CALORIMETRY

Calorimetry is the study and measurement of heat.

Heat : It is a form of energy which is transferred due to difference in Temperature.

Q)

Which of the 2 samples contains more amount of heat.

~~the c~~ The Que is meaningless because heat is not a content energy of the system.

Heat is the energy in transit only. Once heat is transferred, it becomes internal energy of the system

* calorie is the non-conventional unit of heat.

$$\boxed{1 \text{ cal} = 4.186 \text{ J}}$$

Q) what do you mean by 1 cal = 4.186 J ?

This relation shows the equivalence of heat and work. The temp. increases by 1 C heat can be increased by doing 4.186 J work

The no. 4.186 is called mechanical equivalent of heat.

ii) When heat is given to a body, its Temp may increase

iii) Its state may change

solid $\longrightarrow$ liquid

liquid $\longrightarrow$ gaseous

iv) when heat is withdrawn from a system, then ⇒ its Temp may decrease

⇒ its state may change

gaseous $\longrightarrow$ liquid

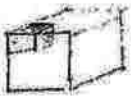
liquid $\longrightarrow$ solid

v) Heat depends on mass, nature of material, change in temp.

$$\boxed{Q = ms\Delta t}$$

vi) specific heat (s or c)

$$s = \frac{Q}{m\Delta t}$$



(intrinsic)

If $m = 1$, $\Delta t = 1$, then $s = Q$

specific heat is the amount of heat required to change the temp. of unit amount of substance by 1°

$$\text{Unit} = \frac{J}{kg\,^\circ C} = \frac{cal}{g\,^\circ C}$$

⇒ specific heat doesn't depends on mass and depends on temp.

» <u>Thermal capacity</u>

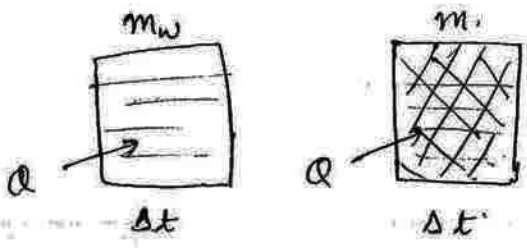
It is the amount of heat required to change the temp of a body by 1°

$$\Delta t \longrightarrow Q$$

$$1 \longrightarrow \frac{Q}{\Delta t} = \text{thermal capacity}$$

$$= \frac{ms\cancel{\Delta t}}{\cancel{\Delta t}} = \boxed{ms}$$

» <u>water equivalent</u>



$$Q_{water} = Q_{body}$$

$$m_w s_w \cancel{\Delta t} = ms\cancel{\Delta t}$$

$$\therefore \boxed{m_w s_w = ms}$$

water equivalent is the amount of water which has same thermal capacity as the given body

» Latest heat (L): The amount of heat required to change the state of unit amount of substance is called latest heat

$$\boxed{Q = mL} \qquad L = \frac{cal}{gm}$$

>> Calorimeter : It is a container in which study of a mixture can be carried out.

It is generally made up of <u>copper</u> because of its low specific heat.

Calorimeter is insulated from the surrounding

Principle of calorimetry :

heat given = heat taken

* <u>Some values</u> :

<u>s for water</u> → $\boxed{1 \text{ cal/g}^\circ\text{c}}$

<u>s for Ice</u> → $\boxed{0.5 \text{ cal/g}^\circ\text{C}}$

<u>s for steam</u> → $\boxed{0.47 \text{ cal/g}^\circ\text{C}}$

Ice $\xrightarrow{0^\circ c}$ water	$L_f = 80$ cal/g
water $\xrightarrow{100^\circ c}$ steam	$L_v = 540$ cal/g

Q) Find the value of the following in SI

i) $s = 1$ cal/g°c

ii) $L = 80$ cal/g

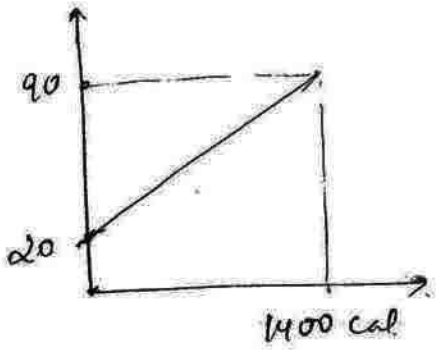
i) $s = 1$ cal/g°c

$$= \frac{4.186 \text{ J}}{10^{-3} \text{ kg K}} = 4186 \text{ J/kg K} = 4200 \text{ J/kg}^\circ\text{C}$$

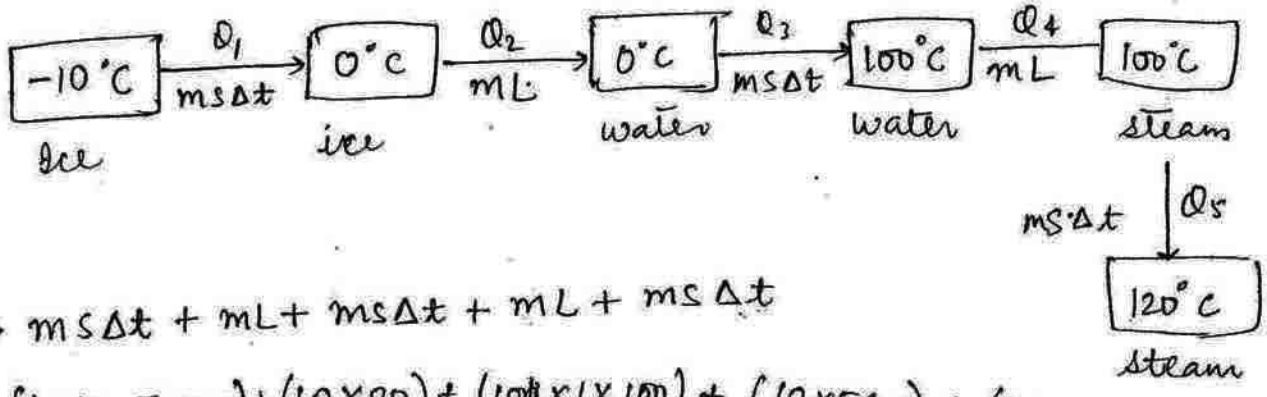
ii) $$L = 80 \text{ cal/g} = \frac{80 \times 4.186}{10^{-3} \text{ kg}} = 3.36 \times 10^5 \text{ J/kg}$$

Q) Find the amount of heat required to increase the temp of 200 gm of water from 20°c to 90°c

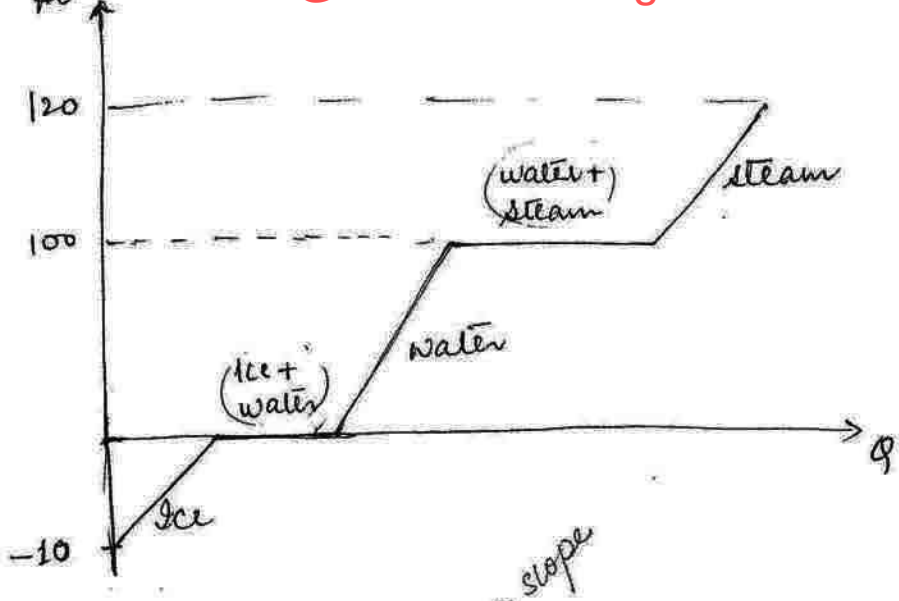
$$Q = ms\Delta t$$
$$= 200 \times 1 \times (90-20)^\circ c$$
$$= 14000 \text{ cal.}$$
$$= (14000 \times 4.2) J = 5.88 \times 10^4 J$$



Q) Find the amount of heat required to convert 10 gm ice at -10°c to steam at 120°c



$$Q \Rightarrow ms\Delta t + mL + ms\Delta t + mL + ms\Delta t$$
$$= (10 \times 0.5 \times 10) + (10 \times 80) + (10 \times 1 \times 100) + (10 \times 540) + (10 \times 0.47 \times 20)$$
$$= 7344 \text{ cal}$$

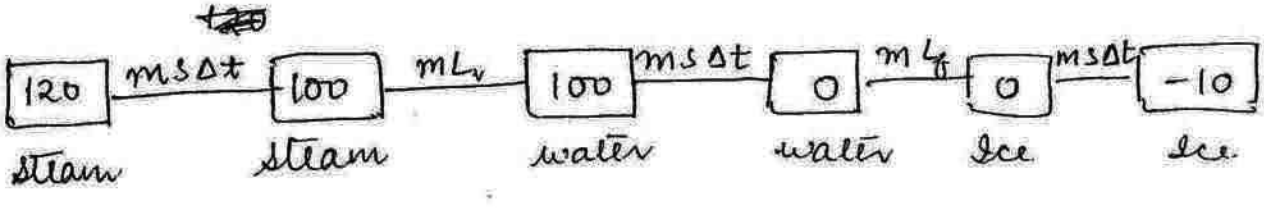


$S_{water} < S_{ice} < S_{steam}$ (slope)

$$\text{Slope} = \frac{\Delta y}{\Delta x} = \frac{\Delta t}{Q} = \frac{\cancel{\Delta t}}{ms\cancel{\Delta t}}$$

$$\therefore \boxed{\text{Slope} = \frac{1}{ms}}$$

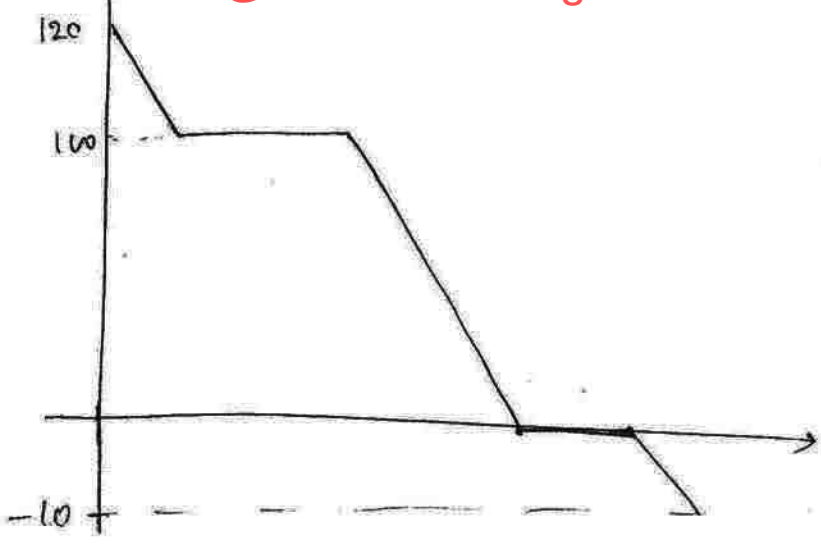
Q) Find the amount of heat ~~drawn~~ withdrawn from 10 gm steam at 120°C so that it is converted into ice at −10°C.



$$Q \Rightarrow ms\Delta t + mL_v + ms\Delta t + mL_f + ms\Delta t$$

$$\Rightarrow (10\times0.47\times20) + (10\times540) + (10\times1\times100) + (10\times80) + (10\times0.5\times10)$$

$$\Rightarrow 94 + 5400 + 1000 + 800 + 50 \Rightarrow 7344 \text{ cal}$$



Q) Mass of a body is 2 kg and specific heat is 0.2 cal/g°c. Find thermal capacity of the body.

Thermal capacity = ms

$= 0.2 \times 2000$

$= 400$ cal/°C

Q) mass of a body is 10 kg. and its specific heat is 600 J/kg°C. Find water eq. of body

$m_w S_w = ms$

$m_w \times 4200 = 10 \times 600$ $\left(\because S_w = \frac{1 \times 4.2}{10^{-3}} = 4200\right)$

$m_w = \frac{10 \times 6}{42} = \frac{10}{7}$

$= 1.4$ kg

Q) ~~m_{eq}~~ water equi. of a container is 20 g and it contains 80 gm of water at 20°c. Find the amount of heat needed to increase the temp upto 100°c

$$\left(\begin{array}{l} \because m_w s_w = \overset{\text{container}}{m_1 s_1} \\ 20 \times 1 = m_1 s_1 \\ \therefore m_1 s_1 = 20 \end{array} \right)$$

$$Q = Q_{water} + Q_{container}$$

$$= m s \Delta t + m_1 s_1 \Delta t$$

$$= 80 \times 1 \times 80 + 20 \times 1 \times 80$$

$$= 8000 \text{ cal}$$

Q) Mass of a body is 2 kg and its $s = (2t+2)$ J/kg °c. Find heat needed to ↑ the temp. from 10°c to 20°c

~~2 kg~~

$$Q = \int m s \, dt$$

$$= \int_{10}^{20} 2(2t+2)\, dt$$

$$= 2(t^2 + 2t)_{10}^{20} = 640 \text{ J}$$

Q) Mass of a body is M and its specific heat $s = at + bt^2$ Find amount of heat req to ↑ its temp from t_0 to $2t_0$

$$\because Q = \int m s \, dt$$

$$= \int_{t_0}^{2t_0} M(at + bt^2) \Rightarrow M\left[\frac{at^2}{2} + \frac{bt^3}{3}\right]_{t_0}^{2t_0}$$

$$\left[\frac{\quad}{2} + \frac{\quad}{3} \quad \frac{\quad}{2} \quad \frac{\quad}{3}\right]$$

$$\Rightarrow \left[\frac{3at_0^2}{2} + \frac{7bt_0^3}{3}\right] \Rightarrow \frac{Mt_0^2}{6}\left[9a + 14bt_0\right]$$

Q) 10 gm ice at 0°c is mixed with 10 gm H_2O at 80°C. Find final temp.

water (80°c)

$ms\Delta t$ ↓ 800 cal →

water (0°c)

Ice (0°c)

mL ↓ 800 cal

water (0°c)

at equilibrium: $t = 0$

Ice = 0

water = 20gm (10+10)

Q) 10 gm ice at 0°c is mixed with 10gm of water at 60°c Find final temp and contents of mix.

Ice (0°c)

mL ↓ 800 cal ✗

water (0°c)

water (60°c)

$ms\Delta t$ ↓ 600 →

water (0°c)

let (m)gm ice melts

$Q = mL$

$600 = m \times 80 \quad \therefore m = \frac{600}{80} = 7.5\,g$

Q. 10 gm ice at 0°c is mixed with 10gm water at 100°c. Find final temp

Ice (0°c)

$mL \downarrow$ 800 cal

water (0°c)

water (100°c)

$ms\Delta t \downarrow$ 1000 cal

water (0°c)

$Q = ms\Delta t$

$200 = 20 \times 1 \ (t - 0)$

$t = 10°c$

Q 2gm steam at 100°c is mixed with 10 gm ice at 0°c. Find final temp

steam (100°c)

$mL \downarrow$ 1080 cal

water (100°c)

$ms\Delta t \downarrow$ $2 \times 1 \times (100 - t)$

water (t°c)

Ice (0°c)

$mL \downarrow$ 800 cal.

water (0°c)

$ms\Delta t \downarrow$ $10 \times 1 \times (t - 0)$

water (t°c)

$1080 + 2(100 - t) = 800 + 10t$

$1080 + 200 - 2t = 800 + 10t$

$12t = 480$

$\therefore t = \frac{480}{12} \Rightarrow 40°C$

Q) 4gm steam at 100°c is mixed with 10 gm ice at −10°c. Find final temp and content of mixture.

steam (100)

$mL \downarrow$ 2160 cal X

water (100)

$\downarrow$

Ice (−10°C)

$mS\Delta t \downarrow$ 50 cal

ice (0°C)

$mL \downarrow$ 800

~~ice~~ water (0°)

$\downarrow$ 1000 cal

water (100°)

let (m)gm steam is converted,

$$Q = mL$$

$$1850 = m \times 540 \quad \therefore \quad m = \frac{1850}{540} = 3.4g.$$

at equi,

$\boxed{t = 100}$

$\boxed{\text{steam} = 0.6 \text{ gm}}$ $(4 - 3.4)g$

$\boxed{\text{water} = 13.4g}$ $(10 + 3.4)g$

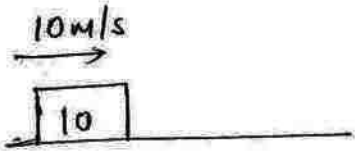
Questions based on mechanism:

» When some part of mechanical energy is converted to ~~the~~ internal energy of molecules then either the temp ↑es or state changes.

» The part of the mechanical energy which is converted to internal energy is called thermal energy.

» The effect produced by thermal energy is same as that produced by heat.

Q)



$s = 200\ J/kg^\circ C$

body stops moving after some-time. If 80% of loss in KE goes to the body, then find ~~the~~ increase in its temp.

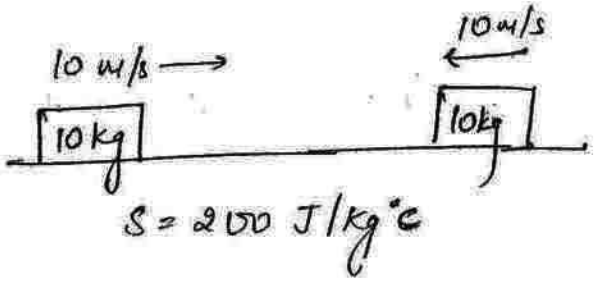
$$80\% \frac{1}{2} m v^2 = m s \Delta t$$

$$\frac{80}{100} \times \frac{1}{2} \times \cancel{10} \times 10^2 = \cancel{10} \times 200 \times \Delta t$$

$$\therefore \Delta t = \frac{80 \times \cancel{100}}{\cancel{100} \times 2 \times 200} = \frac{1}{5}$$

$$= \boxed{0.2}$$

Q)



There is no friction and collission is completely <u>inelastic</u>. Find ↑ in Temp of each body

$K_i = \frac{1}{2} \times 10 \times 100 \Rightarrow 500 + 500 \Rightarrow 1000$ J

$K_f = 0$

Q = loss in KE

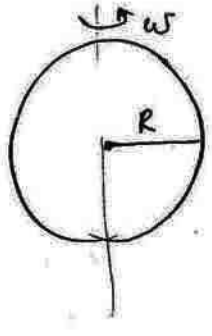
$ms\Delta t = 1000$

$20 \times 200 \times \Delta t = 1000$

(10+10)

$\therefore t = \frac{1}{4} = 0.25°C$

Q)



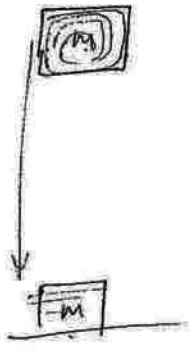
Sphere stops rotating after some time. Find ↑ in temp

$\frac{1}{2} I \omega^2 = ms\Delta t$

$\Rightarrow \frac{1}{\cancel{2}}\left(\frac{\cancel{2}}{5} \cancel{m} R^2\right)\omega^2 = \cancel{m}s\Delta t$

$\therefore \Delta t = \frac{R^2\omega^2}{5s}$

Q) Find the height from which a block of ice should be dropped so that it completely melts on striking the ground



$E_i = mgh$

$E_f = 0$

Q = Loss in ME

$mL = mgh$

∵ change in state

$\therefore h = \frac{L}{g} \quad \frac{cal}{gm} \times \left(\frac{s^2}{m}\right)$

$= \frac{80 \times 4.2 \times 10^3}{10}$ (S.I unit) $\left(\frac{J}{kg}\right)\frac{s^2}{m}$

$\Rightarrow 33600$ m

$\Rightarrow 33.6$ Km

Q) A bullet of mass m is fired with velocity v into a target. If 50% loss of KE goes to the bullet, then find ↑ in its temp

50% of KE = $ms\Delta t$

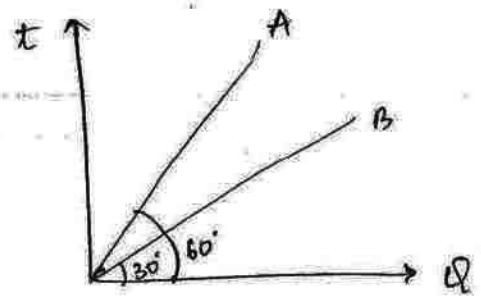
$\Rightarrow \frac{50}{100} \times \frac{1}{2} \times \cancel{m} \times v^2 = \cancel{m} \times s\Delta t$

$$\boxed{\Delta t = \frac{v^2}{4s}}$$

Q) A lead bullet of mass m is fired is 27°c. The bullet melts after it hits the target, If 75% of loss in KE goes to the bullet. Then find the ~~fo~~ speed with which it was fired (m.P = 327°c, S, L)

$$mS\Delta t + mL = \frac{3}{4} \times \frac{1}{2} mV^2$$

Q)



Find S_A / S_B

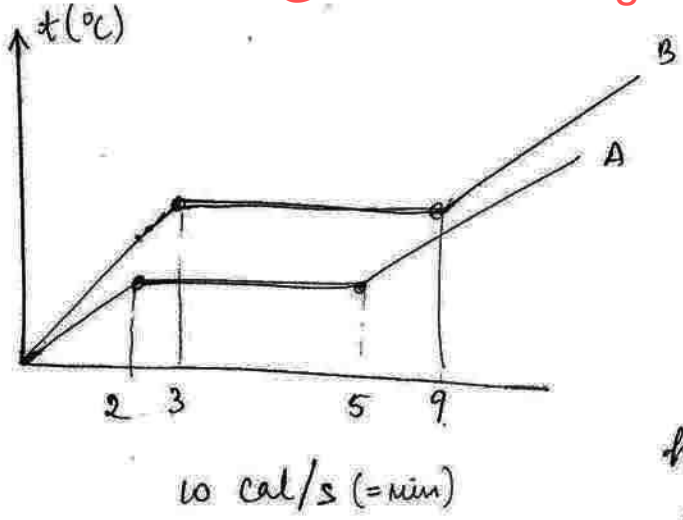
$$\text{Slope} = \frac{\Delta y}{\Delta x} = \frac{\Delta t}{Q}$$

$$\text{slope} = \frac{\cancel{\Delta t}}{mS\cancel{\Delta t}} = \frac{1}{\underbrace{mS}_{\text{constant}}} \quad \therefore \quad \text{slope} \propto \frac{1}{S}$$

$$\frac{S_A}{S_B} = \frac{\tan \theta_B}{\tan \theta_A}$$

$$= \frac{\tan \cancel{30}\, 60}{\tan \cancel{60}\, 30} = \frac{1}{\sqrt{3}}$$

(Q)



Both the solids are heated at the constant rate of 10 cal/min. Find the ratio of heat given to them during their complete fusion

$H_A = 10 \times 3 \Rightarrow (5-2)$

$H_B = 10 \times 6 \Rightarrow (9-3)$

$\because$ the Temp remains constant during fusion.

$$\therefore \frac{H_A}{H_B} = \frac{3}{6} = \frac{1}{2}$$

* Cryogenics : measurement of temp close to 0K
* Pyrometry : measurement of very high temp.
* $\boxed{W = QJ}$
* $$\Delta\theta = \frac{m_1 s_1 \Delta\theta_1 + m_1 s_2 \Delta\theta_2}{m_1 s_1 + m_1 s_2}$$