



SBBM
Notes Series

Unit 11

THERMAL TRANSFORMATION

- 1 Quick Revision sheet notes
- 2 Topical wise notes with detailed theory
- 3 Side boxes with detailed explanation
- 4 Short response Questions with answers (Hot Questions)
- 5 MCQs with explanation
- 6 Exercise Short Questions with MCQs
- 7 Exercise numericals





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Quick Review Sheet

Notes

SBBM One Page Revision Sheet

UNIT 11 — THERMAL TRANSFORMATIONS

Pressure Exerted by Gas Particles

Pressure:

Force exerted by gas particles on unit area of container walls.

$$P = \frac{F}{A}$$

(Pressure = Force / Area)

F = Force

A = Area

Unit:

Pascal (Pa) = N/m^2

3 FACTORS AFFECTING GAS PRESSURE

A Effect of Temperature ($T \uparrow$)

- ✓ Particles move faster
- ✓ Collisions become more frequent
- ✓ Force of collisions increases

→ Pressure increases ($P \uparrow$)

Relationship: $P \propto T$
(at constant volume)



B Effect of Volume ($V \downarrow$)

- ✓ Less space for particles
 - ✓ More wall collisions
- Pressure increases ($P \uparrow$)

→ Boyle's Law:

$$P \propto \frac{1}{V}$$

(at constant temperature)



C Effect of Number of Particles ($n \uparrow$)

- ✓ More particles in fixed volume
 - ✓ More collisions
- Pressure increases ($P \uparrow$)

✓ Quick Exam Revision

- ✓ Mention "collisions with container walls"
- ✓ Write formula clearly ($P \propto T$, $P \propto \frac{1}{V}$, $P \propto n$)
- ✓ State condition (constant V / constant T)
- ✓ Draw neat labelled diagram if required



Thermal Expansion

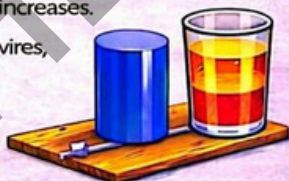
1 Linear Thermal Expansion (Solids)

Definition: Linear thermal expansion is the increase in length of a solid when its temperature increases.

Applies to: Long objects such as rods, wires, railway tracks.

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

- L_0 = original length
- ΔT = change in temperature
- α = coefficient of linear expansion



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

2 Volumetric Thermal Expansion (Solids)

Definition: Volumetric expansion is the increase in volume of a solid when its temperature increases.

Factors Affecting Expansion:

- Original volume (V_0)
- Temperature change (ΔT)
- Nature of material (β)



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

- $\Delta V = V_0(1 + \beta \Delta T)$ $V = V_0(1 + \beta \Delta T) \approx 3\alpha$ (for isotropic solids only)

3 Applications of Thermal Expansion

1 Expansion Joints

- Gaps are left to allow expansion
- Prevents bending and cracking

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

2 Opening a Bottle Cap

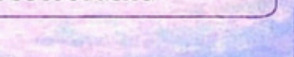
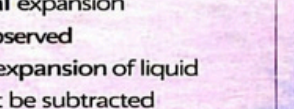
- Metal lid expands more than glass when heated
- Cap loosens easily.

Formula Used:

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

- Apparent expansion \neq real expansion
- Apparent expansion = observed
- Real expansion = actual expansion of liquid
- Container expansion must be subtracted

KEY EXAM ALERT



Expansion of Liquids

Liquids have no fixed shape, so linear expansion is **NOT** defined separately. Only volumetric expansion is considered.

$$\Delta V_{\text{real}} = \gamma V_0 \Delta T$$

Expansion of container:

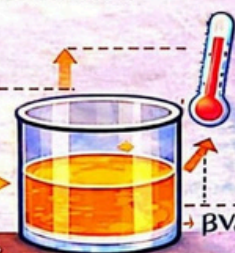
$$\Delta V_{\text{container}} = \beta V_0 \Delta T$$

Apparent expansion

$$\Delta V_{\text{apparent}} = \Delta V_{\text{real}} - \Delta V_{\text{container}}$$

KEY EXAM ALERT:

- Apparent expansion \neq real expansion
- Apparent expansion = observed
- Container expansion must be subtracted



Unit 11—Thermal Transformation

(SBBM One Page Revision Sheet)

Kinetic Theory of Matter

All matter is made up of very tiny particles which are in constant random motion.

- These particles possess kinetic energy.
- Their motion increases when temperature increases.
- Higher temperature → Higher kinetic energy → Faster particle movement.



States of Matter



Solid

- Particles are very closely packed.
- Strong forces of attraction.
- Particles can only vibrate at their fixed positions.
- Definite shape and definite volume.



Liquid

- Particles are close but not fixed.
- Forces of attraction are weaker than in solids.
- Particles can slide past each other.
- Definite volume, but no definite shape.



Gas

- Particles are far apart.
- Very weak forces of attraction.
- No definite shape and no definite volume.

Changing States of Matter



Melting (Solid → Liquid)

Ice → Water



Freezing: (Liquid → Solid)

Water → Ice → Example: Water → Ice

Vaporization: (Liquid → Gas)

Vaporization: Liquid changes into gas.
Example: Water boiling into steam.



Evaporation

Water boiling into steam.



Condensation

Water slowly evaporating at room temperature.



Sublimation

Dry ice, camphor



Deposition

Frost formation on cold surfaces.

Quick Comparison Table

State	Particle Arrangement	Force of Attraction	Motion
Solid	Very close	Strong	Vibrate at fixed position
Liquid	Close	Moderate	Slide past each other
Gas	Far apart	Very weak	Free, random, high speed

SBBM One Page Revision Notes:

Evaporation

Liquid Water

Water Vapor

What is Evaporation?

Evaporation is the process where liquid water turns into water vapor (gas) due to heat.



Heat



Low Humidity



Large Surface Area
also speeds up evaporation



Important Points

- ✓ Heat from the sun or another source provides energy that causes water to evaporate.
- ✓ Molecules at the surface gain enough energy to become water vapor (gas).
- ✓ It is an essential part of the water cycle, returning water to the atmosphere.

Water evaporates faster when the temperatures is higher, the air is dry, and there is more wind.
A larger surface area of water also speeds up evaporation.

LATENT HEAT (At 1 atm)

What is Latent Heat?

- ✓ Latent heat is the amount of heat energy absorbed or released per kilogram of a substance during a change of state.
- ✓ Temperature remains constant
- ✓ Only state changes
- ✓ Occurs at fixed melting/boiling point (at 1 atm)

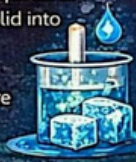


Types of Latent Heat

A Latent Heat of Fusion (L_f)

The heat energy required to convert 1 kg of a solid into a liquid at its melting point without temperature change.

SI Unit: J kg^{-1}



b Latent Heat of Vaporization (L_v)

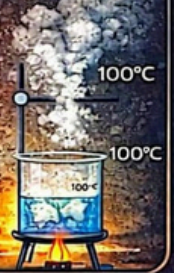
The heat energy required to convert 1 kg of a liquid into a gas at its boiling point without temperature change.

SI Unit: J kg^{-1}



Phase Change: Ice to Vapour (at 1 atm)

- ① Ice at 0°C melts \rightarrow absorbs latent heat of fusion (L_f). Temperature remains constant at 0°C .
 - ② Water temperature rises from 0°C to 100°C (temperature increases; no latent heat involved)
 - ③ Water at 100°C boils \rightarrow absorbs latent heat of vaporization (L_v). Temperature remains constant at 100°C during boiling.
 - ④ Steam at 100°C forms \rightarrow temperature remains constant until all liquid converts into steam.
- ✓ No fusion involved in boiling step.



Latent Heats of Some Common Substances

Material	Melting Point ($^\circ\text{C}$)	L_f (J kg^{-1})	Boiling Point ($^\circ\text{C}$)
Water	0	334	100
Mercury	-39	11.8	357
Lead	327	24.5	1749
Aluminum	660	397	2470
Silver	961	105	2162
Gold	1063	65	2660

Formulas

- ✓ During Melting or Freezing: $\Delta Q = mL_f$
- ✓ During Boiling or Condensation: $\Delta Q = mL_v$

Key Points to Remember

- ✓ Temperature does not change during a phase change.
- ✓ Energy goes into breaking or forming intermolecular bonds, not increasing temperature.
- ✓ Water has a very high latent heat of fusion and vaporization.
- ✓ Latent heat depends on the nature of the substance.
- ✓ Always use J kg^{-1} as the SI unit in exams.
- ✓ Always mention "at 1 atm" in long answers.
- ✓ Latent heat depends on the nature of the substance.



Topical Wise Notes
SRQs + MCQs

UNIT:11 THERMAL TRANSFORMATIONS

Topic : 11.1 KINETIC MOLECULAR THEORY (KMT)

1. Kinetic Molecular Theory (KMT) - Key Points

Particle Nature: All matter consists of tiny particles (atoms/molecules) in constant motion.

Intermolecular Forces: Attraction decreases as distance increases (strong in solids, moderate in liquids, negligible in gases).

Temperature & Energy: Temperature \propto average kinetic energy; heating speeds up particles, cooling slows them.

Macroscopic Effects: Particle collisions cause gas pressure; increased motion on heating produces expansion.

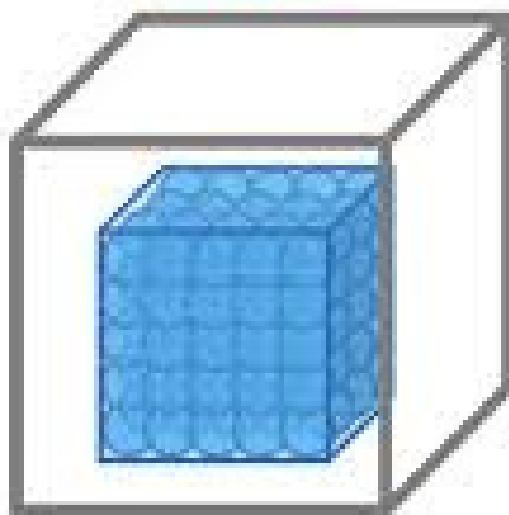
All matter is composed of extremely small particles (atoms or molecules) that are in continuous motion. These particles attract one another with forces whose strength decreases rapidly as the distance between them increases. As you raise the temperature of a substance, you increase the average kinetic energy of its particles; as you cool it, you remove kinetic energy. This interplay between motion and attraction underlies every change of state.

STATES OF MATTER

SOLIDS

1. Particles in solids are closely packed in a regular pattern due to low kinetic energy.
2. At low temperatures, particles vibrate about fixed positions but do not have enough energy to move freely.
3. Solids have a definite shape and volume because intermolecular forces are strong at lower temperatures.
4. When a solid is heated, its particles gain energy and start vibrating faster.
5. Upon reaching a certain temperature (melting point), the solid turns into a liquid.

Solid



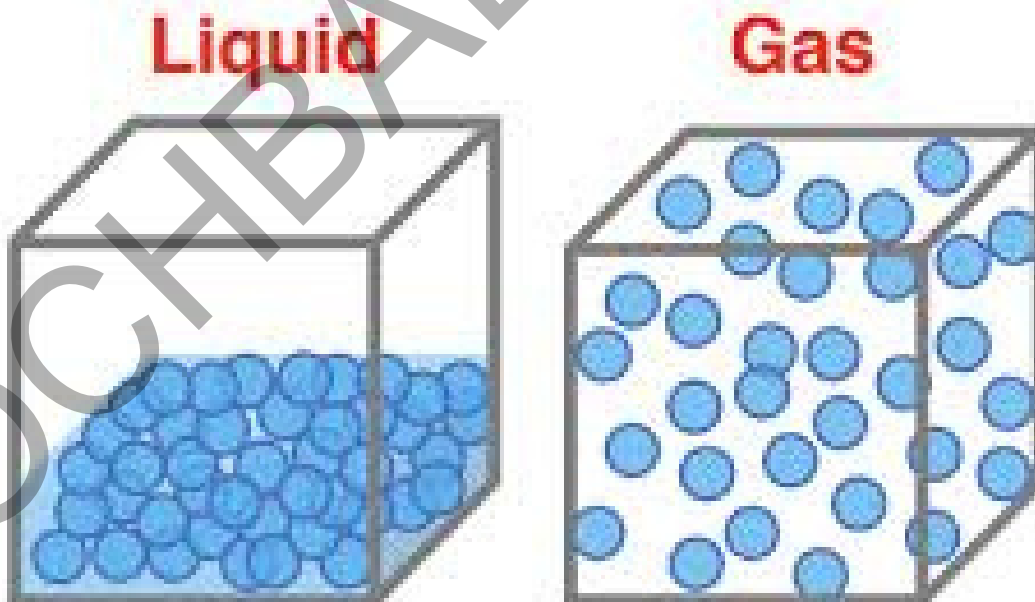
LIQUID

1. In liquids, particles have more kinetic energy than in solids, allowing them to move past each other.
2. At moderate temperatures, the intermolecular forces are weaker than in solids, but still strong enough to keep the particles close.

3. Liquids have a definite volume but take the shape of their container due to the ability of particles to flow.
4. When the temperature increases, particle movement increases, reducing the effect of intermolecular forces.
5. On reaching the boiling point, the liquid changes into a gas through the process of vaporization.

GAS

1. Gaseous particles have high kinetic energy due to high temperatures.
2. They are far apart and move rapidly in all directions, overcoming almost all intermolecular forces.
3. Gases have neither a definite shape nor a definite volume; they expand to fill their container.
4. When gases are cooled, their particles lose energy, move slower, and come closer.
5. On reaching the condensation point, gases condense into liquids, and further cooling can turn liquids into solids (freezing point



SOLIDS	LIQUID	GAS
<p>1. Particles are tightly packed in a fixed and orderly arrangement</p> <p>2. Solids have a definite shape and definite volume.</p> <p>3. They do not flow.</p> <p>4. Solids are not compressible.</p> <p>5. They have strong intermolecular forces.</p> <p>6. Kinetic energy of particles is very low; particles only vibrate in place.</p> <p>7. Solids have high density.</p> <p>8. They do not expand to fill a container</p> <p>9. They are rigid and maintain their shape.</p> <p>10. Examples: Ice, stone, iron.</p>	<p>1. Particles are closely packed but not in a fixed arrangement.</p> <p>2. Liquids have a definite volume but no definite shape.</p> <p>3. They flow easily and take the shape of their container.</p> <p>4. Liquids are slightly compressible.</p> <p>5. Intermolecular forces are weaker than in solids.</p> <p>6. Particles have moderate kinetic energy and slide past each other.</p> <p>7. Liquids have moderate density.</p> <p>8. They do not expand to fill the container completely.</p> <p>9. Liquids are not rigid and can be poured.</p> <p>10. Examples: Water, milk, oil.</p>	<p>1. Particles are far apart and move freely in all directions.</p> <p>2. Gases have no definite shape and no definite volume.</p> <p>3. They flow very easily and fill the entire container.</p> <p>4. Gases are highly compressible.</p> <p>5. Intermolecular forces are very weak.</p> <p>6. Particles have very high kinetic energy and move randomly.</p> <p>7. Gases have low density.</p> <p>8. They expand and spread out quickly.</p> <p>9. Gases are not rigid and do not maintain any shape.</p> <p>10. Examples: Air, oxygen, carbon dioxide.</p>

The Core Theory

1. Composition: All matter is made of tiny particles (atoms or molecules).
2. Motion: These particles are in constant, random motion.
3. Energy: Particles possess Kinetic Energy (KE) because of their motion.
4. Intermolecular Forces (IMF): There are forces of attraction between particles.
5. Temperature: The average KE of particles is directly proportional to the absolute temperature.

Categorizing Factor

The factor that categorizes matter into three states is the difference Kinetic Energy and Intermolecular Forces.

The Three States of Matter

1. Solids

1. IMF: Extremely strong; particles are locked in a fixed lattice.
2. Density: High (particles are closely packed).
3. Volume: Fixed/Definite.
4. Velocity: Very low; particles only vibrate about their fixed positions.
5. Action upon Heating: Particles vibrate more violently until the lattice breaks (Melting).

2. Liquids

1. IMF: Moderate; enough to keep particles together but allows them to slide past each other.
2. Density: Relatively high (slightly less than solids).
3. Volume: Fixed, but takes the shape of the container.
4. Velocity: Moderate; random motion within the bulk of the liquid.

3. Gases

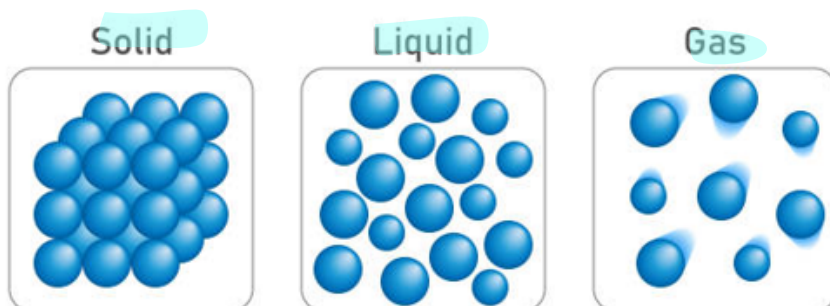
1. IMF: Negligible/Very weak.
2. Density: Very low.
3. Volume: Indefinite (fills any available space)
4. Velocity: Very high; rapid, random, straight-line motion.
5. Action upon Heating: Pressure increases (if volume is fixed) or volume increases drastically."

PARTICLE ARRANGEMENT IN PHASES OF MATTER

Solid

Image Description: Particles are packed tightly together in a fixed arrangement.

States of matter



Liquid

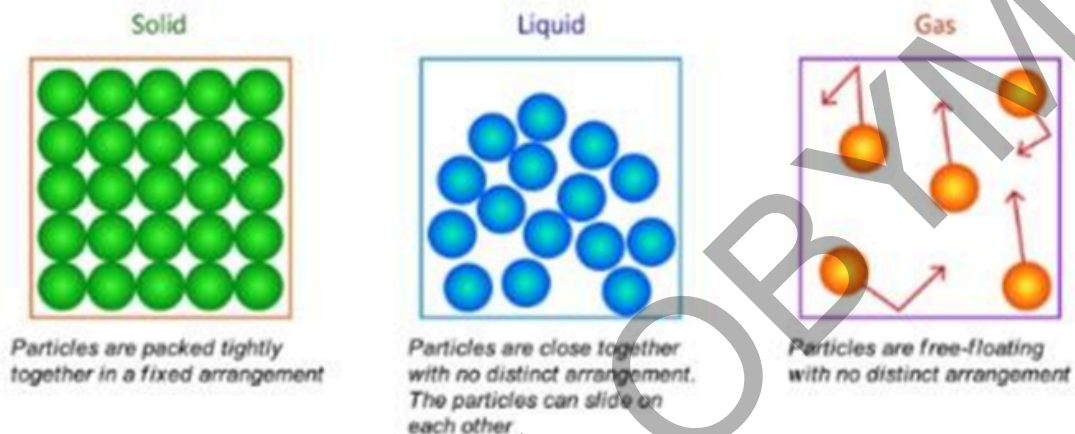
Image Description: Particles are close together with no distinct arrangement. The particles can slide on each other.

Gas

Image Description: Particles are free-floating with no distinct arrangement.

Comparison Table and diagram

PARTICLE ARRANGEMENT IN PHASES OF MATTER



Comparison Table

Characteristic	Solid	Liquid	Gas
IMF	Very Strong	Moderate	Negligible
Density	Highest	High	Lowest
Volume	Fixed	Fixed	Indefinite
Particle Motion	Vibration only	Sliding/ Translation	Rapid & Random
Compressibility	Incompressible	Negligible	Highly compressible

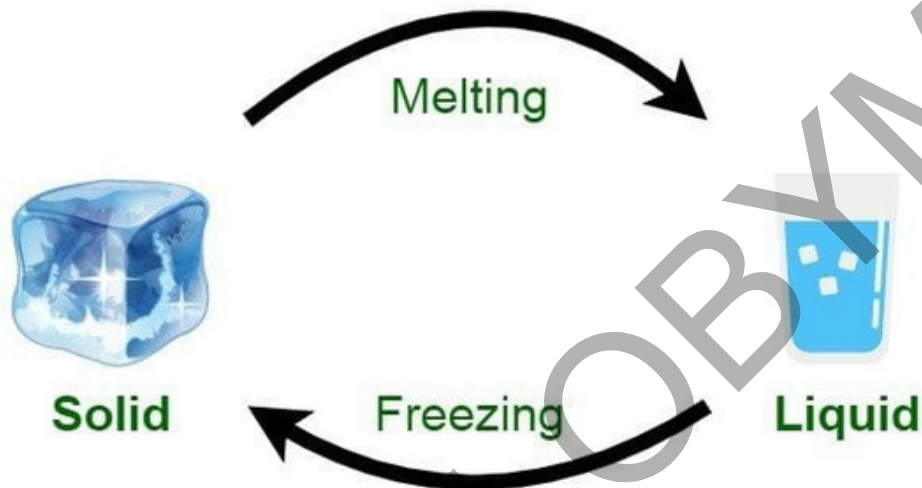
11.1.1 CHANGES OF STATES OF MATTER

FREEZING

1. Attractive forces among particles usually decrease with increasing temperature.
2. Temperature affects the attractive forces between particles.
3. Pressure also affects phase changes by changing particle spacing.
4. Increasing pressure brings particles of solids and gases closer; decreasing pressure separates them.
5. Freezing is the process where a liquid changes into a solid.
6. When a liquid is placed in a colder surrounding, it loses heat, particles come closer, and it becomes solid at the freezing point.
7. **Example:** Water freezes into ice at 0°C , the freezing point of water.

MELTING

1. Melting is when a solid changes into a liquid.
2. A solid absorbs heat when placed in a warmer surrounding.
3. At the melting point, particles gain enough energy to overcome bonding forces.
4. Particles start to move freely, and the solid melts into a liquid.
5. **Example:** Ice melts at 0°C in warm surroundings.
6. The melting point and freezing point are the same temperature.



VAPORIZATION

1. Vaporization is the process of converting a liquid into gas (vapor).
2. When a liquid is heated, its particles gain kinetic energy.
3. On continuous heating, kinetic energy becomes high enough to overcome attractive forces.
4. Particles escape the liquid and become gas.
5. This happens at a specific temperature called the boiling point.

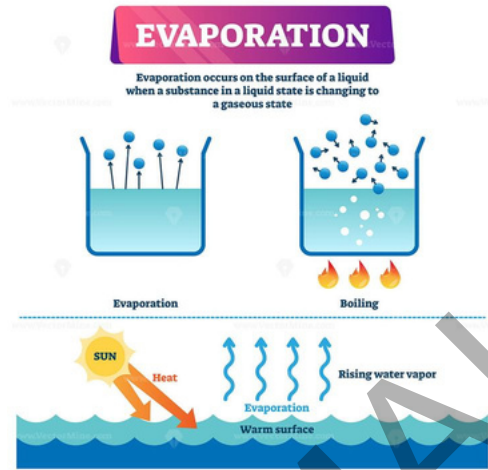
-Vaporization-



-Lorem Ipsum-

EVAPORATION

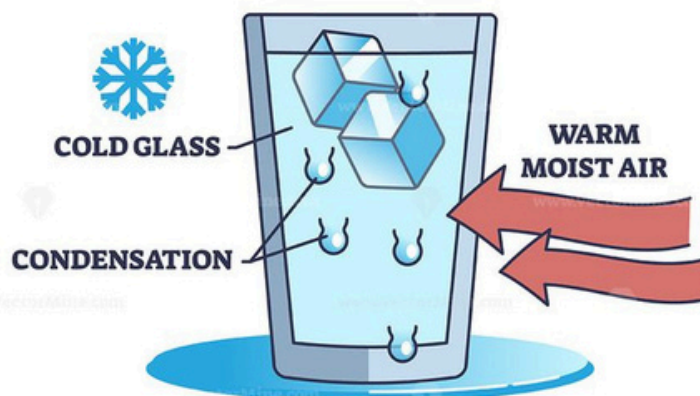
1. Evaporation is when a liquid changes into gas (vapor) at any temperature. Particles on the surface gain energy and escape into the air.
2. Evaporation increases with higher temperature, airflow, and surface area.
3. Example: Wet clothes drying in the sun.



CONDENSATION

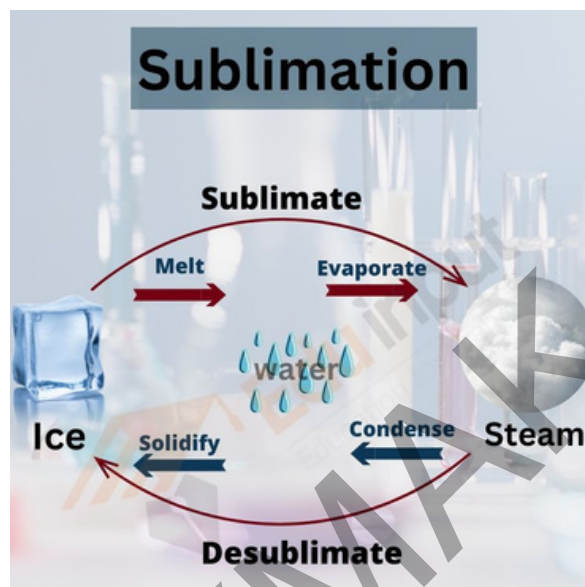
1. Condensation is when gas (vapor) cools down and changes back into liquid. This happens when warm, moist air touches a cooler surface.
2. Warm air can hold more moisture than cold air. When air cools, it cannot hold as much moisture, so vapor turns into water droplets.
3. Examples of condensation:
4. Dew drops form on grass at night when cool air cools the ground and causes vapor to condense.
5. Car windscreens fog up when warm, moist air touches the cold glass and water vapor condenses.
6. Bathroom mirrors fog after a hot shower due to condensation of water vapor on the cooler mirror surface.

CONDENSATION



SUBLIMATION

1. Solid changes directly into gas without passing through the liquid phase.
2. Common example: Dry ice (solid carbon dioxide) turns into carbon dioxide gas (smoke).
3. Dry ice temperature: -78.5°C .
4. When exposed to room temperature and pressure, its molecules gain enough energy to overcome attractive forces and become gas.



DEPOSITION

1. Gas changes directly into solid without becoming liquid.
2. It is the reverse process of sublimation.
3. **Example:** Frost formation on cold surfaces like leaves and window panes.
4. On cold nights, water vapor in the air comes into contact with cooler surfaces.
5. The vapor loses heat and changes directly into ice crystals, forming frost.

Feature	Boiling	Evaporation
Definition	A rapid phase change from liquid to gas (vapor) that occurs when the liquid reaches its boiling point.	A slow, gradual phase change from liquid to gas that occurs at the surface of the liquid at any temperature.
Temperature	Occurs at a specific temperature (the boiling point), which depends on the surrounding pressure (e.g., 100°C for water at sea level).	Occurs at any temperature below the boiling point. The rate increases as temperature rises.
Location	Takes place throughout the entire volume of the liquid. Bubbles of vapor form within the liquid and rise to the surface.	Takes place only at the surface of the liquid. No bubbles are formed within the liquid.
Energy Source	Requires a continuous, significant input of external heat (e.g., from a stove, fire, or heater).	Uses the internal (kinetic) energy of the liquid molecules. It is driven by the surrounding temperature and air movement.
Speed of Process	A fast and violent process.	A slow and gentle process.
Key Factors	Primarily affected by external pressure (atmospheric pressure). Lower pressure lowers the boiling point.	Primarily affected by temperature, surface area, humidity, and air movement (wind).
Bubble Formation	Yes. Bubbles form inside the liquid.	No. There is no bubble formation.
Example	Water bubbling vigorously in a kettle.	A puddle of water drying up on a sunny day.

SRQs

1. Why do tyres burst in summer?

- 1) **Temperature (T):** In summer, high temperatures increase the Kinetic Energy (KE) of the air molecules inside the tyre.
- 2) **Pressure (P):** Faster molecules hit the tyre walls more frequently and with greater force, increasing internal pressure.
- 3) **Density:** As T increases, if the tyre can't expand much, the density of the air doesn't change, but the pressure eventually exceeds the strength of the rubber.
- 4) **Conclusion:** The high internal pressure overcomes the elastic limit of the tyre, causing it to burst.

2. Why do solids expand upon heating?

- 1) **Mechanism:** When a solid is heated, particles gain KE and vibrate more vigorously.
- 2) **Amplitude:** The amplitude of vibration increases (the particles move further from their equilibrium position).
- 3) **Spacing:** As they push against their neighbors with more force, the average distance between particles increases.
- 4) **Conclusion:** This increase in molecular spacing results in the macroscopic expansion of the solid.

3. Why do gases exert pressure on walls?

- 1) **Chain of Logic:** temperature increase kinetic energy increase resulting in more velocity causing collision between particles and walls to increase significantly.
- 2) **Motion:** Molecules move in random motion at higher speeds.
- 3) **Collisions:** They hit the container walls more often and with more momentum.
- 4) **Conclusion:** Since $\text{Pressure} = \text{Force} / \text{Area}$, these more frequent/violent collisions result in an increase in Pressure (P).

4. Why is Freezing the reverse of Melting?

- 1) **Melting:** [Solid to Liquid]. Energy is absorbed to break the lattice (IMF decreases).
- 2) **Freezing:** [Liquid to Solid]. Energy is released; particles slow down (KE decreases) until IMF pulls them back into a fixed, regular lattice.
- 3) **Conclusion:** They are exact opposites in terms of energy flow and molecular arrangement.

5. Why does Ice float on water?

1.

Density: Because the same mass of water occupies more volume as ice, its density becomes lower than liquid water.

2.

Principle: Objects with lower density float on higher-density fluids.

6. Why do cold bottles/windcreens become foggy?

(Condensation)

1.

The Cause: Air contains invisible water vapor (gas).

2.

The Contact: When warm air hits a cold surface (bottle or glass), the vapor molecules lose KE rapidly.

3.

Phase Change: The IMF pulls the gas molecules together, turning them into tiny droplets of liquid water.

4.

Conclusion: This process is Condensation. On a car windscreen, it happens when the inside air is warmer than the colder air outside.

7. How does temperature affect the velocity of gas particles?

1.

Explanation: Temperature is a measure of average KE ($KE = \frac{1}{2}mv^2$); as it increases, velocity increases.

2.

Conclusion: Higher temperature leads to faster, more frequent collisions.

8. Compare the density of the three states of matter.

1.

Explanation: Solids have the highest density (closely packed), liquids are slightly less, and gases have the lowest.

2.

Conclusion: Density depends on the arrangement and spacing of molecules.

9. What happens to the IMF of a solid when it is heated?

1.

Explanation: Heating increases vibration; eventually, the energy overcomes the IMF holding the lattice together.

2.

Conclusion: This leads to the transition from solid to liquid.

10. Why do gas particles exert pressure on the walls of a container?

1.

Explanation: Due to their rapid, random motion, they constantly collide with the walls, exerting a force.

2.

Conclusion: Pressure is simply the force of these molecular collisions per unit area.

11. Explain why liquids have a fixed volume but no fixed shape.

1.

Explanation: IMF is strong enough to keep them together (fixed volume) but weak enough to let them slide (no fixed shape).

2.

Conclusion: This balance defines the fluid nature of liquids.

12. Explain the mechanism of melting in terms of energy.

1.

Explanation: Initially, heat increases KE (Temp rises). At the melting point, heat increases Potential Energy (PE) to break IMF.

2.

Conclusion: Temperature remains constant during the actual phase change.

MCQs

1. Which factor is responsible for the transition between states of matter?

- A) Number of electrons
 - B) Color of the substance
 - **C) Balance between Kinetic Energy (KE) and Intermolecular Forces (IMF)**
 - D) Total mass of the sample
- *Explanation: The state of matter is determined by whether the particle motion (KE) can overcome the attraction (IMF).*

2. In which state do particles move in rapid, random, straight-line motion?

- A) Solid
 - B) Liquid
 - **C) Gas**
 - D) Lattice
- *Explanation: Gas particles have negligible IMF and high KE, allowing free random motion.*

3. What is the primary motion of particles in a solid?

- **A) Vibration about a fixed position**
 - B) Translation from one end to another
 - C) Circular orbits
 - D) No motion at all
- *Explanation: Strong IMF locks solid particles into a lattice, so they can only vibrate.*

4. Why are liquids difficult to compress?

- A) Their particles are moving too fast.
 - B) Their particles are very far apart.
 - **C) Their particles are already closely packed with little space.**
 - D) They have no intermolecular forces.
- *Explanation: Like solids, liquid particles are in contact, leaving almost no room to be pushed closer.*

5. As the temperature of a gas increases, the pressure increases because:

- A) The particles get bigger.
 - **B) The particles collide with walls more frequently and with more force.**
 - C) The particles stick to the walls.
 - D) The density increases.
- *Explanation: Higher Temperature = Higher KE = Higher Velocity = Harder/more frequent collisions.*

6. The average kinetic energy of molecules is a measure of:

- A) Volume
 - B) Pressure
 - **C) Temperature**
 - D) Density
- *Explanation: Temperature is the macroscopic manifestation of microscopic kinetic energy.*

7 Which state of matter has a fixed volume but no fixed shape?

- A) Solid
- **B) Liquid**
- C) Gas
- D) Ideal Gas
- *Explanation: Liquids have enough IMF (Intermolecular Forces) to keep a fixed volume but not enough to maintain a fixed shape.*

8. What happens to the density of most substances when they change from liquid to gas?

- A) It increases.
- **B) It decreases significantly.**
- C) It stays the same.
- D) It doubles.
- *Explanation: Gas particles spread out over a huge volume, making them much less dense than liquids.*

9. The "Molecular Model" states that all matter is made of:

- A) Continuous blocks of energy
- **B) Tiny particles in constant motion**
- C) Stationary spheres
- D) Liquid droplets
- *Explanation: This is the fundamental postulate of the Kinetic Theory.*

10. When a solid expands upon heating, the particles:

- A) Increase in size.
- **B) Increase their amplitude of vibration.**
- C) Stop moving.
- D) Decrease in mass.
- *Explanation: They push their neighbors further away as they vibrate more violently.*

11. Why do gases fill the entire volume of any container?

- A) They are very heavy.
- B) They have strong attraction to the walls.
- **C) They have negligible IMF and high KE.**
- D) They are forced by gravity.
- *Explanation: No forces hold gas particles together, so they spread until they hit an obstacle.*

12. During a phase change (like melting), the temperature:

- A) Increases rapidly.
- B) Decreases.
- **C) Remains constant.**
- D) Becomes zero.
- *Explanation: The heat energy is used as Latent Heat to change PE, not KE.*

13. Evaporation is a:

- **A) Surface phenomenon**
- B) Bulk phenomenon
- C) High-temperature-only process
- D) Chemical change
- *Explanation: It only involves high-energy molecules escaping from the surface.*

14. Why does evaporation cause cooling?

- A) It adds heat to the liquid.
- B) It increases the density.
- **C) High-energy particles leave, lowering the average KE of the remaining liquid.**
- D) It creates wind.
- *Explanation: Losing "hot" particles leaves the "colder" ones behind.*

15. The process of a gas turning into a liquid is called:

- A) Sublimation
- B) Deposition
- **C) Condensation**
- D) Freezing
- *Explanation: Particles lose KE and IMF pulls them together into a liquid.*

16. Which process is the reverse of Sublimation?

- A) Melting
- B) Boiling
- **C) Deposition**
- D) Evaporation
- *Explanation: Deposition is Gas to Solid, while Sublimation is Solid to Gas.*

UNIT:11 THERMAL TRANSFORMATIONS

Topic : 11.2 THERMAL EXPANSION

Matter increases in size when heated due to particle movement
Heating makes particles gain kinetic energy and vibrate more, pushing them apart

Expansion depends on the material type, temperature change, and initial amount of matter.

For the same temperature rise, gases expand the most, solids the least.

THERMAL EXPANSION IN SOLIDS

Types of Expansion in Solids

1. Linear expansion (1D): change in length
2. Surface area expansion (2D): change in surface area
3. Volumetric expansion (3D): change in volume

Linear Thermal Expansion of Solid

1. It is the increase in length of a solid when heated.
2. Heating causes atoms to gain kinetic energy and vibrate more.
3. Increased vibration makes atoms move slightly farther apart, increasing length.
4. The expansion in length (ΔL) is directly proportional to the temperature increase (ΔT) and the original length (L_0).
5. Longer rods expand more because they contain more atoms contributing to expansion.
6. Expansion varies with the material's atomic structure and bonding strength.
7. Example: Aluminum rods expand more than steel rods of the same length and temperature change

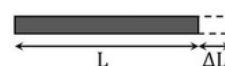
Linear Thermal Expansion – Mathematical Explanation

Consider a metal rod with:

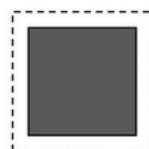
1. Original length = L_0
2. Initial temperature = T_0
3. Final length after heating = L
4. Final temperature = T

Thermodynamics

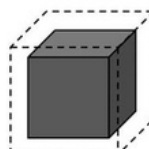
Thermal Expansion



Linear Expansion $\frac{\Delta L}{L_0} = \alpha \Delta T$



Area Expansion $\frac{\Delta A}{A_0} = 2\alpha \Delta T$



Volume Expansion $\frac{\Delta V}{V_0} = 3\alpha \Delta T$

Increase in length:

$$\Delta L = L - L_0$$

Increase in temperature:

$$\Delta T = T - T_0$$

The increase in length (ΔL) is directly proportional to original length (L_0) and temperature increase (ΔT):

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

Combining,

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

where α is the coefficient of linear thermal expansion.

α is defined as:

$$\alpha = \Delta L / (L_0 \times \Delta T) = (\Delta L / L_0) \div \Delta T$$

Interpretation:

1. α represents fractional change in length per unit temperature increase (per Kelvin).
2. It shows how much the rod expands per 1 K rise relative to its original length.

SI unit of α is K^{-1} .

VOLUMETRIC EXPANSION IN SOLIDS

1. Volumetric expansion is the change in volume of a solid on heating (3-dimensional expansion).
2. When a solid object is heated, particles gain kinetic energy, vibrate more vigorously, and move farther apart.
3. This causes the solid's volume to increase.
4. The increase in volume (ΔV) is directly proportional to:
5. The increase in temperature (ΔT)
6. The original volume (V_0)
7. Different materials expand differently on heating.

Mathematical Formulation

1. Original volume = V_0 at temperature T°
2. Final volume = V at temperature T
3. Increase in volume: $\Delta V = V - V_0$
4. Increase in temperature: $\Delta T = T - T_0$
5. Volume expansion is directly proportional to original volume and temperature increase:
6. $\Delta V \propto V_0$, $\Delta V \propto \Delta T$
7. Combined:
8. $\Delta V = \beta \times V_0 \times \Delta T$
9. β is the coefficient of volumetric thermal expansion.
10. β is defined as:
11. $\beta = \Delta V / (V_0 \times \Delta T) = (\Delta V / V_0) \div \Delta T$
12. β shows fractional change in volume per kelvin rise in temperature.
13. SI unit of β is K^{-1} .

Thermal Expansion Experiment

Apparatus:

Metal rod (steel), bolt and nut (brass or aluminum), Bunsen burner, stand, clamps

Procedure.

1. Fix the metal rod horizontally and tightly fasten the bolt on it.
2. Heat the rod slowly using the Bunsen burner
3. The rod expands as it heats, pushing against the bolt.
4. If the expansion pressure is strong enough, the bolt will snap.

Conclusion:

Metals expand when heated. This expansion creates pressure on connected parts like bolts. If the pressure is too high, it can break the bolt. This experiment shows why thermal expansion must be considered in engineering.

The volume expansion coefficient (β) is equal to three times the linear expansion coefficient (α):

$$\beta = 3\alpha$$

SRQs

1. Explain why railway tracks are laid with gaps between them.

Railway tracks are made of steel, which expands when heated. During summer, temperature increases significantly. Due to thermal expansion, the length of rails increases. If no gaps are provided, the rails cannot expand freely. This creates internal compressive stress in the metal. The stress may cause bending or buckling. Such bending can make the track uneven and dangerous for trains. It may cause derailment. To prevent this, small gaps are left between rails. These gaps allow rails to expand safely. In winter, the rails contract and the gaps become slightly larger. Thus, gaps ensure safety in all seasons.

2. Define coefficient of linear expansion and explain its physical meaning.

The coefficient of linear expansion is represented by α . It is defined as the change in length per unit original length per degree rise in temperature.

Mathematically: $\alpha = \Delta L / (L\Delta T)$

Its SI unit is $^{\circ}\text{C}^{-1}$.

It shows how sensitive a material is to temperature change. If α is large, the material expands more. If α is small, expansion is less. Different materials have different α values. It helps engineers choose suitable materials in construction and machinery. Thus, α measures expansion per degree temperature change.

3. Explain volumetric expansion in solids.

Volumetric expansion is the increase in volume of a solid when temperature increases. On heating, molecules vibrate faster. This increases intermolecular distance. As a result, length, width, and height increase, so total volume increases.

It is represented by β .

Formula: $\Delta V = \beta V\Delta T$

Unit of β is $^{\circ}\text{C}^{-1}$.

Volumetric expansion occurs in three dimensions. For solids, $\beta \approx 3\alpha$. It is important in storage tanks and engineering design.

4. Why does a metal lid become loose when heated?

A metal lid fits tightly on a jar at room temperature. When heated, the lid absorbs heat energy. Its molecules vibrate faster and move slightly apart. This increases its circumference and diameter. Glass expands less than metal because it has a lower coefficient of expansion. Therefore, the metal lid expands more than the glass jar, making it loose and easier to remove. This is a practical application of thermal expansion.

5. Derive the relation between β and α .

Consider a cube of side L . Volume, $V = L^3$

When heated, each side increases by ΔL . New side = $(L + \Delta L)$

New volume = $(L + \Delta L)^3$

Using approximation: $\Delta V \approx 3L^2 \Delta L$

Divide both sides by $V = L^3$:

$\Delta V / V = 3 (\Delta L / L)$

Since, $\alpha = \Delta L / (L\Delta T)$ $\beta = \Delta V / (V\Delta T)$

Therefore, $\beta = 3\alpha$

Hence, volumetric expansion is approximately three times linear expansion for solids.

6. Why do bridges have gaps between their sections?

Bridges are made of materials like steel and concrete that expand when heated. In summer, high temperatures increase their length. If no gaps are provided, compressive stress develops. This stress can cause bending or cracking. To prevent damage, engineers leave small gaps between sections. Rollers or sliding joints may also be used. In winter, materials contract and the gaps prevent sections from colliding. Thus, expansion gaps ensure structural safety and durability.

7. Why do metals expand more than glass when heated?

All solids expand when heated, but the amount depends on their bonding. Metals have a higher coefficient of expansion than glass. Metallic bonds are relatively flexible, so atoms move farther apart when heated. Glass has strong covalent bonds that resist expansion. Therefore, metals expand more than glass. This difference is important in construction and machinery design.

8. Why do holes in metal plates expand when heated?

When a metal plate is heated, it expands in all directions. The surrounding material moves outward uniformly. As a result, the diameter of the hole also increases. The hole expands as part of the overall expansion of the plate. This principle applies to rings, tubes, and hollow cylinders. It shows that thermal expansion affects all dimensions of a solid.

9. Describe an experiment to measure the coefficient of linear expansion.

A metal rod is clamped at one end. A pointer is attached to the free end to measure expansion on a scale. The initial length and temperature are recorded. The rod is heated uniformly. The increase in length (ΔL) is measured. The change in temperature (ΔT) is also noted. Using the formula:

$$\alpha = \Delta L / (L\Delta T)$$

The coefficient of linear expansion is calculated. The experiment demonstrates thermal expansion practically.

10. How does thermal expansion affect liquid storage tanks?

Metal tanks expand when temperature rises. The liquid inside also expands. If the tank is completely full, pressure develops inside. This may cause leakage or structural damage. Engineers leave some empty space at the top of the tank to allow safe expansion. Expansion joints may also be used. Proper design prevents accidents and ensures safety.

MCQs

1. Thermal expansion in solids occurs because:

- A) Mass increases
- B) Molecules become larger
- C) Intermolecular distance increases ✓
- D) Density increases

Explanation: Heating increases particle vibration which increases the distance between molecules.

2. The coefficient of linear expansion depends on:

- A) Shape
- B) Material ✓
- C) Length
- D) Colour

Explanation: Different materials have different coefficients of thermal expansion.

3. If temperature rise doubles, expansion will:

- A) Remain same
- B) Double ✓
- C) Become half
- D) Stop

Explanation: Expansion is directly proportional to the change in temperature.

4. Railway tracks have gaps to:

- A) Reduce friction
- B) Save material
- C) Allow expansion ✓
- D) Reduce weight

Explanation: Gaps allow rails to expand safely in hot weather.

5. Volumetric expansion occurs in:

- A) One dimension
- B) Two dimensions
- C) Three dimensions ✓
- D) No dimension

Explanation: Volume expansion happens in length, width, and height.

6. If expansion is prevented, the solid may:

- A) Melt
- B) Crack ✓
- C) Evaporate
- D) Freeze

Explanation: Preventing expansion creates stress that can crack the solid.

7. Density decreases on heating because:

- A) Mass increases
- B) Volume increases ✓
- C) Particles disappear
- D) Weight decreases

Explanation: When volume increases and mass stays constant, density decreases.

8. Aluminium expands more than steel because:

- A) It is lighter
- B) Larger coefficient ✓
- C) Softer
- D) Less dense

Explanation: Aluminium has a higher coefficient of expansion than steel.

9. Unit of linear expansion coefficient is:

- A) m
- B) °C
- C) °C⁻¹ ✓
- D) kg

Explanation: It is measured per degree change in temperature.

10. Volumetric coefficient is approximately:

- A) a
- B) $2a$
- C) $3a$ ✓
- D) $4a$

Explanation: The volumetric expansion coefficient is about three times the linear coefficient.

11. On cooling, solids:

- A) Expand
- B) Contract ✓
- C) Melt
- D) Break

Explanation: Cooling reduces particle motion and decreases intermolecular distance.

12. Expansion depends on:

- A) Original length ✓
- B) Colour
- C) Pressure
- D) Shape only

Explanation: Linear expansion depends on the initial length of the object.

13. Heating increases:

- A) Mass
- B) Kinetic energy ✓
- C) Volume only
- D) Density

Explanation: Heat increases the kinetic energy of particles.

14. Glass cracks with hot water because:

- A) It melts
- B) Unequal expansion ✓
- C) Mass increases
- D) Pressure increases

Explanation: Different parts of glass expand at different rates causing cracks.

15. Bridge rollers are used to:

- A) Increase height
- B) Allow expansion ✓
- C) Reduce cost
- D) Improve design

Explanation: Rollers allow bridges to expand and contract with temperature changes.

16. Thermal expansion is greatest in:

- A) Solids
- B) Liquids
- C) Gases ✓
- D) Metals only

Explanation: Gas particles are far apart so they expand the most.

17. If no gaps are left, rails may:

- A) Shrink
- B) Buckle ✓
- C) Melt
- D) Freeze

Explanation: Without gaps, thermal expansion causes rails to bend.

18. Volumetric expansion formula is:

- A) $\Delta L = \alpha L \Delta T$
- B) $\Delta V = \beta V \Delta T$ ✓
- C) $P = F/A$
- D) $V = IR$

Explanation: This formula shows how volume changes with temperature.

UNIT:11 THERMAL TRANSFORMATIONS

Topic : 11.2.2 THERMAL EXPANSION IN LIQUID

Thermal Expansion in Liquid

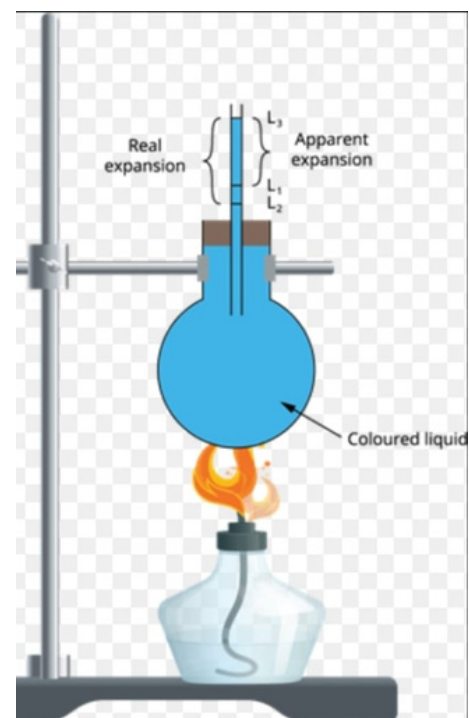
1. Liquids expand when heated because their particles have weaker forces between them than solids and can move more freely.
2. When heated, the particles gain kinetic energy and push against each other, increasing the liquid's volume.
3. Liquids expand more than solids due to these weaker attractive forces.
4. To measure volume change, liquids are heated in a container since they cannot be heated alone. Both the liquid and container expand during heating.
5. There are two types of volume expansion for liquids:
6. **Real volume expansion:** The actual increase in the liquid's volume when heated.
7. **Apparent volume expansion:** The observed increase in volume, which accounts for both liquid expansion and container expansion.
8. The coefficient of volume expansion for liquids (γ) measures the fractional increase in real volume per degree Kelvin.
9. $\gamma = \Delta V \div (V_0 \times \Delta T)$

1. The coefficient of volume expansion for liquids is related to the coefficient of linear expansion (α) by:
$$\gamma = 3\alpha$$

Apparent Volume Expansion Thermal Expansion of Liquids

Experiment Explanation:

1. A colored liquid is placed in a glass flask with a narrow neck.
2. Initial level of liquid before heating is V_1 .
3. When heating starts from the bottom:
4. The liquid level falls to V_2 before rising.
5. Then the liquid level rises to V_3 after further heating.



Reason for Initial Fall:

1. The glass flask gets heated first.
2. Glass expands, increasing its volume.
3. This makes the liquid level fall to V2.
4. This is due to expansion of the container, not the liquid.

Real and Apparent Expansion:

1. The fall from V1 to V2 is due to expansion of the flask.
2. The rise from V2 to V3 is due to actual expansion of the liquid.
3. So:

Apparent expansion = rise in liquid level from V1 to V3.

Real expansion = rise in liquid level from V2 to V3

Important Relationships

Real Expansion = Apparent Expansion + Expansion of Flask

Volume Relation:

(The actual rise in liquid level from V2 to V3 equals the total rise from V1 to V3 plus the fall from V1 to V2)

Coefficients of Expansion

γ_R = Coefficient of real (actual) volume expansion of the liquid

γ_A = Coefficient of apparent volume expansion

γ_G = Coefficient of volume expansion of the glass flask

Relationship:

$$\gamma_R = \gamma_A + \gamma_G$$

1. Real expansion is always greater than apparent expansion
2. Different liquids have different coefficients of volume expansion
3. The unit of the volume expansion coefficient is per Kelvin (K)

SRQs

1. Define real expansion of liquids.

Real expansion of a liquid is the true increase in its volume when the liquid is heated, ignoring the expansion of the container. When a liquid is heated, its molecules move faster and occupy more space, causing an increase in volume. This expansion depends only on the properties of the liquid.

Formula: $\Delta V = \beta V \Delta T$

Where: β = coefficient of volumetric expansion

V = initial volume

ΔT = temperature change

Real expansion is always slightly greater than apparent expansion because the container also expands when heated.

2. Define apparent expansion of liquids.

Apparent expansion is the observed increase in the volume of a liquid when it is heated inside a container. Since the container also expands, the observed rise in liquid level appears smaller than the actual increase in volume.

Relation: $\beta_{\text{apparent}} = \beta_{\text{real}} - 3\alpha$

Where: β_{real} = real volumetric expansion

α = linear expansion coefficient of container

Apparent expansion is always less than real expansion.

3. Explain why real expansion is greater than apparent expansion.

Real expansion measures the true increase in liquid volume. When a liquid is heated in a container, the container also expands outward. Part of the liquid's volume increase is accommodated by the expanding container. Therefore, the observed expansion (apparent expansion) is smaller.

Apparent expansion = Real expansion - Container expansion

Hence, real expansion is always greater than apparent expansion.

4. Write the formula relating real and apparent expansion.

The relation between real and apparent expansion is:

$\beta_{\text{apparent}} = \beta_{\text{real}} - 3\alpha$

Here: β_{apparent} = apparent volumetric expansion

β_{real} = real volumetric expansion

α = linear expansion coefficient of container

The factor 3 is used because volumetric expansion of a solid is approximately three times its linear expansion.

5. Why is mercury preferred in thermometers?

Mercury is preferred in thermometers because it has a high and uniform coefficient of expansion. It remains liquid over a wide temperature range. It does not wet glass, giving clear readings. It expands uniformly with temperature, which makes measurements accurate. It also has a high boiling point, so it does not evaporate easily.

6. Explain the effect of container expansion on apparent expansion.

When a liquid is heated inside a container, both the liquid and the container expand. The expansion of the container increases the space available. As a result, the liquid level rises less than it would in a rigid container. Therefore, apparent expansion is less than real expansion. The effect depends on the expansion coefficient of the container material.

7. State the difference between real and apparent expansion.

Real expansion is the true increase in volume of a liquid when heated, independent of the container. Apparent expansion is the observed increase in volume when the liquid is heated in a container. Real expansion is always greater than apparent expansion because the container absorbs some of the expansion.

8. If a liquid has apparent expansion 0.0009 per °C and container expansion 0.0001 per °C, find real expansion.

Formula: $\beta_{\text{real}} = \beta_{\text{apparent}} + \text{Container expansion}$

Given: $\beta_{\text{apparent}} = 0.0009$

Container expansion = 0.0001

$\beta_{\text{real}} = 0.0009 + 0.0001$

$\beta_{\text{real}} = 0.001 \text{ per } ^\circ\text{C}$

9. Why is apparent expansion used in thermometers?

Thermometers measure the rise of liquid in a narrow tube. This observed rise represents apparent expansion. Real expansion cannot be observed directly because the container also expands. Therefore, thermometers rely on apparent expansion to measure temperature accurately.

10. Describe an experiment to measure apparent expansion.

Take a glass container of known volume and fill it with a liquid such as mercury or alcohol. Mark the initial level of the liquid. Heat the container gently and observe the rise in the liquid level. Measure the increase in volume using the scale.

Formula: $\beta_{\text{apparent}} = \Delta V / (V\Delta T)$

Where: ΔV = change in volume

V = initial volume

ΔT = temperature change

This observed value gives apparent expansion. Real expansion can be calculated by adding container expansion.

MCQs

1. What is real expansion of a liquid?

- A) Expansion measured in a glass container
- B) Expansion ignoring container effects
- C) Expansion of the container itself
- D) Expansion due to freezing

Answer: B

Explanation: Real expansion refers to the actual increase in the volume of the liquid itself due to a temperature increase, disregarding any expansion of the container.

2. What is apparent expansion of a liquid?

- A) Expansion ignoring container effects
- B) Expansion including container effect
- C) Expansion at absolute zero
- D) Expansion in a vacuum

Answer: B

Explanation: Apparent expansion is the expansion of the liquid observed relative to the container. It is the real expansion of the liquid minus the expansion of the container.

3. Which of the following is larger?

- A) Real expansion
- B) Apparent expansion
- C) Both are equal
- D) None

Answer: A

Explanation: Real expansion is always greater than apparent expansion because the container itself also expands, making the liquid's rise appear less than its actual volume increase.

4. If a liquid expands in a container, what causes apparent expansion to be less than real expansion?

- A) Container contracts
- B) Container expands
- C) Temperature decreases
- D) Liquid evaporates

Answer: B

Explanation: The container expands along with the liquid, increasing its own capacity. This provides extra space for the liquid to occupy, so the observed (apparent) rise is less than the true (real) expansion.

5. Which liquid property is measured by real expansion?

- A) Coefficient of linear expansion
- B) Coefficient of volumetric expansion
- C) Surface tension
- D) Viscosity

Answer: B

Explanation: Real expansion is a change in volume, so it directly measures the liquid's coefficient of volumetric (or cubical) expansion.

6. If the liquid is in a glass flask, which type of expansion is observed?

- A) Real expansion
- B) Apparent expansion
- C) Linear expansion
- D) None

Answer: B

Explanation: When a liquid is inside a container, any expansion we directly observe, like the liquid rising up the neck of a flask, is the apparent expansion.

7. What happens to a liquid when heated in a rigid container?

- A) Real expansion occurs
- B) Apparent expansion occurs
- C) No expansion is observed
- D) Liquid contracts

Answer: B

Explanation: Even in a "rigid" container, the container expands slightly. The expansion observed relative to the container's markings is still the apparent expansion.

8. The difference between real and apparent expansion depends on:

- A) Shape of the container
- B) Coefficient of expansion of the container
- C) Volume of the liquid
- D) None

Answer: B

Explanation: The difference (Real - Apparent) is exactly equal to the volume expansion of the container itself, which depends on its coefficient of expansion.

9. Which formula represents apparent expansion?

- A) $\beta_{\text{apparent}} = \beta_{\text{real}} - 3\alpha$
- B) $\beta_{\text{apparent}} = 3\alpha - \beta_{\text{real}}$
- C) $\beta_{\text{apparent}} = \beta_{\text{real}} + 3\alpha$
- D) $\beta_{\text{apparent}} = \beta_{\text{real}} \beta_{\text{apparent}}$

Answer: A

Explanation: The coefficient of apparent expansion (β_{app}) equals the real expansion of the liquid (β_{real}) minus the expansion of the container ($\approx 3\alpha$, where α is the linear expansion coefficient of the solid).

10. If real expansion is 0.001 per °C and container expansion is 0.0001 per °C, apparent expansion is:

- A) 0.0011
- B) 0.0009
- C) 0.0010
- D) 0.0001

Answer: B

Explanation: Apparent expansion = Real expansion - Container expansion. Therefore, $0.0010 - 0.0001 = 0.0009$ per °C.

11. Which is true for all liquids?

- A) Real expansion < Apparent expansion
- B) Real expansion > Apparent expansion
- C) Real expansion = Apparent expansion
- D) Liquid does not expand

Answer: B

Explanation: Since all containers (solid materials) expand to some extent when heated, the real expansion of a liquid is always greater than its apparent expansion.

12. Why does mercury show less apparent expansion in glass?

- A) Mercury contracts
- B) Glass expands slightly
- C) Temperature decreases
- D) Glass contracts

Answer: B

Explanation: The glass container expands, increasing its internal volume. This makes the rise of the mercury column appear slightly less than the actual volume expansion of the mercury.

13. If the container has high expansion coefficient, apparent expansion will be:

- A) Much higher than real
- B) Slightly higher than real
- C) Much lower than real
- D) Equal to real

Answer: C

Explanation: A high container expansion means the container's volume increases significantly, accommodating more of the liquid's expansion and making the observed (apparent) expansion much smaller than the real expansion.

14. Which of these is used in thermometers for measuring temperature?

- A) Water
- B) Mercury
- C) Alcohol
- D) Both B & C

Answer: D

Explanation: Both mercury and alcohol are commonly used in thermometers because they have relatively uniform and visible expansion over a wide temperature range.

15. Coefficient of volumetric expansion of a liquid is usually:

- A) Greater than solids
- B) Less than solids
- C) Same as solids
- D) Zero

Answer: A

Explanation: Liquids generally expand more than solids for the same rise in temperature, meaning their coefficient of volumetric expansion is higher.

16. Apparent expansion is measured when:

- A) Liquid is in free space
- B) Liquid is in container
- C) Container is removed
- D) Liquid freezes

Answer: B

Explanation: Apparent expansion is, by definition, the expansion observed when the liquid is confined within and expanding along with its container.

17. If the container contracts on heating, apparent expansion will:

- A) Increase
- B) Decrease
- C) Remain same
- D) Become zero

Answer: A

Explanation: If the container contracts (a hypothetical scenario, as most expand), it would provide less space, forcing the liquid to rise more. Thus, the observed apparent expansion would increase.

18. Real expansion can be calculated if:

- A) Coefficient of container and apparent expansion are known
- B) Only apparent expansion is known
- C) Only container expansion is known
- D) None

Answer: A

Explanation: Since $\text{Apparent} = \text{Real} - \text{Container}$, the Real expansion can be found by adding the container's expansion (calculated from its coefficient) to the observed apparent expansion.

19. Which is negligible for water in a metal container?

- A) Real expansion
- B) Apparent expansion difference
- C) Heat capacity
- D) Surface tension

Answer: B

Explanation: The difference (Real - Apparent) is the container's expansion. For water in a metal container, the difference might be significant if the metal expands a lot. The question likely implies a scenario with minimal container expansion, making the difference negligible. However, based on standard concepts, "Apparent expansion difference" is the most direct answer as it refers to the difference between real and apparent.

20. Apparent expansion is always _____ than real expansion.

- A) Greater
- B) Smaller
- C) Equal
- D) None

Answer: B

Explanation: Apparent expansion is always smaller than real expansion because a part of the liquid's real expansion goes into filling the extra space created by the expansion of the container itself.

UNIT:11 THERMAL TRANSFORMATIONS

TOPIC : 11.2.3 APPICATIONS AND CONSEQUENCES OF THERMAL EXPANSIION IN REAL LIFE

Thermometers:

- 1.Liquid mercury or alcohol expands when heated
- 2.The liquid rises in the calibrated capillary tube
- 3.The height of the liquid column shows the temperature

Bimetallic strip thermostat :

- 1.Made of two different metals (brass and iron) joined together
- 2.Metals expand at different rates when heated
- 3.Unequal expansion causes the strip to bend
- 4.The bending acts as a switch to control heating devices

Expansion joints:

- 1.Used in bridges, buildings, and pipelines
- 2.Allow materials to expand and contract due to temperature changes
- 3.Prevent structural damage by absorbing thermal stress

Opening the cap of a bottle :

- 1.Heating the metal cap causes it to expand
- 2.Expansion increases the cap's diameter slightly
- 3.Makes it easier to open the cap

Power lines:

- 1.Power cables expand and sag in hot weather
- 2.Extra slack is provided during installation
- 3.Prevents cables from snapping due to expansion

Designing instrument in machinery:

- 1.Parts are designed to accommodate thermal expansion
- 2.Ensures proper fitting and functioning despite temperature changes
- 3.Prevents malfunction and damage caused by expansion or contraction

Consequences of thermal expansions:

1. Without accounting for thermal expansion, machines and structures can face serious problems.
2. Concrete and asphalt expand and contract with temperature changes; without joints, this causes cracks.
3. Overheated power lines may sag too much, leading to power outages.
4. Railway tracks can buckle in hot weather if expansion gaps are missing.
5. Pipes can burst if heated fluid expands and there's no space for it.
6. Measuring instruments may give incorrect readings if not calibrated for expansion.
7. Repeated expansion and contraction weakens metals, damaging machines, airplanes, and buildings.

SRQs

1. Why does a liquid-in-glass thermometer work?

A liquid-in-glass thermometer works because the liquid inside (mercury or alcohol) expands more than the glass when heated. As temperature increases, the liquid rises in the narrow capillary tube. This rise indicates temperature.

2. Why does a bimetallic strip bend when heated?

A bimetallic strip is made of two different metals joined together. When heated, one metal expands more than the other. Due to different expansion rates, the strip bends. This principle is used in thermostats.

3. Why are expansion joints provided in bridges?

Expansion joints are provided to allow materials to expand in hot weather and contract in cold weather. Without these joints, bridges may crack or develop internal stress due to thermal expansion.

4. Why does a tight metal lid loosen in hot water?

When hot water is poured over a metal lid, the metal expands. Since metal expands more than glass, the lid becomes loose and can be opened easily.

5. Why are overhead power lines given slack?

Power lines are given slack so that when temperature decreases in winter, the wires contract without snapping. Slack prevents breakage due to contraction.

6. Why does water bottle crack in a freezer?

Water expands when it freezes (below 4°C). If there is no extra space in the bottle, the expanding ice creates pressure and the bottle may crack.

7. Why are rivets heated before installation?

Rivets are heated before installation so they expand. After fitting, they cool and contract, forming a tight and strong joint between metal plates.

8. Why does a pendulum clock slow down in summer?

In summer, the pendulum rod expands due to heat. This increases its length, which increases the time period of oscillation. As a result, the clock runs slow.

9. Why are low-expansion glasses like Pyrex used in laboratories?

Low-expansion glasses resist cracking during sudden temperature changes. They experience very small expansion, reducing thermal stress.

10. Why is thermal expansion important in machine design?

If thermal expansion is ignored, machine parts may expand and stick, jam, or break. Engineers design machines considering expansion rates to ensure smooth operation.

MSQs

1. Which property allows a liquid-in-glass thermometer to measure temperature?

- A) Glass contracts more than liquid
- B) Liquid expands more than glass
- C) Glass expands faster than liquid
- D) Liquid freezes easily

Answer: B

Explanation: For the thermometer to show a reading, the liquid inside (like mercury or alcohol) must expand significantly more than the glass tube containing it.

2. Why does a bimetallic strip bend when heated?

- A) Both metals expand equally
- B) One metal expands faster than the other
- C) The strip absorbs heat uniformly
- D) Metals melt slightly

Answer: B

Explanation: A bimetallic strip consists of two different metals bonded together. When heated, one metal expands more than the other, causing the strip to bend towards the metal with the lower expansion.

3. What is the purpose of expansion joints in bridges?

- A) Prevent cracking due to heat expansion
- B) Reduce bridge weight
- C) Prevent water accumulation
- D) Allow more traffic

Answer: A

Explanation: Expansion joints are gaps built into bridges to allow the materials to expand safely on hot days without buckling or cracking the structure.

4. Why does a tight metal jar lid loosen in hot water?

- A) Water lubricates the lid
- B) Metal lid expands more than glass
- C) Lid melts slightly
- D) Heat reduces friction

Answer: B

Explanation: Metals generally have a higher coefficient of expansion than glass. When hot water is poured over the lid, the metal expands more and faster than the glass jar, making the lid easier to turn.

5. Why are overhead power lines given slack (sag)?

- A) For aesthetics
- B) Metals contract in cold, tight wires could break
- C) Sag improves conductivity
- D) Sag prevents heat absorption

Answer: B

Explanation: The slack (or sag) is provided so that when temperatures drop and the wires contract, they are not pulled so tight that they snap.

6. What happens to a Brass-Steel bimetallic strip when cooled?

- A) Bends toward Steel
- B) Bends toward Brass
- C) Stays straight
- D) Alternates directions

Answer: B

Explanation: Brass expands and contracts more than steel. When cooled, brass contracts more, so the strip bends towards the brass side.

7. Why does a glass bottle of water crack in a freezer?

- A) Water shrinks when freezing
- B) Water expands below 4°C , creating pressure
- C) Glass melts slightly in cold
- D) Bottle freezes slowly

Answer: B

Explanation: Water exhibits anomalous expansion. Below 4°C , it expands as it cools further and freezes. This expansion inside a sealed glass bottle creates immense pressure, causing the bottle to crack.

8. Why is Mercury used in thermometers instead of water?

- A) Mercury expands irregularly
- B) Mercury sticks to glass
- C) Mercury remains liquid over a wide range and expands uniformly
- D) Mercury freezes easily

Answer: C

Explanation: Mercury is a good thermometer fluid because it remains in a liquid state over a wide range of temperatures and its expansion is fairly uniform and visible.

9. Why do railway tracks buckle in summer without expansion gaps?

- A) Steel contracts in heat
- B) Concrete beneath melts
- C) Rails expand with nowhere to go
- D) Train pressure causes bending

Answer: C

Explanation: On hot days, the steel rails expand in length. If there are no expansion gaps, the rails have no room to expand and will buckle sideways from the compressive stress.

10. Why are rivets heated before installation?

- A) To soften for drilling
- B) Contraction during cooling provides a tight grip
- C) To prevent oxidation
- D) To reduce weight

Answer: B

Explanation: Hot rivets are inserted into plates. As they cool, they contract, pulling the plates together tightly and forming a strong, secure joint.

11. What happens to a hole in a metal plate when the plate is heated?

- A) Hole becomes smaller
- B) Hole becomes larger
- C) Hole stays same
- D) Plate melts first

Answer: B

Explanation: When a metal plate expands, all its dimensions increase, including the diameter of any holes. The material expands outward, making the hole larger.

12. Why does a pendulum clock slow down in summer?

- A) Pendulum shortens
- B) Pendulum rod expands, increasing swing period
- C) Air resistance increases
- D) Temperature has no effect

Answer: B

Explanation: The rod of the pendulum expands in the summer heat, making the pendulum longer. A longer pendulum takes more time to complete one swing, causing the clock to lose time (run slow).

13. Why does a glass crack when cold water is poured into a hot glass?

A) Uneven contraction creates thermal stress

B) Water freezes instantly

C) Glass absorbs heat evenly

D) Glass melts inside

Answer: A

Explanation: The inner surface of the glass cools and contracts rapidly, while the outer surface remains hot and expanded. This uneven contraction creates stress that cracks the glass.

14. Why is slack given to rails during installation?

A) Reduce noise

B) Allow free thermal expansion

C) Prevent rusting

D) Easier installation

Answer: B

Explanation: Small gaps (slack) are left between rail sections to provide space for the rails to expand on hot days without buckling.

15. Which material has near-zero expansion?

A) Aluminium

B) Brass

C) Invar (steel alloy)

D) Glass

Answer: C

Explanation: Invar is a nickel-steel alloy famous for having a very low coefficient of thermal expansion, meaning its dimensions change very little with temperature.

16. Why does a thermostat cut off power at high temperature?

A) Thermostat melts

B) Bimetallic strip bends, breaking the circuit

C) Heat sensor stops electricity

D) Wires expand

Answer: B

Explanation: In a simple thermostat, the bimetallic strip bends when heated. This bending movement can break an electrical contact, cutting off the power supply.

17. Why can the Eiffel Tower grow 6 inches in summer?

- A) Iron melts slightly
- B) Iron expands due to heat
- C) Towers have mechanical elevators
- D) Wind pushes it up

Answer: B

Explanation: The iron structure of the Eiffel Tower expands when heated by the summer sun, causing the entire structure to increase in height by a few inches.

18. Which of these materials expands the most when heated?

- A) Aluminium
- B) Steel
- C) Brass
- D) Glass

Answer: A

Explanation: Among the common materials listed, aluminium typically has the highest coefficient of linear expansion.

19. What is the main danger of ignoring thermal expansion in pipelines?

- A) Pipes may shrink
- B) Pipes may burst due to liquid expansion
- C) Pipes become slippery
- D) No effect

Answer: B

Explanation: If a liquid inside a closed pipeline expands due to heat and there is no room for the pipe to expand or the liquid to flow, the immense pressure can cause the pipe to burst.

20. Why does a bimetallic strip straighten again after cooling in a thermostat?

- A) Metals lose heat evenly
- B) Metals contract differently; strip returns to original shape
- C) Bimetallic strip bends permanently
- D) Thermostat resets automatically

Answer: B

Explanation: The bending is elastic. Upon cooling, both metals contract, with the one that expanded more also contracting more, causing the strip to return to its original straight shape.

21. Why are low-expansion glass types like Pyrex used in labs?

- A) They are cheap
- B) They resist cracking under temperature changes
- C) They absorb more heat
- D) They expand faster than metals

Answer: B

Explanation: Low-expansion glass is resistant to thermal shock. It can withstand rapid temperature changes without cracking because it expands and contracts very little, reducing internal stress.

22. Why is steel preferred for railway tracks?

- A) Low cost
- B) Moderate expansion and high strength
- C) High expansion and weak
- D) Flexible like rubber

Answer: B

Explanation: Steel provides a good balance of high strength to bear loads and a manageable coefficient of expansion that can be accommodated with expansion gaps.

23. Why do bridge supports use rollers instead of fixing both ends rigidly?

- A) To allow vibration absorption
- B) To accommodate thermal expansion and contraction
- C) To increase bridge height
- D) To prevent corrosion

Answer: B

Explanation: Roller supports allow one end of the bridge to move freely as the structure expands and contracts with temperature changes, preventing the buildup of destructive stresses.

24. Why does thermal expansion matter in machine design?

- A) Machines overheat otherwise
- B) Parts can stick or break if expansion is ignored
- C) Materials become soft
- D) Only for aesthetics

Answer: B

Explanation: Engineers must account for thermal expansion by providing clearances (gaps) between parts. If not, parts that expand when heated could seize, jam, or cause failure.

25. How does anomalous expansion of water affect household appliances?

- A) Water pipes never crack
- B) Freezing water in closed pipes can burst them
- C) Water always contracts when cooled
- D) No effect on appliances

Answer: B

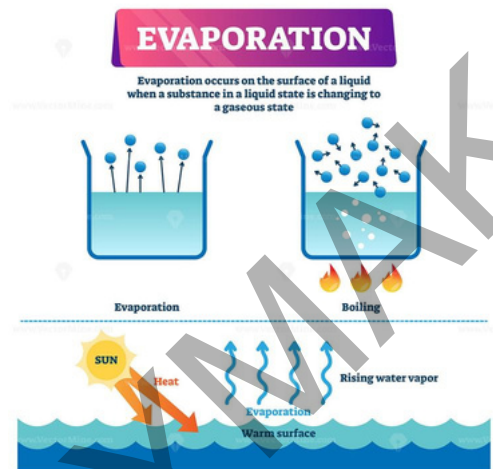
Explanation: When water freezes in pipes during winter, it expands. This expansion creates enormous pressure, which can burst the pipes, causing significant damage.

UNIT:11 THERMAL TRANSFORMATIONS

TOPIC : 11.4 EVAPORATION

Cause of evaporation

1. Molecules in a liquid constantly move and collide with each other and container walls.
2. These collisions cause molecules to have different kinetic energies.
3. Some molecules gain enough kinetic energy to escape from the liquid surface as vapour.



Evaporation causes cooling

1. High-energy molecules near the surface escape as vapour.
2. Remaining molecules have lower average kinetic energy.
3. Lower average kinetic energy lowers the temperature of the liquid.
4. This temperature drop causes a cooling effect.
5. When liquid evaporates from the surface of solids, it lowers the solid's temperature too.
6. This cooling principle is used in refrigerators and air conditioners.

Factors affecting the rate of evaporation

1. The rate of evaporation is how fast molecules at the surface escape and turn into gas.
2. Higher rate of evaporation means faster evaporation of the liquid.

3. Temperature:

The rate of evaporation \propto temperature (directly proportional).

Higher temperature increases the kinetic energy of molecules, increasing the rate of evaporation.

Example: Water evaporates faster in sunshine or hot areas than in shade or cooler areas.

4. Surface Area:

The rate of evaporation \propto surface area (directly proportional).

Larger surface area allows more molecules to escape, increasing evaporation speed.

This is why spreading wet clothes helps them dry faster.

5. Humidity:

The rate of evaporation \propto $1/\text{humidity}$ (inversely proportional).

Dry air (low humidity) can absorb more water vapor, increasing evaporation rate.

Example: Air coolers work better in dry months (June) than in humid months (August).

6. Wind Speed:

Increased wind speed increases the rate of evaporation.

Wind blows away moisture near the surface, allowing more evaporation.

It dries faster on windy days compared to calm days.

UNIT:11 THERMAL TRANSFORMATIONS

TOPIC : 11.3.5 APPLICATIONS OF EVAPORATION

Refrigeration using Evaporation: Refrigeration using Evaporation without CFCs

1. Refrigerant—a liquefied gas—evaporates inside the fridge coils, absorbing heat and cooling the interior.
2. Warm air in the fridge passes over cold evaporator coils, triggering this evaporation.
3. The resulting refrigerant vapour moves to the compressor, where its pressure and temperature rise.
4. Hot, high-pressure gas then flows into the condenser coils and releases heat to the surroundings.
5. As it cools in the condenser, the refrigerant condenses back into liquid form.
6. Liquid refrigerant returns to the evaporator coils to repeat the cycle continuously.
7. Chlorofluorocarbons (CFCs) were once used but are now banned for depleting the ozone layer.
8. Eco-friendly alternatives—ammonia, water, propane, butane—are used instead to prevent ozone damage.

Food preservation:

1. Many food items are preserved by removing water content through evaporation.
2. Evaporation concentrates the flavor and prevents spoilage.
3. Examples include dried fruits and dried meats.

Production of salts:

1. In the production of salt from seawater, water evaporates in large quantities.
2. As water evaporates, salt is left behind.
3. The salt can then be collected for use.

Air Conditioning

1. Air conditioners cool air using evaporation.
2. Warm air passes over coils with cool liquid refrigerant.
3. The liquid evaporates, absorbing heat and cooling the air.
4. Cooled air circulates back into the room.

Fever Control

1. Wet cloth is applied to the forehead during high fever.
2. Heat from the body transfers to the water.
3. Water evaporates, removing heat and cooling the skin.
4. This helps keep brain temperature safe and prevents injury.

SRQs

Q1. Why does evaporation occur at all temperatures but boiling does not?

1. Energy Distribution in Molecules

In a liquid, molecules have different kinetic energies at any temperature.

2. Escape of High-Energy Molecules

Even at low temperature, some molecules have enough energy to escape from the surface.

3. Surface Limitation

Evaporation happens only at the surface, so full heating of the liquid is not required.

4. Boiling Requirement

Boiling occurs only when vapor pressure equals atmospheric pressure, which happens at a fixed temperature.

5. Core Difference

Evaporation is a gradual surface process, while boiling is a bulk process requiring a specific boiling point.

Q2. Why does evaporation increase when temperature rises?

1. Increase in Kinetic Energy

Higher temperature increases molecular motion.

2. More Energetic Molecules

A larger number of molecules gain enough energy to overcome intermolecular forces.

3. Increased Escape Rate

More molecules leave the surface per second.

4. Direct Proportionality

Rate of evaporation increases directly with temperature.

5. Practical Observation

Water dries faster in summer than in winter.

Q3. Why does high humidity slow down evaporation?

1. Definition of Humidity

Humidity is the amount of water vapor present in air.

2. Saturation Concept

Air has a limited capacity to hold water vapor.

3. Reduced Concentration Gradient

If air already contains vapor, fewer molecules can escape into it.

4. Slower Evaporation Rate

High humidity decreases the rate of evaporation.

5. Real Example

Clothes dry slowly on rainy days.

Q4. Why do we feel cold when sweat evaporates?

1. Latent Heat Requirement

Evaporation requires heat energy.

2. Heat Source

Sweat absorbs heat from the skin.

3. Loss of High-Energy Molecules

High-energy molecules leave first.

4. Drop in Average Energy

Remaining molecules have lower kinetic energy.

5. Cooling Sensation

This decrease in temperature produces a cooling effect.

Q5. Why does wind speed increase evaporation?

1. Vapor Layer Formation

A thin layer of vapor forms above the liquid surface.

2. Removal of Saturated Air

Wind blows away this moist layer.

3. Fresh Air Replacement

Dry air replaces the saturated air.

4. Increased Escape Opportunity

More molecules can now evaporate easily.

5. Practical Example

Clothes dry faster on windy days.

Q6. Why does temperature remain constant during boiling?

1. Latent Heat of Vaporization

Heat supplied is used to change liquid into gas.

2. Bond Breaking

Energy breaks intermolecular attractions.

3. No Kinetic Energy Increase

Molecular speed does not increase during boiling.

4. Constant Thermometer Reading

Temperature stays fixed at boiling point.

5. Phase Change Completion

Temperature rises again only after all liquid converts to vapor.

Q7. Why are bubbles formed during boiling but not in evaporation?

1. Internal Vapor Formation

During boiling, vapor forms inside the liquid.

2. Vapor Pressure Equality

Boiling begins when internal vapor pressure equals atmospheric pressure.

3. Bubble Rise

Vapor bubbles rise to the surface due to buoyancy.

4. Surface Limitation in Evaporation

Evaporation occurs only at the surface.

5. Visual Difference

Boiling is visible and vigorous, evaporation is silent and invisible.

Q8. Why does water boil at a lower temperature on mountains?

1. Lower Atmospheric Pressure

At high altitude, air pressure is reduced.

2. Vapor Pressure Condition

Boiling occurs when vapor pressure equals atmospheric pressure.

3. Easier Achievement

Lower external pressure requires less heat.

4. Reduced Boiling Point

Water boils below 100°C .

5. Cooking Impact

Food cooks slowly due to lower boiling temperature.

Q9. Why is steam at 100°C more dangerous than water at 100°C ?

1. Same Temperature

Both are at 100°C .

2. Extra Energy Storage

Steam contains latent heat of vaporization.

3. Condensation Process

When steam touches skin, it condenses.

4. Heat Release

Latent heat is released onto the skin.

5. Severe Burns

This extra energy causes deeper burns.

Q10. How does surface area affect evaporation?

1. Surface Phenomenon

Evaporation occurs only at the surface.

2. Molecular Exposure

Greater surface area exposes more molecules.

3. Higher Escape Probability

More molecules escape simultaneously.

4. Direct Relationship

Evaporation rate increases with surface area.

5. Example

Tea in a saucer cools faster than in a cup.

MCQs

1. Why do wet clothes dry faster in summer than in winter?

- A) Air pressure increases
- B) Temperature increases molecular energy
- C) Humidity increases
- D) Surface area decreases

Answer: B

Explanation: Higher temperatures in summer provide more kinetic energy to water molecules, allowing them to escape into the air more quickly.

2. Why does water in a saucer evaporate faster than in a glass?

- A) Saucer is heavier
- B) Saucer has less water
- C) Saucer has larger surface area
- D) Saucer has higher temperature

Answer: C

Explanation: A larger surface area allows more water molecules to be exposed to the air, increasing the rate of evaporation.

3. Why do we feel cold after taking a bath?

- A) Water temperature increases
- B) Skin absorbs water
- C) Evaporation absorbs heat from skin
- D) Air pressure decreases

Answer: C

Explanation: The water on our skin evaporates, and this process requires heat (latent heat of vaporization), which is absorbed from our body, making us feel cold.

4. Why does perfume smell spread quickly in a room?

- A) It boils quickly
- B) It is volatile
- C) It is heavier than air
- D) It has high boiling point

Answer: B

Explanation: Perfume is volatile, meaning it has a low boiling point and weak intermolecular forces, causing its molecules to evaporate and diffuse rapidly into the air.

5. Why does water boil at lower temperature on mountains?

- A) Temperature is low
- B) Wind speed is high
- C) Atmospheric pressure is low
- D) Humidity is high

Answer: C

Explanation: At higher altitudes, atmospheric pressure is lower, so water molecules need less energy (lower temperature) to overcome this pressure and form vapor.

6. Why is steam more dangerous than boiling water at 100°C?

- A) Steam is invisible
- B) Steam contains latent heat
- C) Steam is lighter
- D) Steam is cooler

Answer: B

Explanation: Steam contains additional energy in the form of latent heat of vaporization, which is released when it condenses on the skin, causing more severe burns.

7. Why does evaporation slow down on a rainy day?

- A) Wind decreases
- B) Humidity is high
- C) Surface area reduces
- D) Temperature increases

Answer: B

Explanation: The air is already saturated with moisture (high humidity), so it has a reduced capacity to accept more water vapor, slowing down evaporation.

8. Why does alcohol evaporate faster than water?

- A) Stronger bonding
- B) Higher boiling point
- C) Weaker intermolecular forces
- D) Higher density

Answer: C

Explanation: Alcohol has weaker intermolecular forces (like hydrogen bonding is less extensive than in water), so its molecules can escape into the air more easily.

9. Why does temperature remain constant during boiling?

- A) No heat is supplied
- B) Heat increases kinetic energy
- C) Heat breaks intermolecular forces
- D) Molecules stop moving

Answer: C

Explanation: The heat energy supplied during boiling is used to overcome the intermolecular forces of attraction to change the state from liquid to gas, not to increase the kinetic energy (temperature).

10. Why does wind increase the rate of evaporation?

- A) It cools the liquid
- B) It increases pressure
- C) It removes moist air
- D) It decreases surface area

Answer: C

Explanation: Wind carries away the air molecules that have become saturated with water vapor, creating room for more evaporation to occur.

11. Why is boiling considered a bulk process?

- A) It occurs only at surface
- B) It occurs throughout liquid
- C) It is slow
- D) It needs no heat

Answer: B

Explanation: Boiling happens when the vapor pressure of the liquid equals the atmospheric pressure, allowing vapor bubbles to form and rise from the entire volume of the liquid.

12. Why do we see bubbles during boiling but not during evaporation?

- A) Evaporation is fast
- B) Boiling forms vapor inside liquid
- C) Evaporation forms bubbles
- D) Boiling occurs at surface

Answer: B

Explanation: During boiling, the temperature is high enough for vapor bubbles to form within the liquid itself. Evaporation is a surface phenomenon and does not create internal bubbles.

13. Why does water level decrease in an open bowl kept for many days?

- A) Water absorbs air
- B) Water freezes
- C) Continuous evaporation
- D) Boiling occurs

Answer: C

Explanation: Over time, water molecules at the surface continuously gain enough energy to escape into the air as vapor, a process called evaporation, which lowers the water level.

14. Why is evaporation faster in dry weather?

- A) Air contains less moisture
- B) Temperature decreases
- C) Pressure increases
- D) Surface area decreases

Answer: A

Explanation: Dry air has a lower humidity, meaning it is not saturated with water vapor and can easily accept more water molecules evaporating from a surface.

15. Why does a pressure cooker cook food faster?

- A) Pressure decreases
- B) Boiling point increases
- C) Temperature decreases
- D) Humidity decreases

Answer: B

Explanation: The increased pressure inside the cooker raises the boiling point of water, allowing the water and steam to reach a higher temperature, which cooks the food faster.

SRQs

1. What is evaporation?

Ans:

Evaporation is the process by which a liquid changes into vapor from its surface at temperatures below its boiling point. It occurs when surface molecules gain enough energy to escape into the air.

2. Why does evaporation produce a cooling effect?

Ans:

Evaporation causes cooling because the fastest-moving liquid molecules escape by absorbing heat from the surroundings. This removal of heat lowers the temperature of the remaining liquid and nearby environment.

3. Explain refrigeration using evaporation without CFCs.

Ans:

Modern refrigerators use eco-friendly refrigerants instead of harmful CFCs. The liquid refrigerant evaporates inside cooling coils, absorbing heat from the interior. This lowers the temperature and keeps food fresh while protecting the ozone layer.

4. Why are CFCs harmful and avoided in refrigeration?

Ans:

CFCs damage the ozone layer by breaking down ozone molecules. The ozone layer protects Earth from harmful ultraviolet radiation. Therefore, safer refrigerants are used to prevent environmental damage.

5. How does evaporation help in food preservation?

Ans:

Evaporation removes water from food, reducing moisture content. Microorganisms like bacteria and fungi need water to grow. Without moisture, food remains safe, fresh, and usable for longer periods.

6. Give examples of foods preserved using evaporation.

Ans:

Examples include dried fruits, vegetables, fish, milk powder, spices, and grains. Removing water prevents spoilage and increases shelf life.

7. Explain how salt is produced by evaporation.

Ans:

Seawater is collected in shallow ponds and exposed to sunlight and wind. Water evaporates, leaving behind salt crystals. These crystals are collected, purified, and used for cooking and industrial purposes.

8. Why are shallow ponds used for salt production?

Ans:

Shallow ponds increase surface area, allowing faster evaporation. More water is exposed to sunlight and air, which speeds up the formation of salt crystals.

9. How does evaporation help in air conditioning?

Ans:

Air conditioners use refrigerants that evaporate inside cooling coils. During evaporation, heat is absorbed from indoor air. This process cools the air, which is then circulated back into the room.

10. What are the main applications of evaporation in daily life?

Ans:

Evaporation is used in refrigeration, air conditioning, drying clothes, food preservation, cooling of the body through sweating, and production of salt.

11. How does evaporation help dry clothes?

Ans:

Water in wet clothes absorbs heat from surroundings and evaporates into the air. Wind and sunlight speed up this process, leaving the clothes dry.

12. Why do wet floors dry faster in hot weather?

Ans:

Higher temperature increases molecular energy, allowing water to evaporate faster. Dry air and wind also speed up evaporation.

13. How does wind affect evaporation?

Ans:

Wind removes water vapor from the surface, allowing more liquid to evaporate quickly. This increases the rate of evaporation.

14. Why is evaporation faster in deserts?

Ans:

Deserts have high temperatures, strong sunlight, low humidity, and dry air. These conditions increase evaporation rates.

15. State advantages of evaporation.

Ans:

Evaporation provides cooling, preserves food, produces salt, dries clothes, and helps regulate body temperature through sweating

MCQs

1. Evaporation is the process in which:

- A) Solid changes into liquid
- B) Liquid changes into vapor from its surface**
- C) Gas changes into liquid
- D) Solid changes into gas

Answer: B

Explanation: Evaporation is a surface phenomenon where a liquid turns into vapor at a temperature below its boiling point.

2. Evaporation causes cooling because:

- A) Heat is released
- B) Heat is absorbed from surroundings
- C) Temperature increases
- D) Air becomes warm

Answer: B

Explanation: The liquid molecules that escape need energy (latent heat), which they absorb from the surface and surrounding air, causing a cooling effect.

3. In refrigerators, cooling occurs due to:

- A) Condensation
- B) Freezing
- C) Evaporation of refrigerant
- D) Melting of ice

Answer: C

Explanation: A refrigerant liquid evaporates inside the cooling pipes, absorbing heat from the interior of the fridge and lowering its temperature.

4. Why are CFCs not used in modern refrigerators?

- A) They are expensive
- B) They damage the ozone layer
- C) They produce heat
- D) They freeze quickly

Answer: B

Explanation: Chlorofluorocarbons (CFCs) were found to rise into the stratosphere and deplete the protective ozone layer, so they were phased out.

5. Evaporation helps preserve food by:

- A) Increasing moisture
- B) Removing water content
- C) Heating food
- D) Changing color of food

Answer: B

Explanation: Microorganisms need water to grow. By removing water through evaporation, food can be preserved for a longer time.

6. Which food is preserved using evaporation?

- A) Fresh milk
- B) Dried fruits
- C) Ice cream
- D) Soup

Answer: B

Explanation: Dried fruits like raisins, apricots, and figs are made by allowing the water content in the fresh fruit to evaporate.

7. Salt is produced from seawater by:

- A) Freezing
- B) Evaporation
- C) Condensation
- D) Filtration

Answer: B

Explanation: Seawater is trapped in shallow ponds. The sun's heat evaporates the water, leaving the dissolved salt crystals behind.

8. Air conditioners cool rooms by:

- A) Releasing heat
- B) Evaporation of refrigerant absorbing heat
- C) Producing steam
- D) Increasing humidity

Answer: B

Explanation: Similar to a refrigerator, an AC uses the evaporation of a refrigerant in its coils to absorb heat from the room air, which is then circulated outside.

9. Which is NOT an application of evaporation?

- A) Refrigeration
- B) Food drying
- C) Salt production
- D) Rusting

Answer: D

Explanation: Rusting is a chemical reaction (oxidation) of iron in the presence of moisture and air, not a process that utilizes evaporation.

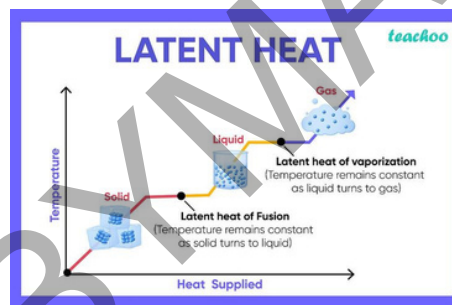
UNIT:11 THERMAL TRANSFORMATIONS

TOPIC : 11.4 LATENT HEAT

When a substance undergoes a phase change such as melting, freezing, boiling, or condensation, it either absorbs or releases heat. However, this heat does not cause a change in temperature. Instead, it is used to break or form intermolecular forces within the substance. This energy is called latent heat.

Definition:

Latent heat is the amount of heat energy (ΔQ) absorbed or released by a substance during a phase change without any change in its temperature.



Phase Changes and Temperature-Heat Graph

A typical temperature-time graph during heating illustrates how a substance absorbs heat.

A to B: Ice at -20°C is heated. The temperature increases to 0°C , but the state remains solid.

B to C: At 0°C , ice begins to melt. Temperature remains constant. The heat added here is used to overcome the forces holding the particles in the solid state this is called the latent heat of fusion (L_f).

C to D: The melted ice (now water) is heated from 0°C to 100°C . Temperature rises steadily.

D to E: At 100°C , water starts to boil, changing into vapour. The temperature remains constant as the heat is used for the latent heat of vaporisation (L_v).

E to F: All water has turned into vapour. Further heat raises the temperature of steam above 100° .

Important concept

Temperature relates to the average kinetic energy of particles. During a phase change, kinetic energy does not increase, but potential energy increases as intermolecular bonds are broken. Thus, temperature stays constant during phase changes.

UNIT:11 THERMAL TRANSFORMATIONS

11.4.1 LATENT HEAT OF FUSION

Definition:

The latent heat of fusion (L_f) is the amount of heat energy required to convert 1 kg of a solid substance into its liquid form at its melting point without any change in temperature.

Mathematical Expression:

$$\Delta Q = m \times L_f$$

Where:

ΔQ = heat absorbed (J)

M = mass of the substance (kg)

L_f = specific latent heat of fusion ($J \text{ kg}^{-1}$)

SI Unit: Joule per kilogram ($J \text{ kg}^{-1}$)

Example: Latent heat of fusion of ice is:

$$L_f = 3.33 \times 10^5 \text{ J kg}^{-1}$$

NOTE: When liquid freezes back into a solid, the same amount of heat is released.

SRQs

1. What is latent heat?

Ans:

Latent heat is the heat energy absorbed or released when a substance changes its physical state without any change in temperature.

2. Why is latent heat called hidden heat?

Ans:

It is called hidden heat because the heat energy does not raise the temperature. Instead, it is used to break or form bonds between particles during a change of state.

3. What happens to temperature during a change of state?

Ans:

The temperature remains constant until the entire substance changes its state because the heat supplied is used for the phase change.

4. Define latent heat of fusion.

Ans:

Latent heat of fusion is the heat required to convert a solid into liquid at its melting point without any change in temperature.

5. Give an example of latent heat of fusion.

Ans:

Ice melting into water at 0°C is a common example. Heat is absorbed but temperature remains constant.

6. What happens during freezing?

Ans:

During freezing, a liquid releases latent heat to the surroundings while changing into a solid at constant temperature.

7. Write the formula for latent heat.

Ans:

The formula is

$$Q = mL$$

8. Differentiate between latent heat of fusion and vaporization.

Ans:

Latent heat of fusion changes solid to liquid, while latent heat of vaporization changes liquid to gas. Vaporization requires much more heat than fusion.

MCQs

1. Latent heat of fusion is the heat required to:

- A) Convert liquid to gas
- B) Convert solid to liquid
- C) Convert gas to liquid
- D) Convert liquid to solid

Answer: B

Explanation: 'Fusion' means melting. This is the energy needed to change a substance from a solid state to a liquid state without changing its temperature.

2. Ice melting at 0°C is an example of:

- A) Condensation
- B) Latent heat of vaporization
- C) Latent heat of fusion
- D) Sublimation

Answer: C

Explanation: Ice is a solid, and it is changing into liquid water. The heat absorbed during this process at a constant temperature is the latent heat of fusion.

3. During freezing, heat is:

- A) Absorbed
- B) Released
- C) Destroyed
- D) Stored

Answer: B

Explanation: Freezing is the opposite of melting. When a liquid turns into a solid, it releases the latent heat of fusion into the surroundings.

4. The formula for latent heat of fusion is:

- A) $Q = m \times L_v$
- B) $Q = m \times L_f$
- C) $P \times V = T$
- D) $V = IR$

Answer: B

Explanation: The heat energy (Q) required for a phase change is calculated by multiplying the mass (m) of the substance by its specific latent heat (L). L_f stands for latent heat of fusion.

5. Latent heat of vaporization is the heat required to:

- A) Convert solid to liquid
- B) Convert liquid to gas
- C) Convert gas to solid
- D) Convert solid to gas

Answer: B

Explanation: 'Vaporization' means boiling or evaporation. This is the energy needed to change a substance from a liquid state to a gaseous state at a constant temperature.

6. Water boiling at 100°C is an example of:

- A) Fusion
- B) Sublimation
- C) Vaporization
- D) Freezing

Answer: C

Explanation: Boiling is a rapid form of vaporization where the entire liquid changes into gas at its boiling point.

7. Sweating cools the body because of:

- A) Condensation
- B) Evaporation
- C) Freezing
- D) Melting

Answer: B

Explanation: Sweat on the skin evaporates by absorbing the necessary latent heat of vaporization from the body, which cools it down.

8. Which has the greater value?

- A) Latent heat of fusion
- B) Latent heat of vaporization
- C) Both equal
- D) None

Answer: B

Explanation: It takes more energy to completely separate liquid molecules into a gas (vaporization) than to just loosen them into a more fluid state (fusion). For water, L_v is about $2,260 \text{ kJ/kg}$, while L_f is 334 kJ/kg .

9. During boiling, temperature:

- A) Increases continuously
- B) Decreases
- C) Remains constant
- D) Becomes zero

Answer: C

Explanation: All the heat supplied during boiling is used as latent heat of vaporization to overcome intermolecular forces, not to increase the kinetic energy (temperature) of the molecules.

UNIT:11 THERMAL TRANSFORMATIONS

11.4.4 LATENT HEAT OF VAPORIZATION

Definition:

The latent heat of vaporisation (L_v) is the amount of heat energy required to convert 1 kg of a liquid into its gaseous form at its boiling point without any change in temperature.

Mathematical Expression:

$$\Delta Q = m \times L_v$$

Where:

ΔQ = heat absorbed (J)

M = mass of substance (kg)

L_v = specific latent heat of vaporisation ($J \text{ kg}^{-1}$)

SI Unit: Joule per kilogram ($J \text{ kg}^{-1}$)

Example: Latent heat of vaporisation of water is:

$$L_v = 2.26 \times 10^6 \text{ J kg}^{-1}$$

Note: When gas condenses into liquid, this same amount of heat is released.

11.4.3 EXPERIMENT TO FIND LATENT HEAT OF FUSION OF ICE

Apparatus:

Beaker, ice, stand, burner, thermometer, stopwatch, stirrer.

Procedure:

1. Place ice cubes into a beaker
2. Insert a thermometer into the beaker.
3. Place the beaker on a stand and light the burner beneath it.
4. Start the stopwatch as heating begins.
5. As ice starts to melt, observe that temperature stays at 0°C .
6. Note the time taken (t_2) for complete melting.
7. Continue heating and note the time (t_1) taken to raise the temperature of water from 0°C to 100°C .
8. Plot a temperature-time graph to analyze heating.

Calculations

Let

M = mass of ice (kg)

C = specific heat capacity of water = $4200 \text{ J kg}^{-1} \text{ K}^{-1}$

$\Delta T = 100^\circ\text{C} = 100 \text{ K}$

T_1 = time to raise temp from 0°C to $100^\circ\text{C} = 4.6 \text{ min}$

T_2 = time for complete melting of ice = 3.7 min

Heat to raise temperature of water:

$$\Delta Q = m \times c \times \Delta T = m \times 4200 \times 100 = m \times 4.2 \times 10^5 \text{ J}$$

Rate of heat absorption:

$$\text{Rate} = \Delta Q / t_1$$

Heat absorbed during melting:

$$\Delta Q_{(\text{fusion})} = \text{Rate} \times t_2 = m \times (4.2 \times 10^5) \times (3.7 / 4.6)$$

Latent heat of fusion (L_f):

$$L_f = \Delta Q_{(\text{fusion})} / m = 3.37 \times 10^5 \text{ J kg}^{-1}$$

This is close to the theoretical value of $3.33 \times 10^5 \text{ J kg}^{-1}$.

11.4.4 EXPERIMENT TO FIND LATENT HEAT OF VAPORISATION OF WATER

Apparatus:

Beaker, water, thermometer, burner, stopwatch.

Procedure:

1. Heat water in a beaker until it reaches 100°C .
2. Continue heating while maintaining temperature at 100°C .
3. Start stopwatch and measure time (t_2) for complete vaporisation.
4. Use previous time ($t_1 = 4.6 \text{ min}$) for heating from 0°C to 100°C .
5. Plot the temperature-time graph.

Calculations

Let:

M = mass of water (kg)

T_2 = time for vaporisation = 24.4 min

$C = 4200 \text{ J kg}^{-1} \text{ K}^{-1}$

$\Delta T = 100 \text{ K}$

Heat to raise temp from 0°C to 100°C :

$$\Delta Q = m \times c \times \Delta T = m \times 4.2 \times 10^5 \text{ J}$$

Rate of heat absorption:

$$\text{Rate} = \Delta Q / t_1$$

Heat absorbed during vaporisation:

$$\Delta Q_{(\text{vap})} = \text{Rate} \times t_2 = m \times (4.2 \times 10^5) \times (24.4 / 4.6)$$

Latent heat of vaporisation (L_v):

$$L_v = \Delta Q_{(\text{vap})} / m = 2.23 \times 10^6 \text{ J kg}^{-1}$$

This is close to the actual value: $L_v = 2.26 \times 10^6 \text{ J kg}^{-1}$

General steps for calculating heat.

1. Heat the substance to its melting point.
2. Measure time for complete melting (t_2).
3. Measure time to raise temperature from 0°C to 100°C (t_1).
4. Measure time for complete vaporisation (t_3).
5. Use: $\Delta Q = m \times c \times \Delta T$
6. Find rate: $\text{Rate} = \Delta Q / t_1$
7. Multiply rate $\times t_2$ or t_3 to get total energy used.
8. Use:

$$L_f = \Delta Q_{(\text{fusion})} / m$$

$$L_v = \Delta Q_{(\text{vap})} / m$$

Important concepts

$$L_f \text{ for ice} = 3.33 \times 10^5 \text{ J kg}^{-1}$$

$$L_v \text{ for water} = 2.26 \times 10^6 \text{ J kg}^{-1}$$

1. Temperature remains constant during phase changes
2. Added heat is used for breaking bonds, not increasing kinetic energy.

SRQs

1. Define latent heat of vaporization.

Ans:

Latent heat of vaporization is the heat required to convert a liquid into gas at its boiling point without any change in temperature.

2. Give an example of latent heat of vaporization.

Ans:

When water boils at 100°C and changes into steam, heat is absorbed but temperature remains constant.

3. Why is latent heat of vaporization greater than fusion?

Ans:

More energy is required to completely separate particles when changing from liquid to gas than from solid to liquid.

4. How does sweating cool the body?

Ans:

Sweat evaporates from the skin and absorbs latent heat from the body. This removal of heat lowers body temperature.

5. Why does boiling water remain at 100°C ?

Ans:

The heat supplied during boiling is used to convert water into steam rather than increasing temperature.

6. What happens during condensation?

Ans:

During condensation, gas changes into liquid and releases latent heat to the surroundings.

7. State uses of latent heat.

Ans:

Latent heat is used in refrigeration, air conditioning, cooling by sweating, and industrial processes involving heating and cooling.

UNIT:11 THERMAL TRANSFORMATIONS

11.5 PRESSURE EXERTED BY GAS PARTICLES

DEFINITION OF PRESSURE

Pressure (P) is the force (F) exerted by gas particles per unit area (A).

$$P = F / A$$

It is caused by collisions of gas particles with the walls of the container.

More frequent or stronger collisions result in higher pressure.

1. Effect of temperature on pressure

(At constant Volume (V) and Number of Particles (n))

When temperature increases

Gas particles gain kinetic energy.

They move faster and collide more frequently and forcefully with container walls.

Pressure increases.

When temperature decreases

Particles move slower with less force.

Collisions decrease in frequency and strength.

Pressure decreases.

Relationship:

$$P \propto T \text{ (at constant } V \text{ and } n).$$

2. Effect of volume on pressure (Boyle's law)

(At constant Temperature (T) and n)

When volume decreases

Particles have less space to move.

Collisions with walls become more frequent.

Pressure increases.

When volume increases

Particles have more space.

Collisions with walls become less frequent.

Pressure decreases.

Relationship:

$$P \propto 1/V \text{ (at constant } T \text{ and } n)$$

$$P_1 \times V_1 = P_2 \times V_2$$

Effect of number of particles on pressure

(At constant T and V)

When the number of particles increases

More particles collide with the container walls.

Pressure increases.

When the number of particles decreases:

Fewer collisions occur.

Pressure decreases.

Relationship:

$$P \propto n \text{ (at constant } T \text{ and } V)$$

Final relationship

$$P \propto T \text{ (if } V \text{ and } n \text{ are constant)}$$

$$P \propto 1/V \text{ (if } T \text{ and } n \text{ are constant)}$$

$$P \propto n \text{ (if } T \text{ and } V \text{ are constant)}$$

SRQs

1. Explain why gas particles exert pressure.

Gas particles are in continuous, random motion. As they move, they collide with the walls of their container. Each collision exerts a small force on the wall. The total pressure is the sum of all these collision forces per unit area. More frequent collisions or stronger collisions produce higher pressure. Factors like temperature, volume, and number of particles affect this motion.

Example: Heating the gas increases particle speed, so they hit the walls harder and more often, increasing pressure. Decreasing the volume increases collisions per area, raising pressure. Adding more particles also raises collision frequency.

2. How does temperature affect gas pressure?

Temperature measures the average kinetic energy of gas particles. As temperature rises, particles move faster, colliding more frequently and forcefully with container walls. This increases pressure. Cooling slows particles, reducing pressure.

Example: A sealed soda can in the sun builds pressure as heating accelerates particle motion, explaining the principle behind pressure cookers.

3. Describe the effect of volume on gas pressure.

Volume is the space a gas occupies. At constant temperature and particle number:

Reducing volume → particles collide more often → pressure increases.

Increasing volume → fewer collisions → pressure decreases.

This relationship is described by Boyle's Law: $P \propto 1/V$.

Example: Pumping air into a bicycle tire reduces air volume slightly, sharply increasing pressure.

4. Explain the effect of the number of gas particles on pressure.

More particles → more collisions per unit area → higher pressure (at constant temperature and volume). Fewer particles → lower pressure.

Example: Adding air to a sealed balloon increases internal pressure. Releasing air reduces pressure.

5. State Boyle's Law with an example.

Boyle's Law: At constant temperature, the pressure of a fixed amount of gas is inversely proportional to its volume: $P \propto 1/V$ or $P \times V = \text{constant}$.

Example: Pushing a syringe plunger decreases volume, increasing pressure; pulling it increases volume, reducing pressure.

6. State Gay-Lussac's Law with an example.

Gay-Lussac's Law: At constant volume, the pressure of a gas is directly proportional to its absolute temperature: $P \propto T$.

Example: A sealed can of paint left in the sun heats up → pressure doubles if temperature doubles (in Kelvin).

7. Why does pressure increase when gas is heated in a rigid container?

In a rigid container, volume is fixed. Heating the gas increases kinetic energy → particles collide more frequently and forcefully → pressure rises.

Example: Soda cans left in sunlight may explode due to increased internal pressure.

8. Why does pressure decrease when gas expands at constant temperature?

Expanding gas increases space for particles. Collisions per unit area decrease → pressure decreases.

Example: A balloon expands → internal pressure drops slightly.

9. How is pressure related to kinetic energy of particles?

Pressure arises from particle collisions with container walls. Higher kinetic energy → faster motion → more frequent and forceful collisions → higher pressure. Lower kinetic energy → lower pressure.

10. Explain why increasing particle number raises pressure.

More particles → more collisions with walls → higher pressure (if volume and temperature are constant).

Example: Adding more air to a sealed container increases pressure; releasing particles lowers pressure.

MCQs

1. Which factor increases the pressure of a gas if the volume and amount of gas are constant?

- A) Decreasing temperature
- B) Increasing temperature
- C) Decreasing number of particles
- D) Increasing volume

✓ Answer: B - Increasing temperature increases kinetic energy, leading to more frequent collisions.

2. If the volume of a gas is halved while temperature is constant, the pressure:

- A) Remains the same
- B) Doubles
- C) Halves
- D) Quadruples

✓ Answer: B - According to Boyle's Law, $P \propto 1/V$.

3. Increasing the number of gas particles in a fixed container at constant temperature:

- A) Decreases pressure
- B) Increases pressure
- C) Has no effect
- D) Decreases temperature

✓ Answer: B - More particles → more collisions → higher pressure.

4. At constant volume and particle number, if temperature doubles:

- A) Pressure doubles
- B) Pressure halves
- C) Pressure remains the same
- D) Pressure quadruples

✓ Answer: A - Pressure \propto Temperature (Gay-Lussac's Law).

5. A gas in a container exerts pressure due to:

- A) Weight of particles
- B) Collisions of particles with container walls
- C) Gravity
- D) Volume of container

✓ Answer: B - Pressure arises from collisions.

6. Which combination will result in the highest gas pressure?

- A) Low temperature, high volume, few particles
- B) High temperature, low volume, many particles
- C) Low temperature, low volume, few particles
- D) High temperature, high volume, few particles

✓ Answer: B - Pressure increases with higher temperature, more particles, and smaller volume.

7. Pressure of a gas decreases when:

- A) Temperature increases
- B) Volume increases
- C) Number of particles increases
- D) Gas is compressed

✓ Answer: B - Larger volume → fewer collisions per unit area.

8. The kinetic theory explains gas pressure by stating that:

- A) Particles are stationary
- B) Particles exert force by collisions
- C) Pressure depends only on mass
- D) Particles attract each other strongly

✓ Answer: B - Moving particles collide with walls, creating pressure.

9. If a container is rigid and gas is heated, the pressure:

- A) Decreases
- B) Remains constant
- C) Increases
- D) Becomes zero

✓ Answer: C - Higher temperature → faster particles → higher pressure.

10. Boyle's Law states that for a fixed amount of gas at constant temperature:

- A) $P \propto V$
- B) $P \times V = \text{constant}$
- C) $P \propto 1/T$
- D) $V \propto T^2$

✓ Answer: B - Pressure and volume are inversely proportional.

11. Charles' Law is concerned with:

- A) Pressure and volume
- B) Volume and temperature
- C) Number of particles and pressure
- D) Mass and volume

✓ Answer: B - Volume \propto Temperature at constant pressure.

12. Increasing gas temperature while keeping volume fixed:

- A) Decreases particle speed
- B) Increases pressure
- C) Decreases pressure
- D) Has no effect

✓ Answer: B - Higher kinetic energy \rightarrow more collisions \rightarrow higher pressure.

13. The factor that does NOT affect gas pressure is:

- A) Temperature
- B) Volume
- C) Number of particles
- D) Shape of container

✓ Answer: D - Only T, V, and n affect pressure.

14. If the number of gas particles doubles at constant volume and temperature, pressure:

- A) Halves
- B) Remains same
- C) Doubles
- D) Quadruples

✓ Answer: C - More particles \rightarrow more collisions.

15. In the kinetic theory of gases, pressure is:

- A) Due to particle weight
- B) Due to collisions of particles
- C) Independent of particle motion
- D) Due to container shape

✓ Answer: B - Pressure arises from collisions with walls.

16. Which gas will exert higher pressure in the same container if all conditions are equal?

- A) Gas with slower particles
- B) Gas with faster particles
- C) Gas with fewer particles
- D) Gas at lower temperature

✓ Answer: B - Faster particles \rightarrow more forceful collisions.

17. If a gas is compressed at constant temperature, collisions with walls:

- A) Increase
- B) Decrease
- C) Remain same
- D) Stop

✓ Answer: A - Smaller volume → more frequent collisions.

18. Pressure is measured in:

- A) Celsius
- B) Pascal
- C) Liter
- D) Newton

✓ Answer: B - SI unit of pressure is Pascal (Pa).

19. Doubling temperature and halving volume at the same time:


- A) Pressure stays same
- B) Pressure doubles
- C) Pressure quadruples
- D) Pressure halves

✓ Answer: C - $P \propto T/V$, so P quadruples.

20. The main reason gases exert pressure is:

- A) Gravity
- B) Continuous random motion of particles
- C) Magnetic force
- D) Liquid surface tension

✓ Answer: B - Random motion causes collisions, creating pressure.



Exercise SRQs MCQs
and Numericals

SRQs

(QNO1) Why do dew drops form on leaves and grass in a spring morning?

(ANSWER)

Dew drops form due to condensation. During the night, surfaces like leaf Cool down. When warm and moist air touches these cool surfaces, the water vapor in the air condenses into liquid droplets, forming dew.

(QNO2) What is the effect of pressure and temperature variation on sublimation and deposition?

(ANSWER)

Sublimation is the change from solid to Liquid when temperature increases and pressure is low-Deposition, is the change from gas to solid, when temperature decreases and pressure is high.

(QNO3) Why do vapors form on the handle and cylinder of a fire extinguisher when it is discharged?

(ANSWER)

A fire extinguisher contains a cold Liquid pressure. When it is released, the Liquid rapidly cools the surrounding air. Water vapor from the warm air, Condenses on the cold surface of the extinguisher handle, forming droplets.

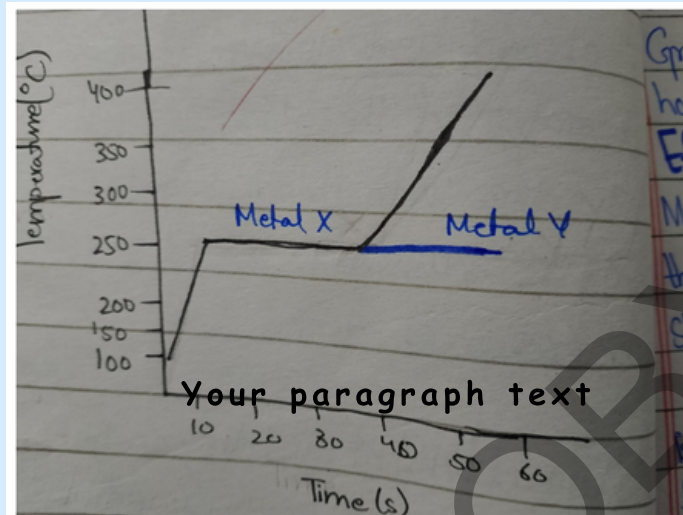
(QNO4) How does sweating helps to cool down our body during exercise?

(ANSWER) Sweating helps to cool our body through .

evaporation. When sweat evaporates from the skin, the high energy particles esc ty particles escape, leaving behind low kinetic energy particles. This loss of heat cools the skin, and helps reduce body temperature.

(QN05) Consider a piece of metal X initially at a temperature of 100°C . It is placed on a heater (which is providing heat at constant rate) until it reaches a final temperature of 400°C . The metal has a melting point of 250°C .

(I) Draw a graph temperature time graph illustrating the changes in the temperature of metal X as it is heated.



(ii). Now, examine a different metal, Y, which has a higher latent heat of fusion compared to metal X. Both metals have identical melting points and heat capacities. The heating procedure for metal Y is conducted under the same energy supply rate as metal X. Describe how the temperature-time graph for metal Y will differ from that of metal X, considering the implications of its greater latent heat of fusion.

(ANSWER)

1) Initial Heating. (100 to 250°C).

1. Both metals heat at the same rate.
2. Graphs will have the upward slope.

2) Melting Point (250°C): Temperature remains constant during melting.

1. Metal "Y" stays at 250°C for longer due to higher latent heat of fusion.
2. Graph for metal y shows a longer horizontal line.

3) Effect For Higher Latent Heat: More energy is needed to complete the phase change.

1. Slows down temperature rise.

CONCLUSION: The key difference Is the longer flat section at metal 250°C . for metal "Y" showing that it absorbs more energy without rise a temperature

(QN06) How does the pressure in a Car tyre change during a long drive On a hot day?

During a long drive on a hot day, tyre pressure increases because higher temperature increases the kinetic energy of particles, making them collide more with the tyre walls. Too much pressure, can cause the tyre to burst.

| Temperature is directly proportional to Kinetic Energy.

(QN07) How does, & understanding thermal expansion help prevent cracks in sidewalks during hot weather?

Understanding thermal expansions helps prevent cracks in side walls. As the side walks heat up, they expand. Without expansion joints, repeated expansion and Contraction can cause cracks. Proper joints allow space for this expansion making sidewalks more durable.

(QN08) Imagine you are stuck in the snow with your car. Which would be more effective for melting the snow trapped underneath, a pot of hot water or a high-powered heat Lamp?

A pot of hot water is more effective for matting the snow, because it provides direct heat and speeds up the melting process, unlike a head lamp which heats slowly and indirectly. The water also covers more area, as it spreads, melting snow effectively.

(QN09) How does evaporation water from plants leaves help to transport water and nutrients of throughout the plant?

Evaporation of water from a plant's leaf, called transpiration, creates a force that pulls water upward from the roots of the stem. This This upward flow helps transport water and nutrients to all parts of the plant.

(QNO:10): Why does adding ice to a drink cool it down more effectively than adding cold water?

Adding ice to a drink cods it more effectively than adding cold water because ice absorbs heat as it melts, Lowering temperature of the drink. Cold water only just mixes with the drink and does not heat as much, so it does not cod the drink as much as ice does.

(QNO: 11) What are the challenges for superconductivity to occur?

Some challenges for superconductivity to Occur include:

- 1.It is requires expensive cooling.
- 2.It uses a very high energy.
- 3.Difficulties in practical use
- 4.Limited materials behave as superconductors
- 5.Complex insulation requirements.

MCQs

1. During a hot summer day, a metal bridge might expand slightly. This expansion is caused by

- A. the bridge rusting and weakening.
- B. the metal atoms in the bridge vibrating more intensely. ✓
- C. the weight of cars driving over the bridge.
- D. a decrease in the air pressure around the bridge.

Explanation:

When temperature increases, atoms in a solid gain kinetic energy and vibrate more. This increases the average distance between atoms, causing thermal expansion.

2. Fog forms on a cold window pane in the morning. Which change of state is occurring?

- A. Melting
- B. Boiling
- C. Condensation ✓
- D. Deposition

Explanation:

Condensation occurs when water vapor (gas) changes into liquid droplets due to cooling. The cold window cools the vapor in air, forming fog droplets.

3. Which process involves the change of state from a gas to a solid without passing through the liquid phase?

- A. Deposition ✓
- B. Melting
- C. Freezing
- D. Sublimation

Explanation:

Deposition is the direct conversion of gas into solid (reverse of sublimation). Example: frost forming from water vapor.

4. Boiling point of water is:

- A. 212°C
- B. 212°F ✓
- C. 100 K
- D. 373°C

Explanation:

Water boils at 100°C , which is equal to 212°F or 373 K. Among the options, only 212°F is correct.

5. $\text{J kg}^{-1} \text{K}^{-1}$ is the unit of:

- A. Specific Heat Capacity ✓
- B. Heat Capacity
- C. Latent Heat of Fusion
- D. Heat Energy

Explanation:

Specific heat capacity is the heat required to raise the temperature of 1 kg of a substance by 1 K (or 1°C).

6. Evaporation takes place from

- A. surface ✓
- B. bottom
- C. center
- D. any location

Explanation:

Evaporation occurs only at the surface of a liquid, where molecules with higher energy escape into the air.

7. Relation between linear and volume expansion of solids is

- A. $\beta = \alpha/3$
- B. $\beta = 1.5 \alpha$
- C. $\alpha = \beta/3$ ✓
- D. $\alpha = 3 \beta$

Explanation:

Actually the standard relation is:

$$\beta = 3\alpha$$

8. Heat added to a substance, at its melting point, is used to:

- A. increase K.E. of particle.
- B. decrease K.E. of particles
- C. increase the attraction between particles
- D. decrease the attraction between particles ✓

Explanation:

At melting point, temperature stays constant. The added heat is used to overcome intermolecular forces, weakening attraction between particles so the solid becomes liquid.

9. 336 J/g is latent heat of fusion of a material. How much heat is required to melt 10 g of material at its melting point?

- A. 336 J
- B. 3360 J ✓
- C. 33600 J
- D. 3.36×10^5 J

Formula:

$$Q = mL$$

Where:

$$m = 10 \text{ g}$$

$$L = 336 \text{ J/g}$$

$$= 3360 \text{ J}$$

10. Which of the following factors increases the rate of evaporation?

- A. Decrease in temperature
- B. Increase in humidity
- C. Increase in wind speed ✓
- D. Decrease in surface area

Explanation:

Wind removes water vapor from the surface quickly, allowing more molecules to escape → faster evaporation.

11. What is value of α for a solid if its β is $9 \times 10^{-7} \text{ K}^{-1}$?

- A. $3 \times 10^{-7} \text{ K}^{-1}$ ✓
- B. $4.5 \times 10^{-7} \text{ K}^{-1}$
- C. $9 \times 10^{-7} \text{ K}^{-1}$
- D. $27 \times 10^{-7} \text{ K}^{-1}$

Formula:

$$\beta = 3\alpha$$

$$\alpha = \beta / 3$$

$$\alpha = (9 \times 10^{-7}) / 3$$

$$\alpha = 3 \times 10^{-7}$$

Answer: A. $3 \times 10^{-7} \text{ K}^{-1}$

12. The process that involves the latent heat of vaporization is

- A. Melting of ice
- B. Freezing of water
- C. Evaporation ✓
- D. Condensation of steam

Explanation:

Latent heat of vaporization is the heat required to change liquid → gas without temperature change.

13. The sum and difference of the coefficient of real and apparent expansion of a liquid are in the ratio 2:1. The ratio of the coefficient of real expansion and apparent expansion must be

A. 1 : 1

B. 2 : 1

C. 2 : 3

D. 3 : 1 ✓

Given:

$$R+A):(R-A)=2:1$$

Solving Gives:

$$R:A=3:1$$

14. Latent heat refers to the energy absorbed or released by a substance during a change of state, but with no change in temperature. What does "latent" mean in this context?

A. Constant

B. Visible

C. Hidden ✓

D. Transparent

Explanation:

"Latent" means hidden, because heat energy is absorbed or released without changing temperature during a change of state.

NUMERICALS

Example 11.2

You are designing a hot air balloon. The balloon's fabric has a volume of 500 cubic meters at 20 °C. You need to know how much the volume will increase when hot air of 80 °C fills the balloon. The fabric material has a coefficient of volumetric expansion of $\beta = 3.5 \times 10^{-5} \text{ K}^{-1}$. Calculate the volume increase of the balloon fabric when filled with hot air.

GIVEN:

- Original volume, $V_0 = 500 \text{ m}^3$
- Coefficient of volume thermal expansion, $\beta = 3.5 \times 10^{-5} \text{ K}^{-1}$
- Change in temperature $\Delta T = 80^\circ\text{C} - 20^\circ\text{C} = 60 \text{ K}$

REQUIRED:

Change in volume ' $\Delta V = ?$ '

SOLUTION:

Increase in volume is calculated by the formula:

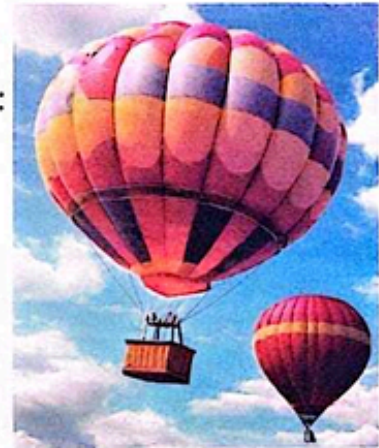
$$\Delta V = \beta V_0 \Delta T$$

putting values

$$\begin{aligned} \Delta V &= (3.5 \times 10^{-5} \text{ K}^{-1})(500 \text{ m}^3)(60 \text{ K}) \\ &= 1.05 \text{ m}^3 \end{aligned}$$

So, the increase in volume of the hot air balloon is 1.05 m³.

ANSWER: $\Delta V = 1.05 \text{ m}^3$



Hot Air Balloon

Example 11.3

A laboratory flask is filled with 250 ml of glycerine at a temperature of 20 °C. Calculate the volume of glycerine at 70 °C. The coefficient of volumetric thermal expansion for glycerine is $500 \times 10^{-6} \text{ K}^{-1}$.

GIVEN:

- Original volume, $V_0 = 250 \text{ ml} = 250 \times 10^{-6} \text{ m}^3$
- Coefficient of real expansion, $\gamma_r = 500 \times 10^{-6} \text{ K}^{-1}$
- Change in temperature $\Delta T = 70 \text{ }^\circ\text{C} - 20 \text{ }^\circ\text{C} = 50 \text{ }^\circ\text{C} = 50 \text{ K}$

REQUIRED:

Change in volume ' $\Delta V = ?$ '

SOLUTION:

Increase in volume of the glycerine is calculated by the formula:

$$\Delta V = \gamma_r V_0 \Delta T$$

putting values:

$$\Delta V = (500 \times 10^{-6} \text{ K}^{-1})(250 \times 10^{-6} \text{ m}^3)(50 \text{ K})$$

$$\Delta V = 6.25 \times 10^{-6} \text{ m}^3 = 6.25 \text{ ml}$$

ANSWER:

$$\Delta V = 6.25 \text{ ml}$$

So, the increase in the volume of glycerine is 6.25 ml when its temperature rises by 50 °C.

ANSWER:

$$\Delta V = 6.25 \text{ ml}$$

Example 11.4

Find the amount of heat required for melting the ice-cream having mass 0.5 kg at -20°C . (Latent heat of fusion for ice-cream $L_f = 3.347 \times 10^5 \text{ J/kg}$, melting point of ice-cream is -10°C and specific heat capacity for ice-cream is $c = 2.1 \times 10^3 \text{ J/kg}^{\circ}\text{C}$).

GIVEN:

- Mass of ice-cream, $m = 0.5 \text{ kg}$
- Initial temperature, $T_0 = -20^{\circ}\text{C}$
- Final temperature (melting point), $T = -10^{\circ}\text{C}$
- Specific heat capacity of ice-cream, $c = 2.1 \times 10^3 \text{ J/kg}^{\circ}\text{C}$
- Latent heat of fusion, $L_f = 3.347 \times 10^5 \text{ J/kg}$

REQUIRED:

Heat for melting ice-cream
 $\Delta Q = ?$

SOLUTION:

Change in temperature is given by: $\Delta T = T - T_0$

$$\Delta T = (-10^{\circ}\text{C}) - (-20^{\circ}\text{C}) = 10^{\circ}\text{C} = 10^{\circ}\text{C}$$

First, we will provide heat to increase the temperature of the ice-cream from -20°C to -10°C (melting point).

$$\begin{aligned}\Delta Q_1 &= mc \Delta T = (0.5)(2.1 \times 10^3)(10) \\ &= \Delta Q_1 = 1.05 \times 10^4 \text{ J}\end{aligned}$$

Now, we find heat required for melting ice-cream at its melting point:

$$\begin{aligned}\Delta Q_2 &= mL_f \quad \Delta Q_2 = (0.5)(3.347 \times 10^5) \\ &= 16.735 \times 10^4 \text{ J}\end{aligned}$$

Total heat required will be: $\Delta Q = \Delta Q_1 + \Delta Q_2 = 16.735 \times 10^4 \text{ J}$

$$\Delta Q = 17.785 \times 10^4 \text{ J} = 177.85 \text{ kJ}$$

ANSWER:

$$\Delta Q = 177.85 \text{ kJ}$$

Q1.

Consider a steel bar of length 1.5 m at 10°C. It is heated to raise its temperature to 100°C.

Calculate (a) increase in length (b) final length at 100°C

(Coefficient of linear thermal expansion of steel,

$$\alpha = 1.2 \times 10^{-5} / \text{K})$$

GIVEN:

- Initial length, $L_0 = 1.5 \text{ m}$
- Initial temperature, $T_0 = 10^\circ\text{C}$
- Final temperature, $T = 100^\circ\text{C}$
- Temperature change, $\Delta T = T - T_0$
 $= 100^\circ\text{C} - 10^\circ\text{C} = 90^\circ\text{C}$
- Coefficient of linear expansion, $\alpha = 1.2 \times 10^{-5} / \text{K}$

REQUIRED:

- (a) Increase in length, $\Delta L = ?$
- (b) Final length, $L = ?$

SOLUTION:

For linear expansion,

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

(a) Increase in length (ΔL):

$$\begin{aligned}\Delta L &= (1.2 \times 10^{-5} / \text{K}) \times (1.5 \text{ m}) \times (90 \text{ K}) \\ &= (1.8 \times 10^{-5}) \times 90 \text{ m} \\ &= 1.62 \times 10^{-3} \text{ m} \\ &= \underline{1.62 \times 10^{-3} \text{ m} \times 100 \text{ cm/m} = 0.162 \text{ cm}}\end{aligned}$$

(b) Final length at 100°C (L):

$$\begin{aligned}L &= L_0 + \Delta L \\ &= 1.5 \text{ m} + 1.62 \times 10^{-3} \text{ m} \\ &= 1.50162 \text{ m} \\ &= \underline{1.50162 \text{ m} \approx 1.502 \text{ m (approx.)}}\end{aligned}$$

ANSWER:

(a) Increase in length, $\Delta L = \underline{1.62 \times 10^{-3} \text{ m} = 0.162 \text{ cm}}$

(b) Final length at 100°C, $L = \underline{1.50162 \text{ m} \approx 1.502 \text{ m}}$

Q2.

A solid cube of side length 10 cm at 25°C is heated. What will be increase in its volume at 125°C if its coefficient of linear thermal expansion is $9 \times 10^{-6}/\text{K}$

(Coefficient of linear thermal expansion of solid, $\alpha = 9 \times 10^{-6}/\text{K}$)

GIVEN:

- Initial side length, $L_0 = 10 \text{ cm}$
- Initial temperature, $T_0 = 25^\circ\text{C}$
- Final temperature, $T = 125^\circ\text{C}$
- Coefficient of linear expansion, $\alpha = 9 \times 10^{-6}/\text{K}$
- Temperature change, $\Delta T = T - T_0 = 125^\circ\text{C} - 25^\circ\text{C} = 100^\circ\text{C}$

REQUIRED:

- Increase in volume, $\Delta V = ?$

SOLUTION:

For linear expansion,

$$\Delta V = 3\alpha V_0 \Delta T$$

(a) Increase in volume (ΔV):

$$V_0 = L_0^3$$

$$V_0 = (10 \text{ cm})^3 = 1000 \text{ cm}^3$$

$$\Delta V = 3\alpha V_0 \Delta T$$

$$\Delta V = 3 \times (9 \times 10^{-6}/\text{K}) \times 1000 \text{ cm}^3 \times 100 \text{ K}$$

$$= 3 \times 9 \times 10^{-6} \times 1000 \times 100$$

$$= 27 \times 10^{-3}$$

$$= 2.7 \text{ cm}^3$$

ANSWER:

- Increase in volume, $\Delta V = 2.7 \text{ cm}^3$

Q3.

A steel railroad track segment is 10 meters long at a cool morning temperature of 15°C . The coefficient of linear expansion for steel is 1.2×10^{-5} per $^\circ\text{C}$. Later in the day, the temperature rises to 30°C . How much will the steel track segment expand in length.

(Coefficient of linear thermal expansion of steel, $\alpha = 1.2 \times 10^{-5}/^\circ\text{C}$)

GIVEN:

- Initial length, $L_0 = 10 \text{ m}$
- Initial temperature, $T_0 = 15^\circ\text{C}$
- Final temperature, $T = 30^\circ\text{C}$
- Coefficient of linear expansion, $\alpha = 1.2 \times 10^{-5}/^\circ\text{C}$
- Temperature change, $\Delta T = T - T_0 = 30^\circ\text{C} - 15^\circ\text{C} = 15^\circ\text{C}$

REQUIRED:

- Increase in length, $\Delta L = ?$

SOLUTION:

For linear expansion,

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

(a) Increase in length (ΔL):

$$\begin{aligned}\Delta L &= (1.2 \times 10^{-5}/^\circ\text{C}) \times (10\text{m}) \times (15^\circ\text{C}) \\ &= (1.8 \times 10^{-4}) \text{ m} \\ &= 1.8 \times 10^{-3} \text{ m} \\ &= \underline{0.0018 \text{ m} = 1.8 \text{ mm}}\end{aligned}$$

ANSWER:

- Increase in length, $\Delta L = 0.0018 \text{ m} = 1.8 \text{ mm}$

Q4.

A 2 liter (2000 cm^3) glass bottle is filled completely with orange juice at room temperature of 20°C . The coefficient of volumetric thermal expansion of orange juice is 5×10^{-5} per $^\circ\text{C}$. If the bottle is left in a hot car where the temperature reaches 40°C . What volume of orange juices will overflow? (Expansion of glass bottle is negligible.)

(Coefficient of linear thermal expansion of steel, $\alpha = 12 \times 10^{-5}/^\circ\text{C}$)

GIVEN:

- Initial volume, $V_0 = 2000 \text{ cm}^3$
- Initial temperature, $T_0 = 20^\circ\text{C}$
- Final temperature, $T = 40^\circ\text{C}$
- Coefficient of volumetric expansion, $\beta = 5 \times 10^{-5}/^\circ\text{C}$
- Temperature change, $\Delta T = T - T_0 = 40^\circ\text{C} - 20^\circ\text{C} = 20^\circ\text{C}$

REQUIRED:

- Volume of orange juice overflow, $\Delta V = ?$

SOLUTION:

For volumetric expansion,

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

(a) Increase in volume (ΔV):

$$\begin{aligned}\Delta V &= (5 \times 10^{-5}/^\circ\text{C}) \times (2000 \text{ cm}^3) \times (20^\circ\text{C}) \\ &= (5 \times 10^{-5}) \times 2000 \times 20 \\ &= 5 \times 10 \times 20 \times 10^{-5} \times 10^2 \\ &= 2 \text{ cm}^3\end{aligned}$$

ANSWER:

- Volume of orange juice overflow, $\Delta V = 2 \text{ cm}^3$

Q5.

How much heat is required to change 15 kg of ice at its melting point?

GIVEN:

- Mass of ice, $m = 15 \text{ kg}$
- Latent heat of fusion of ice, $L_f = 3.3 \times 10^5 \text{ J/kg}$

REQUIRED:

- Heat required, $Q = ?$

SOLUTION:

For heat required

$$\begin{aligned} Q &= m \times L_f \\ &= 15 \text{ kg} \times 3.3 \times 10^5 \text{ J/kg} \\ &= 4.95 \times 10^6 \text{ J} \end{aligned}$$

Q6.

How much heat is required to change 7 Kg of water into steam at its boiling point?

GIVEN:

- Mass of water, $m = 7 \text{ kg}$
- Latent heat of vaporization of water,
 $L_v = 2.25 \times 10^6 \text{ J/kg}$

REQUIRED:

- Heat required, $Q = ?$

SOLUTION:

For heat required

$$\begin{aligned} Q &= m \times L_v \\ &= (7 \text{ kg}) \times (2.25 \times 10^6 \text{ J/kg}) \\ &= 1.575 \times 10^7 \text{ J} \end{aligned}$$

Q7.

4 kg of ice has temperature of -20°C . It is heated to convert to steam. Its final temperature is 120°C . Calculate the total amount of heat energy involved for this conversion of ice into steam.

- Specific heat of ice = $2100\text{ J/kg}^{\circ}\text{C}$
- Specific heat of water = $4200\text{ J/kg}^{\circ}\text{C}$
- Specific heat of steam = $2000\text{ J/kg}^{\circ}\text{C}$
- Latent heat of fusion = $3.3 \times 10^5\text{ J/kg}$

GIVEN:

- Mass of ice, $m = 4\text{ kg}$
- Initial temperature, $T_i = -20^{\circ}\text{C}$
- Final temperature, $T_f = 120^{\circ}\text{C}$

REQUIRED:

- Heat required, $Q = ?$

SOLUTION:

(a) Heating ice from -20°C to 0°C

$$\begin{aligned}Q_1 &= m \times c_{\text{ice}} \times \Delta T_1 \\&= 4\text{ kg} \times 2100\text{ J/kg}^{\circ}\text{C} \times (0^{\circ}\text{C} - (-20^{\circ}\text{C})) \\&= 168,000\text{ J}\end{aligned}$$

(b) Melting ice at 0°C

$$\begin{aligned}Q_2 &= m \times L_f \\&= 4\text{ kg} \times 3.3 \times 10^5\text{ J/kg} \\&= 1.32 \times 10^6\text{ J}\end{aligned}$$

(c) Heating water from 0°C to 100°C

$$\begin{aligned}Q_3 &= m \times c_{\text{water}} \times \Delta T_2 \\&= 4\text{ kg} \times 4200\text{ J/kg}^{\circ}\text{C} \times (100^{\circ}\text{C} - 0^{\circ}\text{C}) \\&= 1.68 \times 10^6\text{ J}\end{aligned}$$

(d) Converting water at 100°C to steam

$$\begin{aligned}Q_4 &= m \times L_v \\&= 4\text{ kg} \times 2.26 \times 10^6\text{ J/kg} \\&= 9.04 \times 10^6\text{ J}\end{aligned}$$

(e) Heating steam from 100°C to 120°C

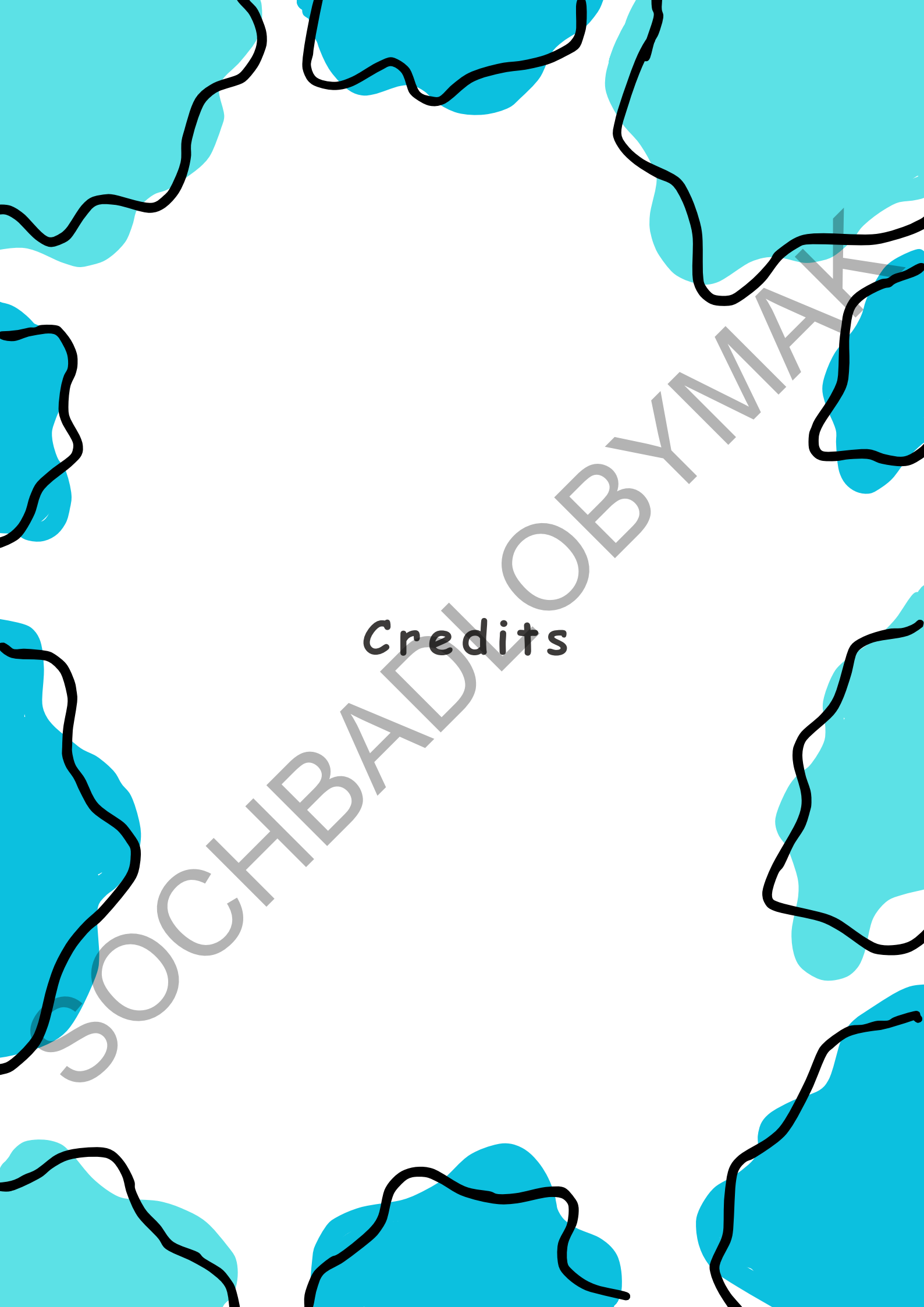
$$\begin{aligned}Q_5 &= m \times c_{\text{steam}} \times \Delta T_3 \\&= 4\text{ kg} \times 2000\text{ J/kg}^{\circ}\text{C} \times (120^{\circ}\text{C} - 100^{\circ}\text{C}) \\&= 160,000\text{ J}\end{aligned}$$

ANSWER:

- Total heat energy involved, $Q_{\text{total}} = 1.236 \times 10^7\text{ J}$

$$\begin{aligned}&= 168,000\text{ J} + 1.32 \times 10^6\text{ J} + 1.68 \times 10^6\text{ J} + 9.04 \times 10^6\text{ J} + 160,000\text{ J} = 12,360,000 = 1.236 \times 10^7\text{ J} \\&= 12,360 \times 10^3\text{ J}\end{aligned}$$

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