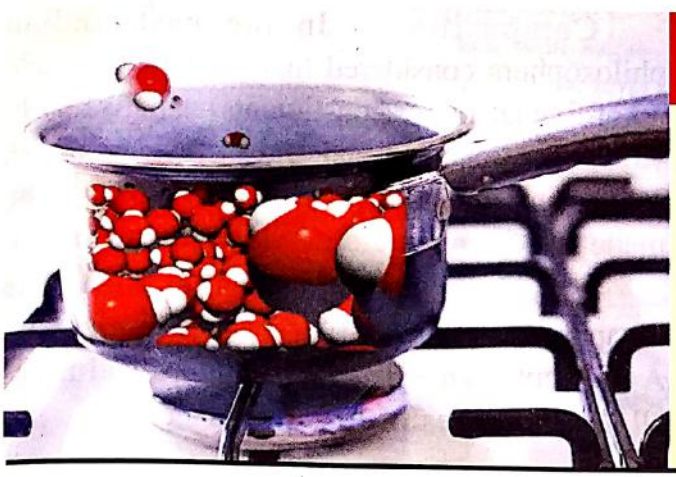

# 1 Matter

**Theme :** Building on previous learning in classes VI and VII. In this class, the theme aims at introducing children, the kinetic theory that will help them in understanding the difference in the three states of matter. The theory states that all matter is made of tiny particles that in an object are always in motion that may move slow or fast. In solids, the particles have less energy hence, do not move around freely. In liquids, they have relatively more energy and move freely within the container. The particles of gases have much more energy and move freely at high speeds. The increase or decrease in the movement or energy is the result of heating or cooling of an object. Heating an object increases the energy of particles whereas cooling decreases the energy of particles of an object.

## In this chapter you will learn to

- distinguish the three states of matter in terms of movement of particles
- relate the three states of matter with energy of movement of particles in them
- describe the changes of state using kinetic theory:
  - Boiling
  - Melting
  - Evaporation
  - Sublimation
  - Freezing
  - Vaporization
  - Fusion
  - Condensation
  - Deposition
- identify appropriate observable parameters in experiments
- present the results in the form of tables
- consider results using scientific knowledge and communicate these

## LEARNING OBJECTIVES

- Revising previous concepts learnt by children.
- Building on children's previous learning.
- Demonstrating matter in three states.
- Demonstrating change of state, solid to liquid, liquid to gas etc.
- Demonstrating the phenomenon of melting and boiling.
- Engaging children to undertake activities related to melting and boiling, condensation and freezing and make observations followed by discussion.
- Engaging children (individually/in groups) to observe change of state; solid to liquid, liquid to gas and record what is observed.
- Explaining the different terms like boiling, melting, freezing, condensation, sublimation etc. with examples from daily life.

- Observations of above mentioned phenomena in possible classroom situations (using different samples).
- Children observing solids and liquids (compare and contrast the physical characteristics).
- Encouraging children to prepare a comparison table of different states based on shape, texture and volume.
- Asking children to describe the interconversion of states using examples like water, naphthalene balls etc. and additional examples of all types of change of state.
- Engaging children in pairs or small groups in investigation of the related change of state due to addition of energy (heating or cooling) due to a substance.
- Engaging children (individually/in groups/in pairs) in the design of activities to show that melting or boiling occurs at a fixed temperature for a substance.

## KNOWING CONCEPTS

- Kinetic theory of matter.
- Three states of matter in terms of movement of particles.
- Energy contents in the three states of matter.
- Change of state in matter using the kinetic theory:
  - Boiling
  - Melting
  - Evaporation
  - Sublimation
  - Freezing
  - Vaporization
  - Fusion
  - Condensation
  - Deposition
- Change of state diagrams (using the terms mentioned above).

## MATTER

We have read in class VI, that matter is something which occupies space, has mass and can be perceived by our senses. *For example*, air, water, iron, hydrogen, oxygen, milk, oil, sugar, salt etc. all are matter. Actually, matter means all the living and non-living things of the universe.

**Composition :** In the past, Indian philosophers considered that matter was made up of five tatvas (or constituents) namely akash, vayu, tejas (or agni), jal and prithvi. Later on, Maharishi Kanada considered matter to be made up of **tiny particles** which he called **anu**.

Now, it is established that matter is composed of tiny particles called **molecules**. A molecule can exist free in nature and it has all the properties of that substance.

### Do You Know ?

1. A molecule composed of atoms can exist independently and freely in nature.
2. A molecule composed of one atom is called monoatomic molecule (such as helium, neon, argon, etc.).
3. A molecule composed of two atoms is called a diatomic molecule (e.g. hydrogen molecule, oxygen molecule, nitrogen molecule, etc.) and a molecule composed of more than two atoms is called polyatomic molecule (e.g. water, ammonia, carbon dioxide etc.).

### ACTIVITY 1

**To demonstrate that matter is composed of tiny particles.**

Take a 100 mL beaker. Fill it half with water. Mark the level of water in the beaker [Fig. 1.1 (a)]. Now, add some sugar in the water of the beaker. Stir it with a glass rod so that sugar gets dissolved in water

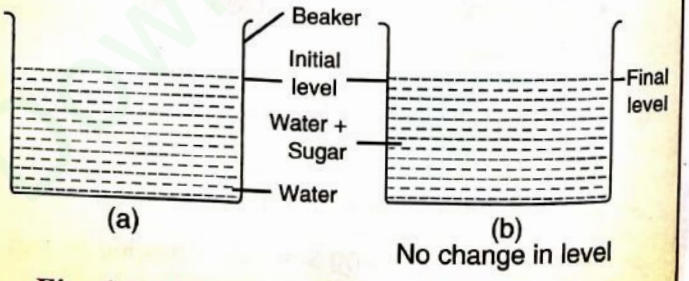


*Fig. 1.1 Matter is composed of tiny particles*

[Fig. 1.1 (b)]. Note the level of water with sugar. You will notice that there is no change in the level of water with sugar. This shows that each substance (water and sugar) is composed of tiny particles. The particles of sugar mix with the particles of water. They simply occupy the spaces between the particles of water.

## CHARACTERISTICS OF MOLECULES

The molecules of matter have the following characteristics :

1. They are very small in size.
2. They have spaces between them.
3. They are in constant motion as they possess kinetic energy.
4. They attract each other.

**1. They are very small in size :** A molecule is of size nearly $10^{-10}$ metre. It is too small that it cannot be seen even with the help of a microscope.

### ACTIVITY 2

Dissolve a crystal of potassium permanganate in 100 mL of water taken in a beaker (Fig. 1.2). You will see that the colour of water is pink.

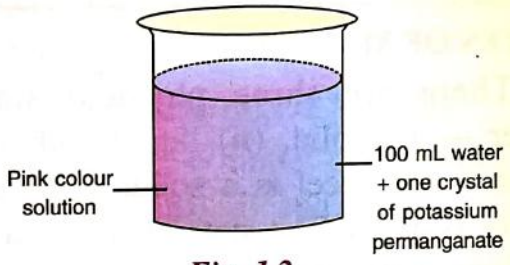


*Fig. 1.2*

Now, take about 10 mL of the above solution in another beaker. Mix 90 mL of water in it. Again you will see that the colour of solution is pink. Repeat the above process several times. Each time you dilute the solution, the colour remains pink.

This shows that the size of a particle of potassium permanganate is so small that it makes the water pink.

**2. The molecules of matter have spaces between them :** The spacing between the molecules of matter is called inter-molecular space. It is less in solids, more in liquids and still more in gases. In other words molecules are more closely packed in solids, less in liquids and still less in gases.

### ACTIVITY 3

Take 100 mL of water in a measuring cylinder. Add gently 20 grams of salt in water and stir it well so as to dissolve the salt evenly in water. It is noticed that the level of water does not change (Fig. 1.3). It shows that the molecules of salt occupy the spaces between the molecules of water.

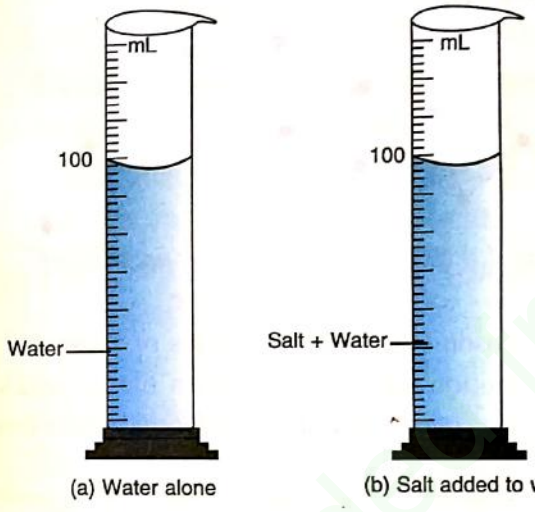


*Fig. 1.3 The molecules of salt occupy the spaces between the molecules of water*

**3. The molecules are in constant motion :** The molecules of matter are not at rest, but they are constantly in motion. In solids, the molecules vibrate about their mean positions without leaving their positions. In liquids, the molecules are free to move well within the boundary of the liquid. In gases, the molecules can move in a random manner everywhere in space available to them.

**ACTIVITY 4**

Spray a perfume in a corner of a room. You will find that the smell of perfume spreads everywhere inside the room in a negligible time. This shows that the molecules of perfume are in random motion.

**ACTIVITY 5**

Take a beaker. Fill it partly with water. Add some lycopodium powder in the beaker containing water. Stir the contents of the beaker with a glass rod. Take out few drops of this suspension on a glass plate. Place it on the table and illuminate it with a table lamp. Observe the glass plate through a microscope. It is found that the fine particles of lycopodium powder move rapidly in a random manner and their path is zig zag as shown in Fig. 1.4.

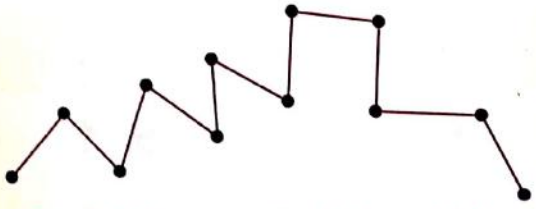

*Fig. 1.4 Zig zag path of fine particle of lycopodium powder*

The reason is that the molecules of water are in random motion which collide with the suspended fine particles of lycopodium powder and make them to move in a zig zag path.

4. **Molecules attract each other :** The molecules of matter exert a force of attraction on each other. This force of attraction is called **inter-molecular force.**

The inter-molecular force is neither due to their masses (*i.e.* gravitational force) nor due to their charges (*i.e.* electrostatic force). This force is a strong attractive force. It is effective between the molecules only upto a separation of $10^{-9}$ metre. As the separation between the molecules becomes more than $10^{-9}$ metre, this force vanishes.

The force of attraction between the molecules of a solid is very strong, between the molecules of a liquid is less strong and between the molecules of a gas is negligible.

The inter-molecular force of attraction between the molecules of same substance is called **force of cohesion**, while the force of attraction between the molecules of two different substances is called **force of adhesion**. These forces are responsible in liquids for their property of surface tension and viscosity.

**Do You Know ?**

1. The liquids and gases can flow because the molecular forces of attraction in them are weak.
2. Adhesives have strong molecular forces of attraction.

**ACTIVITY 6**

Try to break a piece of coal into small particles. You will find it difficult to break it in minute particles. This shows that the particles of coal are bound by the strong forces of attraction amongst themselves.

## STATES OF MATTER

There are three physical states of matter — (i) solid, (ii) liquid and (iii) gas. *For example*, steel is a solid, oil is a liquid and air is a gas. The state of a substance can be changed by changing its physical condition such as temperature. Water can exist in all the three states, viz, ice (solid state), water (liquid state) and steam (gaseous state).

Solids are rigid. They have a definite size (volume) and a definite shape.

Liquids are not rigid. They have a definite volume, but no definite shape. They

take the shape of the vessel in which they are placed.

Gases are also not rigid. They have neither a definite volume nor a definite shape. They take the volume and shape of the container.

The properties which decide the state of a substance, *i.e.* solid, liquid or gas are :

1. Inter-molecular space.
2. Force of attraction between the molecules.
3. Kinetic energy of molecules due to their motion.

**Solid :** When inter-molecular force is very strong and kinetic energy is very small, the inter-molecular space is reduced and matter exists as a solid.

**Liquid :** When inter-molecular force between the constituent molecules is not much strong and kinetic energy is sufficient for the molecules to move to and fro, the inter-molecular space is increased and matter exists as a liquid.

**Gas :** When inter-molecular force is negligible and kinetic energy is very high, matter exists as a gas.

## MOLECULAR MODEL OF SOLIDS

1. Each solid is made up of very tiny particles called molecules. These molecules are very small in size and they can be assumed to be the tiny rigid balls.
2. The separation between two molecules in a solid (*i.e.* inter-molecular spacing) is very small.
3. The molecules in a solid can only vibrate to and fro about their mean positions. They do not leave their positions.
4. The molecules in a solid are closely packed due to the strong attractive forces between them as shown in Fig. 1.5.

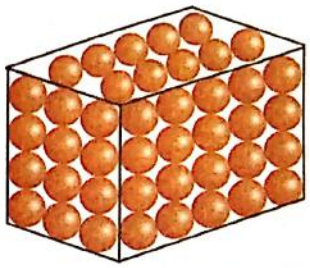

*Fig. 1.5 Arrangement of molecules in a solid*

Thus, the molecules in a solid are in fixed positions and due to the strong inter-molecular forces, they do not leave their positions, so a solid has a definite shape and a definite size (volume).

## MOLECULAR MODEL OF LIQUIDS

1. Each liquid is made up of very tiny particles called molecules. These molecules are very small in size and they are not in a rigid arrangement.
2. The inter-molecular spaces in liquids is more than that in solids.
3. The liquid molecules can move about freely within the boundary of a liquid.
4. The molecules in a liquid are less closely packed, their positions are not fixed as they are free to move within the boundary of a liquid as shown in Fig. 1.6. This is because the inter-molecular forces in a liquid are weak in comparison to that in solids.

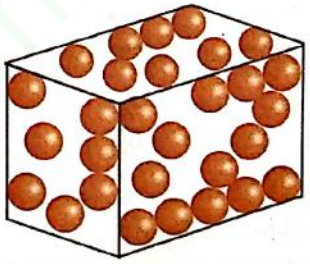

*Fig. 1.6 Arrangement of molecules in a liquid*

Thus, the liquid molecules can slide over one another due to which a liquid can flow. The inter-molecular forces, although are weak, but they are sufficient to keep the molecules within the boundary of liquid. So, liquids do not have a definite shape, but they have a definite volume.

## MOLECULAR MODEL OF GASES

1. Like solids and liquids, gases are made up of very tiny particles called molecules. These molecules are very small in size and they can be assumed to be non-rigid balls.
2. The separation between the molecules is quite large as compared to that in liquids and solids.
3. The molecules in a gas can move about freely in the space available to them.
4. The molecules in a gas are wide apart and their positions are not fixed because the inter-molecular forces in them are very weak. The arrangement of molecules in a gas is shown in Fig. 1.7.

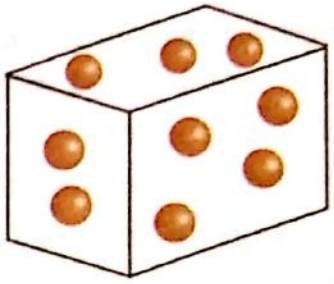

*Fig. 1.7 Arrangement of molecules in a gas*

Thus, the gas molecules are quite free to move here and there in all space available to them because of their weak inter-molecular forces. This is why, the gases have neither a definite shape nor a definite volume.

## DISTINCTION BETWEEN SOLIDS, LIQUIDS AND GASES

| Solids | Liquids | Gases |
|---|---|---|
| 1. A solid has a definite shape and a definite volume. | 1. A liquid has a definite volume, but not definite shape. | 1. A gas has neiher a definite volume nor a definite shape. |
| 2. The molecules in a solid are rigid. | 2. The molecules in a liquid are non-rigid. | 2. The molecules in a gas are non-rigid. |
| 3. The molecules in a solid can only vibrate to and fro about their mean positions. | 3. The molecules in a liquid can move within the boundary of the liquid. | 3. The molecules of a gas can move freely in the available space. |
| 4. The molecules remain fixed at their positions. | 4. The molecules do not remain fixed at their positions. | 4. The molecules do not remain fixed at their positions. |
| 5. The inter-molecular forces are very strong. | 5. The inter-molecular forces are less strong (moderate). | 5. The inter-molecular forces are weak. |
| 6. The molecules in a solid are closely packed. | 6. The molecules in a lqiuid are loosely packed. | 6. The molecules in a gas are wide apart. |
| 7. A solid cannot flow. | 7. A liquid can flow. | 7. A gas can flow. |

List of few solids, liquids and gases

| Solids | Liquids | Gases |
|---|---|---|
| Ice | Water | Steam |
| Aluminium | Benzene | Air |
| Silver | Chloroform | Oxygen |
| Calcium | Oil | Hydrogen |
| Gold | Honey | Chlorine |
| Iron | Glycerine | Nitrogen |
| Sodium-chloride | Hydrochloric-acid | Ammonia |
| Sugar | Nitric acid | Sulphur dioxide |
| Wood | Alcohol | Nitric oxide |
| Plastic | Spirit | Helium |
| Wax | Dettol | Argon |

## CHANGE OF STATE

We know that matter exists in three different states namely, solid, liquid and gas.

*The process of change from one state to another state either by absorption or rejection of heat at a constant temperature is called change of state.*

### Change of solid into liquid or vice-versa :

When a solid is heated, it changes into its liquid at a fixed temperature. This process is called **melting** or **fusion**. The reverse happens when this liquid is cooled. The liquid freezes into solid at the same fixed temperature. This process is called **freezing**.

### Change of liquid into gas or vice-versa :

When a liquid is heated, it changes into its vapour (or gas) at a fixed temperature. This process is called **boiling** or **vaporization**. The reverse happens when this vapour is cooled. The vapour condenses into liquid at the same fixed temperature. The process is called **condensation**.

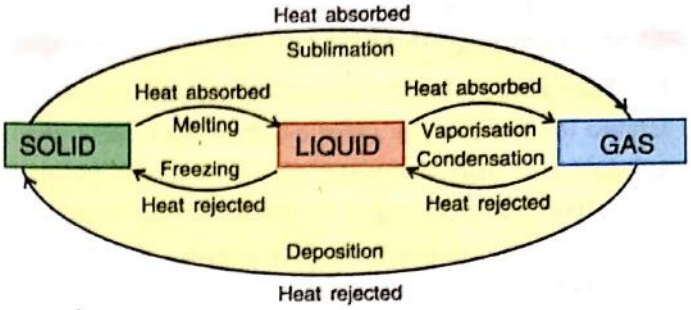


*Fig. 1.8 Change of state*

### Change of solid into gas or vice-versa :

In some cases (like camphor, iodine), a solid on heating directly changes to its vapour or gaseous state (without changing into liquid). This process is called **sublimation**. In the reverse process, the gas on being cooled directly changes into solid. This process is called **deposition**.

The above changes in state of matter are shown in Fig. 1.8.

It may be noted that the change of state of a substance occurs at a fixed temperature and during the process, the quantity of heat given to (or taken from) the substance, does not cause a change in its temperature. This heat is called latent heat (or hidden heat) because it is not manisfested by any change in temperature.

## MELTING

The change from the solid state to the liquid state on heating at a fixed temperature is called **melting**. The temperature at which a solid changes into liquid without further increase in temperature is called the **melting point of the solid**. *For example*, ice (solid) at 0°C melts to form water (liquid) at 0°C by the absorption of heat.

The process of melting can be demonstrated by the following activity.

**ACTIVITY 7**

Take a test tube. Put some wax in the test tube. Clamp the test tube in a vertical stand and place the test tube in a beaker of water placed on a wire guaze at a tripod stand. Clamp a thermometer in the same vertical stand and insert the thermometer in the test tube such that the bulb of the thermometer is inside the wax as shown in Fig 1.9. Heat the beaker over the flame of a burner and record the temperature of the wax after every minute. Record your observations.

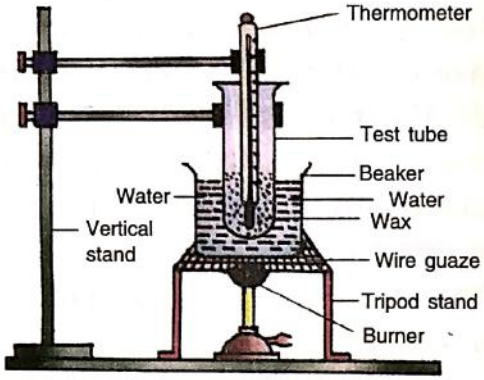


*Fig. 1.9 Melting of wax*

**Observations :**

| Time in minute | Temperature of wax in °C |
|---|---|
| 0 | 25 |
| 1 | 30 |
| 2 | 35 |
| 3 | 40 |
| 4 | 45 |
| 5 | 50 |
| 6 | 55 |
| 7 | 55 |
| 8 | 55 |
| 9 | 55 |
| 10 | 60 |
| 11 | 65 |
| 12 | 70 |

**Conclusion :** From the above observations, you will note that wax melts at 55°C during which heat is supplied, but temperature does not rise. Thus, the melting point of wax is 55°C. It is only after the melting of the whole wax, the temperature begins to rise.

## FREEZING

*The change from liquid state to solid state on cooling at a fixed temperature by rejecting heat is called* ***freezing.***

The temperature at which a liquid changes into solid without further decrease in temperature is called the **freezing point of the liquid**. *For example*, water (liquid) at 0°C freezes to form ice (solid) at 0°C by rejecting heat.

The process of freezing can be demonstrated by the following activity.

**ACTIVITY 8**

In activity-7 given above, when the temperature of melted wax has reached 70°C, remove the burner. Allow the beaker to cool and note the temperature of wax after every minute.

**Observations :**

| Time in minute | Temperature of wax in °C |
|---|---|
| 0 | 70 |
| 1 | 65 |
| 2 | 60 |
| 3 | 55 |
| 4 | 55 |
| 5 | 55 |
| 6 | 55 |
| 7 | 50 |
| 8 | 45 |
| 9 | 40 |
| 10 | 35 |
| 11 | 30 |
| 12 | 25 |

**Conclusion :** In the above observations, you will notice that melted wax changes into solid wax *i.e.* it freezes at 55°C when the temperature does not fall further on cooling. After the complete wax has frozen, its temperature begins to fall again.

*Note :* 1. The process of melting and freezing can also be demonstrated with powdered naphthalene or solid ice.

2. For a substance, the melting point and freezing point are the same. *For example*, melting point of wax is 55°C and freezing point of melted wax is also 55°C.

The melting point and the heat absorbed for change of state from solid to liquid, for some solids are given in the following table.

**Melting point and heat absorbed during melting for some substances**

| Substance | Melting point | Heat absorbed |
|---|---|---|
| 1. Ice | 0°C | $336 \times 10^3$ J $kg^{-1}$ |
| 2. Wax | 55°C | $147 \times 10^3$ J $kg^{-1}$ |
| 3. Napthalene | 80°C | $147 \times 10^3$ J $kg^{-1}$ |
| 4. Copper | 1085°C | $1806 \times 10^3$ J $kg^{-1}$ |

**Do You Know ?**

1. The amount of heat rejected during freezing of a substance is same as the amount of heat absorbed during melting for the same mass of a substance.
2. The amount of heat absorbed or rejected during the change of state for a unit mass of substance is called specific latent heat. It is measured in joule per kilogram.
3. Water expands on freezing whereas wax, lead etc. contract on freezing.
4. Melting point of ice decreases with increase of pressure on it, but the melting point of wax increases with increase of pressure on it.
5. Melting point of ice decreases when salt is added to it. This mixture of salt added to ice is called freezing mixture. It is used for preparing Kulfies.

## EXPLANATION OF MELTING BY MOLECULAR MODEL

In a solid, the molecules are closely packed *i.e.* they have less inter-molecular spacing. The molecules only vibrate about their mean positions, so they have a small kinetic energy. They have strong molecular forces of attraction amongst them. On heating a solid, the kinetic energy of molecules increases due to which they begin to vibrate more violently. At a particular temperature (called the melting point), the molecules acquire sufficient kinetic energy to become far separated from each other by overcoming the forces of attraction between them. They become free to move within the substance *i.e.* the state of substance becomes liquid. In this state the heat energy absorbed by the substance does not change the temperature of the substance, but is utilized in doing work against the forces of attraction in increasing the separation between the molecules (*i.e.*, their potential energy increases).

## VAPORIZATION OR BOILING

*The change from liquid state to gaseous (or vapour) state on heating at a constant temperature by absorption of heat is called vaporization or* ***boiling.***

The temperature at which liquid changes into vapour without further increase in temperature is called the **boiling point of the liquid**. *For example*, water (liquid) at 100°C changes to steam (gas) at 100°C by absorption of heat.

The vaporization of a liquid can be demonstrated by the following activity.

## ACTIVITY 9

Take a beaker. Pour some water in the beaker. Place the beaker on a wire guaze placed over the tripod stand. Clamp a thermometer in a vertical stand and insert it in the beaker as shown in Fig. 1.10. Heat the beaker over the flame of a burner and record the temperature of water after every minute.

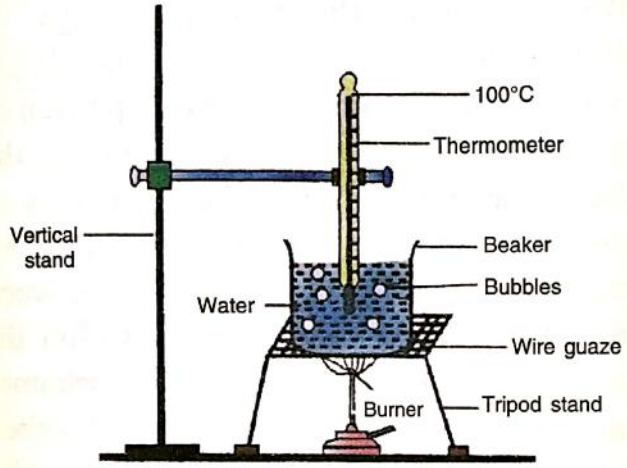


*Fig. 1.10 Vaporization of water*

You will notice that the temperature of water rises continuously till the water starts boiling at 100°C. Once the water starts boiling, its temperature does not rise any further, although the heat is still being supplied. Now the bubbles formed through the water are seen. At this temperature water begins to boil and changes into steam. Thus, the boiling point of water is 100°C.

**Condensation :** The change from vapour state to liquid state at a constant temperature on rejecting heat (or on cooling) is called **condensation**. The temperature at which vapour changes into liquid without any further decrease in temperature is called **condensation point of the vapour**. *For example*, steam (gas or vapour) at 100°C condenses to water (liquid) at 100°C on cooling (*i.e.* by rejecting heat).

## Do You Know ?

1. For a substance, the boiling point and the condensation point are same. *For example*, boiling point of water is 100°C and condensation point of steam is also 100°C.

2. The amount of heat absorbed or rejected during the change from liquid to vapour state or from vapour to liquid state is same for the same mass of the substance.

3. All liquids expand on heating.

4. The boiling point of a liquid increases with the increase of pressure on it. This is why it is difficult to cook vegetables at the mountains where pressure is low but it is easy to cook vegetables in a pressure cooker in which pressure is increased by keeping the water vapour inside the cooker.

5. The boiling point of a liquid increases when impurities are added to it.

The boiling point and heat absorbed for change of state from liquid to vapour, for some liquids are given in the following table.

**Boiling point and heat absorbed during vaporization of some liquids**

| Liquid | Boiling point | Heat absorbed for vaporization |
|---|---|---|
| 1 Water | 100°C | $2260 \times 10^3$ J kg$^{-1}$ |
| 2 Alcohol | 78·3°C | $856{\cdot}8 \times 10^3$ J kg$^{-1}$ |
| 3 Ether | 35°C | $352{\cdot}8 \times 10^3$ J kg$^{-1}$ |

## EXPLANATION OF VAPORIZATION BY MOLECULAR MODEL

In a liquid, the molecules move in all directions but within the boundary of the liquid. They exert small forces of attraction on each other. They have a low kinetic energy. On heating (absorbing heat), the average kinetic energy of molecules of liquid increases. At a particular temperature (boiling point), the molecules acquire sufficient kinetic energy to

overcome the forces of attraction between themselves and they become free to leave the liquid surface. This is called vaporization. Thus, a liquid changes into vapour at a particular temperature by the absorption of heat energy. The heat energy absorbed does not change the kinetic energy of the molecules, but is utilised in doing work against the forces of attraction in increasing the separation between the molecules *i.e.*, in increasing their potential energy.

## EVAPORATION

Evaporation is another process by which a liquid changes into vapour. The change of state from liquid to vapour at all temperatures from the surface of liquid is called evaporation. It is to be noted that

1. Evaporation takes place at all temperatures, but vaporization takes place only at a fixed temperature which is the boiling point of the liquid.
2. Evaporation is a slow and gradual process whereas vaporization is a rapid and violent process.
3. Evaporation takes place only at the surface of the liquid whereas vaporization takes place over the entire liquid.
4. Evaporation has cooling effect, but vapourization does not produce cooling.

The process of evaporation can be demonstrated by the following activity.

**ACTIVITY 10**

Spray some water on the floor, you will find that after some time the floor dries up. It dries up because the water evaporates (*i.e.* it changes into vapour). Similarly, a wet cloth dries up after sometime due to evaporation of water from the cloth.

## RATE OF EVAPORATION

The rate of evaporation of a liquid depends mainly on the following five factors :

(i) **The temperature of liquid :** A wet cloth dries up on a hot day much faster than on a cold day. Thus, the rate of evaporation is higher if the temperature of liquid is high.

(ii) **The area of the exposed surface :** A cloth dries up faster if it is spread out than if it is folded up. Thus, the rate of evaporation increases if the area of surface exposed increases.

(iii) **The nature of liquid :** Volatile liquids with low boiling point such as alcohol, spirit, ether etc. evaporate much faster than water. This is why volatile liquids are stored in tightly closed bottles.

(iv) **The flow of air above the liquid :** If air is blown above the liquid surface, it moves away the molecules of liquid from the surface with it, so the liquid evaporates more quickly. This is why to cool the milk, we blow air above it.

(v) **The presence of humidity :** In dry air, evaporation is faster than in humid air. This is why wet clothes dry faster in dry summer days than in rainy season.

## EXPLANATION OF EVAPORATION BY THE MOLECULAR MODEL

In a liquid, the molecules are in motion within its boundary. They collide with each other. During the collision, some molecules below the surface of liquid acquire sufficient

kinetic energy to overcome the force of attraction of other molecules and their inter-molecular spacing increases. Such molecules move to the surface of liquid and they absorb heat from the surrounding so as to escape out in atmosphere with the atmospheric air molecules. This process is called evaporation.

**Do You Know ?**

1. More the temperature of a liquid, higher will be the rate of molecules escaping from its surface.

2. More the area of exposed surface, more will be the number of molecules escaping out of the surface.

3. In a volatile liquid, the force of attraction among molecules is negligible. So, they escape out more easily.

4. On blowing air, the air molecules take away the liquid molecules from the surface with them and other molecules of the liquid occupy their place. This increases the rate of evaporation.

5. In humid air, the water molecules present in the air near the surface of the liquid do not allow the molecules of the liquid to escape out easily. They decrease the rate of evaporation.

## EVAPORATION PRODUCES COOLING

If a little alcohol (or spirit) is poured on the palm, it gives soothing (or cooling) sensation. If some alcohol (or spirit) is poured on cotton (or wool) wrapped around the bulb of a thermometer, the reading of the thermometer falls. This shows that cooling is produced when a liquid evaporates. The reason for producing cooling in evaporation is that when a liquid changes into vapour, it requires heat. This heat is supplied by the surroundings of the liquid (such as palm or cotton wrapped around the thermometer in the above examples). This results in fall in temperature (or cooling) in the surroundings.

## APPLICATIONS OF EVAPORATION

(1) In summer, water gets cooled in an earthen pot (surahi). The reason is that water seeps out on surface through the pores in the pot and it evaporates. The heat required for evaporation is taken from water inside the pot which therefore gets cooled.

(2) Doctors advice to put the strips of wet cloth on the forehead of a patient having high fever. The reason is that water of the strips evaporates. During evaporation, water takes heat from the body of the patient and thus the temperature of his body decreases.

(3) We often pour tea in a saucer to cool it faster. In the saucer, the surface area increases and evaporation becomes faster.

(4) Evaporation of sweat from our body helps to maintain the body temperature at 37°C (or 98·6°F). When sweat evaporates, it requires heat which it takes away from our body. As a result, temperature falls to keep the body at 37°C.

**Difference between evaporation and boiling**

| Evaporation | Boiling |
|---|---|
| 1. It is a slow process. | 1. It is a rapid process. |
| 2. It takes place at the surface of liquid. | 2. It takes place through out the mass of liquid. |
| 3. It takes place at all temperatures. | 3. It takes place at a specific constant temperature which is called the boiling point of the liquid |
| 4. The temperature of the surroundings falls. | 4. The temperature of surroundings remains constant. |

## SUBLIMATION AND DEPOSITION (OR SOLIDIFICATION)

**Sublimation** : Sublimation is the process by which a solid when heated, directly changes into its vapour (gaseous state) without first changing into liquid.

**Deposition** or **solidification** : It is a process when a vapour (or gas) on cooling changes directly into a solid without first changing into liquid. These processes are shown in Fig. 1.11.

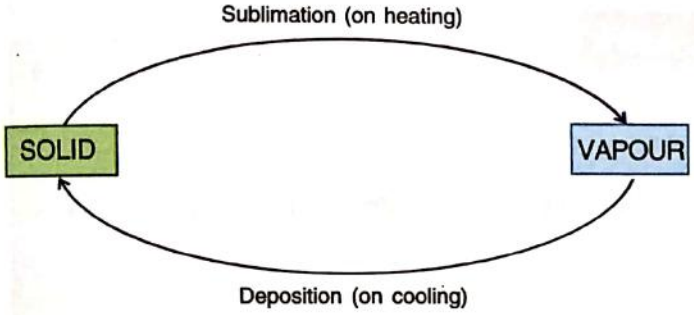


*Fig. 1.11 Sublimation and deposition*

*For example,* when ammonium chloride, iodine, camphor, napthalene and solid carbon dioxide (dry ice) are heated, they directly change into their vapours and when their vapours are cooled, they change into their solids.

*Note :* 1. Carbon dioxide gas when cooled converts into solid carbon dioxide which is called dry ice.

2. Sometimes sublimation also takes place without heating. *For example*, naphthalene balls (or moth balls) which we use to protect woolen clothes from insects, directly changes into vapour and with time they become small in size.

The process of sublimation and deposition (or solidification) can be easily demonstrated by the following activity.

**ACTIVITY 11**

Take some camphor or ammonium chloride. Powder it. Keep the powder in a china dish. Now cover the china dish with an inverted funnel as shown in Fig. 1.12. Then close the end of funnel with a piece of cotton.

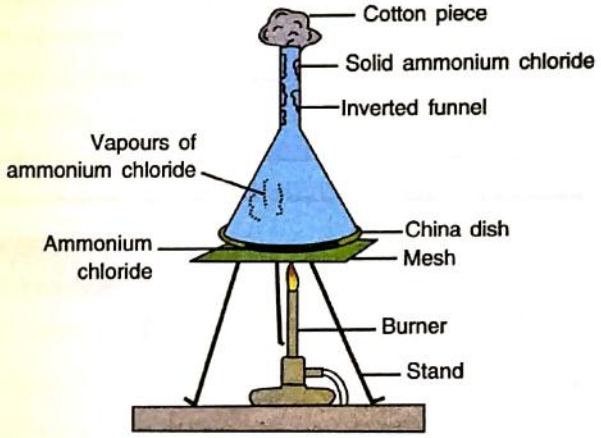


*Fig. 1.12 Sublimation and deposition of ammonium chloride*

Now, place the dish on a wire mesh kept on a tripod stand to heat it by a burner. You will notice that the fumes (*i.e.* vapours) of ammonium chloride are seen in the funnel above the dish. These vapour when rise, get cooled and change to solid ammonium chloride which gets deposited on the inner walls of funnel. Thus, ammonium chloride on heating changes directly from solid to vapour and these vapour on cooling directly change to solid.

## EXPLANATION OF SUBLIMATION BY THE MOLECULAR MODEL

In some solids, the inter-molecular forces of attraction are weak. In such solids, on heating, the molecules acquire sufficient kinetic energy to overcome the force of attraction and they become free to move. Thus, their inter-molecular separation becomes very large and they change to vapour.

## Do You Know ?

1. The average kinetic energy of molecules of a substance is a measure of its temperature.
2. In general when a substance absorbs heat, the average kinetic energy of its molecules increases due to which its temperature rises. But if the substance gives out heat, the average kinetic energy of its molecules decreases due to which its temperature falls.
3. During the change of state, when a substance absorbs or gives out heat, there is no change in average kinetic energy of its molecules and so the temperature of the substance does not change during the change of state. Actually the heat absorbed (or rejected) increases (or decreases) the average potential energy of its molecules. The heat so absorbed (or rejected) is called the latent heat or hidden heat.

## RECAPITULATION

- Anything which occupies space and has mass is called matter.
- All forms of matter are composed of molecules.
- Molecule is the smallest unit of matter which can exist independently. A molecule is made up of two or more atoms of same type or of different types.
- A molecule of a substance has all its properties.
- Molecules in matter are always in a state of motion (translational or vibrational) and so they possess kinetic energy.
- On heating, the increase in temperature increases the kinetic energy of the molecules.
- The force of attraction between the molecules of same kind is called the force of cohesion, whereas the force of attraction between the molecules of different kinds is called the force of adhesion.
- The force of attraction between the molecules is also called inter-molecular force of attraction. The space between the molecules of matter is called inter-molecular space.
- In case of solids, inter-molecular space is the least and so inter-molecular force of attraction is maximum.
- In liquids, the inter-molecular space is more than in solids and the inter-molecular force of attraction is less than in solids.
- In gases, the inter-molecular spaces are maximum while the inter-molecular force of attraction is negligibly small.
- A substance can exist in three different states the solid, liquid and gas.
- The process of change from one state to the other state at a constant temperature is called change of state.
- The change from the solid state to the liquid state on heating at a fixed temperature is called melting and the change from the liquid state to the solid state on cooling at the same fixed temperature is called freezing
- The constant temperature at which a substance changes from its solid state to the liquid state by absorbing heat is called its melting point. Similarly, the constant temperature at which a substance changes from the liquid state to the solid state by giving out heat is called its freezing point. The melting point and freezing point of a substance are same. The melting point of ice or the freezing point of water is 0°C.
- The heat absorbed by a substance during melting and the heat given out by it during freezing for the same mass without change in temperature, are same.

- Ice at 0°C absorbs $336 \times 10^3$ joule per kilogram of heat to convert into water at 0°C while water at 0°C rejects $336 \times 10^3$ joule per kilogram of heat to convert into ice at 0°C.
- The change from the liquid state to the gaseous (or vapour) state on heating at a fixed temperature is called boiling or vaporization. The reverse process of change from the vapour state to the liquid state on cooling at the same fixed temperature is called condensation.
- The constant temperature at which a substance changes from the liquid state to its vapour state by absorbing heat is called its boiling point. The boiling point of water is 100°C.
- The heat absorbed by a liquid during vaporization and the heat given out by it during condensation of the same mass without change in temperature, are same.
- Water at 100°C absorbs $2260 \times 10^3$ joule per kilogram of heat to change into steam at 100°C, while steam at 100°C changes into water at 100°C by giving out $2260 \times 10^3$ joule per kilogram of heat.
- The vaporization of a liquid can take place in the following different ways :

  (i) through boiling at a fixed temperature, and

  (ii) through evaporation at all temperatures.
- The change from the liquid state to the vapour state at all temperatures from the surface of liquid is called evaporation. Evaporation is a slow process.
- Evaporation produces cooling.
- The rate of evaporation of a liquid depends on (i) the temperature of liquid, (ii) the area of the surface exposed, (iii) the nature of liquid, (iv) the wind or blowing air above the liquid surface, and (v) the presence of humidity.
- The process of change of solid directly into gas (or vapour) at a fixed temperature without changing into liquid is called sublimation while the reverse process of change of vapour (or gas) directly into solid at a fixed temperature without changing into liquid is called deposition or solidification e.g. camphor, ammonium chloride etc. sublime when heated and solidify when cooled at a fixed temperature.

## TEST YOURSELF

### A. Objective Questions :

1. Write **true** or **false** for each statement :
   (a) The temperature of a substance remains unaffected during its change of state.
   (b) Ice melts at 100°C.
   (c) Water at 100°C has more heat than steam at 100°C.
   (d) Evaporation of a liquid causes cooling.
   (e) Water evaporates only at 100°C.
   (f) Boiling takes place at all temperatures.
   (g) Evaporation takes place over the entire mass of the liquid.
   (h) The process of a gas converting directly into solid is called vaporization.
   (i) At high altitudes, water boils above 100°C.
   (j) The melting point of ice is 0°C.

   **Ans: True**—(a), (d), (j)
   **False**—(b), (c), (e), (f), (g), (h), (i)

2. Fill in the blanks :
   (a) Evaporation takes place at ..... temperature.
   (b) ..... process is just the reverse of melting.
   (c) ..... is a process that involves direct conversion of a solid into its vapour on heating.
   (d) The temperature at which a solid converts into a liquid is called its .....

(e) The smallest unit of matter that exists freely in nature is called .....

(f) Molecules of a substance are always in a state of ..... and so they possess .....

(g) Inter-molecular space is maximum in ..... less in ..... and the least in .....

(h) Inter-molecular force of attraction is maximum in ....., less in ..... and the least in .....

Ans: (a) all (b) freezing (c) sublimation (d) melting point (e) molecule (f) motion, kinetic energy (g) gases, liquids, solids (h) solids, liquids, gases

3. Match the following :

| Column A | Column B |
|---|---|
| (a) Molecules | (i) water boils |
| (b) 100°C | (ii) evaporation |
| (c) 0°C | (iii) changes from solid to gas |
| (d) At all temperatures | (iv) matter |
| (e) Camphor | (v) water freezes |

Ans: (a)–(iv), (b)–(i), (c)–(v), (d)–(ii), (e)–(iii)

4. Select the correct alternative :

(a) The inter-molecular force is maximum in :

(i) solids (ii) gases
(iii) liquids (iv) none of the above.

(b) The inter-molecular space is maximum in :

(i) liquids (ii) solids
(iii) gases (iv) none of the above.

(c) The molecules can move freely anywhere in :

(i) gases (ii) liquids
(iii) solids (iv) none of the above.

(d) The molecules move only within the boundary of :

(i) liquids (ii) gases
(iii) solids (iv) none of the above.

(e) The temperature at which a liquid gets converted into its vapour state is called its :

(i) melting point (ii) boiling point
(iii) dew point (iv) freezing point.

(f) Rapid conversion of water into steam is an example of :

(i) evaporation (ii) freezing
(iii) melting (iv) vaporization.

(g) Evaporation takes place from the :

(i) surface of liquid
(ii) throughout the liquid
(iii) mid-portion of the liquid
(iv) bottom of liquid.

(h) Boiling takes place from :

(i) the surface of the liquid
(ii) throughout the liquid
(iii) mid-portion of liquid
(iv) none of the above.

Ans: (a)–(i), (b)–(iii), (c)–(i), (d)–(i), (e)–(ii), (f)–(iv), (g)–(i), (h)–(ii)

## B. Short/Long Answer Questions :

1. Define the term matter. What is it composed of ?
2. State three properties of molecules of a matter.
3. What do you mean by the inter-molecular spaces ? How do they vary in different states of matter ?
4. What is meant by inter-molecular forces of attraction ? How do they vary in solids, liquids and gases ?
5. Which of the following are correct ?

(a) Solids have definite shape and definite volume.

(b) Liquids have definite volume but no definite shape.

(c) Gases have definite volume but no definite shape.

(d) Liquids have both definite shape and definite volume.

Ans: Correct : (a) and (b)

6. Discuss the three states of matter : solid, liquid and gas on the basis of molecular model.

7. What do you mean by the change of state ? Write the flow chart showing the complete cycle of change of state.
8. Differentiate between melting point and boiling point, giving atleast one example of each.
9. Describe the process of condensation and sublimation with examples.
10. Explain the terms melting and melting point.
11. Describe an experiment to demonstrate that a substance absorbs heat during melting without change in its temperature.
12. Explain the terms vaporization and boiling point.
13. A liquid can change into vapour state
    (a) at a fixed temperature, and
    (b) at all temperatures
    Name the processes involved in the two cases.
14. Some ice is taken in a beaker and its temperature is recorded after each one minute. The observations are listed below :

| Time (in minute) | Temperature (in °C) |
|---|---|
| 0 | 0 |
| 1 | 0 |
| 2 | 0 |
| 3 | 0 |
| 4 | 0 |
| 5 | 0 |
| 6 | 3·8 |
| 7 | 7·6 |
| 8 | 11·4 |

From the above observations what conclusion do you draw about the melting point of ice ?

**Ans:** Melting point of ice = 0°C

15. Describe an experiment to demonstrate that water absorbs heat during boiling at a constant temperature.
16. State (a) the melting point of ice and (b) the boiling point of water.
17. What is evaporation ?
18. State three factors which affect the rate of evaporation of a liquid.
19. Wet clothes dry more quickly on a warm dry day than on a cold humid day. Explain.
20. Water in a dish evaporates faster than in a bottle. Give reason.
21. Why are volatile liquids such as alcohol and spirit stored in tightly closed bottles ?
22. A certain quantity of water is heated from 20°C to 100°C. Its temperature is recorded after each 1 minute. The observations are :

| Time (in minute) | Temperature (in °C) |
|---|---|
| 0 | 20 |
| 1 | 30 |
| 2 | 40 |
| 3 | 50 |
| 4 | 60 |
| 5 | 70 |
| 6 | 80 |
| 7 | 90 |
| 8 | 100 |
| 9 | 100 |
| 10 | 100 |
| 11 | 100 |
| 12 | 100 |

What conclusion do you draw from the above table about the boiling point of water ? Explain.

**Ans:** Boiling point of water = 100°C

23. Why is cooling produced on evaporation of a liquid ?
24. Explain with an example to demonstrate that when a liquid evaporates, it take heat from its surroundings.
25. Give two applications of evaporation.
26. Explain why in hot summer days water remains cool in earthen pots.
27. A patient suffering from high fever is advised to put wet cloth strips on his forehead. Why ?
28. What do you mean by sublimation ? Explain with an example.
29. Why does the size of naphthalene balls decrease when left open ?
30. Describe an experiment to demonstrate the process of sublimation.

## Project Work

Take a beaker. Fill it half with water. Add two spoons of table salt in the water of beaker. Stir the contents of beaker with a spoon. What do you observe ? Where do the particles of salt go ?

Taste few drops of the salt solution. You will find it salty. Now heat the beaker over a gentle flame till the entire water of the beaker vapourizes. See the contents of beaker. What is left in the beaker ? Taste it. Does it still taste salty ?

How is this residue left ?

**Hint :**

1. The particles of salt occupy space between the inter-molecular spacing of water.
2. On heating when the water vaporizes, the inter-molecular spacing of water increases till only the particles of salt are left behind.