

10 THERMAL PROPERTIES OF MATTER

1 VSAQ + 2 SAQ [2M + 4M + 4M = 10M]

CONCEPTS & DEFINITIONS

1. Heat is a form of energy that flows between a body and the surrounding medium by virtue of temperature difference between them. The degree of hotness/coldness of a body is quantitatively represented by temperature.

2. **Relation between Fahrenheit and Celsius scales :**

$$\frac{F - 32}{180} = \frac{C}{100} \text{ where } F = \text{Fahrenheit temperature, } C = \text{Celsius temperature.}$$

Note: $C = \frac{5}{9}(F - 32)$ and $F = \frac{9}{5}(C + 32)$

3. **Ideal gas equation:** $PV = nRT$

4.1. **Thermal Expansion:** Most of the substances expand on heating and contract on cooling. A change in the temperature of a body causes change in its dimensions. The increase in the dimensions of a body due to the increase in its temperature is called thermal expansion.

The expansion in length is called linear expansion.

The expansion in area is called areal expansion.

The expansion in volume is called volume expansion.

4.2. **Coefficient of Linear expansion of a Solid (α):**

If the substance is in the form of a long rod, then for small change in temperature ΔT , the fractional change in length, $\Delta l / l$, is directly proportional to ΔT .

$$\text{Thus } \frac{\Delta l}{l} \propto \Delta T \Rightarrow \frac{\Delta l}{l} = \alpha \Delta T \Rightarrow \alpha = \left(\frac{\Delta l}{l} \right) \frac{1}{\Delta T}$$

Here, α is called the coefficient of linear expansion.

4.3. **Coefficient of Volume expansion (γ):**

Coefficient of Volume expansion is given by $\gamma = \left(\frac{\Delta V}{V} \right) \frac{1}{\Delta T}$

Note: Relation between the coefficients of Linear and Volume expansion of a solid is $\gamma = 3\alpha$

5. **Heat Capacity:** The amount of heat required to raise the temperature of a substance through 1°C

$$\text{Heat capacity} = \frac{dQ}{dT} \quad \text{S.I unit : } \text{JK}^{-1}$$

6.1. **Specific heat :** The amount of heat required to raise the temperature of unit mass of a substance through 1°C or 1K

$$\text{Specific heat (S)} = \frac{1}{m} \frac{dQ}{dT}$$

6.2. **C.G.S Unit :** $\text{Cal gm}^{-1}(\text{}^\circ\text{C})^{-1}$ SI Unit: $\text{J kg}^{-1} \text{K}^{-1}$

$$\text{Dimensional Formula: } [M^0 L^2 T^{-2} K^{-1}]$$

6.3 Molar specific heat : The amount of heat required to raise the temperature of 1 mole of a gas through 1°C or 1K .

$$\text{Molar specific heat } C = \frac{1}{n} \frac{dQ}{dT} \quad \text{Here } n \text{ is the number of moles of the gas}$$

6.4 Specific heats of a Gas : A gas can be heated either at constant pressure or at constant volume. Hence two types of specific heats are possible.

(i) specific heat of a gas at constant pressure (C_p)

(ii) specific heat of a gas at constant volume (C_v)

6.5.1 Specific heat at constant pressure (C_p) : At constant pressure, the quantity of heat necessary to increase the temperature of 1 mole of a gas through one degree, is called specific heat of the gas at constant pressure.

$$C_p = \frac{1}{n} \frac{dQ}{dT} \quad \text{S.I unit is J/mole K}$$

6.5.2 Specific heat at constant volume (C_v) : At constant volume, the quantity of heat necessary to increase the temperature of 1 mole of a gas through one degree, is called specific heat of gas at constant volume.

$$C_v = \frac{1}{n} \frac{dQ}{dT} \quad \text{S.I unit is J/mole K.}$$

6.5.3 Relation between C_p and C_v : $C_p - C_v = R$, R is the universal gas constant.

7. Calorimeter: A device in which heat measurement can be made is called a calorimeter.

Principle of method of mixtures: When a body at higher temperature is brought in contact with another body at lower temperature, the heat lost by the hot body is equal to the heat gained by the colder body, provided no heat is allowed to escape to the surroundings.

8. Change of state:

Vaporisation: The change of state from liquid to vapour is called vaporisation.

Sublimation: The change from solid state to vapour state without passing through the liquid state is called sublimation.

Regelation: The phenomenon of refreezing is called regelation.

Triple point : The point at which the three phases of matter co-exist in equilibrium is called Triple point.

Triple point of Water : For water coordinates of triple point are (0.01°C , 0.006 atm or 273.16K , 4.58 mm of Hg)

Triple point of CO_2 : For CO_2 coordinates of triple point are (-56.6°C , 5.11 atm)

9.1 Latent heat : The amount of heat absorbed or rejected per unit mass of substance during phase change is called Latent heat.

$$\text{Formula : } L = \frac{Q}{m}$$

Units of L : CGS unit : Cal/gm SI unit : J/kg

9.2 Latent heat of Fusion of ice (L_{ice}) : It is the amount of heat absorbed by unit mass of ice to change its phase from ice at 0°C to water at 0°C

$$L_{\text{ice}} = 80 \text{ Cal/gm} = 3.35 \times 10^5 \text{ J/kg.}$$

9.3 Latent heat of Vapourisation (L_{steam}) : It is the amount of heat absorbed by unit mass of water to change its phase from water at 100°C to steam at 100°C .

$$L_{\text{steam}} = 540 \text{ Cal/gm} = 2.26 \times 10^6 \text{ J/kg.}$$

10. HEAT TRANSFER:

10.1 Heat Convection : The transmission of heat from one part to another, by the actual transfer of particles of matter is known as convection.

Types of convection : Convection is of two types 1. Free convection 2. Forced convection

1. Free convection (or) Natural convection: If a fluid when heated, flows due to difference in density, then it is called 'natural convection'.

Ex : Heating Water in a Beaker gets heated due to natural convection.

2. Forced convection : Transfer of heat due to forced movement of the fluid by mechanical means, such as a fan or pump is known as forced convection.

Ex: When Windows of a room are opened then Cool air enters the room and Hot air is pushed out through Ventilators.

10.2 Thermal Radiation: The process of heat transmission from a hot body to a cold body, without the help of any material medium is called Radiation.

10.3 Black body: A body which completely absorbs the radiation of all wavelengths falling on it, is called a black body. Carbon black and Platinum black approximately behave like a Black body. Absorptive power of a Black body is 1.

10.4. Wien's displacement Law: The wavelength λ_m for which energy is maximum decreases with increasing temperature. Thus $\lambda_m T = \text{constant}$.

The value of the Wien's constant is $2.9 \times 10^{-3} \text{ m-K}$

11. Stefan- Boltzmann's Law: Emissive Power of a body is proportional to the fourth power of the absolute temperature.

Mathematically, $H = Ae\sigma T^4$. Here, σ is Stefan-Boltzmann constant. $\sigma = 5.67 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}$

12. Green House Effect: Heating up of earth's surface and atmosphere is known as Green house effect.

13. Newtons Law of cooling : The rate of loss of Heat is directly proportional to the difference in average temperature of the hot body and its surroundings.

If $-\frac{dQ}{dt}$ is the rate of loss of heat by the hot body, then $-\frac{dQ}{dt} \propto (T_{\text{avg}} - T_s)$ or $-\frac{dQ}{dt} = k(T_{\text{avg}} - T_s)$

Here, k is the proportionality constant .

The value of k depends on the nature, shape and area of the cooling surface and T_{avg} is average temperature of hot body and T_s is surrounding temperature.

Imp. Formulae

$$1. \quad \frac{C}{100} = \frac{F - 32}{180} = \frac{K - 273}{100}$$

$$2. \quad T = C + 273$$

$$3. \quad \alpha = \frac{\Delta l}{l(\Delta T)}, \beta = \frac{\Delta A}{A(\Delta T)}, \gamma = \frac{\Delta V}{V(\Delta T)}$$

$$4. \quad \alpha : \beta : \gamma = 1:2:3$$

$$5. \quad H = \sigma AT^4$$

$$6. \quad H = \sigma A(T^4 - T_0^4)$$

$$7. \quad \lambda_m T = \text{constant.}$$

8. Ideal gas equation: $PV = nRT$,

$$(i) \quad \frac{PV}{T} = \text{const. (or)} \quad \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$(ii) \quad \frac{P}{dT} = \text{const. (or)} \quad \frac{P_1}{d_1 T_1} = \frac{P_2}{d_2 T_2}$$

$$(iii) \quad \frac{P}{mT} = \text{const. (or)} \quad \frac{P_1}{m_1 T_1} = \frac{P_2}{m_2 T_2}$$