

Student's Learning Outcomes (SLO's)

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.

Subjective Type Questions

Long Questions prepared in the light of new Examination Techniques:
(Knowledge, Understanding, Application, Analytical & Conceptual)

Introduction

Q.1: What is thermal Physics and its applications in daily life?

Ans. 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: Thermal physics helps us to understand how heat flows, how the

temperature of substances change, and how heat energy is transferred.

Applications: 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 emendate modern technology.

10.1

Thermal Expansion

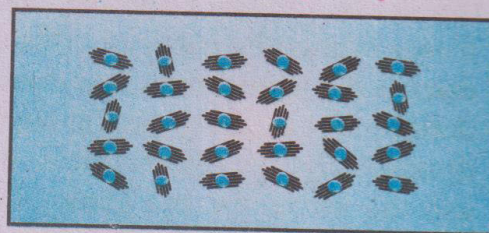
Q.2: What is thermal expansion? Explain in detail with the help of particle motion.

Ans. Thermal expansion is the change in the **length, area, or volume** of a substance when it is heated".

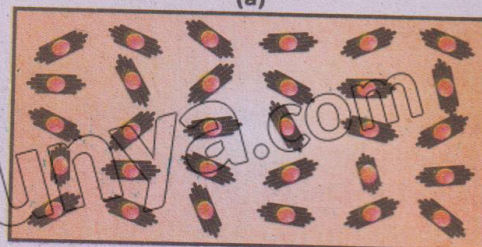
Explanation:

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**.



(a)



(b)

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

Q.3: Explain the phenomenon of thermal expansion in solids in detail.

OR Explain why different solids expand by different amounts when heated? Discuss the role of intermolecular forces and nature of material.

Ans. Thermal Expansion in Solids:

"Thermal expansion in solids is the phenomenon in which a solid increases in its length, area, or volume when its temperature is increased due to an increase in the vibration of its particles."

Explanation: 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.

Types: These are three types of thermal expansion in solids:

- Linear expansion.
- Area (superficial) expansion
- Volume expansion

1. Linear Expansion:

"When the **length** of a solid increases due to heating, it is called **linear expansion**."

(or) "If length of a solid changes upon heating, then it is called **linear thermal**"

expansion.

Explanation: Consider a metal rod of initial length L_0 at temperature T_0 .

When heated to temperature T , its length becomes L .

- Increase in length:

$$\Delta L = L - L_0$$

- Rise in temperature:

$$\Delta T = T - T_0$$

Experimentally, it is found that the change in length ΔL of a solid is directly proportional to its original length L_0 and the temperature change ΔT . Thus,

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

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

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

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

$$L = L_0 (1 + \alpha \Delta T) \dots \dots (10.1)$$

Here α (alpha) is the **coefficient of linear expansion**.

Coefficient of linear expansion:

"The increase in length per unit original length per degree rise in temperature."

Unit: K^{-1} or $^{\circ}C^{-1}$

Table 10.1

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

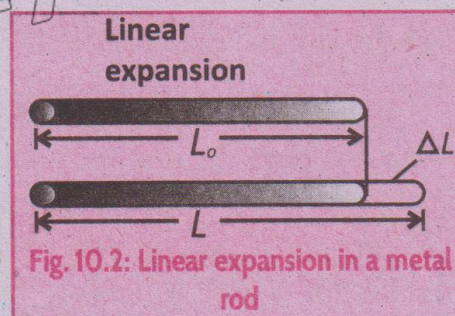
Substance	α (K^{-1})
Aluminium	2.4×10^{-5}
Brass	1.9×10^{-5}
Copper	1.7×10^{-5}
Steel	1.2×10^{-5}
Silver	1.93×10^{-5}
Gold	1.3×10^{-5}
Platinum	8.6×10^{-5}
Tungsten	0.4×10^{-5}
Glass (pyrex)	0.4×10^{-5}
Glass (Ordinary)	0.9×10^{-5}
Concrete	1.2×10^{-5}

2. Volume Expansion:

"When the *volume* of a solid increases due to heating, it is called **volume expansion**."

(OR)

"The volume of a solid also increases when its temperature rises. This is known as



volume thermal expansion."

Explanation: Suppose a solid has an initial volume V_0 at a temperature T_0 , final Volume V when heated to a temperature T . Its new volume becomes:

$$\Delta V = V - V_0$$

And the rise in temperature is:

$$\Delta T = T - T_0$$

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

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

or $\Delta V = \beta V_0 \Delta T$

or $V - V_0 = \beta V_0 \Delta T$

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

Where β (beta) is the **coefficient of volume expansion** which determines how much a material expands with temperature.

Coefficient of volume expansion

"The increase in volume per unit original volume per degree rise in temperature".

Mathematically,

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

Important points:

- Different solids expand by different amounts.
- Metals generally expand more than others, like glass.
- Expansion depends on:

1. Nature of material. 2. Original size. 3. Change in temperature.

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

Examples:

- Gaps left between railway tracks.
- Expansion joints in bridges.
- Electric wires hanging loosely in summer.

Q.4: Explain Thermal expansion in liquids and explain why liquids expand when heated?

Ans. Thermal expansion:

"Thermal expansion in liquids is the increase in the volume of a liquid when it is heated, and the decrease in its volume when it is cooled."

Explanation: When a liquid is heated, its molecules gain kinetic energy and start moving faster. Due to this increased motion, the molecules move farther apart, causing the liquid to occupy more space. Unlike solids liquids do not have a fixed shape, so they expand freely in all directions when heated.

Liquids expand more than solids because the intermolecular forces in liquids are

weaker than in solids.

Volumetric Expansion of Liquids: Liquids expand only in terms of volume, not length or area. The amount of expansion depends on:

- Nature of liquid.
- Change in temperature
- Original volume.

Formula: The volumetric expansion of a liquid is given by the formula.

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

Where,

- ΔV = Change in volume
- V_o = Original volume
- ΔT = Change in temperature
- β = Coefficient of volumetric expansion of the liquid.

Each liquid has a different β value.

Apparent and Real Expansion of liquids: Liquids are usually heated in a container (glass, flask) so both the liquid and the container expand.

Apparent Expansion: "The expansion of the liquid observed in the container is called apparent expansion."

This is less than the real expansion because part of the expansion is used in expanding the container.

Real Expansion: "The actual expansion of the liquid itself, ignoring the expansion of the container, is called real expansion."

Example: A common example of thermal expansion in liquid as seen in flask (Fig 10.3).

• **Apparent Expansion (AC):**

The observed rise in liquid level from the initial point (A) to the final point (C).

Expansion of flask (AB)

When heating begins, the flask expands first, causing the liquid level to drop slightly from A to B.

• **Real Expansion (BC):**

The actual expansion of the liquid, measured from the lowest point (B) to the final point (C).

Relationship:

$$BC = AC + AB$$

$$\text{Real Expansion} = \text{Apparent} + \text{Expansion of flask}$$

Q.5: Explain thermal expansion in gases in detail.

(OR) How does Charle's Law prove that gases expand on heating?

Ans. "When temperature of a gas increases, its volume increases as long as the pressure remains same. This is called thermal expansion of the gas."

(OR)

"It is the increase in volume of a gas when its temperature is increased, and

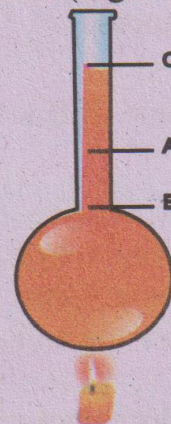


Fig. 10.3: Thermal expansion of a liquid

decreases in volume when its temperature is lowered, provided the pressure remains constant."

Explanation:

Kinetic Energy: As the temperature of a gas increases, the kinetic energy of its particles also increases.

Molecular Motion: This causes the gas molecules to move faster and collide more frequently and force fully with the walls of the container. Thus, collisions exert pressure, on the container walls.

Spreading out: In a flexible container, these collisions push the walls outward, causing the gas to occupy more space (expansion).

Charles's Law: The behavior of gases during expansion follows Charles's Law, which states that:

Statement: "The volume of a gas is directly proportional to its temperature at constant pressure."

$$V \propto T$$

$$\text{or } V = (\text{Constant}) T$$

$$\text{or } \frac{V}{T} = \text{constant}$$

Key characteristics:

Expansion Rate: Gases expand much more significantly than liquids or solids because their intermolecular forces are very weak, allowing particles to move much larger distances.

Pressure vs Volume: If a gas in a flexible container (like a balloon), it expands in volume. If it is in a non-flexible (rigid) container, the pressure rises instead.

Real World Applications and Risks:

Hot air balloons: 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)

Car Engine: In car engines, fuel burns and produces hot gases that expand quickly, pushing the pistons and making the vehicle move.

Weather patterns: In weather patterns, warm air expands and rises, affecting air pressure and causing winds and weather changes.

Safety Hazards: Aerosols cans and gas cylinders can explode if exposed to high temperatures because the gas inside expands beyond what the container can withstand.

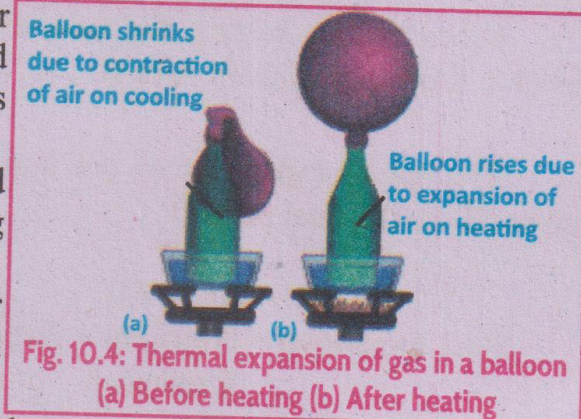


Fig. 10.4: Thermal expansion of gas in a balloon
(a) Before heating (b) After heating

Q.6: Explain the consequences of thermal expansion in real life.

(OR) Explain how thermal expansion is useful in practical applications?

Ans. When material expands or contracts 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 day. 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. 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)

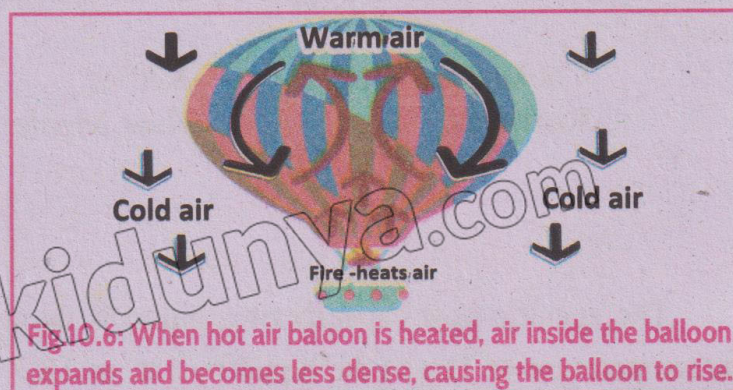


Fig.10.6: When hot air balloon is heated, air inside the balloon expands and becomes less dense, causing the balloon to rise.

Q.7: Define specific heat capacity, write its mathematical formula, its SI unit.

Ans. Definition:

"Specific heat capacity (c) is the amount of heat energy needed to increase the temperature of 1kg of a substance by 1°C (or 1K)."

Factors to heat a material:

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.

Understanding heat absorption: Some substances absorb heat more easily than others.

Example Heating 1kg of water by 1°C requires more energy than heating 1kg of alcohol by the same amount.

Formula: The relationship is expressed as;

$$Q = mc \Delta T \dots\dots (10.4)$$

Where,

- Q = heat energy
- m = mass of the substance
- ΔT = Change in temperature
- c = specific heat capacity.

Unit: The SI Unit of specific heat capacity is $\text{J kg}^{-1} \text{K}^{-1}$

Q.8: Explain specific heat capacity of solids.

(OR) Define the specific heat capacity of solids and state its SI unit.

Ans. "The specific heat capacity of solids is the amount of heat energy needed to raise the temperature of 1kg of a solid by 1°C or 1K."

Applications of different capacity:

1. High specific heat capacity:

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.

2. Low specific heat capacity:

Metals like steel and copper have low specific heat capacities. This means they are used in:

- Cooking items
- Kettles
- Radiators
- Heat engines.

Q.9: Define specific heat capacity of liquids. Discuss its significance with special reference to water and its effects on the environment.

Or Explain effects of large specific heat capacity of water.

Ans. The specific heat capacity of a liquid is the amount of heat energy needed to raise the temperature of 1kg of the liquid by 1°C or 1K."

Explanation: Different liquids have different specific heat capacities based on their molecular structure and ability to store heat.

The case of water: One of the most important liquids in this regard is water, which has a high specific heat capacity of $4200 \text{ J kg}^{-1} \text{ K}^{-1}$. 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
- Natural temperature stabilizer.

Other Liquids: 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:

On climate:

Large water bodies like oceans and lakes absorb heat during the day 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.

Applications in cooling systems:

- 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.

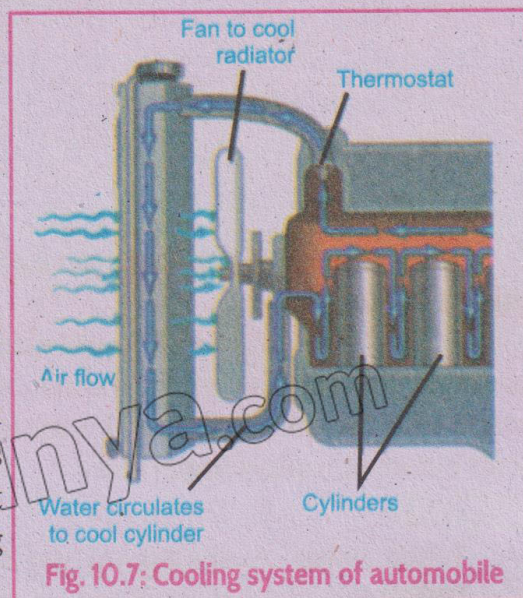


Fig. 10.7: Cooling system of automobile

Q.10: Discuss in detail the process of change in state of a substance using the kinetic molecular model.

Ans. 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:

Melting:

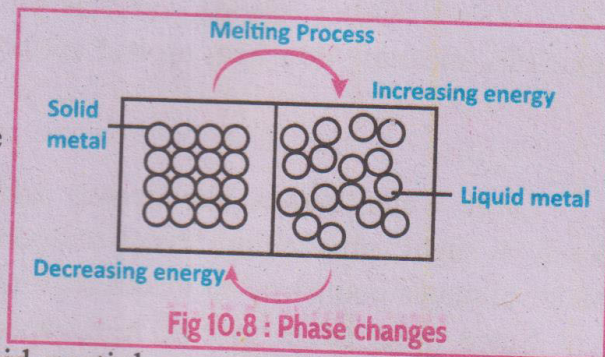
When a substance absorbs energy, the atoms and molecules move more rapidly and hence need more space and separation between atoms or molecules. It may lead to turn a solid to liquid, called melting.

Boiling: As more energy is absorbed the liquid particles move even faster and gain enough separation to turn liquid into a gas known as boiling.

Condensation and solidification: 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.

Intermolecular forces: 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.



Q.11: Explain the process of evaporation, the factors that influence its rate, and why it leads to a cooling effect?

OR Define evaporation in detail. Discuss factors which influence evaporation rate.

OR Define evaporation in detail. Also why cooling caused by evaporation?

Ans. Evaporation:

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

Explanation: 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.

Example

- When water is spilled on the floor, it gradually disappears as it turns into water vapour.

- It helps in drying wet clothes
- Cooling our bodies through sweating.

Factors influence evaporation: 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 large 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.

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.

Example

- When we sweat, the sweat on our skin evaporates, taking heat away from our body and making us feel cooler.
- Wet clothes dry faster on a hot day because water evaporates quickly, cooling the clothes as it evaporates.

This cooling effect due to evaporation is important in everyday life and in nature

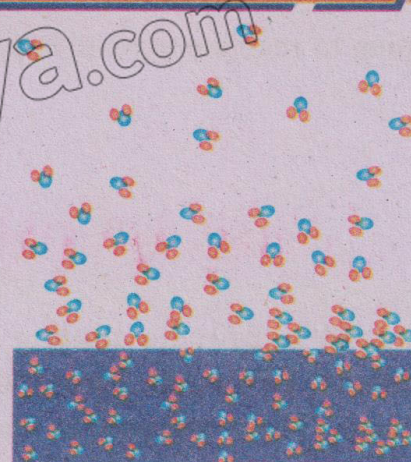
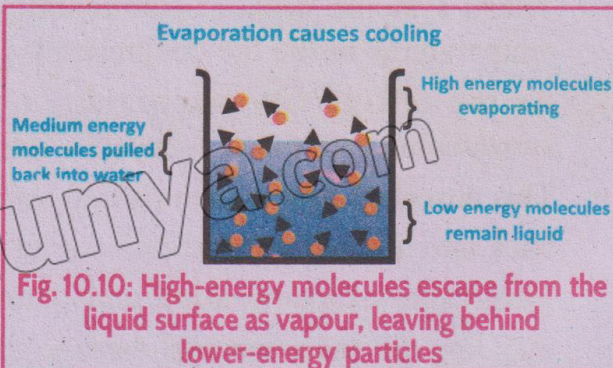


Fig 10.9: Evaporation process
(molecules at the surface of a liquid gain enough energy to escape into the air as vapour, leading to evaporation)



helping to regulate temperatures and keep things cool. (Fig. 10.10)

Q.12: Write down a note on Refrigeration systems without Chlorofluorocarbons (CFCs).
OR Explain the working of a Refrigeration systems without Chlorofluorocarbons (CFCs).
Also write the types of refrigerants used, and the environmental benefits of this technology.

Ans. Definition and modern Refrigerants: A CFC free refrigerator is an appliance designed to provide cooling without using ozone depleting substances. Instead of traditional CFCs (like Feron), these units use "natural refrigerants" such as isobutane and propane. These substances occur naturally in gas and do not contain the chlorine or fluorine atoms responsible for attacking the ozone layer.

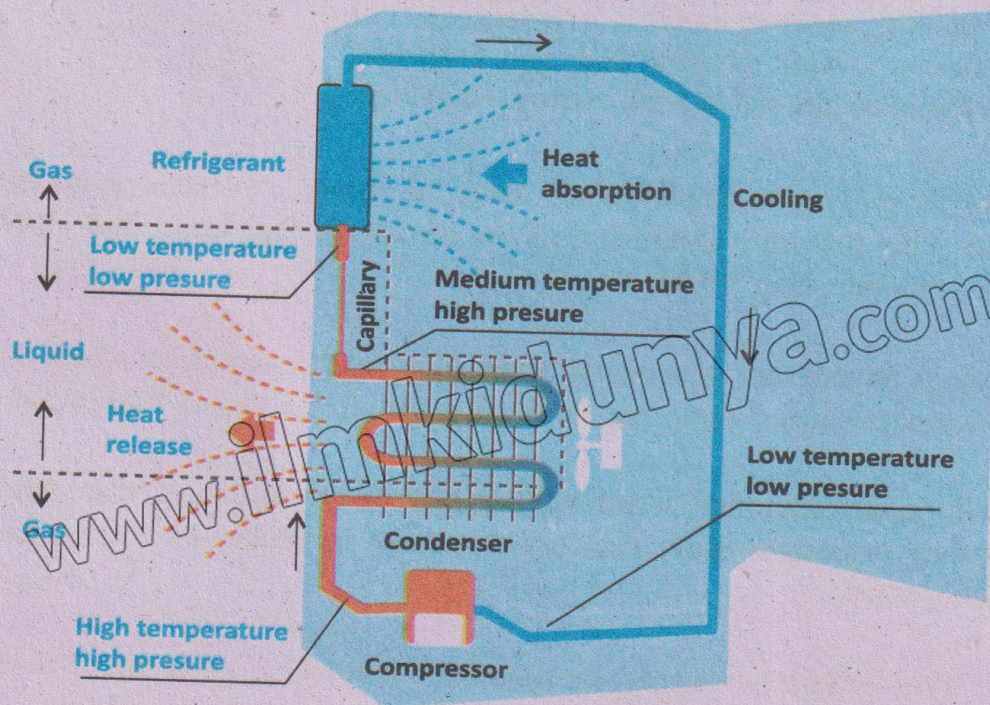


Fig. 10.11: Block diagram of refrigerator

The Refrigeration Cycle: 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 refrigerant 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.

Q.13: Explain the concept of latent heat in detail.

OR Define latent heat. Discuss its two main types.

OR Write a detail note on latent heat of fusion.

Ans. 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 1kg of a solid into a liquid at its melting point while keeping the temperature constant."

Explanation: 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.

Formula: The latent heat of fusion is calculated using the formula:

$$Q = mL_f$$

where

L_f = Latent heat of fusion

Q = Heat energy

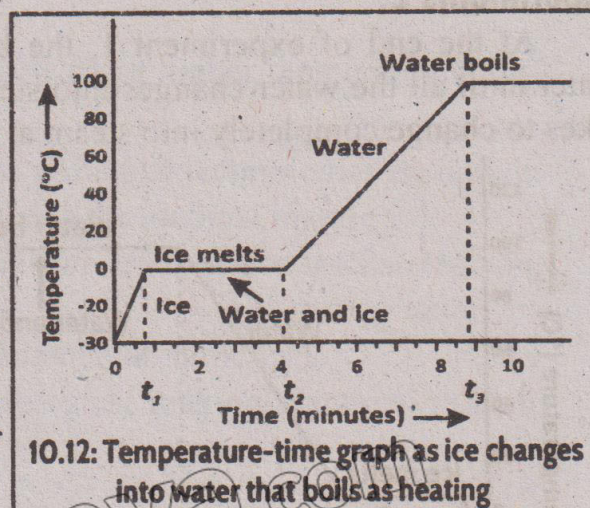
m = Mass of the substance.

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

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.



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

Q.14: Write a detail note on latent heat of vapourization.

OR Explain the concept of latent heat of vapourization in detail.

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

Explanation: 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.

Formula: The latent heat of vapourization is expressed as

$$Q = mL_v \dots\dots\dots (10.6)$$

Where

L_v = Latent heat of vapourization.

Q = Heat energy.

m = Mass of the substance

Example: The latent heat of vapourization 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 .

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

Substance	Melting point ($^\circ\text{C}$)	Boiling point ($^\circ\text{C}$)	Heat of fusion (J kg^{-1})	Heat of vapourization (J kg^{-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	558
Mercury	-39	357	11.7	270
Nitrogen	-210	196	25.5	200
Oxygen	-219	-183	13.8	210
Water	0	100	336.0	2260

Experiments 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 .

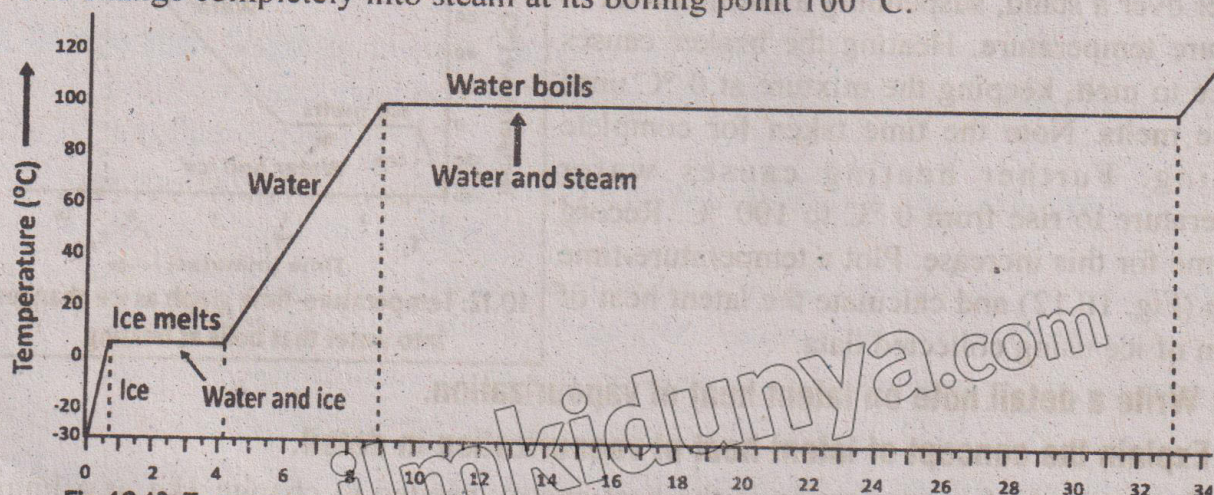


Fig. 10.13: Temperature-time graph as ice changes into water and water into steam on heating. Extend the temperature-time graph as shown in Fig. 10.13. Calculate the latent heat of fusion of ice from the data.

Q.15: Discuss the phenomenon of superconductivity, its key properties, and its impact on modern technology.

OR Explain conductivity and how does superconductivity work?

Ans. "Superconductivity is the phenomenon in which certain materials completely lose their electrical resistance and do not allow magnetic fields to pass through them when cooled below a critical temperature."

Result: As a result, electrical current can flow through a superconducting material without any loss of energy.

Working:

Zero electrical resistance:

Since, there are no collisions, electric current flows without facing any resistance as superconductors have zero electrical resistance

Explanation: The variation of electrical resistivity with temperature for a super conductor and a normal metal. The resistivity of a super conductor drops to zero below the critical temperature (T_c), whereas a normal metal shows a gradual decrease in resistivity.

Materials that show superconductivity:

Some metals and ceramics become superconductors at extremely low temperature.

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

Uses of super conductors: 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 study fundamental particles.

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

DO YOU KNOW?

1. **Why does metal feel colder than wood when touched. If they are both at the same temperature?**

Ans. 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.

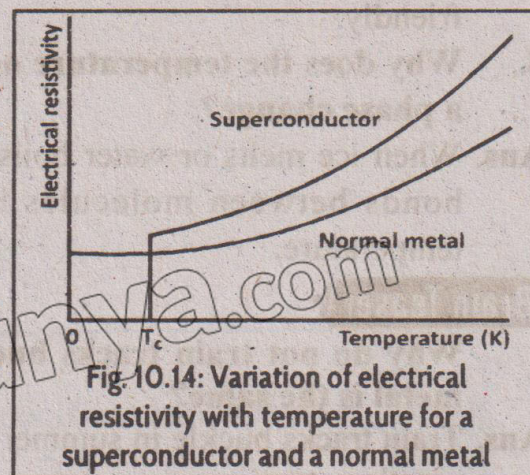


Fig.10.14: Variation of electrical resistivity with temperature for a superconductor and a normal metal

Tidbits

1. Why should we not fill a bottle of water to the top before freezing?

Ans. 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 because it might crack.

2. How does evaporation from our skin help regulate body temperature?

Ans. Evaporation from our skin takes away body heat, keeping us cool. That is our body's natural way of managing temperature and make a person comfortable.

3. How do modern refrigerators cool without using harmful CFCs?

Ans. 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.

4. Why does the temperature not rise when energy is used to break bonds during a phase change?

Ans. 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.

Brain Teaser

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

Ans. Train tracks buckle in summer because metal expands when hot and can't move and creating stress. In winter, metal contracts, but gaps in the tracks absorb the shrinkage, so they don't buckle.

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

Ans. Boiling water does not feel cooled because it is already very hot. Even though evaporation cools the surface, the water's temperature (around 100°C) is much higher than your skin, so it still feels hot.

3. Why do superconductors need extreme cold temperature to work?

Ans. Superconductors need extreme cold because at low temperatures, atoms in the material barely vibrate, letting electrons move, without resistance. At higher temperatures vibrations block this, so superconductivity stops.

Examples

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.

Sol: The formula for linear expansion is:

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

Given that;

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

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

To find: α = Coefficient of linear expansion = ?

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

Using the formula:

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

Substituting the values

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

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

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 336 J g^{-1} .

Sol: The formula to calculate the heat required for melting of ice is:

$$Q = m \times L_f$$

Given that;

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

Latent heat of fusion of ice $L_f = 336\text{ J g}^{-1}$

To find; Heat required $Q = ?$

using the formula $Q = m \times L_f$

Substituting the values $Q = 600\text{ g} \times 336\text{ J g}^{-1}$

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

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

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.



Objective Type Questions

Additional MCQ's

Multiple Choice Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

10.1

Thermal Expansion

- What happens to the kinetic energy of particles when a substance is heated?
(a) It decreases (b) It increases (c) It stays the same (d) It disappears
- The phenomenon where a material decreases in size due to cooling is called:
(a) Thermal expansion (b) Thermal contraction
(c) Linear expansion (d) Volumetric expansion
- In the formula $L = L_0 (1 + \alpha \Delta T)$, what does represent?
(a) Original length (b) Change in length
(c) Coefficient of linear expansion (d) Final temperature

4. Which of these substances has the highest coefficient of linear expansion (α)?
(a) Aluminium (b) Steel (c) Copper (d) Glass (Pyrex)
5. Why do railway tracks have small gaps between them?
(a) To save steel (b) To reduce noise
(c) To allow for expansion in summer (d) To allow for contraction in summer
6. "Sun Kinks" in railway tracks are caused by:
(a) Extreme cold
(b) Lack of space for thermal expansion
(c) Low kinetic energy (d) Excessive moisture
7. If a solid expands in length upon heating, it is specifically called.
(a) Linear thermal expansion (b) Volume thermal expansion
(c) Area expansion (d) Kinetic expansion
8. Why do liquids expand more freely than solids.
(a) They have higher density (b) They do not have a fixed shape
(c) They have lower temperature (d) Their atoms are in a tight, regular pattern
9. The formula for volume thermal expansion is:
(a) $\Delta L = \alpha L_0 \Delta T$ (b) $\Delta V = \beta V_0 \Delta T$ (c) $\theta = mc \Delta T$ (d) $V = \text{constant}/T$
10. Charle's Law states that the volume of a gas is directly proportional to its:
(a) Pressure (b) Mass
(c) Temperature (at constant pressure) (d) Density
11. Which device uses the mal expansion in a narrow tube to measure temperature?
(a) Thermometer (b) Radiator (c) Aerosol can (d) Expansion joint
12. Why do hot air balloons rise?
(a) The air inside become denser
(b) The air inside expands and becomes less dense
(c) The air inside gains more mass (d) Gravity pushes them upward
13. When atoms in a solid vibrate with a larger amplitude, it results in:
(a) Superconductivity (b) Contraction
(c) Expansion (d) Lower kinetic energy
14. What is the SI Unit for the coefficient of linear expansion (α)?
(a) $\text{J kg}^{-1} \text{K}^{-1}$ (b) m/s (c) K^{-1} (d) $^{\circ}\text{C}$

10.2

Specific Heat Capacity

15. Specific heat capacity is defined as the energy needed to raise the temperature of:
(a) 1 kg of a substance by 100°C (b) 1kg of a substance by 1°C (or 1K)
(c) Any mass of a substance by 1K (d) 1 gram of a substance by 10°C
16. What is the SI unit of specific heat capacity?
(a) K^{-1} (b) J/K (c) $\text{J kg}^{-1} \text{K}^{-1}$ (d) kg/J
17. The specific heat capacity fo water is approximately:
(a) $810 \text{ J kg}^{-1} \text{K}^{-1}$ (b) $4200 \text{ J kg}^{-1} \text{K}^{-1}$

- (c) $150 \text{ J kg}^{-1} \text{ K}^{-1}$ (d) $1.11 \times 10^4 \text{ J kg}^{-1} \text{ K}^{-1}$
18. Which substance would heat up the fastest when given the same amount of heat?
(a) Water (high specific heat) (b) Metal (Low specific heat)
(c) Alcohol (d) Dry Soil
19. The energy required to heat a material depends on mass, temperature change, and:
(a) Volume (b) Color (c) Nature of the material (d) Shape
20. In an automobile cooling system, what is the primary role of the radiator?
(a) To heat the water
(b) To cool the water passing through it using a fan
(c) To Pump the fuel (d) To store the oil
21. Coastal areas have milder climates than inland regions because.
(a) Water reflects all sunlight
(b) Water absorbs heat during the day and releases it slowly at night.
(c) Dry soil holds more heat than water (d) Oceans have no specific heat capacity
22. Why does metal feel colder than wood when both are at the same temperature?
(a) Metal is at a lower temperature
(b) Metal conducts heat away from the hand faster
(c) Wood is a better conduction (d) Metal has a higher specific heat capacity
23. Materials with high specific heat capacity are useful for:
(a) Rapid heating / cooling (b) Thermal insulation and heat storage
(c) Making thermometers (d) Creating "Sun kinks"
24. Which component in a car engine regulates water movement based on temperature?
(a) The fan (b) The cylinder
(c) The thermostat (d) The pressure release cap.

10.3

Change in State

25. The process of a liquid turning into a solid is known as:
(a) Melting (b) Solidification (c) Boiling (d) Condensation
26. Intermolecular forces are strongest in which state?
(a) Gas (b) Liquid (c) Solid (d) Plasma
27. Evaporation occurs at which part of a liquid?
(a) The bottom (b) The center
(c) The surface (d) Throughout the entire liquid
28. When a substance turns from a solid to a liquid, it is called:
(a) Condensing (b) Boiling (c) Melting (d) Freezing
29. Does evaporation require a liquid to reach its boiling point?
(a) Yes, it only happens at high heat. (b) No, it can occur at room temperature

- (c) Yes, it requires the entire liquid to be heated.
- (d) No, it only happens when the liquid is freezing

10.4

Evaporation

30. **Evaporation is a natural process that occurs:**
- (a) Only when a liquid reaches its boiling point
 - (b) At all temperatures, involving molecules at the surface.
 - (c) Only in direct sunlight
 - (d) Only when the air is 100% humid.
31. **Which of the following would decrease the rate of evaporation?**
- (a) Increase the surface area of the liquid.
 - (b) Increasing the wind speed over the surface.
 - (c) Increasing the temperature of the liquid
 - (d) Increasing the humidity of the surrounding air
32. **The cooling effect of evaporation occurs because:**
- (a) The liquid absorbs "cold" from the environment
 - (b) High - energy molecules escape, leaving lower -energy molecules behind
 - (c) The process of boiling releases heat into the liquid
 - (d) Pressure increases on the surface of the liquid
33. **In a modern refrigerator, cooling is achieved primarily by:**
- (a) Circulating ice through the cooling coils.
 - (b) The evaporation of a refrigerant at low temperatures.
 - (c) Using harmful CFCs to freeze the air
 - (d) Blowing hot air out of the freezer compartment.

10.5

Latent Heat

34. **The heat energy required to change a substance's state without changing its temperature is:**
- (a) Specific heat capacity
 - (b) Thermal expansion
 - (c) Latent Heat
 - (d) Critical temperature
35. **Latent heat of vaporization is specifically the energy needed to change:**
- (a) 1 kg of solid to liquid at its melting point
 - (b) 1 kg of liquid to gas at its boiling point.
 - (c) 1 kg of gas to liquid by cooling it.
 - (d) Any amount of water to steam at 0°C .
36. **Which substance has the highest melting point?**
- (a) Aluminum (660°C)
 - (b) Gold (1063°C)
 - (c) Copper (1083°C)
 - (d) Lead (327°C)
37. **During the melting of ice at 0°C , the heat energy absorbed is used to:**
- (a) Break the strong bonds between solid particles
 - (b) Increase the temperature of the ice to 100°C .
 - (c) Increase the kinetic energy of the atoms.
 - (d) Create a vacuum within the beaker.

38. The value of the latent heat of fusion for water is:
(a) 2260 J / kg. (b) 4200 J / kg K
(c) 336 J / g or 3.36×10^5 J / kg (d) 2.26×10^6 J / kg

10.6

Superconductivity

39. Super conductivity is a state where a material has:
(a) Infinite electrical resistance.
(b) Zero electrical resistance and no energy loss.
(c) High resistance when cooled to room temperature.
(d) The ability to expand indefinitely.
40. At what temperature does. Lead become a superconductor?
(a) Below 4.2 K (b) Below 7.2 K (c) At 135°C (d) At 0°C
41. Which of the following is a modern use of superconductors?
(a) Mercury thermometers (b) Car radiator cooling systems
(c) MRI machines for medical imaging (d) Steam engine pistons.
42. As a normal metal is cooled, its electrical resistivity:
(a) Drops to zero at the critical temperature. (b) Increases significantly
(c) Shows a gradual decrease (d) Becomes independent of temperature
43. In the kinetic molecular model, the strongest intermolecular forces are found in:
(a) Solids (b) Liquids (c) Gases (d) Superconductors
44. The reason gases exhibit the greatest relative thermal expansion is because.
(a) Their molecules are lightly packed. (b) They have fixed shapes.
(c) Their molecules are far apart with weak forces.
(d) They lose kinetic energy when heated.

Answers

- | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|
| 1. (b) | 2. (b) | 3. (c) | 4. (a) | 5. (c) | 6. (b) | 7. (a) |
| 8. (b) | 9. (b) | 10. (c) | 11. (a) | 12. (b) | 13. (c) | 14. (c) |
| 15. (b) | 16. (c) | 17. (b) | 18. (b) | 19. (c) | 20. (b) | 21. (b) |
| 22. (b) | 23. (b) | 24. (c) | 25. (b) | 26. (c) | 27. (c) | 28. (c) |
| 29. (b) | 30. (b) | 31. (d) | 32. (b) | 33. (b) | 34. (c) | 35. (b) |
| 36. (c) | 37. (a) | 38. (c) | 39. (b) | 40. (b) | 41. (c) | 42. (c) |
| 43. (a) | 44. (c) | | | | | |

Additional Short Questions

Short Answer Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

10.1

Thermal Expansion

1. Define thermal expansion?

Ans. Thermal expansion:

"Thermal expansion is the increase in the length, area, or volume of a substance

when its temperature rises because its particles move faster and spread out."

2. What is thermal contraction?

Ans. Thermal contraction: "It is the decrease in the size of a substance when it is cooled, as the particles lose energy and move closer together."

3. What is linear thermal expansion?

Ans. Linear expansion: "It is the change in the length of a solid when it is heated." The formula is:

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

4. Define the coefficient of linear expansion (α)?

Ans. Coefficient of linear expansion (α):

"It is the fractional change in length per degree change in temperature".

Unit: Its SI unit is K^{-1}

5. What is the relationship between the coefficient of linear expansion (α) and volume expansion (β)

Ans. The coefficient of volume expansion is approximately three times the linear expansion coefficient ($\beta = 3 \alpha$)

6. Why do liquids expand more than solids?

Ans. Unlike solids, liquids do not have a fixed shape and their molecules are less tightly bound, allowing them to expand freely in all directions.

7. Differentiate between apparent and real expansion of a liquid?

Ans. Real expansion is the actual expansion of the liquid, while apparent expansion is what we observe, which doesn't account for the expansion of the container.

Formula: $\text{Real expansion} = \text{Apparent} + \text{Expansion of}$
Expansion Flask

8. State Charle's Law?

Ans. Charle's Law states that: "The volume of a gas is directly proportional to its absolute temperature provided the pressure remains constant".

Formula:

$$V \propto T$$

$$V = (\text{constant}) T$$

$$\frac{V}{T} = \text{constant}$$

9. Why are aerosol cans dangerous when exposed to heat?

Ans. Heating causes the gas inside to expand rapidly, increasing pressure beyond what the container can withstand, leading to an explosion.

10. Why are small gaps left between railway tracks?

Ans. Gaps allow the steel rails to expand safely on hot days. Without them, the tracks would bend or "sun kink", causing derailments.

11. How does a hot air balloon rises?

Ans. Heating the air inside the balloon causes it to expand and become less dense than the cool air outside, creating lift.

12. Define specific heat capacity?

Ans. Specific heat capacity: "It is the amount of heat energy needed to raise the temperature of 1kg of a substance by 1°C (or 1K)"

Unit: Its unit is $\text{J kg}^{-1} \text{K}^{-1}$

13. List the factors that the energy required to heat a material depends on?

Ans. The factors that the energy required to heat a material depends on:

- (i) Mass of the substance (m). (ii) Change in temperature (ΔT).
- (iii) Nature of the material (specific heat c).

14. Why is water used in automobile cooling systems?

Ans. Water has a very high specific heat capacity ($4200 \text{ J kg}^{-1} \text{K}^{-1}$), allowing it to absorb a large amount of heat from the engines with only a small rise in its own temperature.

15. Why do coastal areas have milder climates than inland regions?

Ans. Large water bodies (oceans) absorb heat slowly during the day and release it slowly at night, preventing drastic temperature changes in nearby land.

16. How does energy absorption or loss affect the state of matter?

Ans. Absorbing energy increases molecular movement and separation, causing melting or boiling; losing energy slows molecules down, leading to condensation or solidification.

17. Why do gases exhibit the greatest thermal expansion compared to solids?

Ans. Intermolecular forces are weakest in gases because molecules are far apart, allowing them to expand more freely than in solids where forces are strongest.

18. Define evaporation?

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

19. Why does evaporation cause cooling?

Ans. Higher energy molecules leave the liquid surface, leaving behind lower - energy (cooler) molecules, which drops the temperature of the remaining liquid.

20. How does surface area affect evaporation?

Ans. A larger surface area allows more liquid to be exposed to the air, which speeds up the rate of evaporation.

21. What is the effect of humidity on the rate of evaporation?

Ans. High humidity slows down evaporation because the air is already full of moisture, dry air speeds up.

22. How does sweating help manage body temperature?

Ans. Sweat evaporates from the skin, taking away body heat and cooling us down.

23. How do modern refrigerators cool without CFCs?

Ans. They use environmentally friendly refrigerators that evaporate a low temperatures inside cooling coils, absorbing heat from the surrounding area.

10.5

Latent Heat

24. What is latent Heat?

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

25. Define latent heat of fusion (L_f)?

Ans. "It is the heat energy required to convert 1kg of a solid into a liquid at its melting point while keeping the temperature constant."

26. What is the latent heat of vaporization (H_v)?

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

27. Why does temperature remain constant during a change of state?

Ans. The heat energy is used to break or form bonds between particles instead of increasing their kinetic energy (temperature).

10.6

Superconductivity

28. What is superconductivity?

Ans. It is a property of some materials where they have zero electrical resistance when cooled below a specific "critical temperature".

29. Name two materials that exhibit superconductivity and their temperatures?

Ans. Mercury : Becomes superconductivity below 4.2 K.

Lead : Becomes superconductivity below 7.2 K.

30. What are two practical uses of super conductors?

Ans. MRI machines: To generate strong magnetic fields for medical imaging.

Magler Trains: To float the train above tracks, reducing friction.

Exercise Questions (Solved)

A. Multiple Choice Questions

10.1 When the temperature of a rod of copper is increased, its length:

- (a) remains the same
- (c) decreases

- (b) increases
- (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
- (c) linear expansion

- (b) volume expansion
- (d) none of these

10.3 What does a liquid turn into once it is evaporated?

- (a) Gas
- (c) Air

- (b) Water vapours
- (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

Answers

10.1 (b) 10.2 (c) 10.3 (d) 10.4 (b) 10.5 (c)

B. Short Answer Questions

10.1 What factors influence the thermal expansion of solids?

Ans. The thermal expansion of a solid depends on three primary factors.

1. Original length / volume
2. Change in temperature
3. Nature of the material

10.2 What is latent heat of fusion?

Ans. "Latent heat of fusion is the amount of heat energy required to change a unit mass of a substance from a solid state to a liquid state at its melting point, without any change in temperature."

It is mathematically expressed as. $Q = mL_f$.

Where Q is the heat absorbed, m is the mass, L_f is the specific heat of fusion.

10.3 How do different materials exhibit varying thermal expansion behaviours?

Ans. Different materials have different coefficients of thermal expansion, leading to varying degrees of expansion or contraction for the same temperature change.

10.4 How does evaporation contribute to cooling processes in everyday life?

Ans. Evaporation causes cooling because the most energetic molecules leave the liquid as gas, taking their kinetic energy with them and leaving the remaining liquid cooler.

Sweating: When sweat evaporates from the skin, it absorbs heat from the body, helping us cool down.

Earthen pots: Water in clay pot stays cool because water seeps through tiny pores and evaporates from the outer surface, removing heat from the water inside.

10.5 What is latent heat of vapourization, and how is it calculated?

Ans. "Latent heat of vapourization is the heat absorbed by a unit mass of a liquid at its boiling to convert it into gas without a temperature increase."

It is calculated using the formula $Q = mH_v$.

Where, Q is the total heat energy absorbed, m is the mass, and H_v is the specific latent heat of vapourization.

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.

Ans. Bridges need expansion joints because they are very long, so even small temperature changes cause large expansion, which can create stress and damage if

not allowed to move.

Glass jars with metal lids are small, so their expansion is very slight and does not produce harmful stress. Also, glass expands much less than metal, making the effect negligible.

10.2 Why does a liquid evaporate faster when the air is dry?

Ans. In dry air (low humidity), there is a lower concentration of water molecules in the surrounding gas. This means there are fewer molecules "returning" to the liquid phase (condensation), allowing a higher "net" rate of molecules to escape into the air.

10.3 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?

Ans. When ice melts, the heat supplied is used as latent heat of fusion, not to raise temperature.

This energy goes into breaking the intermolecular bonds that hold water molecules in the solid (ice) structure, allowing them to move freely as a liquid.

This is important because temperature remains constant during a phase change the energy changes the state of matter, not the speed (kinetic energy) of the molecules.

10.4 Why do electric transmission wires sag in summer and tighten in winter?

Ans. Electric transmission wires sag in summer due to thermal expansion and tighten in winter due to thermal contraction.

D. Comprehensive Questions

10.1 How does thermal expansion differ between solids, liquids, and gases? Provide examples to illustrate these differences.

Ans. Thermal expansion differs in amount and behavior for solids, liquids, and gases because of how closely their particles are packed.

Solids:

- Particles are tightly packed and only vibrate.
- Expansion is small

Example: A metal rod becomes slightly longer when heated.

Liquids:

- Particles are less tightly packed.
- Expansion is greater than solids.

Example: Mercury or alcohol rises in a thermometer when heated.

Gases:

- Particles are far apart and move freely
- Expansion is very large.

Example: Air in a balloon expands when heated, making the balloon bigger.

10.2 What are some practical consequences of thermal expansion in everyday life, such as in construction materials or household appliances?

Ans. Thermal expansion affects engineering and daily life.

Construction: Bridges are built with expansion joints (gaps) to prevent the structure from buckling or cracking when the metal concrete expands in heat.

Household Appliances: Bimetallic strips (made of two different metals) are used in thermostats and electric irons. They bend when heated, acting as a switch to regulate temperature.

10.3 What is latent heat, and why is it important in phase transitions like melting and vaporization?

Ans. Latent heat:

"Latent heat is the amount of heat absorbed or released by a substance during a change of state (solid $\leftrightarrow$ Liquid $\leftrightarrow$ Gas) without any change in temperature.

Why it is important?

- During melting, latent heat (fusion) is used to break intermolecular bonds. So a solid becomes a liquid.
- During vaporization, latent heat is used to separate molecules completely so a liquid becomes a gas.
- The temperature remains constant because the energy changes the state, not the kinetic energy of particles.

Importance: Latent heat explains why:

- Ice stays at 0°C while melting.
- Water stays at 100°C while boiling.
- Phase changes require energy even when temperature does not rise.

10.4 Why do solids, liquids, and gases expand when heated? Explain with examples.

Ans. Solids, liquids, and gases expand when heated because their particles gain energy and move more.

Solids:

- Heating increases vibration of particles about fixed positions.
- This causes a slight increase in distance between particles.

Example: Railway tracks or metal rods expand on hot days.

Liquids:

- Heating gives particles more freedom to move
- Particles move farther apart, so volume increases.

Example: Mercury or alcohol rises in a thermometer when heated.

Gases:

- Heating greatly increases speed of particles.
- Particles move much further apart, causing large expansion.

Example: Air in a balloon expands when warmed.

Conclusion:

All states expand on heating because particle motion increases, but gases expand the most, liquids more than solids, and solids the least.

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.

Ans. Evaporation will occur faster in the wide, shallow dish.

Scientific reason:

Evaporation is a surface phenomenon. In wide, shallow dish, a larger surface area of water is exposed to air, so more water molecules can gain enough energy to escape into the air at the same time.

In a tall narrow container, the exposed surface area is smaller, so fewer molecules can evaporate.

Conclusion:

Greater exposed surface area faster evaporation.

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.

Given:

$$\text{Initial length of rod} = L = 1\text{ m}$$

$$\text{Change in length} = \Delta L = 0.02\text{ m}$$

$$\text{Initial Temperature} = T_1 = 20^\circ\text{C}$$

$$\text{Final Temperature} = T_2 = 120^\circ\text{C}$$

$$\text{Change in temperature} = \Delta T = T_2 - T_1 = 120^\circ\text{C} - 20^\circ\text{C} = 100^\circ\text{C} = 100\text{ K}$$

Required:

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

Formula:

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

Solution:

$$\alpha = \frac{\Delta L}{L \Delta T}$$

Substituting the values:

$$\alpha = \frac{0.02\text{ m}}{(1\text{ m})(100\text{ K})}$$

$$\alpha = 0.0002\text{ K}^{-1}$$

$$\alpha = 2.0 \times 10^{-4}\text{ K}^{-1}$$

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?

Given:

$$\text{Initial volume} = V_0 = 1\text{ L} = 1000\text{ cm}^3$$

$$\text{Initial temperature} = T_1 = 20^\circ\text{C}$$

$$\text{Final Temperature} = T_2 = 80^\circ\text{C}$$

$$\text{Change in temperature} = \Delta T = T_2 - T_1$$

$$\Delta T = 80^\circ\text{C} - 20^\circ\text{C} = 60^\circ\text{C}$$

$$\text{Coefficient of volume expansion} = \beta = 2.1 \times 10^{-4}^\circ\text{C}^{-1}$$

Required:

$$\text{Final volume} = V = ?$$

Formula: Using formula for volum expansion

$$\Delta V = \beta V_0 \Delta T$$

Solution: Substituting all values.

$$\Delta V = (2.1 \times 10^{-4}^\circ\text{C}^{-1}) \times (1000\text{ cm}^3) \times (60^\circ\text{C})$$

$$\Delta V = 12.6\text{ cm}^3$$

To find the final volume:

Using

$$V = V_0 + \Delta V = 1000\text{ cm}^3 + 12.6\text{ cm}^3$$

$$V = 1012.6 \text{ cm}^3 \text{ Ans.}$$

10.3 A steel rod initially measures 2 m at 20 °C. If its coefficient of linear expansion is $1.2 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$, what will be its length at 100 °C?

$$\text{Initial length} = L = 2\text{m}$$

$$\text{Initial temperature} = T_1 = 20^\circ\text{C}$$

$$\text{Final temperature} = T_2 = 100^\circ\text{C}$$

$$\text{Temperature rise} = \Delta T = T_2 - T_1 = 100^\circ\text{C} - 20^\circ\text{C} = 80^\circ\text{C}$$

$$\text{Coefficient of linear expansion} = \alpha = 1.2 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$$

Required:

$$\text{Final length} = L = ?$$

Formula:

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

Solution: Substituting values

$$\Delta L = (1.2 \times 10^{-5} \text{ }^\circ\text{C}^{-1}) \times (2\text{m}) (80^\circ\text{C})$$

$$\Delta L = 0.00192 \text{ m}$$

$$\text{Final length} = L = L_0 + \Delta L = 2\text{m} + 0.00192\text{m}$$

$$= 2.00192 \text{ m} = 2.002\text{m}$$

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?

$$\text{Increase in length} = \Delta L = 5\text{cm} = 0.05 \text{ m}$$

$$\text{Original length} = L = 100 \text{ m}$$

$$\alpha = 1.2 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$$

Required:

$$\Delta T = ?$$

Formula: $\Delta L = \alpha L \Delta T$

$$\Delta T = \frac{\Delta L}{L \alpha}$$

Solution: Substituting the values

$$\Delta T = \frac{0.05\text{m}}{(100\text{m}) \times (1.2 \times 10^{-5} \text{ }^\circ\text{C}^{-1})}$$

$$\Delta T = 41.67^\circ\text{C}$$

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 $450 \text{ J kg}^{-1} \text{ K}^{-1}$?

Given:

$$\text{Mass} = m = 2\text{kg}$$

$$\text{Specific heat capacity of iron} = c = 450 \text{ J kg}^{-1} \text{ K}^{-1}$$

$$\text{Initial temperature} = T_1 = 20^\circ\text{C}$$

$$\text{Final temperature} = T_2 = 100^\circ\text{C}$$

$$\text{Change in temperature} = \Delta T = 100^\circ\text{C} - 20^\circ\text{C}$$

$$\Delta T = 80^\circ\text{C} = 80\text{K}$$

Required:

$$Q = ?$$

Formula:

$$Q = mc \Delta T$$

Solution:

$$Q = (2 \text{ kg}) (450 \text{ J kg}^{-1} \text{ K}^{-1}) (80 \text{ K})$$

$$Q = 72,000 \text{ J}$$

$$Q = 72 \text{ kJ}$$

**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 = $3.36 \times 10^5 \text{ J kg}^{-1}$)**

Given

$$\text{Mass of ice} = m = 500 \text{ g} = 0.5 \text{ kg}$$

Latent heat of fusion of ice,

$$L_f = 3.36 \times 10^5 \text{ J kg}^{-1}$$

Required:

$$Q = ?$$

Formula:

$$Q = mL_f$$

Solution:

$$Q = (0.5 \text{ kg}) (3.36 \times 10^5 \text{ J kg}^{-1})$$

$$Q = 168000 \text{ J}$$

$$Q = 168 \text{ kJ}$$

**10.7 Calculate the heat required to completely vaporize 1 kg of water at 100°C .
(Latent heat of vaporization of water = $2.26 \times 10^6 \text{ J kg}^{-1}$)**

Given:

$$\text{Mass of water} = m = 1 \text{ kg}$$

$$\text{latent heat of vaporization of water} = L_v = 2.26 \times 10^6 \text{ J kg}^{-1}$$

Required:

$$Q = ?$$

Formula:

$$Q = mL_v$$

Solution:

$$Q = (1 \text{ kg}) (2.26 \times 10^6 \text{ J kg}^{-1})$$

$$Q = 2.26 \times 10^6 \text{ J}$$

$$Q = 2.26 \text{ MJ}$$

