PROPERTIES OF MATTER

UNIT -7

THE STATES OF MATTER

There are three states of matter, namely solids, liquids, and gases. We are used to finding some substances in each state in everyday life – for example, water is familiar as ice, as water as a stem.

DISTINGUISHING PROPERTIES OF SOLIDS, LIQUIDS AND GASES.

PROPERTY	SOLID	LIQUID	GAS
Intermolecular forces	strong	less strong	much weaker
Motion	vibrate about a fixed mean position; therefore, do not move through the body of the solid	vibrate and move freely at quite high speeds throughout the body of the liquid	move randomly and at high speeds
Intermolecular distance	molecules are very close together, and therefore gives the solid a rigid shape	molecules are slightly further apart than in a solid, and take the shape of the container which holds the liquid	molecules are very far apart, and therefore free to take up any space that is available to them
Compressibility	Almost Incompressible	Very Slightly Compressible	Highly Compressible
Comparative Density	High	High	Low

ENERGY CAN CHANGE THE STATE OF A MATTER.

Changing states of matter occur when matter loses or absorbs energy**:**

The terms for these changes in the state are:

Boiling: conversion from liquid to gas.
Condensing: conversion from gas to liquid.
Freezing: conversion from liquid to solid.
Evaporation: conversion from liquid to gas.

Evaporation is different from boiling. Evaporation is a process by which a liquid becomes a gas at temperatures below its boiling point.

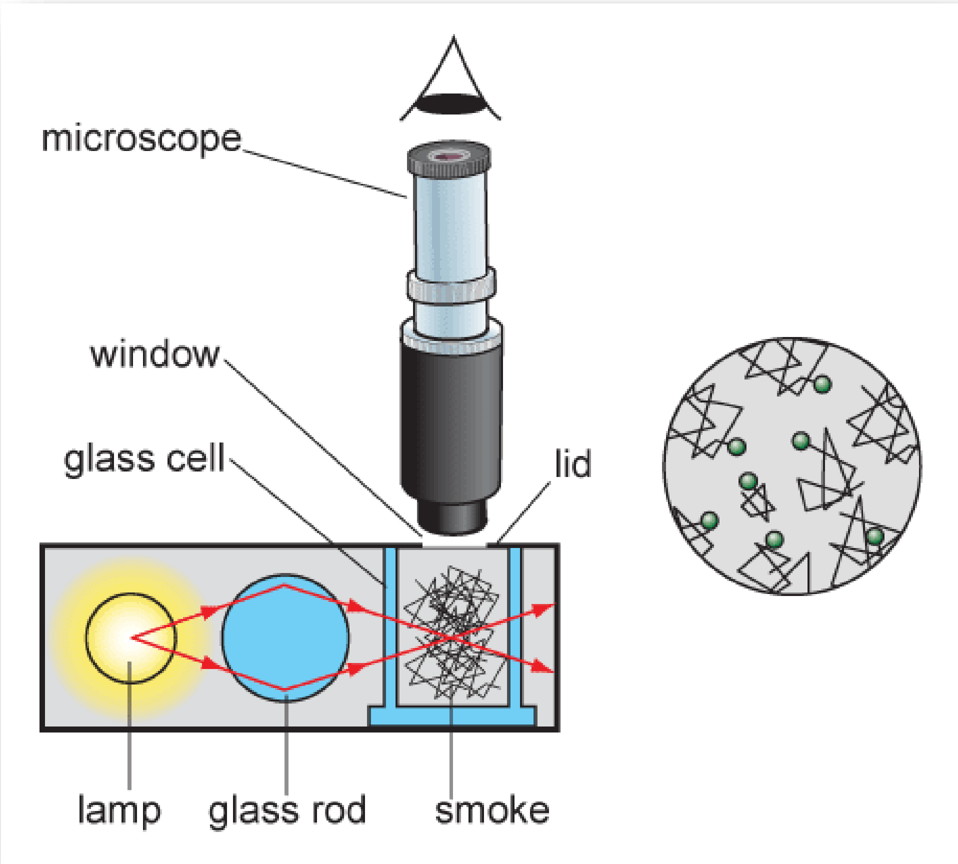
KINETIC MOLECULAR MODEL OF MATTER

The kinetic molecular model of matter is,

> Matter is made up of tiny particles called atoms, or groups of atoms called molecules. These molecules are always in continuous random motion.

BROWNIAN MOTION

The evidence of molecular motion was first discovered by the botanist Robert Brown in 1827. When he observed microscopic particles suspended in a fluid moving in a zigzag random way. Assemble the apparatus as shown in the following figure.



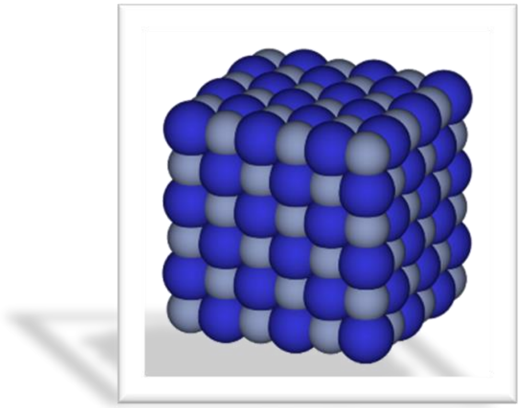
A simple modern version of Brown's experiment is the smoke cell. A small cell of air is placed under a microscope and illuminated strongly from the side. Some smoke is then blown into it. Through the microscope, the particles of smoke can be seen to be in violent random motion just like Brown's pollen grains.

THE KINETIC THEORY CAN BE USED TO DESCRIBE THE PHYSICAL STATES OF MATTER:

The Kinetic Theory of Matter states that matter is composed of a large number a small particles--individual atoms or molecules--that are in constant motion. This theory is also called the Molecular Theory of Matter

SOLID

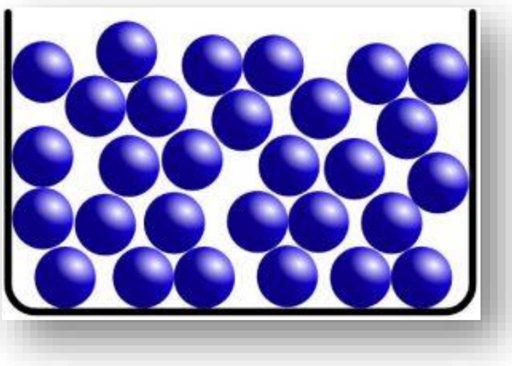
* A solid has a fixed volume and shape at a particular temperature unless physically subjected to some force.



* The greatest forces of attraction are between the particles in a solid and they pack together as tightly as possible in a neat and ordered arrangement.
* The particles are too strongly held together to allow movement from place to place but the particles vibrate about their position in the structure.
* With the increase in temperature, the particles vibrate faster and more strongly as they gain kinetic energy.

LIQUID

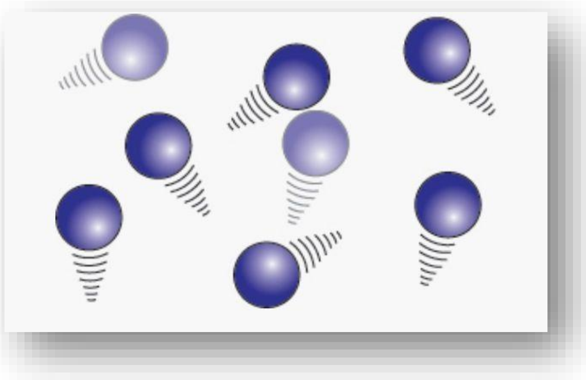
* A liquid has a fixed volume at a given temperature but its shape is that of the container which holds the liquid.



* There are much greater forces of attraction between the particles in a liquid compared to gases, but not quite as much as in solids.
* Particles are quite close together but still arranged at random throughout the container, there is a little close-range order as you can get clumps of particles clinging together temporarily.
* Particles move rapidly in all directions but more frequently collisions with each other than in gases due to shorter distances between particles.
* With the increase in temperature, the particles move faster as they gain kinetic energy, so increased collision rates, increased collision energy and increased rate of diffusion.

GAS

* A gas has no fixed shape or volume, but always spreads out to fill any container.



* There are almost no forces of attraction between the particles so they are completely free of each other.
* The particles are widely spaced and scattered at random throughout the container so there is no order in the system.
* The particles move rapidly in all directions, frequently colliding with each other and the side of the container.
* With the increase in temperature, the particles move faster as they gain kinetic energy.

FORCES AND KINETIC THEORY

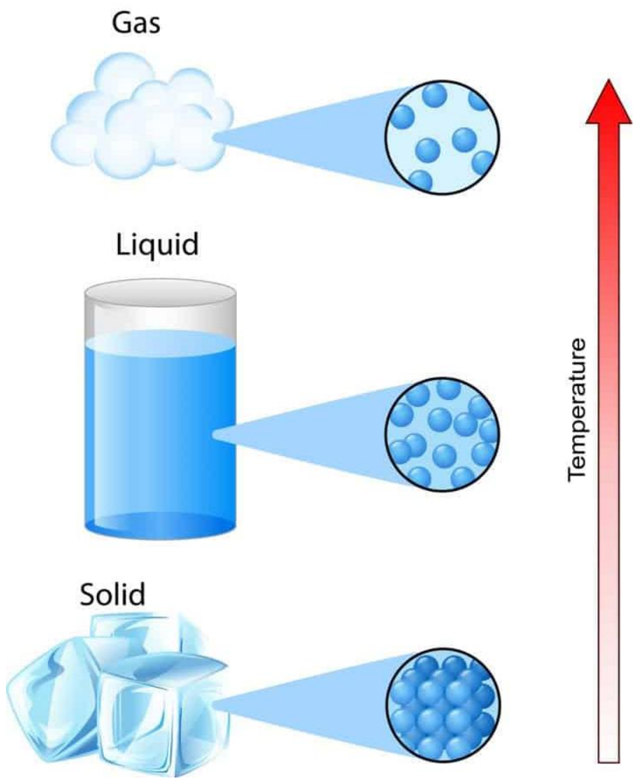
Forces between the molecules are responsible for the different states of matter as well as for the physical properties. According to the Kinetic molecular model, molecules of gases have large kinetic energy as a result, there are no forces of attraction between them, and as a result, molecules of gases can move freely and go farther apart. This is why gases can occupy any available space and can be compressed easily. The boiling and melting points of gases are also very low.

The molecules of liquids as compared to that of the gases have less kinetic energy hence, intermolecular forces come into play. That is why the molecules of liquids are very close to each other but still free to move. Therefore, liquids do not have a fixed shape but a fixed volume. The melting and boiling points of liquids are also high as compared to gases.

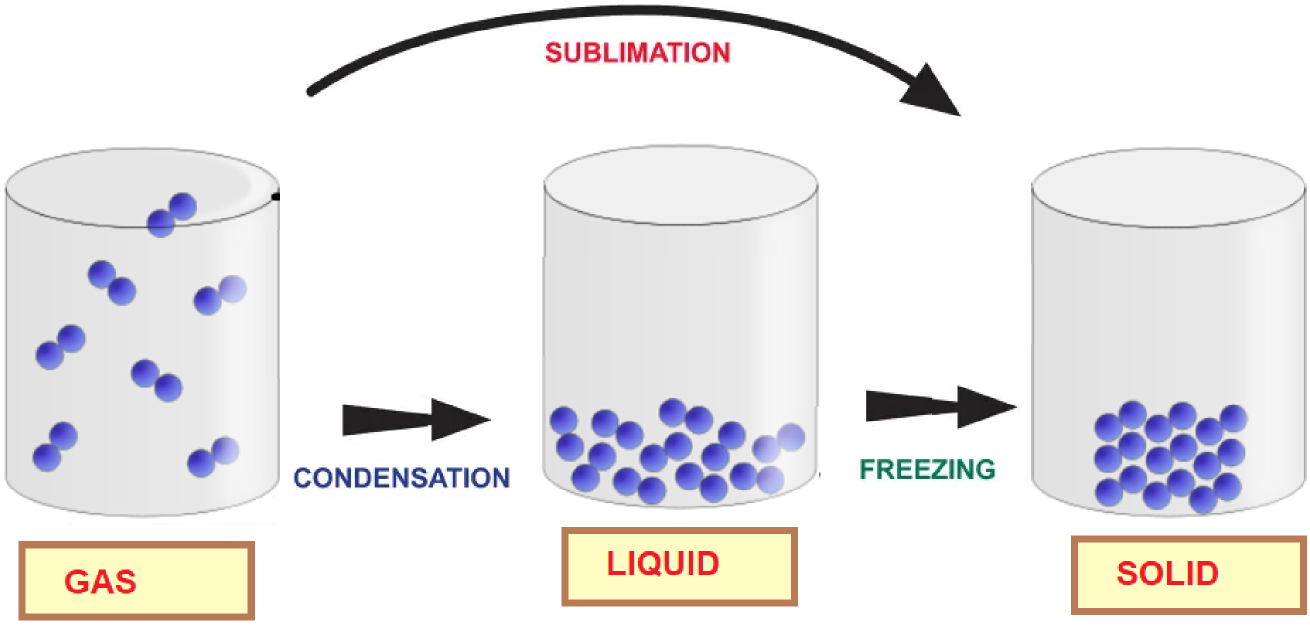
The molecules of solids have extremely lowest energies and, therefore, experience strong attractive forces and can not move freely but only have small vibrations about mean positions. This gives solid a fixed shape and volume. That is why densities and melting and boiling points of solids are very high.

STATE OF MATTER

The state of a substance can be changed either by heating or by cooling it. On the other hand, when a solid substance (Fig) is heated, the molecules start to vibrate more and more strongly. Eventually, the molecules vibrate more violently, and intermolecular forces become weak. As a result, 'material becomes a liquid,' if process of heating is continued further, then molecules have sufficient energy to overcome all of the attractive forces as a result 'substance becomes a gas'.

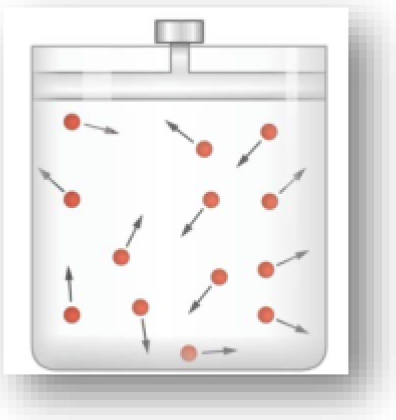


When a gas is cooled (Fig 7.4), the molecules move more slowly and collide with one another, may stick together, and the force of attraction between molecules increases. Keep cooling the gas, and eventually, all of the molecules will stick together to form a liquid. Further cooling will cause all the molecules to stick together to form a solid.



GASES AND THE KINETIC THEORY

Kinetic molecular theory clearly describes the properties and behavior of gases.



THE BEHAVIOR OF GASES

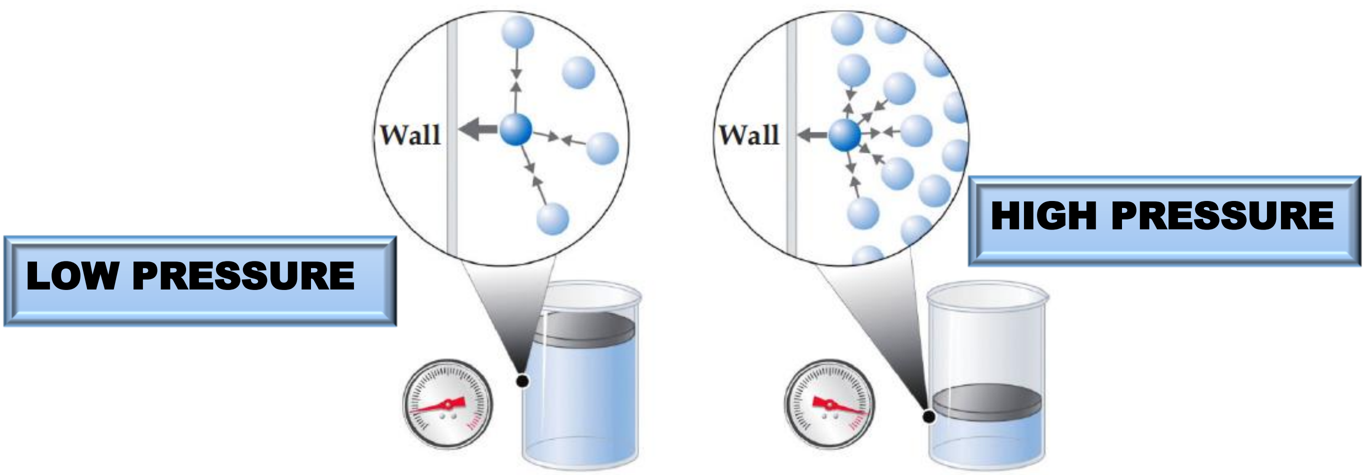
The molecules in the gases have a relatively large distance between them. The molecules in the gases move about very quickly. A gas molecule moves in a straight line. It changes its direction only when it collides with another gas molecule or with the walls of its container

PRESSURE

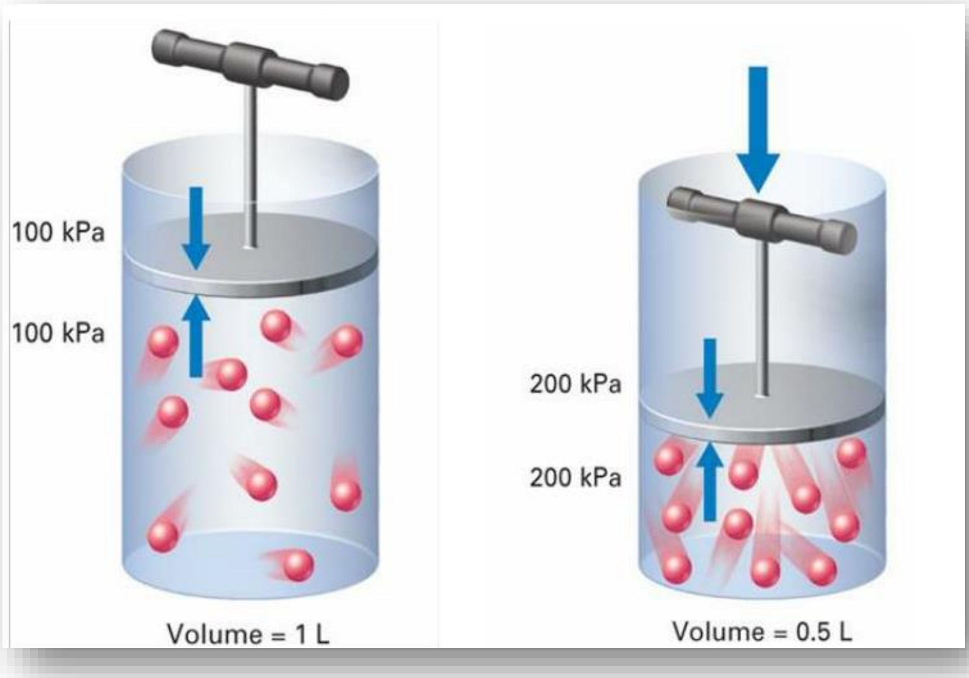
Pressure is defined as the force per unit area

$$Pressure = \frac{Force}{area}$$

All gases exert pressure on the walls of their container. This pressure is the total force exerted per unit area by the gas molecules during collision. The gas molecules exert pressure only when they collide with the walls. The number of collisions is proportional to the number of molecules.

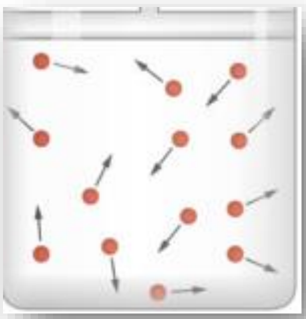


The pressure of a gas can also be increased by compressing it. This is done by reducing the size of the gas container. The gas molecules have been compressed into a smaller volume, so they will collide more frequently with the walls of the container and create more pressure. If the gas is compressed to half its original volume, its pressure will be doubled.



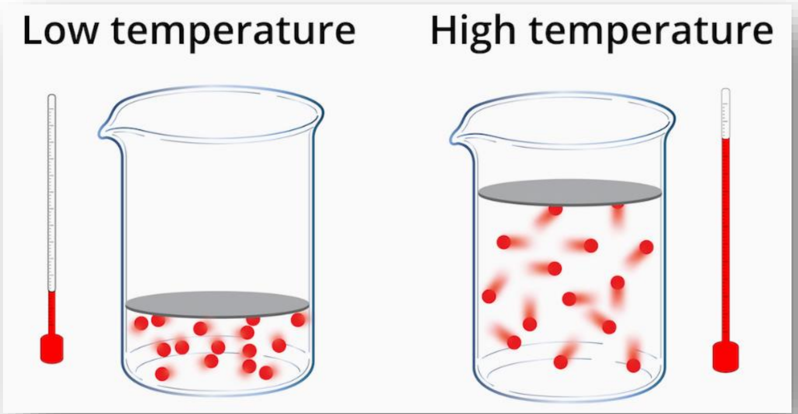
VOLUME

We know that the space occupied by substance is known as volume. The gas has no definite volume because the molecules of the gas are far away from each other and can move freely at high speeds. Therefore, gas always takes up the shape and volume of its container.



TEMPERATURE

The temperature of a gas is determined by the average translational kinetic energy of its molecules. If a gas is heated, the average translational kinetic energy of its molecules increases, and the temperature of the gas rises.



BOYLE'S LAW

In 1660 an English Scientist Robert Boyle presented the following law, which relates pressure & volume.

STATEMENT

The volume of a fixed mass of a gas is inversely proportional to its pressure, provided its temperature remains constant.

MATHMATICAL REPRESENTATION

$$V \alpha \frac{1}{P}$$

$$V = k \frac{1}{P}$$

$$PV = k$$

EXPLANATION

Let V_1 be the volume of gas enclosed in the vessel in first case A. Let the pressure exerted by the gas be P_1.

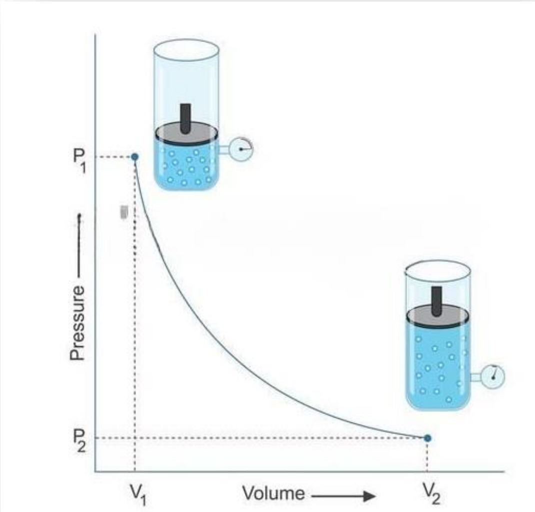
Now, let some pressure be applied to the gas. Let the new pressure be P_2. We can see logically that on application of the pressure, the volume shrinks. Thus, the volume decrease as pressure increases. This is shown in case B.

According to Boyle's law,

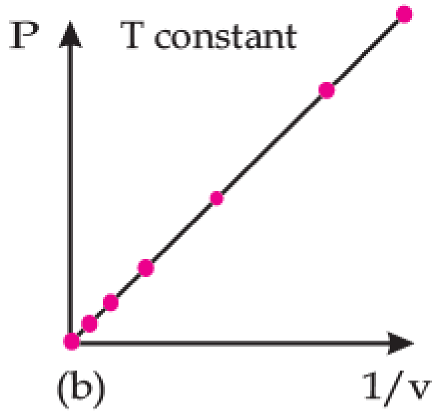
$$P_1V_1 = P_2V_2$$

GRAPHICAL REPRESENTATION

1. If the pressure of the gas is doubled, its volume becomes half.
2. The graph (Fig.7.10) between "p" and "V" between "p" and 1/V" is shown below:
3. The graph between "p" and "V" shows that if pressure increases, then volume decreases and vice-versa, i.e.



4. The graph between “p” and “1/V” shows a straight line passing through the origin.
5. At a constant temperature, the product of pressure and volume is constant. i.e. PV = constant



APPLICATIONS OF (P-V) RELATIONSHIP OF A GAS “BOYLE'S LAW

Some applications of the pressure-volume (p-V) relationship of a gas i.e. Boyle's law, are given below in Fig.

Spray paint Boyle’s law

The paint container contains two substances: one of them is the paint material itself, and the other is a compressed gas in a liquid state in the container. You press the sprayer, and the gas starts to get out of the container. the boiling state starts, the liquefied gas expands and turns into gas, and the gas presses the paint inside the container. The paint material is pushed up to get out of the sprayer nozzle with gas escaping from the container.

SYRINGE

One practical application of Boyle's law is drawing fluid into a syringe. Pulling back on the plunger increases the interior volume of the syringe and reduces its pressure. The fluid outside the syringe is sucked into the barrel until the interior and exterior pressure are balanced.

A BICYCLE PUMP

A bicycle pump is good example of Boyle’s law. As the volume of the air trapped in the pump is reduced, its pressure goes up, and air is forced into the tyre.

UNIT-7

MULTIPLE CHOICE QUESTIONS

BOOK- MCQs

1. An object with particles close together and vibrating describes a___________.
   a) Gas b) Liquid **c) Solid** d) All three
2. A burning candle is an example of ____________ state of matter.
   a) Gas b) Liquid c) Solid **d) All three**
3. During which process a gas becomes a liquid ______.
   a) Melting b) Freezing **c) Condensing** d) Boiling
4. A solid can __________________________ .
   a) have a fixed shape b) be easily compressed
   c) take a shape of container d) have freely moving molecules
5. According to kinetic molecular theory, the pressure exerted by a gas is caused by the ___________.
   a) bombardment of the gas molecules on the walls of the container.
   b) collision between gas molecules.
   c) large distances between gas molecules.
   d) random motion of the gas molecules.
6. If a gas is heated in a sealed cylinder, then_________ increases.
   a) pressure inside the container
   b) average kinetic energy of the particles
   c) temperature of the gas
   d) All of them
7. A gas in a container of fixed volume is heated. What happens to the molecules of the gas?
   a) They collide less frequently. b) They expand.
   c) They move faster. d) They move further apart.
8. In a liquid, some energetic molecules break free from the surface even when the liquid is too cold for bubbles to form. What is the name of this process?
   a) boiling b) condensation c) convection **d) evaporation**
9. What happens to the molecules of a gas when the gas changes into a liquid?
   a) They move closer and lose energy.
   b) They move closer and gain energy.
   c) They move apart and lose energy.
   d) They move apart and gain energy
10. A substance has a melting point of –17 °C and a boiling point of 117 °C. In which state does the substance exist at –10 °C and at 110 °C?

	at -10°C	at 110°C
a	Solid	liquid
b	solid	gas
c	liquid	liquid
d	liquid	gas

Ans = Liquid, Liquid

SELF ASSESSMENT QUESTIONS

Q1: Explain why the measurement of volume of a given liquid remains same although it is measured by measuring cylinders of different shapes and sizes.

Ans The volume of a given liquid remains the same because **volume is the amount of space occupied by the liquid** , and this does not depend on the shape or size of the measuring cylinder.

A liquid has a **definite volume** but no fixed shape. So when it is poured into different measuring cylinders, it changes shape to fit the container, but the **quantity of liquid is unchanged .**

.

Q2: What is the difference between evaporation and boiling?

FEATURE	**EVAPORATION**	**BOILING**
Occurs at	Any temperature below boiling point	At a specific boiling point
Location	Only at the surface of the liquid	Throughout the liquid
Rate of process	Slow	Fast
Heat requirement	Does not need external heat	Requires heat to reach boiling point
Formation of bubbles	No bubbles form	Bubbles of vapor form throughout liquid
Cooling effect	Causes cooling of liquid	No significant cooling effect

Q3: What is the difference between three states of matter? in terms of the spacing between the molecules.

ANS: **Solid:** Molecules are **very closely packed together** with very little space between them.

Liquid: Molecules are **close together** , but there is **more space between them than in a solid** . They can move/slide past each other.

Gas: Molecules are **far apart** with large spaces between them compared with solids and liquids.

Q4: Why Tungsten melts at a much higher temperature than iron?
ANS:

Tungsten melts at a much higher temperature than iron because the **forces between tungsten atoms are stronger** than those between iron atoms.
To melt a metal, enough heat energy must be supplied to overcome the forces holding its atoms in their solid lattice. Tungsten has **very strong metallic bonding** , so its atoms need much more energy to break free from their fixed positions. on the other hand, has weaker metallic bonds compared to tungsten. Therefore, tungsten has a much higher melting point than iron.

Q5: What is the name of process in which a liquid changes into a solid?
ANS:

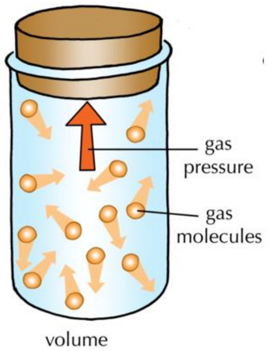
The process in which a liquid changes into a solid is called **freezing** or **solidification** .
Example: Water turning into ice.

Q6: What is the name of temperature at which a liquid changes into a solid?
ANS:

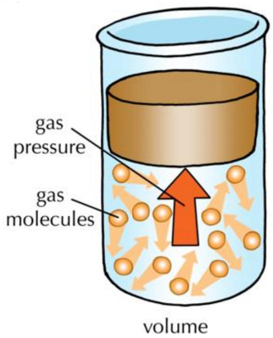
The temperature at which a liquid changes into a solid is called the **freezing point** . It can also be called the **solidification point**
Example: Water freezes at **0 °C**

Q7: Draw diagrams of the molecules in a gas to explain the effect of pressure change on its volume.

1. **Low Pressure (High Volume)**
   - Molecules are far apart.
   - Sketch: Draw a big box with a few dots spread out inside.
   - Label: “Low pressure → molecules have more space → volume is large.”



2. **High Pressure (Low Volume)**
   - Molecules are closer together.
   - Sketch: Draw a smaller box with dots crowded together.
   - Label: “High pressure → molecules compressed → volume decreases.”



Explanation:

When pressure on a gas is increased, the particles are pushed closer together, so the volume decreases.

When pressure is decreased, the particles can spread out, so the volume increases.

This relationship is described by **Boyle's law** :

$$P \times V = \text{constant}$$

Q8: What is the meant by the subscripts 1 and 2 in the equation, $P_1 V_1 = P_2 V_2$

P_1= initial pressure

V_1= initial volume

P_2= final pressure

V_2= final volume

This is **Boyle's Law** , which relates the pressure and volume of a gas **before and after a change** , assuming temperature is constant.

Q9: What is the effect of temperature on average translational kinetic energy of molecules?

ANS:

The **average translational kinetic energy** of molecules is **directly proportional to the absolute temperature** of the gas

$$(K.E)_{avg} = \frac{3}{2} kT$$

$$(K.E)_{avg} \ \alpha \ T$$

Effect:

- If the **temperature increases** , molecules move faster and their average kinetic energy increases.
- If the **temperature decreases** , molecules move more slowly and their average kinetic energy decreases.

STRUCTURED QUESTIONS

KINETIC MOLECULAR MODEL OF MATTER

1. a) "The particles are free to move within the material, has a fixed volume but takes up the shape of its container", which state of matter is being described here?
   b) Write a similar description of the particles that make up a solid.
   c) Write down any two properties of a solid.

ANS:

a) Particles are free to move is not a solid. Fixed volume is not a gas. Takes the shape of the container is the characteristic of a liquid .

b) Particles in a solid are closely packed together , vibrate in place , and cannot move freely . Solids have a fixed shape and fixed volume .

c) The two properties of a solid are given as
   1 Solids have a fixed shape .
   2 Solids have a fixed volume .

2. a) Why the kinetic model of matter is called kinetic?
   b) In which state of matter the molecules are widely separated?
   c) In which state of matter the molecules are most closely packed?
   d) In which state of matter molecules can move freely at high speed?

ANS:

a) The kinetic model explains matter in terms of motion of particles . "Kinetic" comes from movement —the particles of matter are always in motion , whether vibrating, sliding past each other, or moving freely. That's why the kinetic model of matter is called kinetic

b) Molecules are widely separated in a gas

c) Molecules are **very close together** in a **solid** , so solids have a **fixed shape and volume**

d) Molecules move freely and quickly in a gas. The Liquids move freely too, but not as fast as gases

3. a) By using kinetic molecular theory explain why we can walk through air, swim through water but can not walk through a solid wall.
   b) In which state of matter do the molecules have minimum kinetic energy?
   c) Which state of matter is highly incompressible?

ANS:

a) We can understand why we can walk through air, swim through water, but cannot pass through a solid wall by thinking about how particles behave in different states of matter. In gases, like the air around us, the particles are very far apart and move freely, That is why we can easily move through air without feeling resistance. In liquids, such as water, the particles are closer together than in gases but they are not fixed in place; they can slide past each other. This is why we can push our hands or swim through water. In **solid,** Particles are

tightly packed and vibrate only in place, leaving **no space to pass through.** we **cannot walk through a solid wall.**

b) The kinetic energy of particles also depends on how much they move. In solids, particles vibrate only slightly in their fixed positions, so their kinetic energy is the lowest compared to liquids and gases.

c)

- Incompressibility means the volume cannot be easily reduced
- Solids and liquids are closely packed , but liquids can flow to fill a container, so slightly compressible under high pressure
- Solids are the most incompressible , because particles are tightly packed and fixed

.

FORCES AND KINETIC THEORY

4. A sample of a gas is in a sealed test tube is cooled. Describe what happens to:

a) The size of the molecules.
b) The speed at which molecules move.
c) The number of the molecules.
d) The pressure inside the tube.
e) The state of the gas.

ANS:

a) The size of the molecules **does not change significantly** .

Reason: Molecules themselves are rigid structures; cooling affects their motion, not their actual dimensions. Even at very low temperatures, the molecules remain essentially the same size.

b) The speed of the molecules **decreases** .

Reason:

Temperature is a measure of the average kinetic energy of molecules. Lowering the temperature reduces kinetic energy, so molecules move more slowly.

c) The number of molecules **remains the same** .

Reason:

The test tube is sealed, so no molecules can enter or leave. Cooling does not create or destroy molecules.

d) The pressure **decreases** .

Reason:

Gas pressure is due to molecules colliding with the walls of the container. Slower-moving molecules (from cooling) hit the walls less forcefully and less frequently, reducing pressure.

e) The gas remains a gas initially , but if cooled enough, it may condense into a liquid .

Reason:

Cooling reduces kinetic energy. At sufficiently low temperatures, the attractive forces between molecules can dominate, leading to condensation and changes into gas.

5. An inflated car tyre is considered to have a constant volume, regardless of any changes in temperature or pressure. Use the kinetic molecular theory of gases to answer the following:

a) How does air in the tyre exert a pressure on the walls of the tyre?

b) Why is the pressure the same at all points on the inside wall of the tyre?

c) More air is pumped into the tyre while the temperature is kept constant until there are twice as many molecules as before. Explain why you would expect the pressure to be doubled.

ANS:

a) According to the kinetic molecular theory, air molecules are in constant random motion. As they move, they collide with the inside walls of the tyre. The total force from the huge number of molecular collisions per unit area produces the **pressure** on the tyre wall.

b) The air molecules move randomly in all directions and spread out to fill the whole tyre. Since the gas is uniform throughout the tyre, the number of molecules hitting each equal area of the wall per second is the same on average. Therefore, the force per unit area is the same everywhere, so the pressure is the same at all points on the inside wall.

c) If twice as many molecules are pumped into the same tyre volume, there will be twice as many molecules colliding with the walls each second. Since each molecule has the same average kinetic energy and produces the same average effect per collision, the total force on the walls doubles.

$$P \; \alpha \; N$$

where N is the number of molecules. Therefore, if the number of molecules is doubled, the pressure is doubled.

6. Describe the following:

a) What happens to the motion of the molecules of a gas when it cools down?

b) What happens to the motion of a liquid when it cools down?

ANS:

a) When a gas cools, its molecules have **less kinetic energy** , so they move **more slowly on average** . They collide with each other and with the container walls **less energetically** .

b) When a liquid cools, its molecules also have **less kinetic energy** . They still move around each other, but they move **more slowly** and become less able to slide past one another. If cooled enough, the liquid may **freeze** , and the molecules then only **vibrate about fixed positions** in a solid structure.

GASES AND KINETIC THEORY

7. The pressure on 9cm^3 of oxygen gas is doubled at a fixed temperature. What will its volume become?

ANS:

DATA

P_1 = 9 cm^3

V_1 = V

V_2 = 2 V

P_2 = ?

SOLUTIONS

$$P_1 V_1 = P_2 V_2$$

$$(9)(V) = P_2 (2V)$$

$$9 = P_2 \; x \, 2$$

$$\frac{9}{2} = P_2$$

$$4.5 \; cm^3 = P_2$$

8. A container holds $30m^3$ of air at a pressure of 150000Pa. If the volume changed to $10m^3$ by decreasing load on the piston. What will the pressure of the gas become? Assume that its temperature remains constant.

DATA

$V_1 = 30 \; m^3$

$P_1 = 150000$ Pa

$V_2 = 10 \; m^3$

$P_2 = ?$

SOLUTIONS

$$P_1 V_1 = P_2 V_2$$

$$(150000)(30) = P_2 (10)$$

$$450000 = P_2$$

9. Air at atmospheric pressure of 760 mm of Hg is trapped inside a container available with a moveable piston. When the piston is pulled out slowly so that the volume is increased from 100 dm^3 to 150 dm^3, the temperature remaining constant. What will be the pressure of the air becomes?

DATA

$P_1 = 760$ mm

$V_1 = 100 \; m^3$

$V_2 = 150 \; m^3$

$P_2 = ?$

SOLUTIONS

$$P_1 V_1 = P_2 V_2$$

$$(760)(100) = P_2 (150)$$

$$\frac{76000}{150} = P_2$$

$$506.7 \; mm \; Hg = P_2$$