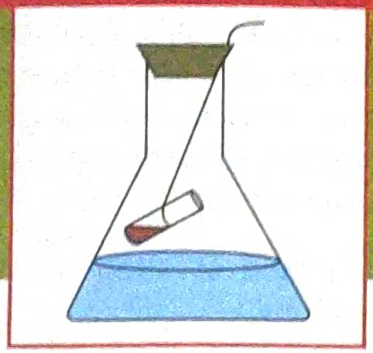


Matter

1

Theme : Matter is composed of atoms/molecules and is found as solid, liquid and gas. These states are changed on the basis of interparticle space and interparticle collisions. Kinetic theory of matter has been postulated to explain the change of state. In a physical and chemical change, the total mass before and after the change remains the same which is known as the law of conservation of mass, which would help in understanding the behaviour of matter.

In this chapter you will learn :

- *Nature of matter.*
- *Main postulates of kinetic theory of matter.*
- *Interparticle space, interparticle attraction and collision.*
- *Law of conservation of mass (statement and explanation with examples).*
- *Interconversion of states of matter.*

LEARNING OUTCOMES

The children will be able to :

- describe the main postulates of kinetic theory of matter.
- explain the reason of change of one state of matter into another and vice-versa.
- define and explain the law of conservation of mass using an example.

INTRODUCTION

We know that chemistry is the branch of science that deals with the study of various kinds of **matter**, which includes their structure, composition and physical and chemical properties.

If we look around us, we see a number of things like, stones, sand, clay, water, minerals, plants, animals, pens, pencils, books, etc. They are all made up of different types of materials and are called **"matter"** in science.

In fact, matter includes all living and non-living things of which the universe is composed of.

WHAT IS MATTER ?

"Matter is anything which has mass, occupies space and can be perceived by our senses."

There are different kinds of matter.

- A book is made up of paper.
- A bag is made up of plastic.
- A dress is made up of cloth.
- A hammer is made up of iron.

Air which we cannot see is also a kind of matter because we can feel it.

- If you blow air in a balloon, it gets inflated because air occupies space.
- If you switch on the fan, you feel air due to the movement of fan.

Thus, air, water, sugar, sand, oxygen, hydrogen, steel, coal, iron, wood, alcohol, milk, oil, etc. are all different kinds of matter because they have mass and occupy space.

MATTER OFFERS RESISTANCE TOO

If you try to walk during an air storm or lift a big stone, you experience some resistance.

WHAT IS MATTER MADE UP OF ? [NATURE OF MATTER]

Ancient philosophers had different beliefs about the nature of matter.

Greek philosophers believed that all kinds of matter are made up of fire, water, air and earth. While ancient Indian philosophers believed that all kinds of matter are made up of five elements — sky, air, fire, water and earth.

Maharshi Kannada, an Indian philosopher was perhaps the first to suggest that matter is made up of very tiny particles called anu (molecule) which is formed of further smaller particles called parmanu (atom).

Parmanu was named as atom by a Greek thinker Democritus.

Later on, John Dalton also suggested that all kinds of matter are made up of extremely small particles called atoms.

An atom is the smallest particle of matter that exhibits all the properties of that matter. They usually do not have independent existence, therefore they combine with each other to form small particles called molecules. These molecules have independent existence.

Both these particles (atoms and molecules), are too small to be seen through a naked eye or through an ordinary microscope.

However, the number of particles in matter can be very large. *Example :* a drop of water contains 10^{21} particles of water.

CHARACTERISTICS OF MATTER

1. Particles of matter are very small : To show this, the following experiment is carried out.

Activity 1

Dissolve two or three crystals of blue vitriol (copper sulphate pentahydrate) in about 10 ml of water to get a clear transparent blue solution. Take four beakers and label them as

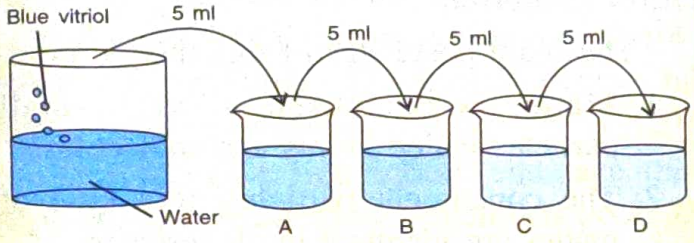
A, B, C and D. Fill each beaker with 50 ml of water. Now transfer 5 ml of solution to beaker A and stir it properly to get a uniform blue colour. Take 5 ml of solution from beaker A, transfer it to beaker B and stir well. Again transfer 5 ml of solution from B to C and then from C to D.

What do you observe ?

The solutions in all the beakers are coloured though they become fainter due to successive dilution.

Thus it is concluded that a small crystal of blue vitriol contains a very large number of tiny particles which show all the properties of the substance.

The whole process can be repeated for potassium permanganate crystals or ink to prove the nature of a particle.



The colour of the solution gets fainter with successive dilution.

2. Particles of matter have interparticle space between them.

Activity 2

Take 100 ml of water in a graduated cylinder and add 20 grams of sodium chloride to it. Dissolve the salt in water by proper stirring with the help of a glass rod. When all the salt has dissolved in water, you will notice that there is no increase in the level of water in the cylinder.

This shows that there must be some **space between the particles of water** in which the salt particles get accomodated when dissolved.

The space between the particles is called **interparticular space** or **intermolecular space.**

3. Particles of matter are in constant random motion : This can be proved by the following :

Brownian motion : Robert Brown gave the evidence for the existence and movement of particles in liquids. He suspended some pollen grains in water and looked into the water through a magnifying glass. He observed that the pollen grains were moving throughout the water in a zig-zag or irregular manner.

Why were the pollen grains moving in an irregular manner ?

This is because water is made up of tiny particles which are also in random motion. The pollen grains move in such a way because they collide with the moving particles of water.

This haphazard, random motion of suspended particles on the surface of a liquid or in air is called **Brownian motion**.

Since this phenomenon was first noticed by Robert Brown, it is called as Brownian motion.

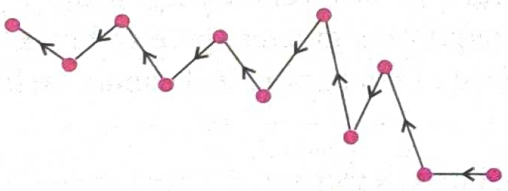
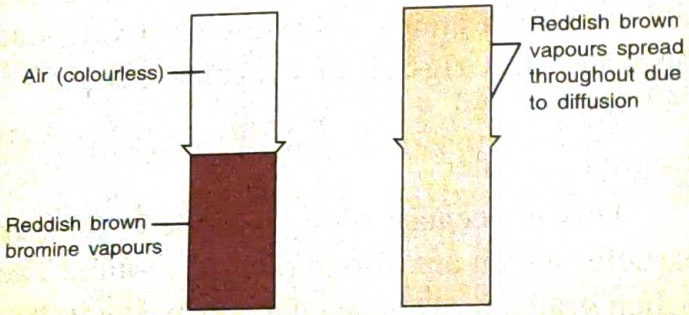


Fig. 1.1 Brownian motion

Diffusion : The intermixing of two or more substances due to the motion of their particles in order to get a uniform mixture is called **'diffusion'**. The rate of diffusion is the fastest in gases and the slowest in solids. It increases with an increase in temperature.

Activity 3

Take a gas jar full of bromine vapours (reddish brown) and invert another gas jar containing air over it. It is observed that after sometime, the reddish brown vapours of bromine also spread out into the upper jar. This mixing is called diffusion.



4. Particles of matter attract each other : There exists a force of attraction between the particles of matter which keeps them together. But the magnitude of force varies from one type of matter to another.

For example : A piece of chalk can be broken into pieces very easily while a piece of coal requires a greater force to break and a metal piece of copper or steel cannot be broken easily.

STATES OF MATTER

The magnitude of intermolecular force of attraction, intermolecular space and random motion of molecules of matter lead to the three main states of matter :

Solids, liquids and gases

Solids : A solid has a definite shape and a definite volume. *Example :* wood, stone, iron, ice, etc.

Liquids : A liquid has a definite volume but no definite shape. *Example :* water, alcohol, mustard oil, fruit juice, milk, etc.

Gases : A gas has neither a definite shape nor a definite volume. *Example :* air, hydrogen, oxygen, water vapour, etc.

KINETIC THEORY OF MATTER

The theory stating that any substance whether solid, liquid or gas is made up of tiny particles called atoms, molecules or ions which are in constant motion is called **"kinetic theory of matter"**.

The main postulates of this theory are :

1. Matter is composed of very small particles called atoms and molecules.
2. The constituent particles of a kind of matter are identical in all respects.
3. These particles have spaces or gaps between them which are known as interparticular or intermolecular spaces.
4. There exists a force of attraction between the particles of matter which holds them together. This force of attraction is known as interparticular or intermolecular force of attraction.
5. Particles of matter are always in a state of random motion and possess kinetic energy, which increases with an increase in temperature and vice-versa.

EXPLANATION OF STATES OF MATTER BASED ON KINETIC THEORY

Solid state : In solids, the particles (molecules) are closely packed. There is a strong force of attraction between the particles (molecules) and the intermolecular space is almost negligible. The molecules are therefore not free to move. They only vibrate about their mean positions.

This makes solids hard and rigid and difficult to compress, giving them a fixed shape and size. Solids have low kinetic energy.

Liquid state : In case of liquids, the particles are not very closely packed. The intermolecular forces of attraction are not as strong as in the case of solids, thus the intermolecular spaces are larger. The molecules are loosely packed, hence liquids are more compressible. The particles are able to move freely and randomly. The kinetic energy is higher than that of solids.

This makes a liquid flow and take the shape of the container into which it is poured. Thus, liquids have a fixed volume but no definite shape.

Gaseous state : In case of gases, the intermolecular forces of attraction are negligible. The particles lie far apart from each other and the intermolecular spaces are therefore, very large. Hence they can be compressed. The forces of attraction are so weak that the particles of gases are free to move within the entire space available to them. They have high kinetic energy. During motion, these particles collide with each other and also with the walls of the container. As a result, gases have neither a fixed shape nor a fixed volume. They completely fill up the space available to them.

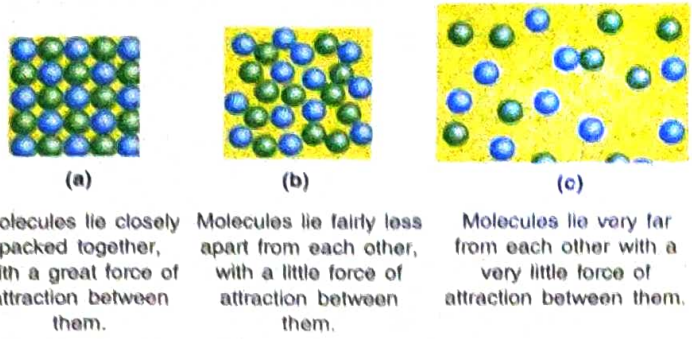


Fig. 1.2 The position of molecules in the (a) solid, (b) liquid and (c) gaseous states.

Note : All substances that can flow are called **fluids**. Both gases and liquids are fluids. If a container having a liquid or a gas is opened, they both can flow out of the container. Gases can flow in all directions freely, but liquids cannot flow upwards or against the gravity on their own.

Table 1.1 Properties of solids, liquids and gases.

S.No.	Property	Solids	Liquids	Gases
1.	**Mass**	Definite	Definite	Definite
2.	**Shape**	Definite	No fixed shape.	No fixed shape.
3.	**Volume**	Definite	Definite	Indefinite
4.	**Packing of particles**	Very closely packed.	Less closely packed.	Least closely packed.

5.	**Intermolecular forces of attraction**	Strongest	Weaker than in solids	Weakest
6.	**Intermolecular space**	Least	More	Most
7.	**Fluidity**	Not possible	Can flow	Can flow
8.	**Compressibility**	Not possible	Negligible	Highly compressible
9.	**Rigidity**	Highly rigid	Less rigid	Not rigid
10.	**Kinetic energy**	Lowest	Higher	Highest

INTERCONVERSION OF STATES OF MATTER

"The phenomenon of change of one state of matter into another and then back to the original state, without any change in its chemical composition is called **interconversion of the states of matter**.

The change in the state of matter is caused by –

(i) change in temperature

(ii) change in pressure

Change of state of matter by changing the temperature

When a substance in solid state is heated, it changes into liquid state after sometime. On further heating, the liquid changes into gaseous state. On cooling, just the reverse happens.

$$\text{Solid} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \text{Liquid} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \text{Gas}$$

This can be explained by the following examples :

- Water is a liquid under ordinary conditions but when it is kept in a deep freezer, it gets cooled and changes into ice at 0°C. Ice when kept at room temperature, again changes back into liquid water.

Similarly water on heating changes into steam at 100°C, which on cooling changes back into liquid water. But there is no change in the chemical composition of water when its state changes from liquid to solid or liquid to gaseous state.

$$\underset{\text{(solid)}}{\text{Ice}} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \underset{\text{(liquid)}}{\text{Water}} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \underset{\text{(gas)}}{\text{Steam}}$$

Another example is candle wax. When candle is burnt, the solid wax melts into liquid wax. On cooling, the molten wax again changes back into solid wax.

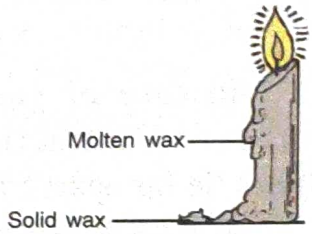


Fig. 1.3 Interconversion of the states of matter (wax) in a candle

$$\text{Solid wax} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \text{Liquid wax}$$

How and why do the changes take place ?

This can be explained as follows : When a substance in solid state is heated, its

constituent particles gain kinetic energy and start vibrating more vigorously. Eventually, a stage is reached at which particles gain enough energy to overcome the forces of attraction between them and they start moving, thus changing into liquid state from the solid state. On further heating, more kinetic energy is acquired, the forces of attraction become almost negligible, increasing the intermolecular spaces and ultimately the liquid state of matter changes into its gaseous state.

When cooling is done, the kinetic energy decreases. Thus, the spaces between the particles decrease and the forces of attraction increase. This also affects the movements of particles. Eventually, the gaseous state changes into liquid state which on further cooling changes into solid state.

There are some substances that directly change from the solid state to the gaseous state without passing through the liquid state. This process is called **sublimation** and such substances are called sublimable substances.

$$\text{Solid state} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \text{Gaseous state}$$

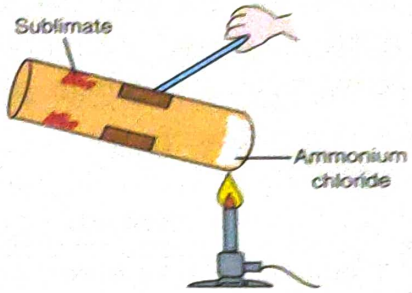
Example : Camphor, iodine, naphthalene, ammonium chloride, dry ice (solid carbon dioxide), etc.

Note : Naphthalene balls are used in bathrooms, wardrobes, etc. to keep the pests away. With the passage of time, they become smaller because they sublime and change into vapour state.

Activity 4

To show that ammonium chloride sublimes on heating.

Take a dry test tube. Hold it with a test tube holder and take a pinch of ammonium chloride in it. Heat the test tube.



Sublimation of ammonium chloride

What do you observe ?

After sometime, the solid ammonium chloride directly changes into white vapour, without changing into its liquid state. The vapour rises and solidifies on the upper cooler part of the test tube. This solid is called the sublimate.

This proves that there are substances which can change from solid to gaseous state on heating and vice versa. The process of changing directly from the gaseous to solid state without passing through the liquid state is called **deposition**.

Do all substances change their states ? Give four examples of substances which do not change their state on heating.

Change of state of matter by changing the pressure

Pressure is also one of the important factors for the change in the state of matter.

A gas can be changed into a liquid, and then into solid, by cooling it and by increasing its pressure. Thus, we can obtain liquid oxygen, liquid hydrogen, etc.

- Air contains mostly nitrogen and oxygen gases. When pressure is increased and temperature is decreased, air changes into its liquid state.
- LPG cylinders contain cooking gas in liquid state at high pressure (under normal conditions, it is a gas).
- Even the hardest rocks under the earth's crust melt at very high temperatures and high pressures.

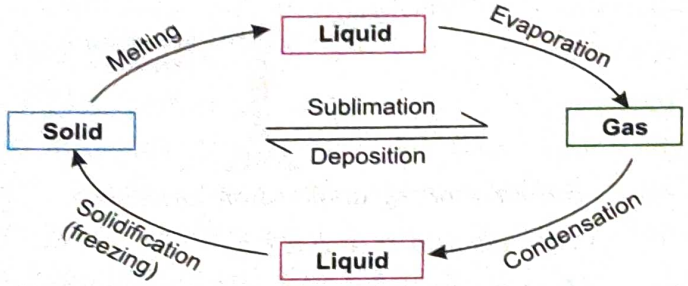


Fig. 1.4 Interconversion of states of matter

TERMS RELATED TO INTERCONVERSION OF STATES OF MATTER

Melting or fusion : The process by which a substance changes from solid state to liquid state is called melting or fusion.

Melting point : The fixed temperature at which a solid changes into a liquid upon heating at atmospheric pressure is called its melting point. The temperature remains constant till whole of the solid changes into liquid. Different substances have different melting points in their pure state. *For example,* melting point of ice is 0°C.

Evaporation : The process by which a substance changes from liquid state to vapour state is called evaporation or vaporisation. Evaporation takes place even at room temperature but it becomes faster on heating.

Boiling point : The fixed temperature at which a liquid starts changing into gaseous state upon heating is called its boiling point. At this temperature, the pressure of the liquid becomes equal to the atmospheric pressure. The temperature remains constant till whole of the liquid changes into vapour state. *Example :* The boiling point of pure water is 100°C.

Condensation : The process by which a substance in gaseous state changes into its liquid state is called condensation or liquefaction.

Condensation point : It is the temperature at which a gas starts changing into its liquid state upon cooling. *Example :* Condensation point of steam is 100°C.

Liquefaction : The process by which a gas is changed into its liquid state by applying pressure and lowering the temperature is called liquefaction.

Freezing : The process by which a substance in liquid state changes into a solid state is called freezing or solidification.

Freezing point : The temperature at which a liquid starts changing into its solid state upon cooling is called its freezing point. *Example :* Pure water freezes at 0°C under normal conditions.

Sublimation : The process by which certain substances change directly from solid to gaseous state on heating is called sublimation. *Example :* Camphor, ammonium chloride, iodine naphthalene, etc.

LAW OF CONSERVATION OF MASS

Lavoisier proposed the law of conservation of mass which states that —

"Matter can neither be created nor be destroyed in a chemical reaction".

However, it may change from one form to another during the reaction process.

It can also be stated as —

"In a chemical reaction, the total mass of the reactants is equal to the total mass of the products".

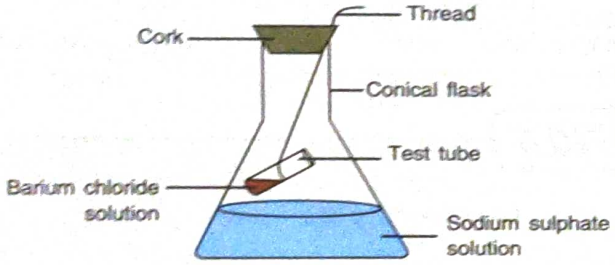
That means there is no change in the mass during a chemical reaction.

Experimental verification of the law of conservation of mass : This can be done by the following activities.

Activity 5

Things required : a conical flask, 10 ml test tube, two measuring cylinders, thread, cork, weighing balance, barium chloride solution and sodium sulphate solution.

$$BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaCl$$
(aq) (aq) (ppt) (aq)



Experimental verification of law of conservation of mass

Take 5 ml of sodium sulphate solution in a measuring cylinder and pour into a concial flask. Take 5 ml of barium chloride solution in another measuring cylinder and pour into a 10 ml test tube. Tie the test tube with a thread and hang the test tube in the flask carefully so that the two solutions do not mix with each other. Put a cork in the mouth of the test tube so that the thread holding the test tube is held firmly in place.

Now carefully weigh the concial flask on a weighing balance and note the reading to get the mass of the concial flask and the substances.

Now tilt and twist the flask so that barium chloride solution mixes with sodium sulphate solution.

You will observe that a white insoluble solid (precipitate) of barium sulphate is formed along with a solution of sodium chloride. Wait for ten minutes to complete the reaction and the solid formed to settle down.

Weigh the contents again and note the reading.

You will observe that —

total mass of the apparatus + reactants

= total mass of the apparatus + products

Hence, the law of conservation of mass is verified.

It is clear from the above experiment that there is no change in the mass before and after a reaction. However, the substances undergo physical and chemical changes.

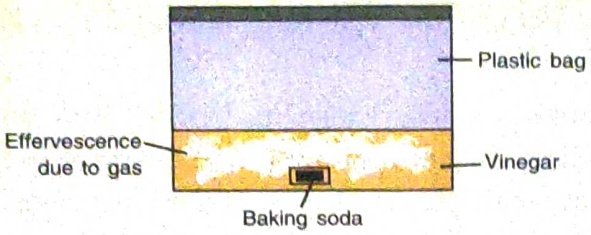
Activity 6

Things required : A plastic bag with zip lock, vinegar, baking soda and a weighing balance.

Take some baking soda on a paper. Take 1/4th cup of vinegar in the plastic bag. Weigh them separately.

Let the mass of plastic bag and vinegar + baking soda and paper = W g.

Now carefully put the baking soda with paper in the plastic bag and lock the zip of the



Experimental verification of law of conservation of mass

bag immediatley so that no gas escapes. Now shake the bag so that baking soda and vinegar come in contact. What do you observe now ?

A strong effervescence or fizz sound occurs indicating the formation of carbon dioxide gas. Wait till the fizz sound persists. Now weigh the plastic bag again. It is approximately W g.

Hence total mass of the reactants = total mass of the products.

The reaction is, baking soda + vineger = carbon dioxide + sodium acetate + water

$NaHCO_3 + CH_3COOH \rightarrow CO_2 + CH_3COONa + H_2O$

Note : To prove the law of conservation of mass, it is necessary to carry out the experiment in a closed container, otherwise if a product is gaseous, it may escape and the desired result will not be obtained.

- When wood is burnt in air, ash is formed. The mass of ash is less than that of wood. This is because the mass of air before the reaction and the mass of gaseous products formed after the reaction are not taken into consideration.
- Similarly when magnesium ribbon is burnt in air, a white solid — magnesium oxide is formed. The mass of magnesium oxide is more than the mass of magnesium. This is because the mass of oxygen used is not considered. If that is considered, the total mass of the reactants and the products is found to be almost equal.

$$\underset{\text{(magnesium)}}{2Mg} + \underset{\text{(air)}}{O_2} \xrightarrow{\text{heat}} \underset{\text{(magnesium oxide)}}{2MgO}$$

RECAPITULATION

- Matter is anything that has mass, occupies space and can be perceived by our senses.
- Matter consists of tiny particles called atoms and molecules.
- There is an intermolecular force of attraction between the particles of matter.
- The gaps between the particles are called intermolecular spaces.
- Particles of matter are always in random motion and they collide with each other.
- Matter exists in three states : solids, liquids and gases.
- Matter can change from one state to another when temperature and pressure are changed.
- The phenomenon of change of one state of matter into another and vice versa is called interconversion of states of matter.
- Matter can neither be created nor be destroyed. Only it can be changed from one form to another during a chemical reaction. This is known as law of conservation of mass.

EXERCISE

1. Define :
   (a) matter
   (b) intermolecular forces of attraction
2. What are the three states of matter ? Define each of them with two examples.
3. Explain interconversion of states of matter. What are the two factors responsible for the change of state of matter ?
4. State the main postulates of kinetic theory of matter.
5. What happens to water if
   (a) it is kept in a deep freezer ?
   (b) it is heated ?
   Explain the phenomenon of change of state of water.
6. (a) State the law of conservation of mass.
   (b) What do you observe when barium chloride solution is mixed with sodium sulphate solution ?
7. Give reasons :
   (a) A gas can fill the whole vessel in which it is enclosed.
   (b) Solids cannot be compressed.
   (c) Liquids can flow.
   (d) When magnesium is burnt in air, there is an increase in mass after the reaction.
8. Fill in the blanks :
   (a) The change of a solid into a liquid is called ..... .
   (b) The process in which a solid directly changes into gas is called ..... .
   (c) The change of water vapour into water is called ..... .
   (d) The temperature at which a liquid starts changing into its vapour state is .....
9. Give two examples for each of the following :
   (a) The substances which sublime.
   (b) The substances which do not change their state on heating.
10. Define :
    (a) Diffusion. (b) Brownian motion.
11. When sodium chloride is added to a definite volume of water and stirred well, a solution is formed, but there is no increase in the level of water. Why ?
12. What do you observe when a gas jar which appears empty is inverted over a gas jar containing Bromine vapours ? Name the phenomenon.
13. Why can a piece of chalk be broken easily into smaller pieces while a coal piece cannot be broken easily ?