

CHAPTER 10

THERMAL PHYSICS



Student's learning outcomes (SLOs)

After studying this unit, student will be able to:

- describe qualitatively the thermal expansion of solids (linear and volumetric expansion).
- explain the thermal expansion of liquids (real and apparent expansion) and gases.
- discuss the pressure and the changes in pressure of a gas in terms of particles [the forces exerted by particles colliding with surfaces, creating a force per unit area.]
- discuss the applications and consequences of thermal expansion in real life.
- define and calculate specific heat for solids and liquids.
- discuss everyday effects due to the large specific heat of water.
- use the terms for the changes in state between solids, liquids and gases (This includes stating the relative order of magnitudes of the expansion of solids, liquids and gases.)
- describe evaporation in terms of particles [in terms of the escape of more energetic particles from the surface of a liquid].
- discuss how temperature, humidity, surface area and air movement over a surface affect evaporation.
- explain how evaporation causes cooling.
- describe the use of cooling caused by evaporation in the refrigeration process without using harmful CFCs.
- define latent heat of fusion and latent heat of vaporization of ice and water. How these can be determined Experimentally? [including illustrating the analysis of data by sketching temperature-time graph on heating ice.]

- describe superconductivity (as when atoms are in this state, their kinetic energy is low, so there is little (or no) resistance to the flow of electrons.
- state that certain materials, when cooled to near absolute zero, can exhibit superconductivity.

Heat and temperature play a vital role in our daily life, from feeling the warmth of the Sun to enjoying a cold drink on a hot day. Thermal physics helps us to understand how heat flows, how the temperature of substances change, and how heat energy is transferred. This field explains important concepts such as temperature, heat transfer, specific heat capacity, phase changes, latent heat and evaporation. Understanding these principles helps us to understand how everyday objects like refrigerators, heat engines, and even Earth's climate function. Thermal physics is not just about daily life, it also helps scientists to explore space, develop efficient energy systems, and demonstrate modern technology.

10.1 Thermal Expansion

Thermal expansion is the change in length, area, or volume of a substance when it is heated. As the temperature rises, the particles within a substance gain more kinetic energy. This causes them to move faster and spread out, leading to expansion of the material (Fig. 10.1-b).

Conversely, when a substance is cooled, its particles lose energy and move closer together, causing the material to contract (Fig. 10.1-a). This phenomenon is known as thermal contraction.

Thermal Expansion in Solids

When solids are heated, they expand, and this expansion remains almost consistent over a broad temperature range. Change in temperature may cause respective change in length or volume of the solids. If length of a solid changes upon heating, then it is called linear thermal expansion. For example, consider a metal rod in Fig. 10.2 with an initial length L_0 at a temperature T_0 . When heated to a

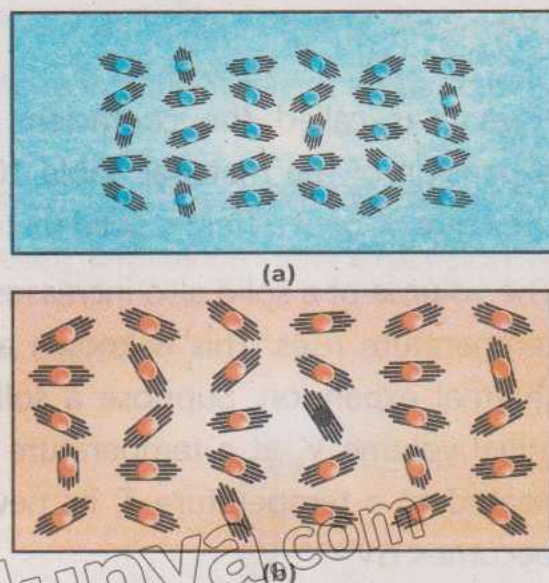


Fig. 10.1: Molecules of an object moving with
(a) smaller amplitude at low temperature
(b) larger amplitude at higher temperature

temperature T , its new length becomes L . Thus, the increase in length of the rod is:

$$\Delta L = L - L_0$$

and the rise in temperature is:

$$\Delta T = T - T_0$$

It has been observed that the change in length ΔL of a solid is directly proportional to its original length L_0 and the temperature change ΔT . Thus,

$$\Delta L \propto L_0 \Delta T$$

$$\text{or } \Delta L = \alpha L_0 \Delta T$$

$$\alpha = \Delta L / L_0 \Delta T$$

$$\text{or } L - L_0 = \alpha L_0 \Delta T$$

$$\text{or } L = L_0 (1 + \alpha \Delta T) \dots\dots\dots (10.1)$$

Here α is called the coefficient of linear expansion of the material. Table 10.1 shows the value of ' α ' of different solid materials.

The volume of a solid also increases when its temperature rises. This is known as volume thermal expansion. Suppose a solid has an initial volume V_0 at a temperature T_0 . When heated to a temperature T , its new volume becomes; $\Delta V = V - V_0$.

and the rise in temperature is: $\Delta T = T - T_0$.

Similar to linear expansion, the increase in volume ΔV is directly proportional to its original volume V_0 and the temperature change ΔT , thus

$$\Delta V \propto V_0 \Delta T$$

$$\text{or } \Delta V = \beta V_0 \Delta T$$

Linear expansion

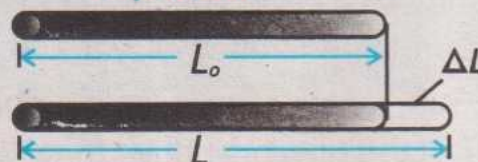


Fig. 10.2: Linear expansion in a metal rod

Table 10.1: Values of some coefficient of linear expansion (α) of different solid materials

Substance	α (K^{-1})
Aluminium	2.4×10^{-5}
Brass	1.9×10^{-5}
Copper	1.7×10^{-5}
Steel	1.2×10^{-5}
Silver	1.93×10^{-5}
Gold	1.3×10^{-5}
Platinum	8.6×10^{-5}
Tungsten	0.4×10^{-5}
Glass (pyrex)	0.4×10^{-5}
Glass (Ordinary)	0.9×10^{-5}
Concrete	1.2×10^{-5}

$$\text{or } V - V_0 = \beta V_0 \Delta T$$

$$\text{or } V = V_0 (1 + \beta \Delta T) \dots\dots\dots (10.2)$$

Here β is called coefficient of volume expansion which determines how much a material expands with temperature. Different solids have different values of β , meaning some expand more than others when heated.

Mathematically,

$$\beta = \frac{\Delta V}{V_0 \Delta T}$$

In solids, atoms are arranged in a tight, regular pattern. As the temperature rises, each atom pushes slightly harder against its neighbours due to increased vibration. Since there is no room to move inwards, the structure expands outward instead.

Thermal Expansion in Liquids

When a liquid is heated, its volume increases. This happens because the heat energy makes the liquid molecules move faster, causing them to spread apart and take up more space. Unlike solids, which have a fixed shape and expand in a limited way, liquids do not have a definite shape, so they expand freely in all directions when their temperature rises.

The degree to which a liquid expands depends on its specific coefficient of volumetric expansion, a property unique to each substance. This expansion is quantified by the formula:

$$\Delta V = \beta V_0 \Delta T \dots\dots\dots (10.3)$$

where ΔV is the change in volume, β is the volume expansion coefficient, V_0 is the original volume, and ΔT is the temperature change.

A common example of thermal expansion in liquid as seen in flask (Fig 10.3). When the flask is heated, the glass expands leading to decrease in liquid level from A to B which is known as expansion of flask (AB). As the liquid heats up, it expands

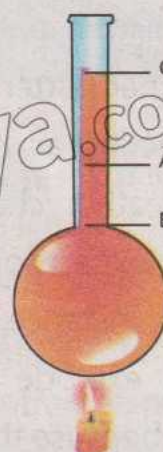


Fig. 10.3 : Thermal expansion of a liquid

and the level rises from B to C which is known as real expansion (BC). Where AC is an apparent expansion. Remember that real expansion is always greater than apparent expansion.

$$BC = AC + AB$$

Thermal Expansion in Gases

When temperature of a gas increases, its volume increases as long as the pressure remains same. This is called thermal expansion of the gas. As the temperature of a gas increases, the kinetic energy of its particles also increases. This causes the gas molecules to move faster and collide more frequently and forcefully with the walls of the container. Thus, collisions exert pressure, on the container walls.

If a gas is in a non flexible container, the increased collisions lead to a rise in pressure. However, in a flexible container, the volume can expand instead, allowing pressure to remain constant. This behaviour aligns with Charles' law, which states that the volume of a gas is directly proportional to its temperature at constant pressure.

The expansion of gases plays an important role in daily life and various industries. For example, in a hot air balloon, the air inside is heated, causing it to expand and become lighter than the cooler air outside. This makes the balloon to rise (Fig. 10.4). Similarly, in car engines, fuel burns and produces hot gases that expand quickly, pushing the pistons and making the vehicle move. In weather patterns, warm air expands and rises, affecting air pressure and causing winds and weather changes. However, the uncontrolled expansion of gases can be dangerous. For instance, aerosol cans and gas cylinders can explode if exposed to high temperatures because the gas inside expands beyond what the container can withstand.

Tidbit

Liquids do not have a fixed shape, so they expand more freely than solids. That is why we should not fill a bottle of water to the top before freezing it, it might crack.



Fig. 10.4: Thermal expansion of gas in a balloon (a) Before heating (b) After heating

Consequences of Thermal Expansion in Real Life

When materials expand or contract due to temperature changes, it can lead to structural, mechanical, and functional consequences. Thermal expansion is commonly used in our daily life such as:

- 1. Thermometers:** In thermometers, thermal expansion in a narrow tube helps in the measurement of temperature.
- 2. Gaps in Railway Tracks:** Steel tracks of the rails expand on hot days. Without room to expand, the tracks may bend or twist a phenomenon called "sun kinks" which can cause train derailments. Small gaps are left between railway tracks to allow them to expand in summer, preventing them from bending (Fig. 10.5-a).
- 3. Bridges:** Bridges have small gaps called expansion joints that allow them to expand in hot weather and contract in cold weather without breaking (Fig. 10.5-b).
- 4. Metal Lids on Jars:** When a metal lid is stuck on a glass jar, running warm water over it makes the lid expand slightly, making it easier to open.

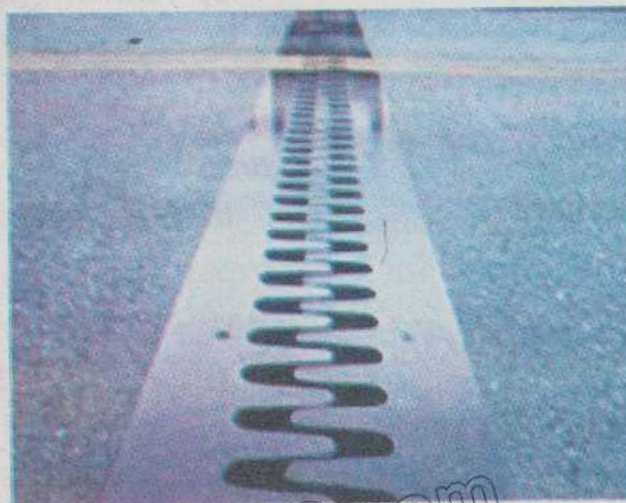


Fig.10.5: (a) Expansion gaps in railway tracks (b) Expansion joints in bridges

- 5. Gas Containers (like aerosols or propane tanks):** Gases expand significantly when heated. If containers are exposed to heat (like being left in the Sun), pressure can build up inside and causes explosions. Warning labels advise users to store these containers away from heat, and pressure relief valves are often included.
- 6. Pipes and Plumbing:** Water pipes can expand and contract, especially with hot water. This may lead to pipe bursts or joint leaks if not properly accounted for. Flexible joints and loops are used in piping systems to absorb movement.

7. Hot Air Balloon: The expansion of heated air is intentionally used to make the balloon rise. Heating the air inside causes it to expand, reducing its density so it lifts the balloon (Fig.10.6).



Brain Teaser

Why do not train tracks buckle in winter but do in summer even though the metal is the same?

Fig. 10.6: When hot air balloon is heated, air inside the balloon expands and becomes less dense, causing the balloon to rise

Example 10.1: A metal rod of length 1.5 m expands by 0.025 m when heated from 30 °C to 180 °C. Calculate its coefficient of linear expansion.

Solution:

Given that;

$$L_0 = \text{Initial length} = 1.5 \text{ m}$$

$$\Delta L = \text{Change in length} = 0.025 \text{ m}$$

$$\Delta T = \text{Change in temperature} = 180^\circ\text{C} - 30^\circ\text{C} \\ = 150^\circ\text{C} \text{ or } 150 \text{ K}$$

To find;

$$\alpha = \text{Coefficient of linear expansion} = ?$$

The formula for linear expansion is:

$$\Delta L = \alpha L_0 \Delta T$$

$$\text{or } \alpha = \Delta L / L_0 \Delta T$$

Substituting the values

$$\alpha = 0.025 \text{ m} / 1.5 \text{ m} \times 150 \text{ K}$$

$$\alpha = \frac{0.025}{225} = 1.11 \times 10^{-4} \text{ K}^{-1}$$

10.2 Specific Heat Capacity

The energy required to heat a material depends on three factors:

1. Mass of the substance
2. Change of temperature
3. Nature of the material

Some substances absorb heat more easily than others. For example, heating 1 kg of water by 1 °C requires more energy than heating 1 kg of alcohol by the same amount. This relationship is expressed using the formula:

$$Q = m c \Delta T \dots\dots\dots(10.4)$$

where

Q = heat energy

m = mass of the substance

ΔT = change in temperature

c = specific heat capacity

Specific heat capacity (c) is the amount of heat energy needed to increase the temperature of 1 kg of a substance by 1 °C (or 1 K). The SI unit of specific heat capacity is $\text{J kg}^{-1} \text{K}^{-1}$.

For Your Information



Metal heats up quickly due to its low specific heat capacity, while wood stays normal because of its higher specific heat capacity.

Specific Heat Capacity of Solids

The specific heat capacity of solids is the heat energy needed to raise the temperature of 1 kg of a solid by 1 °C. Materials with a high specific heat capacity, such as wood and rubber require more heat to increase their temperature, making them useful in applications like cooking utensils and thermal insulation. On the other hand, metals like steel and copper have low specific heat capacities, i.e; they heat up and cool down quickly, so they are used in making cooking items, kettles, radiators, and heat engines.

heat energy needed to raise the



Do You Know?

Why does metal feel colder than wood when touched, if they are both at the same temperature?

Metal is a conductor, wood is an insulator. The metal conducts the heat away from our hands, the wood does not conduct the heat away from our hands as well as the metal, so the wood feels warmer than the metal.



Specific Heat Capacity of Liquids

The specific heat capacity of a liquid is the amount of heat energy needed to raise the temperature of 1 kg of the liquid by 1 °C or 1 K. Different liquids have different specific heat capacities based on their molecular structure and ability to store heat. One of the most important liquids in this regard is water, which has a high

specific heat capacity of $4,200 \text{ J kg}^{-1} \text{ K}^{-1}$. This means water can absorb and store a large amount of heat with only a small temperature increase. Because of this property, water is widely used in cooling systems, heating systems, and as a natural temperature stabilizer. Other liquids, such as alcohol and mercury, have lower specific heat capacities, meaning they heat up and cool down more quickly than water.

Effects of Large Specific Heat Capacity of Water

Large water bodies like oceans and lakes absorb heat during the day and release it slowly at night, preventing drastic temperature changes. This is why coastal areas have milder climates compared to inland regions. Since water has a specific heat capacity of $4200 \text{ J kg}^{-1} \text{ K}^{-1}$, while dry soil has only $810 \text{ J kg}^{-1} \text{ K}^{-1}$, soil heats up five times faster than the same mass of water under the same heat. As a result, land temperatures rise and fall more quickly than sea temperatures, making seasonal temperature changes less extreme in coastal areas.

Water's high specific heat capacity also makes it useful for storing and transferring heat. In an automobile engine, the cooling system uses water to absorb and carry away the heat produced during the engine operation. The pump circulates water through jackets around the engine cylinders, where it absorbs heat (Fig. 10.7). This heated water then flows through the thermostat, which regulates its movement based on temperature. If the water is too hot, the thermostat opens, allowing it to enter the radiator. In the radiator, a fan draws in outside air, which cools the water passing through it. The cooled water then returns to the engine to absorb more heat, and this cycle is repeated. A pressure release cap ensures that the system remains safe by releasing excess pressure. This property helps water to carry away engine heat efficiently, preventing overheating and ensuring smooth engine performance.

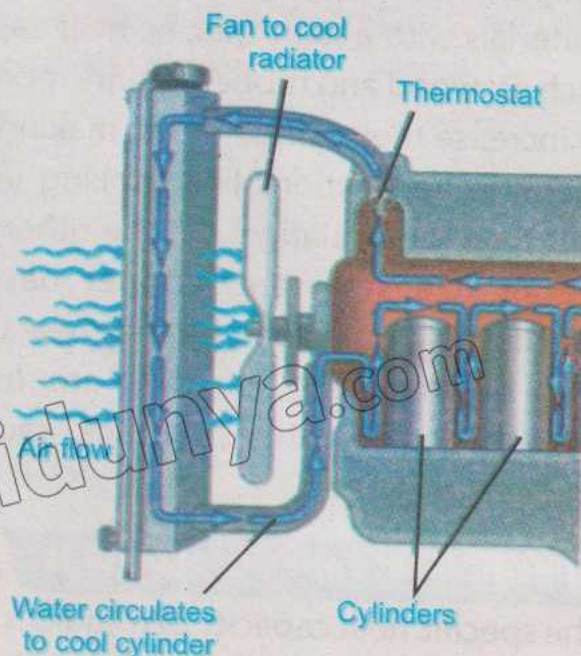


Fig. 10.7: Cooling system of automobile

10.3 Change in State

By absorbing or losing energy, the K.E. of the atoms or molecules of a substance changes that can lead to change in the state of a matter. Change in states of matter occurs when matter loses or absorbs energy.

Change in State of a Substance

When a substance absorbs energy, the atoms and molecules move more rapidly and hence need more space and separation between atoms or molecules. It may lead to turn a solid to liquid, called melting and liquid to gas, known as boiling. By losing energy, the atoms and molecules will slow down and hence there is less space and separation between them. It may lead to turn a gas to liquid, called condensation and a liquid to solid, known as solidification. Keep in mind that intermolecular forces are the strongest in solids due to least separation and weakest in the gases, as the molecules are far apart as compared to liquids and solids. This is the reason that the gases exhibit the greatest relative thermal expansion while solids have the least expansion.

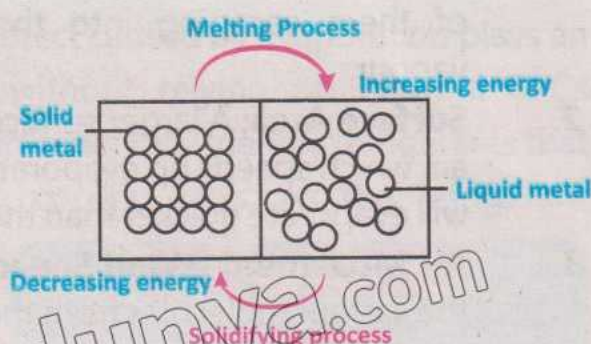


Fig. 10.8: Phase changes

10.4 Evaporation

Evaporation is a natural process by which a liquid changes into a gas at its surface without boiling.

It occurs at all temperatures but is faster at higher temperatures. This change occurs at the surface of the liquid, where some of the particles have enough energy to escape into the air as vapour. Evaporation does not require the entire liquid to be heated, it can occur at room temperature. For instance, when water is spilled on the floor, it gradually disappears as it turns into water vapour. This process plays a key role in everyday life and in nature. It helps in drying wet clothes, and



Fig. 10.9: Evaporation process (molecules at the surface of a liquid gain enough energy to escape into the air as vapour, leading to evaporation)

cooling our bodies through sweating. Several key factors influence how quickly or slowly this takes place:

1. **Temperature:** The higher the temperature, the faster evaporation occurs. When heat is added, the molecules in the liquid move more energetically, increasing the chances of them escaping into the air as vapour.
2. **Surface Area:** A larger surface area allows more liquid to be exposed to the air, which speeds up evaporation. For example, water in a wide, shallow dish will evaporate quicker than the same amount in a tall, narrow container.
3. **Air Movement (Wind Speed):** Wind or air movement helps to carry away the vapour molecules from the surface of the liquid. This prevents saturation of the air above the liquid and allows more molecules to evaporate (Fig. 10.9).
4. **Humidity of the Surrounding Air:** If the air is already full of moisture (high humidity), evaporation slows down. But in dry air, the process occurs more rapidly because the air can absorb more water vapour.
5. **Nature of the Liquid:** Different liquids evaporate at different rates based on their molecular structure. For instance, alcohol evaporates faster than water because its molecules require less energy to escape into the air.
6. **Pressure:** Lower atmospheric pressure can enhance evaporation since there is less force pushing down on the liquid surface, making it easier for molecules to escape.

Tidbit

Evaporation from our skin takes away body heat, keeping us cool. That is our body's natural way of managing temperature.

Cooling Caused by Evaporation

During evaporation, the molecules that evaporate take away heat from the remaining liquid. This process cools the liquid down because the higher-energy molecules leave, leaving behind cooler molecules.

For example, when we sweat, the sweat on our skin evaporates, taking heat away from our body and making us feel cooler. Similarly, wet clothes dry faster on a hot day because

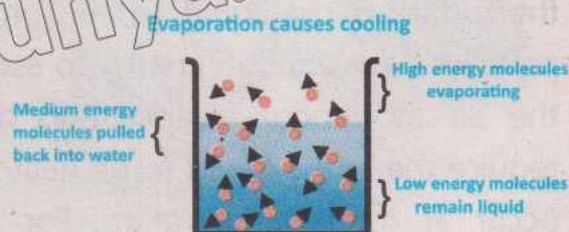


Fig. 10.10: High-energy molecules escape from the liquid surface as vapour, leaving behind lower-energy particles

water evaporates quickly, cooling the clothes as it evaporates.

This cooling effect due to evaporation is important in everyday life and in nature, helping to regulate temperatures and keep things cool (Fig. 10.10).

Refrigeration without Chlorofluorocarbons (CFCs)

In modern refrigeration systems, the cooling effect caused by evaporation plays an important role in lowering temperatures without relying on harmful CFCs (chlorofluorocarbons). These systems use environmentally friendly refrigerants that evaporate at low temperatures inside the cooling coils. As the refrigerant evaporates, it absorbs a large amount of heat from the surrounding area (such as inside a refrigerator), causing the temperature to drop. This absorbed heat is then carried away as the vapour is compressed and condensed back into a liquid outside the cooling compartment (Fig. 10.11). This cycle of evaporation and condensation enables continuous cooling, while avoiding the environmental damage once caused by ozone-depleting CFCs.

Brain Teaser

If evaporation produces cooling, why does not boiling water feel cold?

Tidbit

Refrigerators use an amazing trick: they cool by letting special liquids evaporate inside coils. No harmful CFCs needed today, modern coolants are more eco-friendly.

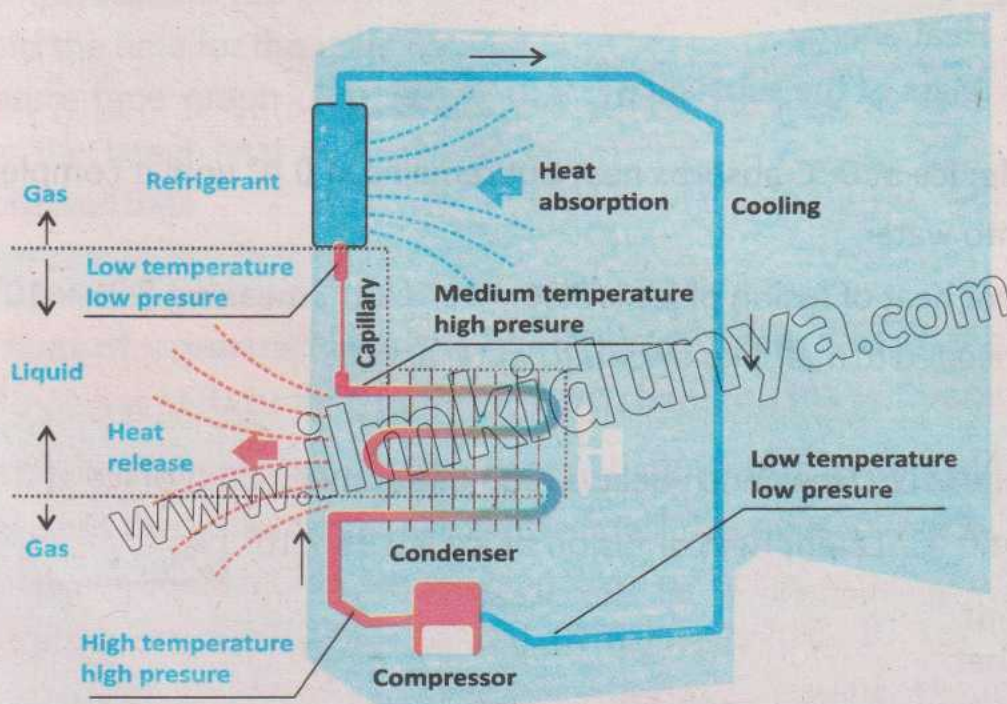


Fig. 10.11: Block diagram of refrigerator

10.5 Latent Heat

Latent heat is the heat energy required to change the state of a substance without changing its temperature.

This heat is used to break or form bonds between particles instead of increasing their movement.

Latent Heat of Fusion

Latent heat of fusion is the heat energy required to convert 1 kg of a solid into a liquid at its melting point while keeping the temperature constant. When a solid melts into a liquid, it absorbs heat without rise in temperature. This heat is used to break the strong bonds between solid particles, allowing them to move more freely as a liquid. The temperature remains constant until the entire solid has melted. The latent heat of fusion is calculated using the formula:

$$Q = m L_f \dots\dots\dots(10.5)$$

where

L_f = Latent heat of fusion

Q = Heat energy

m = Mass of the substance

Example: Ice at 0 °C absorbs heat but remains at 0 °C until it completely melts into water.

The latent heat of fusion of ice is $3.36 \times 10^5 \text{ J kg}^{-1}$ meaning 3.36×10^5 joules of heat is needed to melt 1 kg of ice into water at 0 °C.

Example 10.2: How much heat is required to melt 600 g of ice at 0 °C into water at 0 °C? Latent heat of fusion of ice is $3.36 \times 10^5 \text{ J kg}^{-1}$.

Solution:

Given that;

Mass of ice $m = 600 \text{ g}$
 $= 0.600 \text{ kg}$

Tidbit

When ice melts or water boils, energy is working hard behind the scenes to break bonds between molecules but the thermometer does not show any rise in temperature.

Latent heat of fusion of ice $L_f = 3.36 \times 10^5 \text{ J kg}^{-1}$

To find;

Heat required $Q = ?$

Using the formula $Q = m \times L_f$

Substituting the values $Q = 0.600 \text{ kg} \times 3.36 \times 10^5 \text{ J kg}^{-1}$

$$Q = 201,600 \text{ J}$$

$$\text{or } Q = 201.6 \text{ kJ}$$

Experiment 1: This involves placing small ice pieces in a beaker over a stand, suspending a thermometer to measure temperature. Heating the beaker causes the ice to melt, keeping the mixture at 0°C until all ice melts. Note the time taken for complete melting. Further heating causes water temperature to rise from 0°C to 100°C . Record the time for this increase. Plot a temperature-time graph (Fig. 10.12) and calculate the latent heat of fusion of ice using collected data.

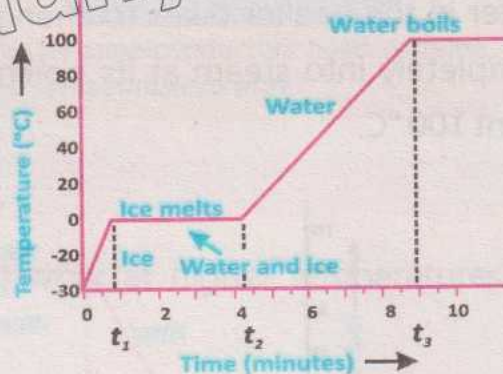


Fig. 10.12: Temperature-time graph as ice changes into water that boils as heating continues

Latent Heat of Vaporization

Latent heat of vaporization is the heat energy needed to change 1 kg of a liquid into gas at its boiling point without changing the temperature.

When a liquid changes into gas, it absorbs heat, but its temperature remains constant until the entire liquid has evaporated. This heat is used to break the bonds between liquid molecules, allowing them to escape as gas. The latent heat of vaporization of water is $2.26 \times 10^6 \text{ J kg}^{-1}$. This means $2.26 \times 10^6 \text{ J}$ of heat energy is needed to convert 1 kg of water into steam at 100°C . The latent heat of

vaporization is expressed as:

$$Q = m L_V \dots\dots\dots (10.6)$$

where L_V is Latent heat of vaporization, Q is heat energy and m is the mass of the substance

Table 10.2 shows the melting point, boiling point, latent heat of fusion, and latent heat of vaporization of some common substances.

Experiment 2: At the end of experiment 1, the beaker contains boiling water. Continue heating water until all the water changes into steam. Note the time which the water in the beaker takes to change completely into steam at its boiling point 100°C .

Table 10.2: Melting point, boiling point, latent heat of fusion, and latent heat of vaporization of some common substances

Substance	Melting point ($^\circ\text{C}$)	Boiling point ($^\circ\text{C}$)	Heat of fusion (J g^{-1})	Heat of vaporization (J g^{-1})
Aluminium	660	2250	39.7	10500
Copper	1083	2595	205.0	4810
Gold	1063	2660	64.0	1580
Helium	-270	-269	5.5	21
Lead	327	1750	23.0	858
Mercury	-39	357	11.7	270
Nitrogen	-210	-196	25.5	200
Oxygen	-219	-183	13.8	210
Water	0	100	336.0	2260

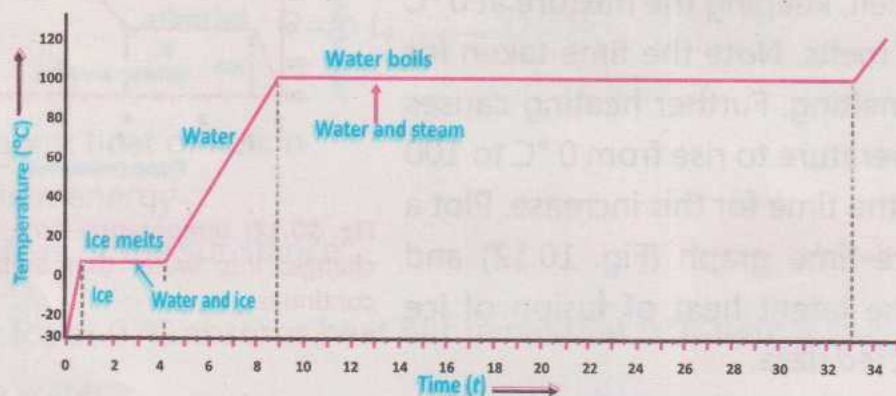


Fig. 10.13: Temperature-time graph as ice changes into water and water into steam on heating

Extend the temperature-time graph as shown in Fig. 10.13. Calculate the latent heat of fusion of ice from the data.

10.6 Superconductivity

Superconductivity is a special property of some materials where they have zero electrical resistance when cooled below a certain temperature, called the critical temperature. In this state, electricity flows without any energy loss, making superconductors very efficient.

How does Superconductivity Work?

Since there are no collisions, electric current flows without facing any resistance as superconductors have zero electrical resistance. Figure 10.14 shows the variation of electrical resistivity with temperature for a superconductor and a normal metal. The resistivity of a superconductor drops to zero below the critical temperature (T_c), whereas a normal metal shows a gradual decrease in resistivity.

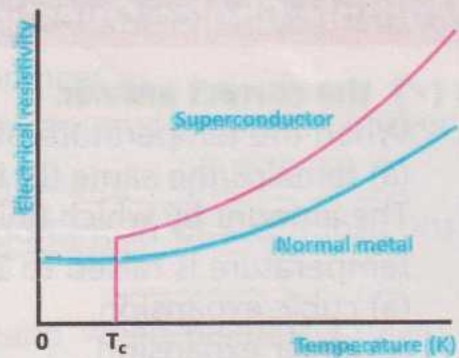


Fig. 10.14: Variation of electrical resistivity with temperature for a superconductor and a normal metal

Materials That Show Superconductivity

Some metals and ceramics become superconductors at extremely low temperatures.

1. Mercury – Becomes superconducting below 4.2 K.
2. Lead – Becomes superconducting below 7.2 K.
3. High-temperature superconductors (ceramics) work at higher temperatures, such as 135 K.

Uses of Superconductors

Superconductors are used in advanced technologies, including:

1. **MRI Machines** : To generate strong magnetic fields for medical imaging.
2. **Maglev Trains** : Use of superconductors to float the train above tracks, reducing friction.
3. **Particle Accelerators**: Help scientists to study fundamental particles.

Superconductors are important for future technologies, making electrical systems more efficient and powerful.

Brain Teaser

Why do superconductors need extreme cold temperature to work?

EXERCISE

A. Multiple Choice Questions

Tick (✓) the correct answer.

- 10.1 When the temperature of a rod of copper is increased, its length:
(a) remains the same (b) increases (c) decreases (d) becomes double
- 10.2 The amount by which unit length of a material increases when the temperature is raised to 1°C , is called the coefficient of:
(a) cubic expansion (b) volume expansion
(c) linear expansion (d) none of these
- 10.3 What does a liquid turn into once it is evaporated?
(a) Gas (b) Water vapours (c) Air (d) Both (a) and (b)
- 10.4 Which property determines how much heat a solid can absorb before its temperature changes significantly?
(a) Density (b) Specific heat capacity (c) Colour (d) Hardness
- 10.5 High-temperature superconductors typically involve which type of material?
(a) Pure metals (b) Organic compounds
(c) Ceramics (d) Liquid crystals

B. Short Answer Questions

- 10.1 What factors influence the thermal expansion of solids?
- 10.2 What is latent heat of fusion?
- 10.3 How do different materials exhibit varying thermal expansion behaviours?
- 10.4 How does evaporation contribute to cooling processes in everyday life?
- 10.5 What is latent heat of vaporization, and how is it calculated?

C. Constructed Response Questions

- 10.1 Why do bridges need expansion joints but glass jars with metal lids do not, even though both experience temperature changes? Discuss in terms of the nature of thermal expansion.
- 10.2 If two liquids are heated under same conditions, but one of them heats up faster, what does this indicate about the specific heat capacity?
- 10.3 Why does a liquid evaporate faster when the air is dry?
- 10.4 When a piece of ice melts, the temperature does not increase even though heat is supplied. Where does the energy go, and why is this important in phase change?
- 10.5 Why do electric transmission wires sag in summer and tighten in winter?

D. Comprehensive Questions

- 10.1 How does thermal expansion differ between solids, liquids, and gases? Provide examples to illustrate these differences.
- 10.2 What are some practical consequences of thermal expansion in everyday life, such as in construction materials or household appliances?
- 10.3 What is latent heat, and why is it important in phase transitions like melting and vaporization?
- 10.4 Why do solids, liquids, and gases expand when heated? Explain with examples.
- 10.5 If we have an equal amount of water in a wide, shallow dish and a tall, narrow container kept at the same temperature, in which container will evaporation occur faster? Explain the reason scientifically.

E. Numerical Problems

- 10.1 A metal rod of length 1 m expands by 0.02 m when heated from 20 °C to 120 °C. Calculate its coefficient of linear expansion. [Ans: $2.0 \times 10^{-4} \text{ K}^{-1}$]
- 10.2 A container holds 1 litre of water at 20 °C. What will be its volume at 80 °C, assuming water's coefficient of volume expansion is 2.1×10^{-4} per °C? [Ans: 1012.6 cm³]
- 10.3 A steel rod initially measures 2 m at 20 °C. If its coefficient of linear expansion is $1.2 \times 10^{-5} \text{ °C}^{-1}$, what will be its length at 100 °C? [Ans: 2.002 m]
- 10.4 A steel bridge expands by 5 cm on a hot summer day. If the bridge originally spanned 100 m, what is the temperature change? [Ans: 41.67 °C]
- 10.5 How much heat is required to raise the temperature of a 2 kg iron bar from 20 °C to 100 °C, given that the specific heat capacity of iron is $450 \text{ J kg}^{-1} \text{ K}^{-1}$? [Ans: 72 kJ]
- 10.6 How much heat is required to melt 500 g of ice at 0 °C into water at 0 °C? (Latent heat of fusion of ice = $3.36 \times 10^5 \text{ J kg}^{-1}$) [Ans: 168 kJ]
- 10.7 Calculate the heat required to completely vaporize 1 kg of water at 100 °C. (Latent heat of vaporization of water = $2.26 \times 10^6 \text{ J kg}^{-1}$) [Ans: 2.26 MJ]