

## Quantity of Heat :

### - Specific heat capacity :-

we know that, when the different substance are taken having same mass & they are heated to same range of temperature, then they absorb different quantity of heat so, different substance have different capacity to acquire heat bet the substance having mass  $m$  is heated through the range of temperature  $\Delta\theta$  (i.e.  $\theta_2 - \theta_1$ )

It is found that,

The heat required to raise such temp is,

i directly proportional to mass (i.e)  $Q \propto m \dots \text{①}$

ii. directly proportional to change in temp (i.e)  $Q \propto \Delta\theta$

Combining eq ① & ②

$$Q \propto m \Delta\theta$$

$Q = ms\Delta\theta$  : where  $s$  is proportionality constant

& it is known as specific heat capacity of the substance.

$$\therefore s = \frac{Q}{m \Delta\theta}$$

If  $m$  = unit of mass,  $\Delta\theta$  = unit of degree,

$\Rightarrow$  Specific heat capacity of substance can be defined as the amount of heat required to raise the temperature of 1 mass unit through 1 degree of temp

It is denoted by  $s$  for solid & liquid and  $c$  for gas

Its unit is  $J/kg^{-1}c^{-1}$  or,  $J/kg^{-1}\circ C^{-1}$  in S.I and,

$Cal/gm^{-1}c^{-1}$  or,  $Cal/gm^{-1}\circ C^{-1}$  in C.G.S

Kerosene :- 2118

Ethanol :- 2424

Carbon :- 506

Copper :- 386.4

## # Heat Capacity :-

The heat required to raise the temperature of certain mass of the substance through unit degree of temp is called heat capacity of substance.

$$q = m \times s$$

## # principle of calorimeter:- Calorimeter:-

when the two bodies, which are the two different temperature are come in contact, then the body at higher temperature will release heat & the body at lower temperature will absorb heat.

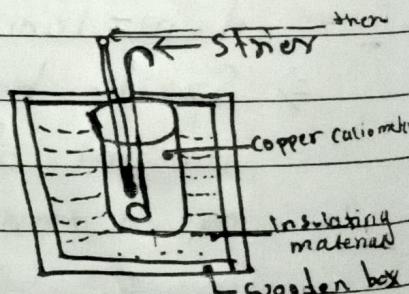
The heat gained by cold body is equal to the heat loss by body under the isolated system is called principle of calorimeter.

$$\text{Heat gain} = \text{Heat loss}$$

This theory describes the principle of conservation of energy.

### - Calorimeter:-

It is the cylinder copper vessel with copper stirrer placed inside the wooden box covered with wool or any other insulating material & covered by lid.



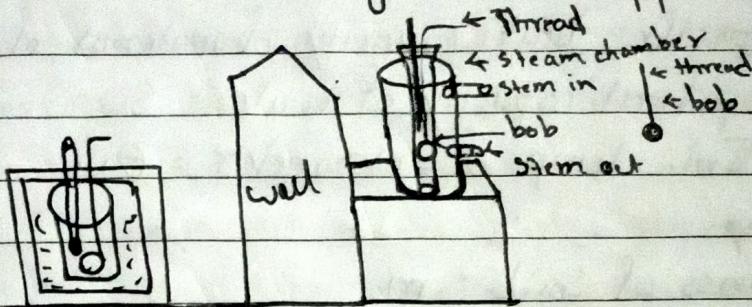
Thermometer is placed inside it, to measure the temperature.

It is used to measure the Specific heat capacity of different solids or liquids, latent heat of solid or liquid etc.

water boils at 94°C in KTM valley due to atm pressure.

# Determination of specific heat capacity of the given solid by the method of mixture.

### Regnault's apparatus



It consists of the copper calorimeter with stirrer inside the wooden box as cold body & the Steam chamber where the solid body is placed, ~~where~~ <sup>whose</sup> sp. heat has to be found.

firstly, the mass of dry calorimeter with stirrer is measured, then about  $\frac{2}{3}$  rd volume of water is taken in ~~calorimeter~~ calorimeter. & it is also weighed. The mass of water is calculated. Now,

a metal body is taken & it is also weighed, It is now suspended inside the hollow cylinder steam chamber & it is now heated by provided steam from the boiler.

The initial temperature of calorimeter & water is noted & when the solid bob is heated to certain temp<sup>r</sup> it is also noted.

Now the calorimeter is placed just below the steam chamber, both are now opened & the bob is dropped inside the calorimeter. It is finally closed and constantly stirred until the mixture's temp<sup>r</sup> reached at the constant temp<sup>r</sup>. It is also noted, In cold body,

Let, In Cold body,

$$\text{mass of calorimeter + string} = m_c$$

$$\text{mass of water} = m_w$$

$$\text{Specific heat capacity of material of calo.} = S_c$$

$$\text{Sp. heat capacity of water} = S_w$$

$$\text{Ini. temp of calorimeter} = \theta_{1i}$$

In hot body.

$$\text{mass of solid} = m_s$$

$$\text{specific heat capacity of solid} = S$$

$$\text{Ini. temp of solid} = \theta_{2i}$$

After mixing hot & cold body

The final temp of mixture after thermal equilibrium =  $\theta$

Heat gained by calorimeter + water

$$\begin{aligned} Q_1 &= m_c S_c (\theta - \theta_1) + m_w S_w (\theta - \theta_1) \\ &= m (\theta - \theta_1) (m_c S_c + m_w S_w) \end{aligned}$$

Heat lost by solid lab

$$Q_2 (\theta_2 - \theta) m_s S$$

from the principle of calorimeter,

Heat gained = Heat lost.

$$Q_1 = Q_2$$

Exponential graph

$$(m_c S_c + m_w S_w) (\theta - \theta_1) = m_s S (\theta_2 - \theta)$$

$$S = \frac{(m_c S_c + m_w S_w) (\theta - \theta_1)}{m_s (\theta_2 - \theta)} \quad \text{--- ①}$$

## # Newton's law of cooling:

It describes the rate at which an external body changes temp<sup>r</sup> through radiation which is proportional to difference bet<sup>n</sup> object temp<sup>r</sup> & its surrounding, provided the diff is small.

- Amount of heat loss depends on different factors, like nature of liquid, nature of vessel, area of exposed surface to surrounding & temp<sup>r</sup> difference bet<sup>n</sup> liquid & its surrounding.

Statement: The rate of heat lost of the body is directly proportion to temp<sup>r</sup> difference between body & its surrounding.

The law holds good only for a small temp<sup>r</sup> difference, which is independent of nature of liquid.

~~As seen~~ The higher the temp<sup>r</sup> difference between the body & surrounding, the more heat is lost by body per unit of time.

- Suppose a liquid at temp<sup>r</sup> θ loses a small amount of heat  $dQ$  in small time  $dt$  &  $\theta_s$  be the temp<sup>r</sup> of surrounding

$$\therefore -\frac{dQ}{dt} \propto (\theta - \theta_s)$$

$$-\frac{dQ}{dt} = \kappa(\theta - \theta_s) \text{ where, } \kappa = \text{proportionality constant}$$

$$\frac{dQ}{dt} = -\kappa(\theta - \theta_s)$$

If  $m$  is the mass of hot liquid with sp. heat capacity  $s$ , then,  $Q = ms\Delta\theta$

In small time  $dt$ , the small change in temp<sup>r</sup> is also  $d\theta$ . Then,  $dQ = msd\theta$ . Dividing both sides by  $dt$ ,

$$\frac{dQ}{dt} = ms \frac{d\theta}{dt}$$

temp  
80°F

time

$$\int \frac{dx}{x} = \log e n + C$$

from eqn (i) & (ii)

$$ms \frac{d\theta}{dt} = -ks(\theta - \theta_s)$$

$$\cdot \frac{d\theta}{(\theta - \theta_s)} = -\frac{ks}{ms} dt \quad \text{(iii)}$$

Integrating both side we get,

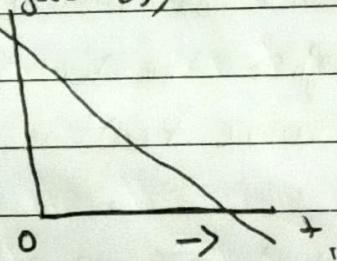
$$\int \frac{d\theta}{(\theta - \theta_s)} = -\frac{ks}{ms} \int dt$$

$$\log_e(\theta - \theta_s) = -\frac{ks}{ms} t + C \quad \text{iv}$$

Comparing above eqn with,  $y = mx + c$

eqn iv shows that linear equation of straight line of x-axis as t variable, y-axis  $\log_e(\theta - \theta_s)$  variable of slope  $= -\frac{ks}{ms}$

$$\log_e(\theta - \theta_s)$$



This linear relation verifies newton's of cooling Again from eqn

$$\frac{d\theta}{dt} = -\frac{ks}{ms} (\theta - \theta_s)$$

As,  $k \propto$  exposed area of body (A),  $ms$  volume of body (V)

# Determination of Specific heat of given liquid by Newton's law of cooling.

**Principle:** when two liquids are cooled under similar condition the rate of cooling are equal

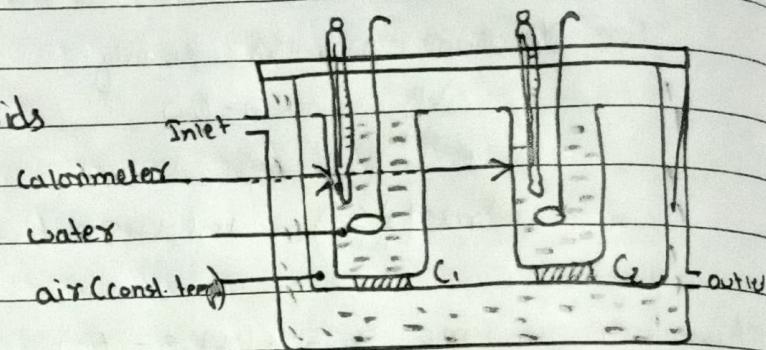


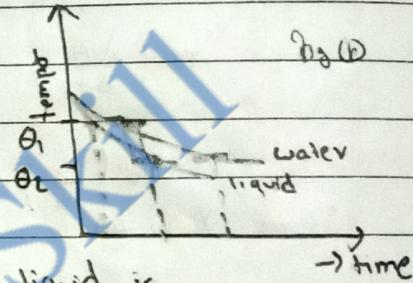
fig: Determination of sp heat of liquid

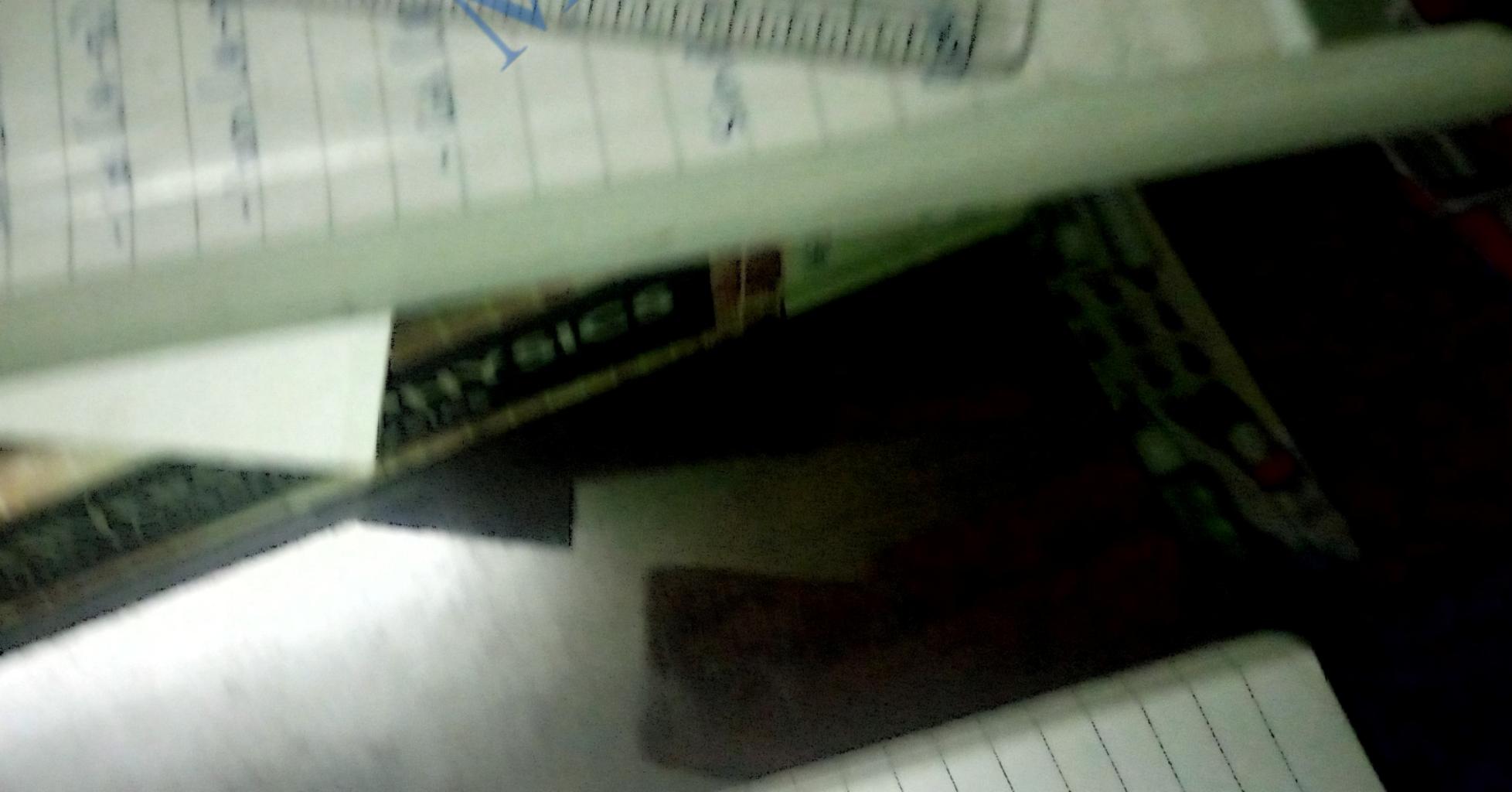
The specific heat capacity of hot liquid is to be found.

They are placed inside the cooling apparatus so that they are allowed to cool down under similar condition.

Thermometer  $T_1$  &  $T_2$  are inserted in the calorimeter  $C_1$  &  $C_2$  inside apparatus. The temp of air is maintained constant by continuously circulating air/water through the wall of container. And the temp inside apparatus is measured by thermometer  $T_3$  now.

The falling temperature of both liquids are noted for every 1 min interval & graph between temp & time is plotted on figure 1. The time taken by both liquid for small temp difference ( $\Delta t$ ) is measured from the graph. Finally the mass of both liquids are measured.





## # Change of phase (state)

The change of matter from one physical state solid, liquid, gas to another state is called change of phase or state.

When substance changes from Solid to liquid the heat supplied at a constant temp. (i.e. melting point) overcomes the intermolecular attraction. This means intermolecular distance increases and molecules are free to move.

Similar case occurs when substance changes from liquid to gas state.

# Latent Heat  $Q = lm$ 

It is found that the amount of heat required to convert the phase of the substances at constant temp. is directly proportional to its mass

$$\therefore Q \propto m$$

$\therefore Q = lm$  [l = proportionality constant of latent heat]

$$l = \frac{Q}{m}$$

⇒ The amount of heat required for unit mass of substance during its changes of state at a constant temperature is called latent heat.

Here, latent → hidden heat.

SI unit is J/kg and CGS unit is cal/gm.

- Two types of latent heat.

## (a) Latent heat of fusion

The heat required to change the solid of unit mass of substance from its Solid State to liquid State at its melting point is called latent heat of fusion of substance. Denoted by :  $l_f$

∴ latent heat of fusion of ice.

$$L_f = 80 \text{ cal/gm}$$

$$= 80 \times 4200$$

$$= 336,000 \text{ J/kg}$$

$$\therefore 3.36 \times 10^5 \text{ J/kg.}$$

### ⑥ latent heat of vaporization.

The heat required to change the state of unit mass of substance from its liquid state to vapour state at its boiling point is called latent heat of vaporization of substance. It is denoted by ( $L_v$ )

latent heat of vaporization of water.

$$L_v = \frac{Q}{m} = 2.26 \times 10^6 \text{ J/kg}$$

### # Illustration of latent heat of water from heat temp graph

⇒ 1 gm of -20°C ice is taken

- AB Slope represent the temperature rise of ice from -20°C to 0°C

- BC represents melting of ice at 0°C by absorbing 80 cal/gm heat  
for 1 gm ~~heat~~ of ice to melt.

- CD represents the temperature rise of water from 0°C to 100°C.

- DE represents the vaporising of water to steam at 100°C by absorbing 540 cal/gm

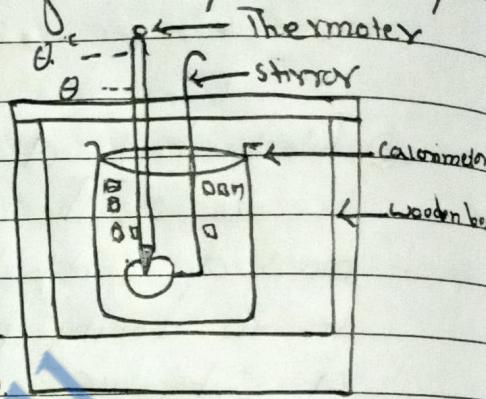
→ Beyond E, the temperature of stem B is rising as long as heat is given.

# The change of phase sequence is reversible too.

## # Determination of latent heat of ice from method of mixture

Principle: It is based on the principle of calorimeter i.e. heat lost by hot body is equal to heat gained by cold body.

The calorimeter with stirrer is taken and is weighed. Then some volume of water at room temperature is added and its mass is also weighed. Its initial temp $\theta_1$  is taken by thermometer.



mixing of ice with water in calorimeter

Some small pieces of ice is taken and is dried with the help of blotting paper then it is inserted inside the calorimeter and is constantly stirred until all ice melts into water. Final temperature of mixture is noted & finally the mixture is weighed. So that mass of ice is noted.

Let,

$$\text{mass of calorimeter \& stirrer} = m_c$$

$$\text{mass of water} = m_w$$

$$\text{mass of ice} = m_i$$

$$\text{Sp. heat of material of the Calorimeter : } S_c$$

$$\text{Sp. heat of water : }$$

$$\text{Latent heat of ice : } L_i$$

unknown

$$\text{Initial temp of calorimeter \& water : } \theta_{i,c}$$

$$\text{Initial temp of ice : } \theta_{i,c}$$

After mixing ice in water inside the calorimeter Final temp of the

Heat lost by the calorimeter & water on cooling from  $\theta_{i,c}$  to  $\theta_i$ .

$$= m_c S_c (\theta_{i,c} - \theta_i) + m_w S_w (\theta_{i,c} - \theta_i)$$

$$= m_c S_c + m_w S_w (\theta_{i,c} - \theta_i)$$

classmate  
Date \_\_\_\_\_  
Page \_\_\_\_\_

Heat gain by ice on converting into water at  $0^{\circ}\text{C}$  & then raising its temp to  $0^{\circ}\text{C}$

$$= m_i l + m_i s_w (0 - 0)$$

$$= m_i l + m_i s_w \theta$$

From principle of calorimetry.

Heat lost by cooled + water = heat gained by ice.

$$m_c s_c + m_w s_w (0_i - \theta) = m_i l + m_i s_w \theta$$

$$\therefore l = \frac{(m_c s_c + m_w s_w (0_i - \theta)) - s_w \theta}{m_i}$$

## # Determination of Latent heat of Vaporization of water by method of mixture.

Principle: It is based on the principle of Calorimetry i.e. heat lost by hot body is equal to heat gain by cold body.

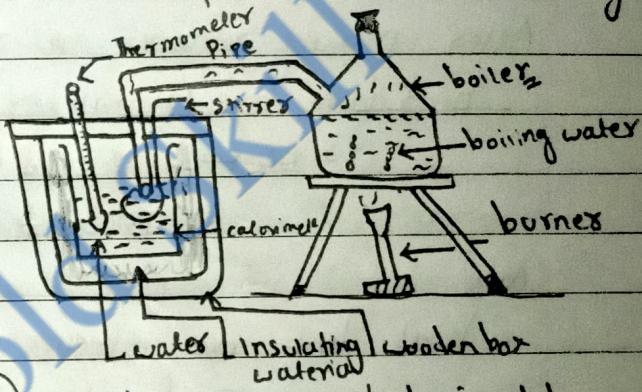


Fig: determination of  $l_v$  in lab

Working:- The dry calorimeter is weighed first & it is fixed with  $\frac{2}{3}$  of water. Mass of water is also noted. It is then placed in the wooden box & its initial temp is noted by thermometer.

On the another side, water is boiled inside the boiler & stem is passed through the connecting pipe for some time in the calorimeter to mix with the water. After some time, the pipe is taken out & the content mixed with stirrer. final temp is noted. finally the calorimeter & mixture is weighed again to obtain the mass of steam.

Let,

$$\text{mass of calorimeter} = m_c$$

$$\text{mass of water} = m_w$$

$$\text{mass of steam added} = m_v$$

Specific heat capacity of material of calorimeter =  $S_c$

$$\text{Sp. heat of water} = S_w$$

$$\text{Latent heat of vaporization of water} = L_v \text{ (unknown)}$$

$$\text{Initial temp of calorimeter + water} = \theta_i^{\circ}\text{C}$$

$$\text{Initial temp of steam} = 100^{\circ}\text{C}$$

$$\text{After mixing, final temp of mixture} = \theta$$

After mixing vapour in room temperature water:-

heat gain by calorimeter = heat lost by steam

$$\Rightarrow m_c S_c (\theta - \theta_i) \rightarrow m_w S_w (\theta - \theta_i)$$

$$= m_c S_c + m_w S_w (\theta - \theta_i)$$

also

heat lost by steam,

$$m_v L_v + m_w S_w (100 - \theta)$$

now, equating

$$\text{or } m_v L_v + m_w S_w (100 - \theta) = m_c S_c + m_w S_w (\theta - \theta_i)$$

$$\text{or, } m_v L_v = m_c S_c + m_w S_w (\theta - \theta_i) - m_w S_w (100 - \theta)$$

$$\text{or, } L_v = \frac{(m_c S_c + m_w S_w (\theta - \theta_i)) - m_w S_w (100 - \theta)}{m_v}$$

$$\text{or, } \frac{m_c S_c + m_w S_w (\theta - \theta_i)}{m_v} - S_w (100 - \theta)$$

## ~~#~~ Effect of pressure on melting point & Boiling point.

### ⇒ Effect of pressure on melting point.

Melting point is that point, where both the liquid & solid phase of the substance can co-exist in equilibrium (temperature).

The effect of pressure on melting point depends on the nature of substances.

For those substances, ~~which~~ which expands on melting, the melting point increases in external pressure & vice-versa.

i.e. Melting point  $\propto$  pressure

Example : Wax, Sulphur, lead etc.

For those substance, which contracts on melting, the melting point of such substance decreases with increase in external pressure & vice-versa.

Regelation :- The phenomenon of melting of ice under the application of pressure & freezing after the removal of pressure is called Regelation.

### ⇒ Effects of pressure on Boiling point

Boiling point is that point, where the liquid & vapour phase of the substance can co-exists in equilibrium.

The boiling point of liquid increases with increase in pressure & vice versa.

i.e. B.P  $\propto$  P

water boils at higher temp<sup>x</sup> at sea level & at lower temp<sup>x</sup> at high altitude.

## # Phase diagram & Triple point...

The pressure-temperature diagram to study different phases of matter is called phase diagram.

There exist three curves.

### ① Vaporization curve (Steam line)

It is the graph betn variations of boiling point of substance with pressure. At each

point of this line, the substances existed in both liquid & vapour state in equilibrium.

on above of this line  $\rightarrow$  liquid

on bottom of this line  $\rightarrow$  vapour.

### ② Fusion curve (Ice line) :- It is the graph betn the variation of melting point of substance with pressure. At each point of this line, the substance existed in both solid & liquid state in equilibrium

on left side of this line  $\rightarrow$  solid.

on right side of this line  $\rightarrow$  liquid.

### ③ Sublimate curve (Haze-brost line)

It is the graph betn the variation of sublimation of the substance with pressure. At each point of this line, the substance existed in both solid & vapour states in equilibrium.

above this line  $\rightarrow$  solid

below this line  $\rightarrow$  vapour.

# Triple point :- The point in the phase diagram, respectively at a particular pressure & temperature at which all the 3 states of matter ie solid, liquid & gaseous state of the substance can co-exist in equilibrium is called triple point.

It is intersection of 3 curves

Example:-  $H_2O$ , triple pt. at  $P = 0.006$  &  $T = 0.012$

$CO_2$ , triple pt. at  $P = 5$  &  $T = -56.6^\circ C$

