Chapter:- 7 :- Heat and Thermodynamics:-

Latent Heat:- (Q_L):- Latent heat of a substance is defined as the amount of heat energy required to change the state of unit mass of the substance (from solid to liquid or liquid to gas) without changing its temp.)

Whenever heat is supplied to a solid its temperature rises. A stage comes when solid is liquid; process of conversion of solid into liquid is called fusion.

Temp. of the substance remains const. till whole of the solid gets converted into liquid because the heat supplied during fusion is not utilized to increase the temp. Therefore it is hidden latent in the substance. This amount of heat is called latent heat.

The magnitude of latent heat depends upon the mass of the substance.

Latent heat :- $Q_L = ML$

L = Specific latent heat.

unit of Latent heat = $\frac{J}{Kg}$

Dimension :- $[M^0 L^2 T^{-2}]$

Specific Latent Heat :-

* S.L.H Fusion of a substance is defined as the amount of heat required to ~~convert~~ convert 1 gm of substance from solid to liquid state at the melting point without any change in temp.

Specific Latent Heat of Vapourisation:-

* S.L.H of vapourisation of a substance is defined as the amount of heat required to convert 1 gm of liquid into its vapour at its boiling point without any change of temp.

Q.1. Calculate the latent heat of fusion for 10 gm of ice given that specific latent heat of fusion of ice is 80 calories. gm^{-1}.

Thermal Expansion:-

* In general when an object is heated whether it be a solid, liquid, gas it expands. It is known as thermal expansion. When a substance is heated, the kinetic energy of its molecules begin vibrating more and usually maintain a greater average separation. Hence the rise in temp. of a substance is accompanied by thermal expansion.

Application Of Thermal Expansion:-

(i) In laying down the rail track a gap in betn two consecutive pieces of rails. In summer the rails expand. If this gap is not their, the rails may bend thereby causing derailm-

-ent of trains.

(ii) Concrete floors are led in the form of small sections with joints in betn. This is also to counter balance large expansion in case of single piece

(iii) The telephone wires get slackened in summers and become tight in winters. This is due to their change of length with change in atmospheric temp.

Expansion of Solid:-

- When a solid substance is heated it expands in all dimensions i.e., along its length, breadth and thickness simultaneously
- Therefore solid undergo three types expansion's:-

(i) Linear expansion (Longitudinal Expansion).
(ii) Superficial Expansion (Areal Expansion).
(iii) Cubical Expansion (Volumetric Expansion).

(i) **Linear Expansion:-** Whenever there is an increase in the length of the body due to heating then the expansion is called linear or longitudinal expansion.

(ii) **Superficial Expansion:-**
Whenever there is an increase in the area of the solid body due to heating then the expansion is called superficial or Areal Expansion.

(iii) **Cubical Expansion:-** Whenever there is an increase in the volume of the body due to heating then the expansion is called cubical or volumetric expansion.

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(ii) Co-efficient of Superficial Expansion (β).-

* Co-efficient of Superficial Expansion of a substance is defined as the change in area of the surface per unit area at 0°c per degree Centigrade rise of temp.

$$\beta = \frac{S_T - S_0}{S_0 \times T} \quad \text{(v)}$$

Where, S_0 = It is the area at 0°c.
S_T = It is the area at T°c.

(iii) Co-efficient of Cubical Expansion (γ):-

* Co-efficient of cubical expansion is defined as the change in volume per unit volume at 0°c per °c rise of temp.

$$\gamma = \frac{V_T - V_0}{V_0 \times T}$$

Where, V_0 = It is the volume of the substance at 0°c.
V_T = It is the volume of the substance at T°c.

Unit of γ - K^{-1} or $°C^{-1}$.

Relation Betn α, β and γ:-

(i) Relation Betn α and β:-
Consider a square sheet having each side 'l_0' at 0°c. Thus, area 'S_0' at 0°c is,

$$S_0 = l_0^2$$

Suppose on heating the sheet to T°c each side expands to l_T.
Hence, area of the sheet at T°c is,

$S_T = l_T^2 = l_0^2(1+\alpha T)^2$ —— (vii) (From eq^n - (iv))

$\left[\because \alpha = \frac{l_T - l_0}{l_0 \times T}\right.$

$\Rightarrow l_T - l_0 = \alpha l_0 T$

$\Rightarrow l_T = \alpha l_0 T + l_0$

$= l_0(1+\alpha T)\Big]$

We know that, $\beta = \frac{S_T - S_0}{S_0 \times T}$

$= \frac{l_T^2 - l_0^2}{l_0^2 \times T}$

$= \frac{l_0^2(1+\alpha T)^2 - l_0^2}{l_0^2 \times T}$

$= \frac{l_0^2[(1+\alpha T)^2 - 1]}{l_0^2 \times T}$

$= \frac{[1 + (\alpha T)^2 + 2\alpha T - 1]}{T}$

$= \frac{\alpha^2 T^2 + 2\alpha T}{T}$

$= \frac{T(\alpha^2 T + 2\alpha)}{T}$

$= \alpha^2 T + 2\alpha$

Since 'α' is very small, the term $\alpha^2 T$ can be ~~neglect~~ neglected being small. Hence

$\beta = 2\alpha$ —— (viii)

(ii) Relation Bet^n α and γ:-

Let V_0 and V_T be the volume of a cube at 0°C and T°C respectively. If l_0 and l_T are the sides of the cube ~~at~~ 0°C and T°C then,

$V_0 = l_0^3$

$V_T = l_T^3 = l_0^3(1+\alpha T)^3$ —— (ix)

(From eq^n (iv))

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we know that, $\gamma = \frac{V_T - V_0}{V_0 \times T}$

$= \frac{l_T^3 - l_0^3}{l_0^3 \times T}$

$= \frac{l_0^3 (1+\alpha T)^3 - l_0^3}{l_0^3 \times T}$

$= \frac{l_0^3 [(1+\alpha T)^3 - 1]}{l_0^3 \times T}$

$= \frac{[1 + (\alpha T)^3 + 3(\alpha T)^2 + 3\alpha T - 1]}{T}$

$= \frac{\alpha^3 T^3 + 3\alpha^2 T^2 + 3\alpha T}{T}$

$= \frac{T(\alpha^3 T^2 + 3\alpha^2 T + 3\alpha)}{T}$

$= \alpha^3 T^2 + 3\alpha^2 T + 3\alpha$

∴ Since α is very small neglating terms involving higher power 'α', we have,

$\gamma = 3\alpha$ —— (x)

(iii) Relation Betn β and γ:-

$\gamma = 3\alpha$

$\beta = 2\alpha$

$\alpha = \frac{\gamma}{3}$

$\alpha = \frac{\beta}{2}$

$\Rightarrow \frac{\gamma}{3} = \frac{\beta}{2}$

$\Rightarrow 2\gamma = 3\beta$

$\Rightarrow \gamma = \frac{3}{2}\beta$

Work and Heat:-

Since both heat and work are considered as the form of mechanical energy, thus, heat and work are inter convertible.

According to Dr. Joule; "Whenever heat is converted into work or work into heat, the quantity of energy disappearing in one form is equivalent to the quantity of energy appearing in the other."

If an amount of work 'W' results in the production of an amount of heat 'H'; then 'W' is directly proportional to 'H'.

$\Rightarrow W \propto H$

$\Rightarrow W = JH$ ——————→ (xi)

Where; 'J' is a constant called "Joule's mechanical equivalent of heat."

Defination of 'J':-

If $H = 1$, then,

$J = W$.

Joule's Mechanical equivalent of heat (J) is defined as the amount of work required to produce a unit quantity of heat.

$$J = \frac{W}{H}$$

Value of $J = 4.2 \times 10^7 \, erg\, cal^{-1}$

$= 4.2 \, J\, cal^{-1}$

unit of $J = \frac{J}{cal}$ or $\frac{erg}{cal}$

First Law Of Thermodynamics:-

"If the quantity of heat supplied to a system is capable of doing work, then the quantity of heat absorbed by the system is equal to the sum of the increase in internal energy of the system and the external work done by it."

$$dQ = du + dW \text{ —— (xiii)}$$

Where, dQ = The heat added to the system.
du = Change in internal energy of the system.
dW = External work done.

Heat:- Heat is the agent which produces in us the sensation of warmth and makes bodies hot.

* It is a form of energy.
* Heat flows from higher to lower temperature.
* In any exchange of heat, heat lost by the hot body is equal to the heat gained by the felt body.
* Substances generally expand when heated.

Temperature:- Temperature is defined as the degree of hotness of a body. It is a scalar quantity.

* When two bodies at different temperatures are brought in thermal contact, the flow of heat energy will continue until the temp. of the two bodies become equal.

The state of the ~~quantity~~ equality in the temp. of two bodies is known as thermal equilibrium.

Units of Heat:-

S.I unit :- Joule (J)

C.G.S unit :- erg ; $1J = 10^7$ erg.

Calorie is another unit of heat.

1 calorie = 4.18 Joule —— (i)

Specific Heat:-

Specific heat capacity of a material is defined as the amount of heat required to raise the temp. of a unit mass of material through 1° centigrade (1°C).

Specific Heat (C):-

$$C = \frac{Q}{M \Delta T} \quad \text{—— (ii)}$$

Where 'C' is the specific heat,

Q is the heat.

M is the mass of the substance.

ΔT is the change in temperature.

S.I unit of C = $\frac{J}{kg \times K}$ (K = kelvin)

or

$\frac{J}{kg \cdot °C}$

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

Q. A body with mass 2 kg observes heat 100 calories when its temp. rises from 20°C to 70°C. What is the specific heat of the body.

Ans:- Given that,

Mass of substance (M) = 2 kg

Temperature (T) = 70°c − 20°c = 50°c
Heat (Q) = 100 calorie.
1 calories = 4·18 Joule
100 calorie = 100 × 4·18 Joule.
= 418 Joule

∴ Specific heat of the body (C) = $\frac{Q}{m \Delta T}$

$= \frac{418}{2 \times 50} = \frac{J}{Kg \cdot °C}$

$= 4 \cdot 18 \; J/Kg \cdot °C$

Change Of State:-

* We know that the three states of matter can be converted into one another.
* Conversion of Solid state into liquid state is called 'fusion'. Conversion of liquid into gaseous state is called vapourisation.
* While conversion of solid directly into gaseous state is called 'Sublimation'.
* The conversion from one state to another can be conveniently studied by the help of a pressure temp. diagram called 'phase diagram'.

Triple point (P):-

* Triple point is a point on the phase diagram giving values of pressure and temp. at which the three states of a given substance co-exist in equilibrium.