

7

CHANGE OF STATE



CHANGE OF STATE OF SUBSTANCES

OBJECTIVES

At the end of this topic, students should be able to:

- explain change of state and vaporization;
- explain melting point;
- state the factors affecting evaporation.

Matter exists in three states: solid, liquid and gas. The state in which matter exists depends on:

- **The nature of the substance.** At normal atmospheric condition, iron is a solid, water is a liquid and oxygen is a gas.
- **The temperature of the substance.** At ordinary temperature, water is a liquid, if heat is added to water, it changes state from liquid to vapour (gas). When water is cooled to 0°C , it freezes and becomes ice (solid). Temperature, therefore, determines the state of a matter.
- **Pressure on the substance.** At ordinary temperature, it is possible to condense gases to liquid if the pressure is high enough.

Change of state by heating or cooling

If a solid is given sufficient energy by heating, it melts and changes to a liquid. The change of state from solid to liquid is called melting or fusion. For example, 1kg of ice at 0°C is melted to water at 0°C when 340,000 Joules of energy is supplied to it. During change of state, there is no change in temperature.

Melting point is the temperature at which a solid changes state to liquid.

Further heating changes liquid to **vapour**. The process of converting a liquid to a vapour is known as **vaporization** while the temperature at which vaporization occurs is known as the boiling point of the substance.

If heat is removed gradually from the substance, it will change state from vapour to liquid. The change of state from vapour to liquid is

called **condensation**. Continuous removal of heat will lower the temperature of the substance until it **freezes**. The change of state from liquid to solid is known as **freezing** or **solidification**. The temperature at which freezing occurs is called the **freezing point** of substance. **The freezing point of a pure substance is equal to its melting point.**

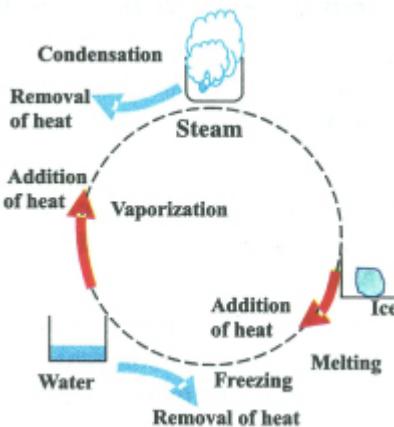


Figure 7.1 Change of state

Change of state occurs at a constant temperature

- Put some pieces of pure melting ice in a beaker and dip a thermometer vertically.
- Observe the temperature of the ice as it melts until all the ice is melted.

If you try this activity, you will notice that the reading of the thermometer is constant at 0°C until the ice melts completely. **The melting point of ice is 0°C and the freezing point of water is 0°C .** Substances which freeze and melt at a particular temperature are called **crystalline substances**. Crystalline substances freeze and melt at constant temperature. Examples of crystalline substances are ice, paraffin, lead, copper and other metals.

How to find the melting point of a substance

Apparatus: A beaker of water, boiling tube, retort and tripod stand, Bunsen burner, thermometer and naphthalene solid.

Procedure

- Half fill the boiling tube with naphthalene solid, insert a thermometer and place the boiling tube vertically in a beaker of water.
- Heat the beaker and its content until the naphthalene melts completely.
- Remove the boiling tube from the water and record the temperatures of molten naphthalene as it cools every 30 seconds.

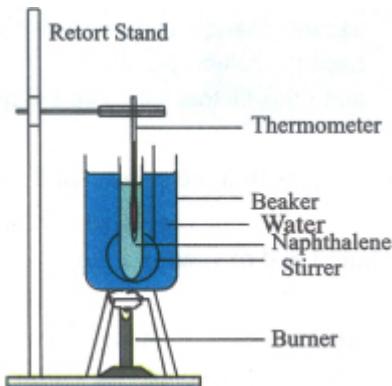


Figure 7.2 Arrangement of apparatus to find the melting point of a substance

Cooling curve of naphthalene

Figure 8.2b shows the plot of temperature against time for naphthalene. It is called the **cooling curve** of the naphthalene.

The cooling curve has three parts:

- steady fall in temperature when the naphthalene is cooling down to the freezing point.
- the horizontal part of the graph, where the temperature is constant, represents the freezing point of the naphthalene or the heat (energy) given out as the naphthalene changes state from liquid to solid.
- the steady fall in temperature as the solid naphthalene cools from freezing point to room temperature.

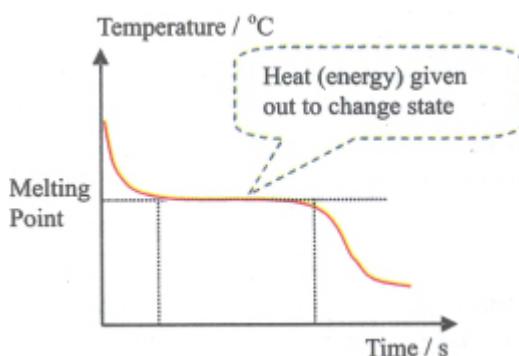


Figure 7.2b Cooling curve of naphthalene

Change of volume during melting and freezing

Change of state leads to change in volume. Most liquids contract as they freeze but water behaves differently, it expands when it freezes. In addition, ice contracts as it melts. The water formed at $0\text{ }^\circ\text{C}$ continues to contract from $0\text{ }^\circ\text{C}$ to $4\text{ }^\circ\text{C}$. Figure 8.3 shows the heating curve of ice as it gains heat between $-10\text{ }^\circ\text{C}$ and $10\text{ }^\circ\text{C}$. The ice expands as it absorbs heat from $-10\text{ }^\circ\text{C}$ to $0\text{ }^\circ\text{C}$, contracts as it changes to water. The water formed continues to contract from $0\text{ }^\circ\text{C}$ to $4\text{ }^\circ\text{C}$ where the volume is least. Between $4\text{ }^\circ\text{C}$ and $10\text{ }^\circ\text{C}$ water expands like most

liquids. Water expands on freezing, if there is no chance to accommodate the expansion, it will lead to the breaking of the container.

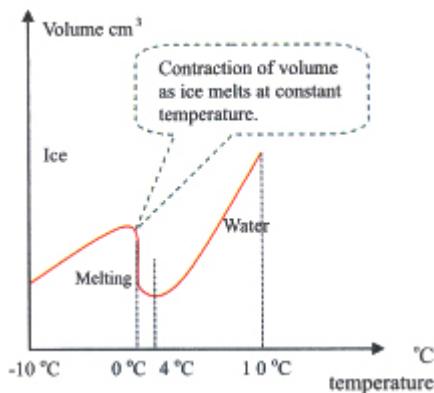


Figure 7.3 Heating curve of ice showing change in volume during melting and freezing

Explaining melting using kinetic theory

The molecules of a solid are packed very close to each other and held together by strong molecular forces. These molecules only vibrate about their fixed positions. When the substance is heated, the molecules gain more energy and vibrate rapidly. The vibration of the molecules increases until the substance reaches its melting point. Absorption of more energy at the melting point does not increase the vibration of the molecules; therefore, the temperature at the melting point is constant. The energy absorbed at the melting point of the substance until it melts only breaks the bonds between molecules and pushes them apart. When the bonds are completely broken, the solid changes to liquid, the molecules begin to move about as they do in a liquid. **The process of breaking the bonds holding the molecules as a solid is known as melting or fusion.**

Evaporation and vaporization

Much evidence abounds to demonstrate that liquids change state to vapour. Such evidences include:

- Wet clothes spread outside dry up.
- Liquids left exposed disappear gradually.
- Sweat produced during rigorous exercise dries up after some minutes rest.
- Vapours are formed when boiling liquids.

In all the examples above, molecules of liquid escape or break away to remain outside the liquid as vapour. When a liquid changes to vapour (gas) at ordinary temperatures, it is said to **evaporate**.

Evaporation is the breaking away of liquid molecules from the surface of the liquid and remaining outside the liquid as vapour.

It occurs at any temperature above the absolute zero without reaching the boiling point of the liquid. The closer the liquid is to its boiling point the faster the rate of evaporation.

Explaining evaporation using kinetic theory

Liquid consists of molecules, which are in constant motion. The molecules of a liquid have different speeds; at the surface are the molecules with greatest energy (speed). The surface molecules have sufficient energy to break away from the bonds holding them as liquid. The escaping molecules remain outside the liquid as vapour.

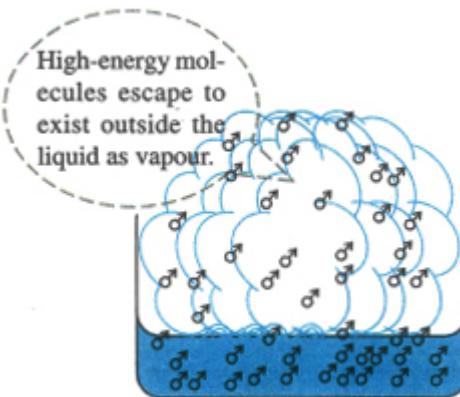


Figure 7.4 Evaporation of liquid

Factors that affect evaporation

The rate of evaporation depends on:

- **Temperature.** Rise in temperature of the liquid increases the rate of evaporation.
- **Surface area of liquid exposed.** Evaporation takes place faster if the area of the liquid exposed is more. Clothes dry faster if spread than folded.
- **Nature of the liquid exposed.** Liquids with low boiling points evaporate faster than liquids with high boiling points. Volatile liquids like petrol and ethanol with low boiling point evaporate faster than non-volatile liquid like oil.
- **Pressure on the liquid.** Increasing the pressure on a liquid increases its boiling point, thereby decreasing the rate of evaporation of the liquid. Evaporation is faster when the pressure on the liquid is low.
- **Wind.** Wind assists evaporation because it carries away the escaping molecules from the liquid surface.
- **Humidity.** Evaporation is low on a humid, non-windy day and high on a dry windy day. The higher the temperature of a liquid, the higher the rate of its evaporation.

Vaporization

Vaporization is rapid evaporation which occurs at the boiling point of the liquid. It takes place at a definite temperature which remains constant as the liquid changes to vapour. Vapour is a gas at low temperatures; it condenses easily to liquid on cooling.

Summary

- The change of state from solid to liquid is called **melting** or **fusion**.
- The process of converting a liquid to vapour is known as **vaporization**.
- The change of state from vapour to liquid is called **condensation**.
- The change of state from liquid to solid is known as **freezing** or **solidification**.
- The **melting point** of ice is $0\text{ }^{\circ}\text{C}$ and the **freezing point** of water is $0\text{ }^{\circ}\text{C}$.
- **Evaporation** is the breaking away of liquid molecules from the surface of the liquid and remaining outside the liquid as vapour.
- **Evaporation** occurs at any temperature above the absolute zero without reaching the boiling point of the liquid.
- **Vaporization** is rapid evaporation which occurs at the boiling point of the liquid.

Practice questions

1. State three states of matter which determine the state in which matter exists.
2. Explain the following:
 - (i) melting and freezing;
 - (ii) melting point and freezing point.
3. (a) Describe an experiment to determine the melting point of solid naphthalene solid.
(b) (i) Sketch the graph expected from the experiment.
(ii) Explain the three stages of the graph and how the melting point can be determined.
4. (a) What is evaporation?
(b) Explain evaporation using kinetic theory of matter.
(c) State the factors which affect the rate of evaporation.



I'd like to play soccer
on the river.

Wait till the water
solidifies in winter.