Thermal Properties of Matter

Introduction

The **thermal properties of matter** describe how substances behave when their temperature changes or when heat is transferred to or from them. Important concepts in this chapter include **temperature, heat, thermal expansion, specific heat capacity, calorimetry, change of state, heat transfer, and Newton's law of cooling**.

Temperature and Heat

Temperature

Temperature is a measure of the degree of hotness or coldness of a body. It determines the direction of heat flow between two bodies.

SI Unit: **Kelvin (K)**

Common temperature scales are:

- Celsius (°C)
- Fahrenheit (°F)
- Kelvin (K)

Relation:

K = °C + 273.15

Heat

Heat is the energy transferred between two bodies due to a difference in temperature. Heat always flows naturally from a body at higher temperature to a body at lower temperature.

SI Unit: **Joule (J)**

Thermal Expansion

Definition

When a substance is heated, its dimensions generally increase. This phenomenon is called **thermal expansion**.

Thermal expansion can be:

- Linear Expansion
- Area Expansion

- Volume Expansion

Linear Expansion

The increase in length of a solid due to heating is called linear expansion.

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

where **α** is the coefficient of linear expansion.

Area Expansion

$$\Delta A = \beta A_0 \Delta T$$

Volume Expansion

$$\Delta V = \gamma V_0 \Delta T$$

For isotropic solids:

$$\beta \approx 2\alpha$$

$$\gamma \approx 3\alpha$$

Applications of Thermal Expansion

Examples

Thermal expansion is considered in many practical situations:

- Gaps are left between railway tracks.
- Expansion joints are provided in bridges.
- Electric wires are kept slightly loose.
- Liquid thermometers work on thermal expansion.
- Bimetallic strips are used in thermostats.

Anomalous Expansion of Water

Special Property

Water behaves differently from most substances between **0°C and 4°C**.

When water is heated from **0°C to 4°C**, it contracts instead of expanding. Its density becomes maximum at **4°C**.

When water is cooled from **4°C to 0°C**, it expands.

This property is called the **anomalous expansion of water**.

Importance

This phenomenon allows aquatic life to survive in cold regions. The surface water freezes, while water below remains liquid.

Heat Capacity

Definition

The **heat capacity** of a body is the amount of heat required to raise its temperature by 1°C or 1 K.

Formula:

$C = Q/\Delta T$

SI Unit: **J/K**

Specific Heat Capacity

Definition

Specific heat capacity is the amount of heat required to raise the temperature of unit mass of a substance by 1°C or 1 K.

Formula:

$Q = mc\Delta T$

where:

- **Q** = Heat supplied
- **m** = Mass
- **c** = Specific heat capacity
- **ΔT** = Change in temperature

SI Unit: **$J\ kg^{-1}\ K^{-1}$**

Water has a high specific heat capacity, which makes it useful as a coolant.

Calorimetry

Principle

Calorimetry deals with the measurement of heat exchanged between bodies.

The principle of calorimetry is based on the **law of conservation of energy**.

In an isolated system:

Heat lost = Heat gained

This principle is used to calculate unknown temperatures, specific heats, and heat exchanged.

Change of State

Definition

Matter can change from one state to another due to changes in temperature or pressure.

The three common states are:

- Solid
- Liquid
- Gas

Changes of state include:

- Melting: Solid → Liquid
- Freezing: Liquid → Solid
- Vaporisation: Liquid → Gas
- Condensation: Gas → Liquid
- Sublimation: Solid → Gas

Latent Heat

Definition

The heat required to change the state of a substance without changing its temperature is called **latent heat**.

Formula:

Q = mL

where:

- **Q** = Heat supplied
- **m** = Mass
- **L** = Specific latent heat

During a change of state, the supplied heat is used to change the arrangement of particles rather than increasing their temperature.

Heat Transfer

Modes of Heat Transfer

Heat can be transferred in three ways:

1. **Conduction**
2. **Convection**
3. **Radiation**

Conduction

Heat transfer through a substance without the actual movement of its particles is called **conduction**.

It is most effective in solids.

Metals are generally good conductors, while materials such as wood, plastic, and wool are poor conductors.

Convection

Heat transfer through the actual movement of particles in a fluid is called **convection**.

It occurs in liquids and gases.

Examples include sea breeze and land breeze.

Radiation

Heat transfer through electromagnetic waves without requiring a medium is called **radiation**.

Radiation can occur through vacuum.

Example: Heat received from the Sun.

Newton's Law of Cooling

Statement

Newton's Law of Cooling states that the **rate of loss of heat of a body is approximately proportional to the temperature difference between the body and its surroundings**, when the temperature difference is small.

The law is applicable when the temperature difference is not very large and the conditions remain constant.

Applications of Thermal Properties

Importance

Thermal properties are important in:

- Designing buildings and bridges
- Refrigeration and cooling systems
- Thermometers
- Cooking
- Industrial processes
- Weather and climate studies
- Heat engines and machines

Key Points

- Temperature indicates the degree of hotness or coldness.
- Heat is energy transferred due to a temperature difference.
- Heating generally causes thermal expansion.
- Water has maximum density at **4°C**.
- Heat capacity is **C = Q/ΔT**.
- Heat supplied is **Q = mcΔT**.
- Calorimetry follows conservation of energy.
- Latent heat changes the state without changing temperature.
- Heat transfer occurs by conduction, convection, and radiation.
- Newton's Law of Cooling relates the rate of cooling to temperature difference.

Chapter Summary

This chapter explains how matter responds to changes in temperature and heat. It covers temperature, heat, thermal expansion, anomalous expansion of water, heat capacity, specific heat capacity, calorimetry, change of state, latent heat, methods of heat transfer, and Newton's Law of Cooling. These concepts are important for understanding heating and cooling processes in nature, daily life, and technology.