law the volume (V) of a given mass of a gas decreases with the increase of pressure (P) at constant temperature.

$V \propto 1/P$ Or $V = K/P$ where K= is the constant

$$PV = K$$

The product of pressure and volume of a fixed mass of a gas is constant at a constant temperature.

If	$P_1V_1 = K$	Then	$P_2V_2 = K$
Where	P_1 = initial pressure		P_2 = final pressure
	V_1 = initial volume		V_2 = final volume

As the both equations have same constant therefore their variable are also equal to each other so $P_1V_1 = P_2V_2$

This equation establish a relationship between pressure and volume. The relationship between volume and pressure can be well defined from following figure (5.7). Where given mass of a gas at constant temperature shows increase in volume by decrease in pressure. On the other hand increase in pressure decreases volume. But the product of pressure and volume is constant in both cases. (Table 5.2)

Table 5.2 Boyl's Relationship between pressure and volume

P (Change in pressure)		V (Change in Volume)		K (Constant pressure)
1.0	x	4	=	4
2.0	x	2	=	4

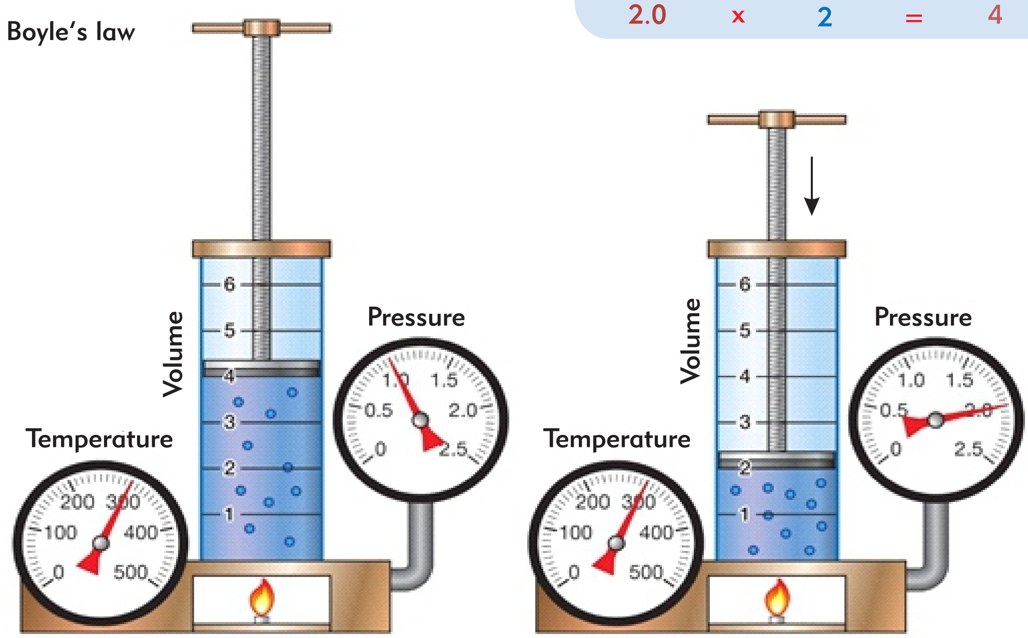


Fig 5.7

Examples 5.1

The pressure of a sample gas is 3 atm and the volume is 5 liters. If the pressure is reduced to 2 atm, what will be the new volume?

Data:

V_1 = 5 liter
P_1 = 3 atm
P_2 = 2 atm
V_2 = ?

Solution:

$$P_1V_1 = P_2V_2$$

$$V_2 = \frac{P_1V_1}{P_2}$$

$$V_2 = \frac{3\times5}{2}$$

$$V_2 = \frac{15}{2}$$

$$V_2 = 7.5 \text{ Litre}$$

The volume will be 7.5 liters.
The volume is increased by decreasing the pressure.

Examples 5.2

The 700 cm^3 of a gas is enclosed in a container under a pressure of 650 mm of Hg. If the volume is reduced to 350 cm^3, what will be the pressure then?

Data:

V_1 = 700cm^3
P_1 = 650mm Hg
V_2 = 350cm^3
P_2 = ?

Solution :

$$P_1V_1 = P_2V_2$$

$$P_2 = \frac{P_1 \; V_1}{V_2}$$

By putting the values P_2 = 650 × 700/350 = 1300mm of Hg

Thus pressure is increased by decreasing volume.

5.2.2 Charles' Law

In 1787 French scientist J.Charles proposed his law to explain the relationship between volume and temperature keeping the pressure constant. He states that "the volume of a given mass of a gas is directly proportional to the absolute temperature if the pressure is kept constant".

Mathematical Representation of Charles' Law:

According to Charles law if temperature of a gas is increased, its volume will also increase.

Mathematically it is represented as:

$$V \propto T$$

Or

$$V = KT$$

$$\frac{V}{T} = K$$

Where K is proportionality constant. When temperature increases the volume also increases.

For example, if we double the temperature from 300 K to 600 K, at constant pressure, the volume of a fixed mass of the gas will become double (Fig 5.8).

Do you know?

Absolute Temperature Scale

Lord Kelvin introduced absolute temperature scale or Kelvin scale.it starts from zero (0K which is equal to -273°C). It is the temperature at which an ideal gas would have zero volume and known as absolute zero. As Celsius and kelvin scales have equal degree range therefore zero kelvin is equal to -273 Celsius, and 273 kelvin is equal to zero Celsius.

Conversion of kelvin temperature and Celsius temperature are vice versa as follows:

$(T)K = (T)°C + 273$

$(T)°C = (T)K - 273$

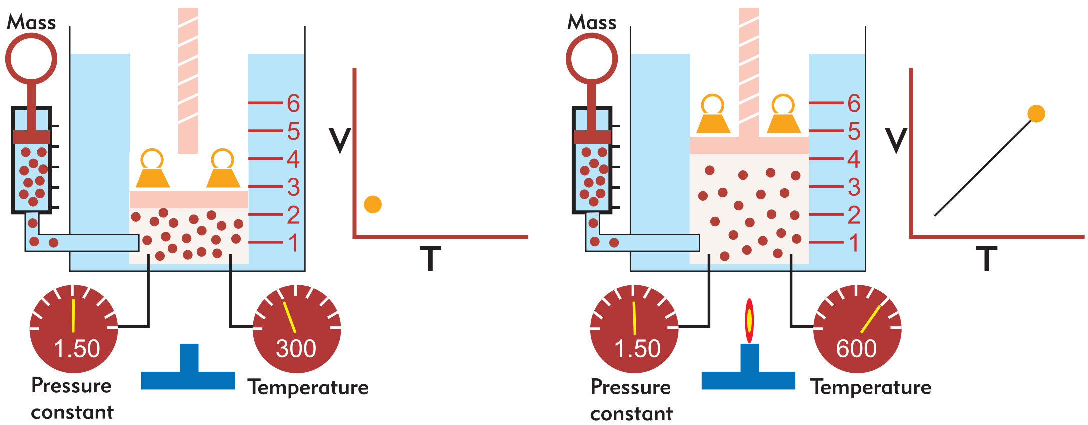


Fig 5.8

Imagine a gas at a certain temperature (T_1) and has volume (V_1). If change in the temperature (T_1) to a new value (T_2), occur then volume (V_1) changes to a new value (V_2). We can use Charles's law to describe both sets of conditions:

Initial State : $\frac{V_1}{T_1} = K$

Final State : $\frac{V_2}{T_2} = K$

The constant, k, is the same in both cases, therefore

Do you know?

Always convert temperature scale from °C to K while solving a problem.

K =273 + °C

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Examples 5.3

A 600 ml sample of gas is heated from 27 °C to 77 °C at constant pressure. What is the final volume?

Data:

$T_1 = 27°C = 27+273\ K = 300\ K$

$T_2 = 77°C = 77+273\ K = 350\ K$

$V_1 = 600ml$

Solution:

By using the equation

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

or

$$V_2 = \frac{V_1\ T_2}{T_1}$$

By putting the values in equation

$$V_2 = \frac{600 \times 350}{300}$$

$$V_2 = 700\ ml$$

The Volume will become 700 ml, which shows increase in volume with raising the temperature.

Examples 5.4

A sample of Hydrogen gas has a volume of 350 cm^3 at 40°C. If gas is allowed to expand up to 700 cm^3 at constant pressure. Find out its final temperature?

Data:

$T_1 = 40\ ^\circ C = 40 + 273\ K = 313\ K$

$V_1 = 350\ cm^3$

$V_2 = 700\ cm^3$

$T_2 = ?$

Solution:

By using the Charles' law equation

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

or

$$T_2 = \frac{V_2\ T_1}{V_1}$$

By putting the values

$$T_2 = \frac{700 \times 313}{350}$$

$$T_2 = 626\ K$$

The expansion in volume is due to increase in temperature.

Test Yourself

- Which variables are kept constant in Boyle's law?
- When a gas is allowed to expand, what will be the effect on its temperature?
- What is absolute zero temperature?
- Can you reduce temperature of a gas by increasing its volume?

5.3 LIQUID STATE

The liquid state is the intermediate between gaseous and solid states. According to their kinetic molecular theory liquid state shows following chractarstics.

- The molecules of a liquid are randomly arranged like gases.
- The molecules of liquids have less kinetic energy than gases.

- The molecules of liquids are fairly free to move.
- The Liquids has no definite shape but assumes the shape of container.
- The Boiling point of liquids depends on the external atmospheric pressure.
- The Liquids are denser and not compressible like gasses.

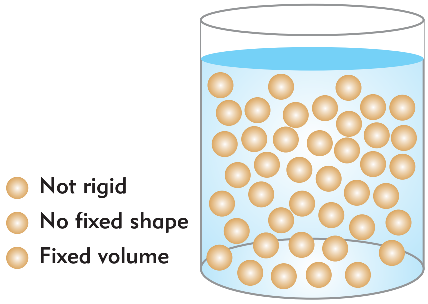
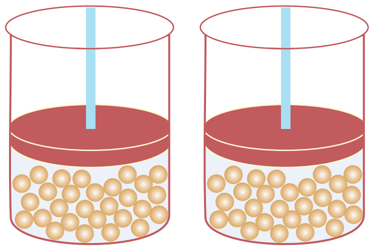


Fig 5.9



Liquid particles are very close together, so they are not compressed easily.

Fig 5.10

Properties of Liquids:

5.3.1 Evaporation

The process by which a liquid changes to a gas phase is called evaporation. Evaporation is endothermic reaction in which heat is absorbed.

For example clothes dry under the sun due to evaporation, in this process water is converted from liquid state into vapours by acquiring Heat.

Fig 5.11

Water (liquid) ⟶ vapour (gas)

The molecules of liquids are in continuous motion they collide with each other but all the molecules do not have same kinetic energy. Majority of the molecules have average kinetic energy and few have more than average kinetic energy. The molecules having more average kinetic energy overcome the attractive forces among the molecules and escape from the surface by evaporation. It is directly proportional to temperature and increase with the increase in temperature.

The evaporation is also considered as cooling process because when high kinetic energy molecules escape in the air in the form of vapours by taking energy from lower molecules as a result the energy of remaining molecules falls down. To compensate this deficiency of energy molecules absorb energy from the surrounding, due to which temperature of surrounding decreases and cooling occurs.

Factors Affecting Evaporation:

I. Surface Area: The evaporation is a surface based process. Greater the surface area greater is evaporation. For example water left in bowl evaporate slowly than water left in a large tub. A saucer is used to cool the tea quickly than tea cup.

ii. Temperature: The rate of evaporation increases with the increase in temperature. Because temperature increases the kinetic molecular energy which overcome the intermolecular forces and makes evaporation rapidly. For example clothes dry quickly in a sunny day than in a cloudy day.

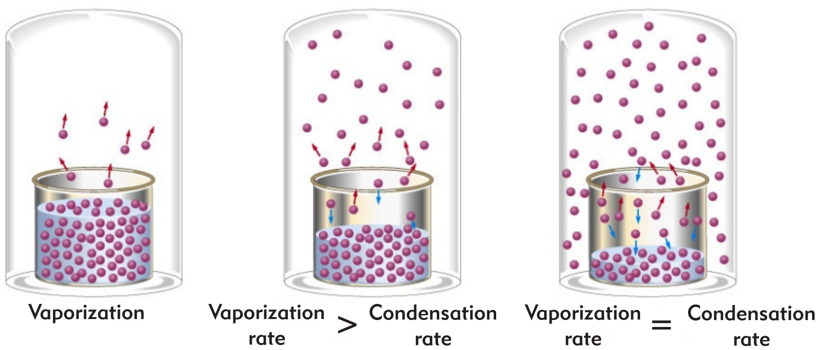
iii. Intermolecular Forces: The rate of evaporation increases with weak intermolecular forces .If intermolecular forces are stronger evaporation is lesser. For example perfume have weak intermolecular forces than water therefore it evaporates quickly.

5.3.2 Vapour pressure

The pressure exerted by vapours at equilibrium on its pure liquid state at a particular temperature is called Vapour Pressure. The equilibrium is a state when rate of evaporation is equal to rate of condensation but in opposite directions.

$$\text{Liquid} \underset{\text{Vaporize}}{\overset{\text{Condensation}}{\rightleftharpoons}} \text{Vapours}$$

Vapour pressure takes place in a closed system on heating because in open system or open surface liquid molecule evaporates and mix-up with air.



When a liquid is heated in a closed container evaporated molecules start gathering over the liquid surface. Initially the vapours condense slowly to liquid .After sometimes condensation process increases and a stage reaches when the rate of evaporation become equal to rate of condensation. At that stage, the number of molecules evaporate will be equal to the number of molecules condensate (coming back) to liquid . At this point, pressure exerted by the vapours on liquid is called vapour pressure. The unit of pressure is expressed in mm of Hg, atmosphere, torr or newton.

Factors Affecting Vapour Pressure:

i. **Nature of Liquid:** The vapour pressure depends upon the nature of liquids .Polar liquids have low vapour pressure than nonpolar liquids at the same temperature. It is because of strong intermolecular forces of molecules and high boiling point of polar liquids. For example water (polar liquid) has less vapour pressure than petrol (non polar liquid).

ii. **Size of Molecules:** The vapour pressure is more in small size molecules because small sized molecules evaporate easily and exert more vapour pressure. For example hexane (C_6H_{14}) has small sized molecules as compared to decane ($C_{10}H_{22}$), due to this hexane evaporate rapidly and exert more pressure.

iii. **Temperature:** The vapour pressure increases with raise in temperature. The average kinetic energy of molecules increases with temperature which causes increase in vapour pressure. For example vapour pressure of water at 0° is 4.58 mm Hg while at 100°C it increases up to 760mm Hg.

5.3.3 Boiling Point

The temperature at which vapour pressure of a liquid become equal to atmospheric pressure is called boiling point of that liquid. When the liquid is heated, bubbles begin to form throughout its volume. The bubbles (contain vapour pressure) which being lighter than the liquid, rise to surface and burst. The vapour pressure in bubble is equal to atmospheric pressure. All bubbles containing vapours will rise to the surface of the liquid and burst into air. It appears that water is boiling. The boiling point varies with the atmospheric pressure.

Factors Affecting Boiling Point:

i. **Atmospheric Pressure:** The boiling point is directly proportional to atmospheric pressure. Boiling point can be increased by increasing atmospheric pressure. For example working of pressure cooker.

ii. **Nature of Liquid:** The boiling point depends upon the nature of liquid as polar liquids have high boiling point than nonpolar liquids, because polar liquids have stronger intermolecular forces than nonpolar liquids. Boiling points of few liquids are given in table 5.3.

iii. **Intermolecular forces:** The intermolecular forces play very important role in the boiling points of liquids. Substances having stronger intermolecular forces have high

Table 5.3 Boiling Points of Some Common Liquids

S.No	Liquids	Boiling (°C)
1	Diethyl ether	34.6
2	Ethyl alcohol	78
3	Water	100
4	n-octane	126
5	Acetic acid	118
6	Mercury	356
7	Sulphuric Acid	330
8	Bromine	58.8

boiling points, because such liquids attain a level of vapour pressure equal to external pressure at high temperature.

5.3.4 Freezing Point:

The temperature at which the vapour pressure of a liquid state becomes equal to the vapour pressure of its solid state is known as Freezing Point of a liquid. At this temperature liquid and solid coexist in dynamic equilibrium.

Factors Affecting Freezing Point:

The freezing point depends upon the temperature and intermolecular forces. In comparison molecules with stronger intermolecular forces are pulled together to form a solid at higher temperature. Due to this they show high freezing point. Molecules with lower intermolecular forces solidify on more lower temperature.

Freezing points of few liquids are given in table(5.4)

Table 5.4 Freezing Points of Some Common Liquids

S.No	Liquids	Freezing point℃
1	Benene	5.12
2	Ethyle alcohol	-114
3	Water	0.0
4	Acetic acid	16.6
5	Mercury	-38.83
6	Sulphuric Acid	10.6
7	Bromine	-7.2

5.3.5 Diffusion:

The diffusion is defined as spreading out of the molecules throughout the vessel. The liquids diffuse less rapidly than gases.

As the molecule of liquid are in cluster and bounded with intermolecular binding forces, the liquid molecules roll over one another and are in continuous motion. They move from higher concentration to lower concentration and mix up with molecules of others liquids and may form homogenous mixture.

For example when few drops of ink are dropped in water filled flask, the molecules of ink move around and after a while spread in whole of flask, thus diffusion takes place as shown in figure 5.12

Fig 5.12

Factors Affecting Diffusion:

i. Inter molecular forces : liquids have weaker intermolecular forces than solid due to this they diffuses faster than solid but less rapidly than gases.

ii. Size of Molecules: Diffusion depends upon size of molecules small size molecules diffuses rapidly than bigger one. For example diffusion of methanol of (CH_3OH) is higher than ethanol (C_2H_5OH).

iii. Shape of molecules: Molecules with irregular shape diffuses slowly while regular shaped molecules diffuses faster because they can easily slip over and move faster.

iv. Temperature: Diffusion increases by increasing temperature because at high temperature intermolecular forces becomes weak due to high kinetic energy of the molecules.

5.3.6 Mobility:

The mobility is ability to move freely. The molecules in a liquid move freely, due to free movement they can adjust their shape in a container. Due to this reason liquids can flow.

Factors Affecting Mobility:

I. Temperature: Mobility increases by increasing the temperature. When temperature increases in a liquid movement of molecules increases accordingly.

ii. Inter molecular forces: Mobility increases by decrease in intermolecular forces. The liquids which have strong intermolecular forces show less mobility.

5.3.7 Density:

The Density of liquid is defined as mass per unit volume. Liquids are denser than gases due to closeness of molecules and small intermolecular spaces. As the molecules of liquids are close to one another, they have strong intermolecular forces they cannot expand freely and shows definite volume which makes liquids denser than gases.

Mathematically it can be expressed as $D = \frac{M}{V}$ $\begin{pmatrix} M = \text{mass} \\ V = \text{volume} \end{pmatrix}$

Factors Affecting Density:

I. Temperature: Density of liquids is slightly affected by the temperature as by increasing temperature liquids increase their volume which decreases density. Different densities of water at different temperature is given in Table 5.5

Table 5.5 Densities of water at different temperature

T (°C)	Density (g/cm^3)
0	0.99984
30	0.99565
60	0.98320
90	0.96535

ii. Pressure : Density of liquids is slightly affected by pressure .Increase in pressure on liquids increases the density, but liquids are not readily compressed due to this density change is negligible.

Test Yourself

- Why increase in temperature causes increase in the process of evaporation?
- Why rate of diffusion in liquids is less than gases? Prove with the help of examples.
- How equilibrium state involved in vapour pressure of liquids in close system? Explain how evaporation causes a cooling effect?
- How boiling point of a substance is affected by atmospheric pressure?

5.4 SOLID STATE

Solids have fixed shape and volume. The molecules in solids are extremely closer to each other, without having space between them. According to kinetic molecular theory solid state shows following characteristics.

- The molecules in solids are closely packed due to stronger forces of attraction.
- The molecules are unable to move freely as they have little space between them.
- The molecules can vibrates and rotate in their fixed position.
- Solids have definite shape and definite volume.
- Pure solids have sharp melting point.

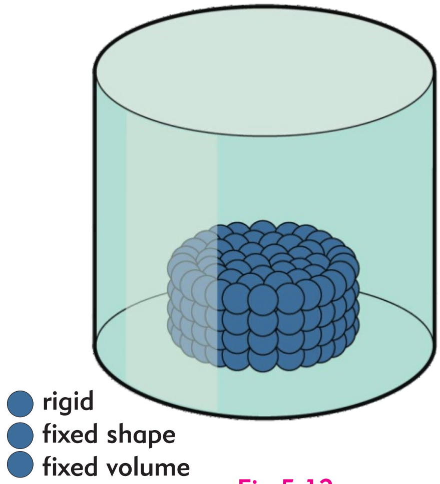


Fig 5.13

Properties of Solid

5.4.1 Melting Point:

The temperature at which a solid starts melting and coexist in equilibrium with liquid state is called melting point. when temperature is raised the kinetic energy of molecules increases. When continuous heat is supplied to solid, molecules leave their fixed position and become mobile, at this stage solid starts melting.

The melting points of different solids are given in table 5.6.

Table 5.6 Melting points of solids

S.No	Solids	Melting point °C
1	Sugar	185
2	Chocolate	36
3	Mercury	-38.83
4	Sodium chloride	801
5	Water	0

5.4.2 Rigidity:

The molecular arrangement of solids is closely packed due to this solids are not mobile. They exhibit vibration at fixed positions. Therefore solids are rigid in their structure.

5.4.3 Density:

The solids are typically denser than a liquid or a gas. Molecules in solid are more tightly packed together because of the greater intermolecular forces. Due to this reason solids have highest densities among three states of matter. Some densities are shown in table 5.7.

Table 5.7 Densities of solids

S.No	Solids	Density (g/cm^3)
1	Aluminum	2.70
2	Iron	7.86
3	Gold	19.3
4	Sodium chloride	2.16
5	Sugar	1.59

5.5 TYPES OF SOLIDS

The solids are classified on the basis of arrangement of molecules. There are two types of solids which are as follows.

i. Crystalline solids
ii. Amorphous solids

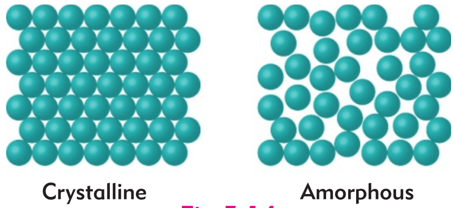


Fig 5.14

5.5.1 Crystalline Solids:

The solids in which molecules are arranged in definite three dimensional geomatrical pattern are called crystalline solids. The arranged molecules in solids are bounded biplane surface called faces which intersect each other at a particular angle. The melting point of crystals are sharp. Sodium chloride and diamond are common examples of crystalline solids.

Fig 5.15 sodium chloride

Fig 5.16 Diamond

5.5.2 Amorphous solids:

The solids in which molecules are not arranged in geometrical pattern are called amorphous solids. They do not have sharp melting point. Plastic ,rubber and glass are examples of amorphous solids.

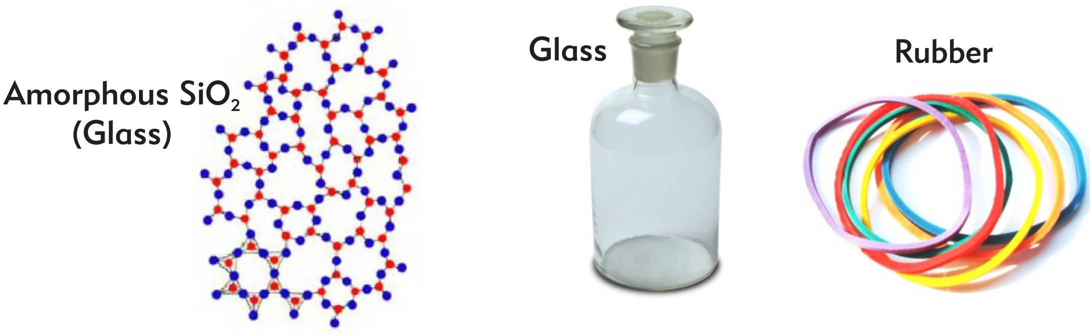


Fig 5.17

5.5.3 Difference between Amorphous and Crystalline Solids	
Amorphous Solids	**Crystalline Solids**
They don't have definite geometrical shape.	They have characteristic geometrical shape.
Amorphous solids do not have particular melting point. They melt over a wide range of temperatures.	They have sharp melting point.
Amorphous solids are isotropic.	Crystalline solids are anisotropic.
Amorphous solids are unsymmetrical.	Crystalline solids are symmetrical.
Amorphous solids do not break at fixed cleavage planes.	Crystalline solids break along particular direction at fixed cleavage planes into small pieces of same shape.

5.6 Allotropy

The existence of an element in more than one crystalline forms is known as allotropy. These forms of the element are called allotropes or allotropic forms. This happens when the atoms of the element are bonded together in a different way. Different bonding arrangements between atoms result in different structures with different physical properties. Only some elements like sulphur, phosphorus, carbon show allotropy.

For example, the allotropes of carbon include:

- Diamond, where the carbon atoms are bonded together in a four-cornered lattice arrangement.

Fig 5.18 Diamond

- Graphite, where the carbon atoms are bonded together in sheets of a six-sided lattice.

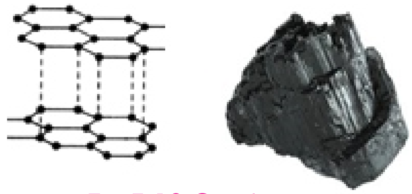


Fig 5.19 Graphite

- Graphene, single sheets of graphite.

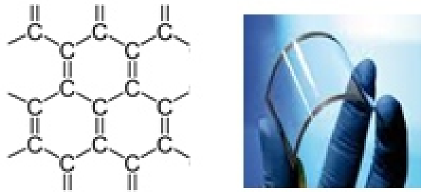


Fig 5.20 Graphene

- Fullerenes, where the carbon atoms are bonded together in spheres, cylinders or egg-shaped formations.

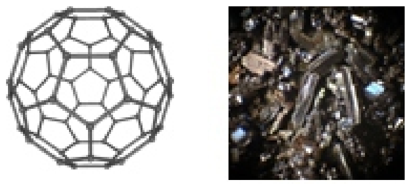


Fig 5.21 Fullerenes

5.7 Plasma State

English scientist William Crookes identify the fourth states of matter known as Plasma. It was discovered by adding energy to a gas. As a result some electrons left their atoms and formed positive and negative ions by ionization. In plasma these charged particles react strongly electric and magnetic fields. If plasma loses heat, the ions will re-form into a gas, emitting the energy which had caused them to ionize.

Fig 5.22

It means that plasma is distinct state of matter containing a significant number of electrically charged particles which affect its electrical properties and behavior.

Some examples of daily life are as follow:

- The lightning makes plasma naturally.
- The Artificial (man-made) uses of plasma include fluorescent light bulbs, Neon signs.
- The use of plasma display of television or computer screens.
- The plasma lamps and globes are popular in children's toys and room decoration.
- Scientists are experimenting with plasma to make a new kind of nuclear power, called fusion, which will be much better and safer than ordinary nuclear power with less radioactive waste.

Fig 5.23

5.8 Bose Einstein Condensate (BEC)

Two scientists Satyendra Bose and Albert Einstein discovered another state of matter in 1920 but they did not have the equipment and facilities to make it happens at that time. Afterward in 1995 two other scientists Eric Cornell and Carl Weiman also proposed another state of matter known as Bose-Einstein Condensate (BEC)

They discovered that as plasma are super-hot and super excited atoms. The atoms in a Bose-Einstein condensate (BEC) are totally opposite. They are super unexcited and super cold atoms.

Let's understand condensation first. Condensation happens when several gas molecules come together and form a liquid. It all happens because of a loss of energy. Gases are really excited or energetic atoms. When they lose energy, they slow down and come close to each other. They can gather into one drop.

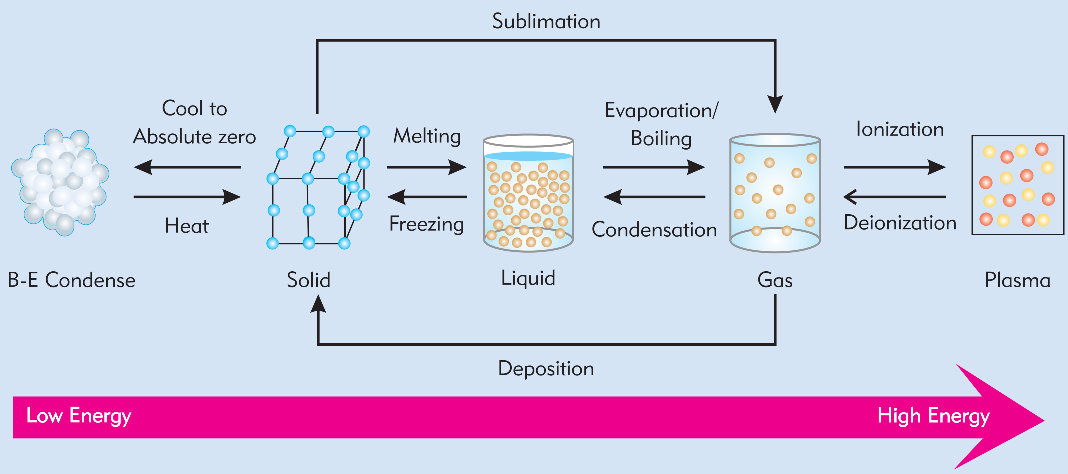
For example, when you boil water. Water vapour in the form of steam condenses on the lid of pot. Vapour cool and become a liquid again. You would then have a condensate.

Do you know?

Absolute Zero is a temperature where all the atomic activities stop theoretically.

The BEC happens at super low temperatures. When we get a temperature near absolute zero, all molecular motion stops due to depletion of energy, and atoms begin to clump. The result of this clumping is the BEC. In common we can not see this state in observable nature, because it is very difficult to reach at very low temperature under normal lab conditions.

Do you know?



Summary

- The states of matter are solid, liquid, gas, plasma, and BE condensate.
- The kinetic particle theory states that all matter is made up of tiny particles that are in constant random motion.
- Solids have fixed shapes and volumes. They cannot be compressed.
- Liquids do not have fixed shapes. They have fixed volumes and cannot be compressed easily.
- Gases do not have fixed shapes or volumes. They can be compressed.
- Boyle's law states that volume of a given mass of a gas is inversely proportional to the pressure at constant temperature.
- Charles law states that volume of a gas is directly proportional to the absolute temperature at a constant pressure.
- Diffusion is mixing up of a gas molecules throughout a space or other gases. Gases diffuse very rapidly.
- Effusion is escaping of a gas molecule through a fine hole into an evacuated space.
- The pressure exerted by vapours in equilibrium with its pure liquid at a particular temperature is called Vapour Pressure.
- The temperature at which vapour pressure of a liquid become equal to atmospheric pressure is called boiling point of liquid
- The Density of liquid depends upon mass per unit volume. Affected by temperature and pressure.
- The temperature at which a solid starts melting and coexist in equilibrium with liquid state is called melting point.
- Freezing point of a liquid is that temperature at which vapour pressure of a liquid state is equal to the vapour pressure of a solid state.
- Solids are rigid and denser than liquid and classified as amorphous and crystalline.
- Amorphous solids are shapeless and do not have sharp melting point.
- Crystalline solids have definite three dimensional pattern of arrangement of molecules.They have sharp melting point.
- The solids exist in different physical forms is known as allotropy.
- Plasma are super-hot and super excited atoms.
- The atoms in a Bose-Einstein condensate (BEC) are super unexcited and super cold atoms.

Exercise

SECTION- A: MULTIPLE CHOICE QUESTIONS

Tick Mark (✓) the correct answer

1. Which of the following gases diffuse fastest?
   (a) Hydrogen (b) Chlorine
   (c) Fluorine (d) Helium
2. The vapour pressure of a liquid increases with the:
   (a) increase of pressure
   (b) increase of temperature
   (c) increase of intermolecular forces
   (d) increase the polarity of molecules
3. The freezing point depends upon:
   (a) Nature of liquid (b) Pressure
   (c) Temperature (d) Volume
4. One atmospheric pressure is equal to:
   (a) 10325 Pascal (b) 106075 Pascal
   (c) 10523 Pascal (d) 101325 Pascal
5. Which of the following does not affect the boiling point :
   (a) Intermolecular forces (b) External pressure
   (c) Initial temperature of liquid (d) Nature of liquid
6. The mobility of liquids is lesser than:
   (a) Solids (b) Gases
   (c) Both a & b (d) None of these
7. Which of the following have sharp melting point in solids :
   (a) Plastic (b) Rubber
   (c) Glass (d) Diamond
8. Which of the following is the lightest form of matter:
   (a) Solid (b) Liquid
   (c) Gases (d) Plasma
9. The liquid molecules leave the surface of liquid in evaporation process because :
   (a) Energy is low (b) Energy is moderate
   (c) Energy is high (d) None of these
10. The density of gases increases when its :
    (a) Pressure increased (b) Temperature increased
    (c) Volume increased (d) None of these

SECTION- B: SHORT QUESTIONS:

1. Define the allotropy with examples?
2. What is Effusion, explain with the examples?
3. Define the following?
   Boiling Point, Melting Point, Freezing Point
4. What is density, how the density of liquid is affected by temperature and pressure?
5. Explain plasma with the daily life examples?
6. Justify that atoms of Bose Einstein condensate are super unexcited and super cooled?
7. How kinetic molecular theory differentiates states of matter?

SECTION- C: DETAILED QUESTIONS:

1. Discuss the property of evaporation in liquids? Which factors affects the evaporation process?
2. Describe the Boyl's law with example?
3. Differentiate between amorphous and Crystalline Solids?
4. Define and explain the Charles' law of gases?
5. Describe the process of diffusion in liquids? State the factors which influence it?
6. How boiling point is affected by different factors?
7. Define vapour pressure and justify that it is visible in a close system only?

SECTION- D: NUMERICALS

1. Convert the following units :
   (A)100°C to K (b) 150°C to K
   (c) 780K to °C (d) 170 K to °C
2. it is desired to increase the volume of a fixed amount of gas from 90.5 to 120 cm^3 while holding the pressure constant. What would be the final temperature if initial temperature is 33°C.
3. A 78ml sample of gas is heated from 35°C to 80°C at constant pressure. What is the final volume?
4. A gas occupies a volume of 40.0 dm^3 at standard temperature (0°C) and pressure (1 atm), when pressure is increases up to 3 atm at unchanged temperature what would be the new volume?
5. The 800 cm^3 of a gas is enclosed in a container under a pressure of 750 mm. If the volume is reduced to 250 cm^3, what will be the pressure?
6. The pressure of a sample gas is 8 atm and the volume is 15 liters. If the pressure is reduced to 6 atm, what is the volume?