CHAPTER 11

QUANTITY OF HEAT ENERGY

Specific Heat capacity:-

↳ The amount of heat required to exchange the temperature of body is,

i) directly proportional to mass of substance,

i.e, $Q \propto m$ ——— (i)

ii) Directly proportional to change in temperature of body.

i.e, $Q \propto \Delta T$ ——— (ii)

Combining eq^n (i) & (ii).

$$Q \propto m \Delta T$$

$$Q = ms\Delta t \quad \text{——— (iii)}$$

Where, 's' is proportionality constant called specific heat capacity of a body.

From equation (iii);

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

$$\Rightarrow \boxed{s = Q} \quad [\because \text{If } m = 1\text{ kg} \ \& \ \Delta T = 1°c]$$

Thus, specific heat capacity of a body is defined as the amount of heat required to change the temperature of unit mass by 1°c/1K.

The SI unit of specific heat capacity is J/Kg°c.

Example:-

Specific heat capacity (s) of water = 4200 $J Kg^{-1} K^{-1}$

Note:-

* $\boxed{1 \text{ cal.} = 4.2 \text{ J}}$
* $\boxed{\frac{4200 \text{ J}}{\text{Kg°C}} = \frac{4200}{4.2 \times 1000} \text{Cal/gm°c} = 1 \text{ cal/gm°c}}$

Heat Capacity or thermal Capacity:-

↳ The heat capacity or thermal capacity is defined as the amount of heat required to change the temperature of that body by $1^\circ C/1K$.

We have, $Q = ms\Delta T$

Where, Q = Quantity of heat, m = Mass of body, ΔT = Change in Temperature.

If $\Delta T = 1^\circ C/1K$

$\Rightarrow \boxed{Q = ms} \Rightarrow$ This is heat ~~energy~~ capacity.

Thus, Heat Capacity of a body is also defined as the product of mass and specific capacity of that body.

principle of Calorimetry:-

↳ When two bodies at different temperature are kept in Contact with each other, the hot body loss heat & Cold body gains heat. The exchange of heat between two bodies takes place untill they acquired same temperature. If there is no exchange of heat with Surrounding. Then,

Heat loss = Heat gain

This is principle of calorimetry.

To determine the specific heat capacity of solid by method of Mixture.

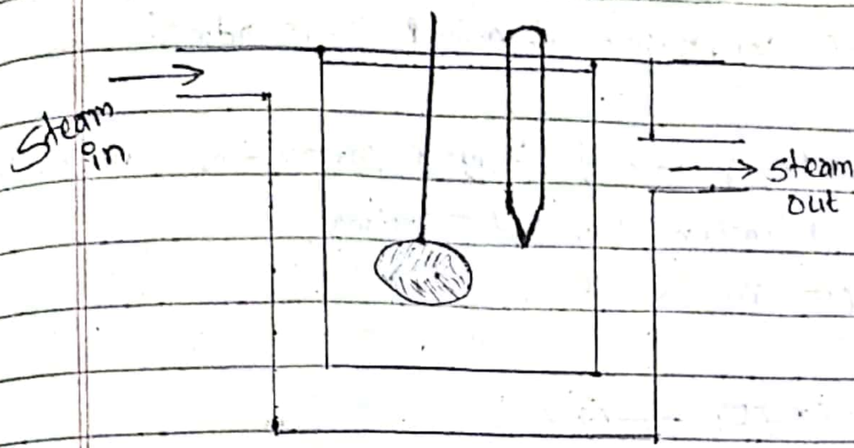

fig: Regnault's Apparatus

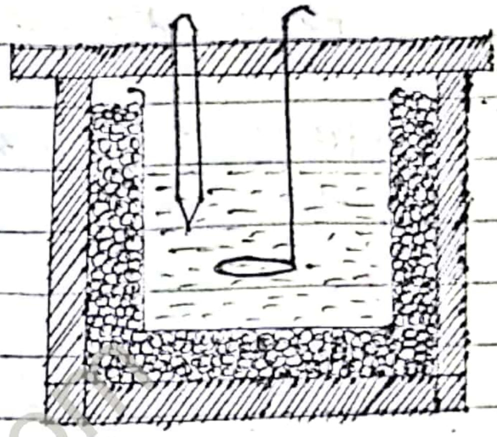

fig: Calorimeter

Let,

mass of solid $= m_s$ Specific heat capacity of Solid $= S_s$

mass of Water $= m_w$ Specific heat capacity of water $= S_w$

mass of Calorimeter $= m_c$ Specific heat capacity of Calorimeter $= S_c$

Initial temperature of solid $= T_1$

Initial temperature of water & Calorimeter $= T_2$

Final temperature of mixture $= T$

According to principle of Calorimetry,

Heat loss = Heat gain

$\Rightarrow m_s S_s (T_1 - T) = m_w S_w (T - T_2) + m_c S_c (T - T_2)$

or, $m_s S_s (T_2 - T) = (m_w S_w + m_c S_c)(T - T_2)$

$$\Rightarrow \boxed{S_s = \frac{(m_w S_w + m_c S_c)(T - T_2)}{m_s (T_2 - T)}}$$ #

Hence,
Knowing the specific heat capacity of water & that of material of Calorimeter, the specific heat capacity of given solid can be determined.

Newton's law of Cooling:-

↳ It states, "the rate of loss of heat by a body is directly proportional to difference of temperature of body & surrounding."

↳ Let, 'T' & 'T_s' are the temperature of body & surrounding respectively then, according to Newton's law of Cooling,

$$\frac{dQ}{dt} \propto (T - T_s)$$

$$\Rightarrow \frac{dQ}{dt} = -K(T - T_s) \quad \text{—— (i)}$$

Where, K is proportionality constant. Negative sign indicates that the difference in temperature decreases as $\frac{dQ}{dt}$ increases.

Again, $Q = ms\,dT$

$$\Rightarrow \frac{dQ}{dt} = ms\frac{dT}{dt} \quad \text{—— (ii)}$$

From eq^n (i) & (ii)

$$ms\frac{dT}{dt} = -K(T - T_s)$$

or, $$\frac{dT}{T - T_s} = \frac{-K}{ms}dt$$

Integrating both sides,

$$\int \frac{dT}{T - T_s} = \frac{-K}{ms}\int dt$$

$$\Rightarrow \text{Log}(T - T_s) = \frac{-K}{ms}t + c$$

Which is the eq^n of form $y = mx + c$, thus, Graph between Log$(T - T_s)$ & (t) is straight line as shown in figure (Graph):-

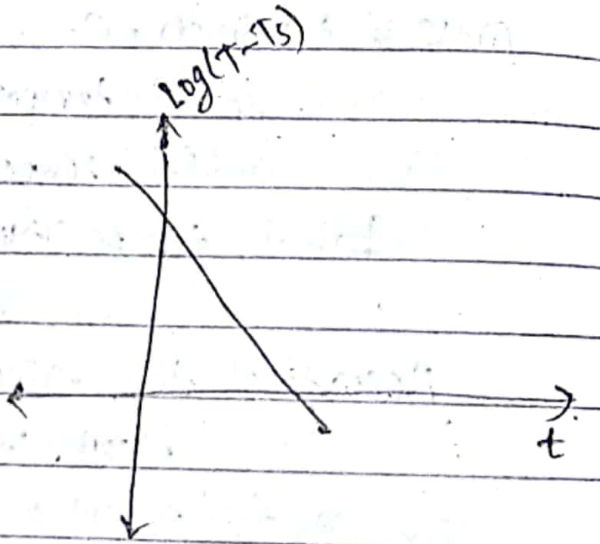

fig: Graphical relation between logarithm of temp^r difference and time of Cooling.

Determination of Specific Heat Capacity of liquid by method of Cooling:-

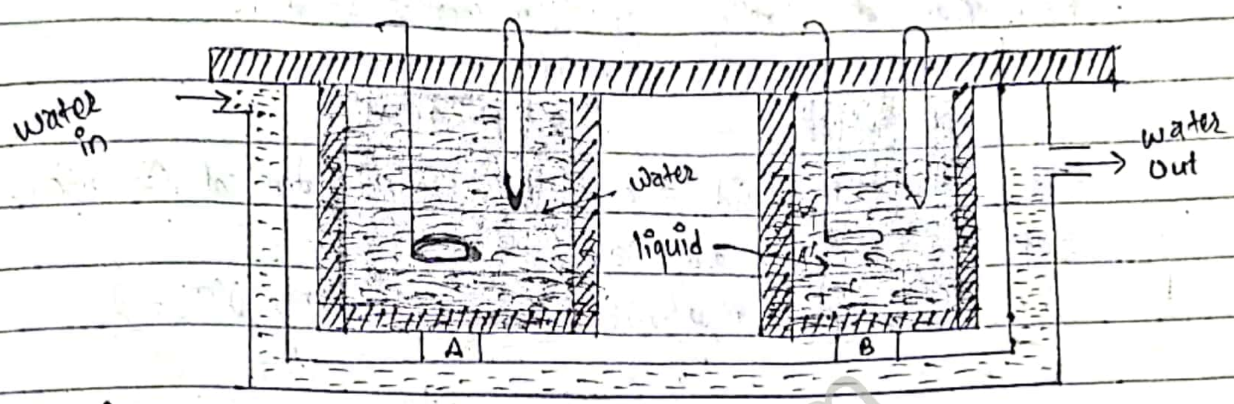

fig: Determination of specific heat Capacity of liquid

Let,

mass of Calorimeter A = m_A
mass of Calorimeter B = m_B
mass of water in Calorimeter A = m_w
mass of liquid in Calorimeter B = m_l
Specific heat Capacity of Calorimeter = S_c
Specific heat Capacity of Water = S_w
Specific heat Capacity of liquid = S_l
Initial tempʳ of both calorimeter = T_1
Final tempʳ of both Calorimeter = T_2
Time taken by Calorimeter A to Cool from T_1 to T_2 = t_1
Time taken by Calorimeter B to Cool from T_1 to T_2 = t_2

Now,
Heat loss by Calorimeter A & water $= m_A S_c(T_1-T_2) + m_w S_w(T_1-T_2)$
$$= (m_A S_c + m_w S_w)(T_1-T_2)$$

Similarly
Heat loss by Calorimeter B & liquid $= m_B S_c(T_1-T_2) + m_l S_l(T_1-T_2)$
$$= (m_B S_c + m_l S_l)(T_1-T_2)$$

Again,
Rate of Cooling of Calorimeter A & water,
$$= \frac{(m_A S_c + m_w S_w)(T_1-T_2)}{t_1}$$

And Rate of Cooling of Calorimeter B & liquid

$$= \frac{(m_B S_c + m_l S_l)(T_1 - T_2)}{t_2}$$

Since, water & liquid are cooled under identical Condition. So their rate of Cooling are same,

i.e, $$\frac{(m_A S_c + m_w S_w)(\cancel{T_1 - T_2})}{t_1} = \frac{(m_B S_c + m_l S_l)(\cancel{T_1 - T_2})}{t_2}$$

or, $m_B S_c = (m_A S_c + m_w S_w)^{t_2}/_{t_1}$

or, $$m_l S_l = (m_A S_c + m_w S_w)\frac{t_2}{t_1} - m_B S_c$$

$$\Rightarrow \boxed{S_l = \left(\frac{m_A S_c + m_w S_w}{m_l}\right)\frac{t_2}{t_1} - \frac{m_B S_c}{m_l}}$$

Hence, # Knowing the value of specific Heat Capacity of Water & Calorimeters, Specific heat capacity of liquid is Calculated.

Latent Heat:-

↳ The amount of heat required to convert a substance from one State to another State without Change in temperature is Known as latent heat.

The heat required during the Change of phase of a Substance depends on its mass.

i.e., $Q \propto m$

$$\Rightarrow \boxed{Q = Lm}$$

Where, L is proportionality Constant Called latent heat.

Its SI unit is $J kg^{-1}$

Types of latent heat:-

[1] Latent heat of fusion (L_f):-

↳ It is defined as amount of heat required by 1 kg of ice at melting point (0°c) to change in water at same temperature.

$$\boxed{L_f = 80 \text{ Cal/gm}} \text{ or } \boxed{3.36 \times 10^5 \text{ J/kg}}$$

[2] Latent heat of vapourization (L_v):

↳ It is defined as amount of heat required to convert 1 kg of water at boiling point (100°c) to steam in same temperature.

$$\boxed{L_v = 540 \text{ cal/gm}} \text{ or, } \boxed{2.268 \times 10^6 \text{ J/kg}}$$

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Measurement of latent heat of fusion by method of mixture.

Let,

mass of Calorimeter = m_c

mass of water = m_w

mass of ice = m_i

Specific heat capacity of water = S_w

Specific heat capacity of Calorimeter = S_c

latent heat of fusion of ice = L_f

Initial temp^r of water & Calorimeter = T_1

final temperature of mixture = T_2

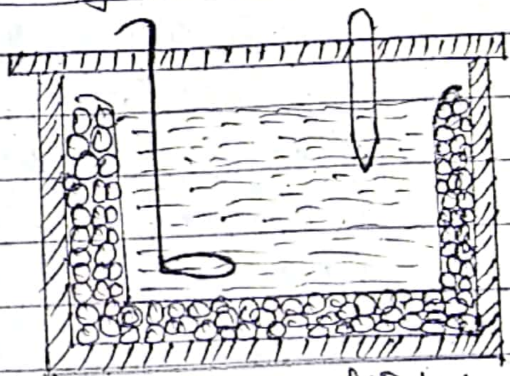


fig: measurement of latent heat of fusion of ice.

Now,

Heat gain by ice $= m_i L_f + m_i S_w (T_2 - 0)$

$= m_i L_f + m_i S_w T_2$

And, Heat Loss by Calorimeter & water $= m_c S_c (T_1 - T_2) + m_w S_w (T_1 - T_2)$

$= (m_c S_c + m_w S_w)(T_1 - T_2)$

$$0^\circ C \text{ (ice)} \rightarrow 0^\circ C \text{ (water)} \rightarrow T_2^\circ C \text{ (water)}$$

Then, According to principle of Calorimetry,

Heat gain = Heat loss

or, $m_i L_f + m_i s_w T_2 = (m_c s_c + m_w s_w)(T_1 - T_2)$

or, $m_i L_f = (m_c s_c + m_w s_w)(T_1 - T_2) - m_i s_w T_2$

$$\Rightarrow \boxed{L_f = \frac{(m_c s_w + m_w s_w)(T_1 - T_2)}{m_i} - s_w T_2} \quad \#$$

Hence, knowing the specific heat capacity of water & calorimeter, the latent heat of fusion of ice can be obtained.

Determination of latent heat of Vapourization of water:-

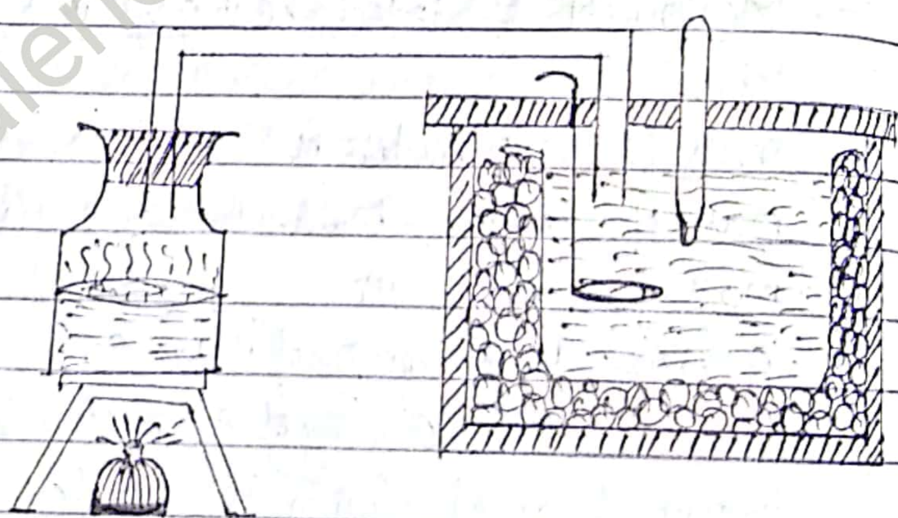


fig: Determination of latent heat of Vapourization of water.

Let,

mass of Calorimeter $= m_c$

mass of Water $= m_w$

mass of Steam $= m_s$

Specific heat Capacity of Calorimeter $= s_c$

$$\underset{\text{Steam}}{100^\circ C} \longrightarrow \underset{\text{water}}{100^\circ C} \longrightarrow \underset{\text{water}}{T_2^\circ C}$$

Specific heat Capacity of water $= S_w$
Latent heat of Vapourization of water $= L_v$
Initial temperature of water & Calorimeter $= T_1$
Final temperature of mixture $= T_2$
Now,
Heat loss by Steam $= m_s L_v + m_s S_w (100 - T_2)$
And Heat gain by water & calorimeter $= m_c S_c (T_2 - T_1) + m_w S_w (T_2 - T_1)$
$= (m_c S_c + m_w S_w)(T_2 - T_1)$

Then,
According to principle of Calorimetry:
Heat gain = Heat loss

or, $(m_c S_c + m_w S_w)(T_2 - T_1) = m_s L_v + m_s S_w (100 - T_2)$

or, $m_s L_v = (m_c S_c + m_w S_w)(T_2 - T_1) - m_s S_w (100 - T_2)$

$$\Rightarrow \boxed{L_v = \frac{(m_c S_c + m_w S_w)(T_2 - T_1)}{m_s} - S_w (100 - T_2)} \ \#$$

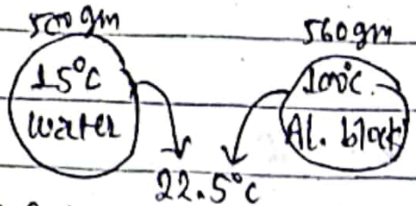
Hence, By knowing the Specific heat Capacity of material of Calorimeter and water, the latent heat of Vapourization of water Can be Calculated.

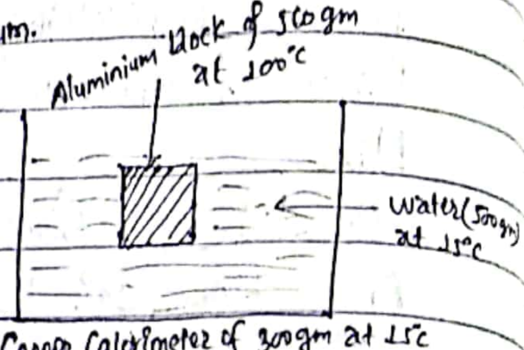
Numericals

$$\boxed{\rho = \frac{m}{v} \Rightarrow v = \frac{m}{\rho}}$$

Q. 1[A] A copper calorimeter of mass 300 gm contains 500gm water at temperature 15°c. A 560 gm block of aluminium at temperature 100°c is dropped in the calorimeter & temp^n is observed to increase to 22.5°c. Find the specific heat capacity of aluminium.

★ Sol^n:-





According to principle of Calorimetry,
Now, Heat loss = Heat gain,

or, $m_a s_a (100 - 22.5) = m_w s_w (22.5 - 15) + m_c s_c (22.5 - 15)$

or, $0.56 \times s_a (77.5) = 0.5 \times (4200)(7.5) + (0.3)(390)(7.5)$

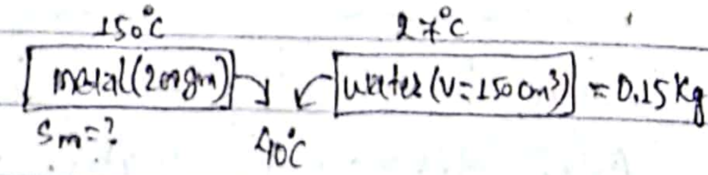
or, $(43.4)\, s_a = 15750 + 877.5$

$\Rightarrow s_a = 383.12 \text{ J Kg}^{-1}\,°c^{-1}$

Hence, specific heat capacity of aluminium is $383.12 \text{ J Kg}^{-1}\,°c^{-1}$.

Q. 1[B] In an experiment on the specific heat of a metal, a 200g block of metal at 150°c is dropped in a copper calorimeter of mass 270g containing 150 cm³ of water at 27°c. The final temp^n is 40°c. Calculate the specific heat of the metal. [$s_c = 390$ J/kg°c]

★ Sol^n:- Given,



Vol^m of water $= 150 \text{cm}^3$

or, $m/\rho = 150 \text{ cm}^3$

or, $m = 150 \times 10^{-6} \text{m}^3 \times 1000 \text{ kg/m}^3 = 0.15 \text{Kg}$

Now, According to principle of Calorimetry,
Heat loss by block metal = Heat gain by calorimeter & water

or, $m_m s_m (150 - 40) = m_c s_c (40 - 27) + m_w s_w (40 - 27)$

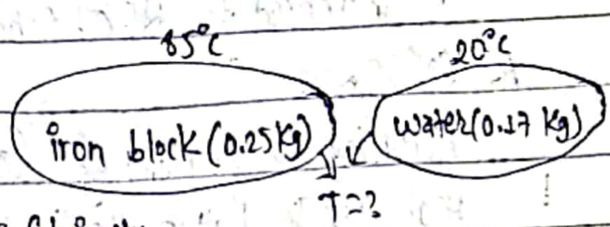
or, $0.2 \times s_m (110) = 0.27 \times 390 (13) + 0.15 \times 4200 (13)$

or, $22\, s_m = 9558.9$

$\Rightarrow s_m = 434.5 \text{ J/kg°c}$

Thus, specific heat capacity of metal is $434.5 \text{ J Kg}^{-1}\,°c^{-1}$.

Q.1[C] A Copper pot with mass 0.5 Kg Contains 0.170 kg of water at a temperature of 20°C. A 0.250 Kg block of iron at 85°c is dropped into the pot. Find the final temperature assuming no heat loss to the Surroundings.



Sol^n :-

Now, According to principle of Calorimetry,

Heat loss by iron block = Heat gain by water & Calorimeter

or, $m_i S_i (85-T) = m_w S_w (T-20) + m_c S_c (T-20)$

or, $0.25 (470) (85-T) = [0.17\times4200 + 0.5\times390] (T-20)$

or, $117 (85-T) = 909 (T-20)$

or, $9945 - 117T = 909T - 18180$

or, $28125 = 1026T$

$\Rightarrow \boxed{T = 27.41°C}$

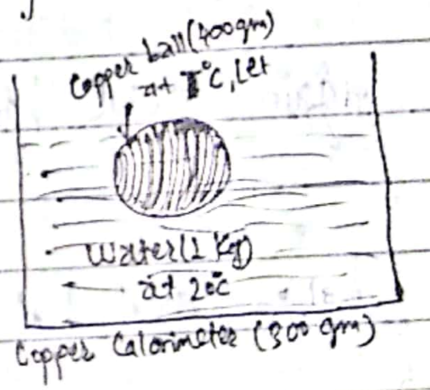
Hence, the resultant temperature is 27.41°c Ans

Q.1[D] A Copper Calorimeter of mass 300 gm Contains 500 gm of water at a temperature of 15°c. A 560 gm block of aluminium at temperature of 100°c is dropped in a water of the Calorimeter and the temperature is observed to increase 22.5°c. Find specific heat capacity of aluminium?

⇒ please refer's to Q.1(A).

Q.1[E] A ball of Copper weighing 400 gm is transfered from a furnace to a Copper Calorimeter of mass 300 gm & Containing 1 kg of water at 20°c. The temperature of water rises to 50°c. What is the original temperature of ball?

Sol^n :- Now,



According to principle of Calorimetry;

Heat loss by ball = Heat gain by Calorimeter & water

or, $m_b S_b (T-50) = m_c S_c (50-20) + m_w S_w (50-20)$

or, $0.4 \times 390 (T-50) = (0.3\times390\times30) + (1\times4200\times30)$

or, $156T - 7800 = 129510$

$\Rightarrow \boxed{T = 880°C}$ Hence, the original temperature ball is 880°C. Ans

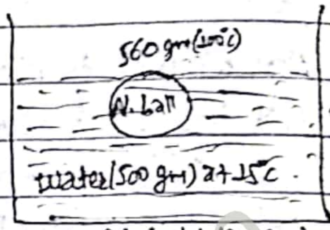
126000

Q.1[F] A Copper Calorimeter of mass 300g contains 500g of water at 15°C. A 560 gm of Aluminium Ball at temperature 100°C is dropped in the Calorimeter & the temperature is increased to 25°C. Find the Specific heat Capacity of aluminium.

★ Solⁿ:- Now,

According to principle of Calorimetry;

Heat loss by ball = Heat gain by water & Calorimeter.



Copper Calorimeter (70 gm) at 15°C

or, $m_b S_b(100-25) = m_w S_w(25-15) + m_c S_c(25-15)$

or, $0.56 \times S_b (75) = [0.5 \times 4200 + 0.3 \times 390] 10$

or, $42\, S_b = 21000 + 1170$

$\Rightarrow \boxed{S_b = 527.85\ J\,Kg^{-1}.C^{-1}}$ thus, Specific heat Capacity of aluminium = $527.85\ J\,Kg^{-1}C^{-1}$.

Q.2[A] How much heat is required to convert 10kg of ice at -10°C into steam at 100°C? [Sp. heat of ice = 2100 $J\,Kg^{-1}K^{-1}$, $L_f = 3.36 \times 10^5\ J\,Kg^{-1}$, $L_v = 2.268 \times 10^6\ J\,Kg^{-1}$]

★ Solⁿ:-

-10°C ice $\xrightarrow{Q_1}$ 0°C ice $\xrightarrow{Q_2}$ 0°C water $\xrightarrow{Q_3}$ 100°C water $\xrightarrow{Q_4}$ 100°C Steam

$Q_1 = m_i S_i[0-(-10)]$
$= 10 \times 2100 (10)$
$= 210000\ J$

$Q_2 = m_i L_f$
$= 10(3.36 \times 10^5)$
$= 3.36 \times 10^6\ J$

$Q_3 = m_i S_w (100-0)$
$= 10 \times 4200 \times 100$
$= 4200000\ J$

$Q_4 = m_i L_v$
$= 10 \times 2.268 \times 10^6$
$= 2.268 \times 10^7\ J$

Again, Total heat required (Q) = $Q_1 + Q_2 + Q_3 + Q_4$

$= (210000 + 3.36 \times 10^6 + 4200000 + 2.268 \times 10^7)\ J$

$= 30450000\ J$

Thus, Total heat required $= 3.045 \times 10^7\ J$ #

Q.2[B] How much heat is required to Convert 5 kg of ice at -10°C into steam at 100°C?

Soln:-

$$\text{-10°C ice} \xrightarrow{Q_1} \text{0°C ice} \xrightarrow{Q_2} \text{0°C water} \xrightarrow{Q_3} \text{100°C water} \xrightarrow{Q_4} \text{100°C steam}$$

Now,

$Q_1 = m_i s_i [0-(-10)]$ $\quad Q_2 = m_i L_f$ $\quad Q_3 = m_i s_w(100-0)$ $\quad Q_4 = m_i L_v$

$= 5 \times 2100 \times 10$ $\quad = 5 \times 3.36 \times 10^5$ $\quad = 5 \times 4200(100)$ $\quad = 5 \times 2.268 \times 10^6$

$= 105000\ J$ $\quad = 16.8 \times 10^5\ J$ $\quad = 2.1 \times 10^6\ J$ $\quad = 11.34 \times 10^6\ J$

Again,

Total heat required (Q) $= Q_1 + Q_2 + Q_3 + Q_4 = (105000 + 16.8 \times 10^5 + 2.1 \times 10^6 + 11.34 \times 10^6)\ J = 1.52 \times 10^7\ J$ #

Q.2[i] How much heat is needed to change 10 g of ice at -10°C to steam at 100°C. [Sp. heat of ice = 0.5 cal/gm°C, L_f = 80 cal/gm, L_v = 540 cal/gm]

Soln:-

$$\text{-10°C ice} \xrightarrow{Q_1} \text{0°C ice} \xrightarrow{Q_2} \text{0°C water} \xrightarrow{Q_3} \text{100°C water} \xrightarrow{Q_4} \text{100°C steam}$$

$Q_1 = m_i s_i [0-(-10)]$ $\quad Q_2 = m_i L_f$ $\quad Q_3 = m_i s_w (100-0)$ $\quad Q_4 = m_i L_v$

$= 10 \times 0.5(10)$ $\quad = 10 \times 80$ $\quad = 10 \times 1(100)$ $\quad = 10 \times 540$

$= 50$ Cal. $\quad = 800$ Cal. $\quad = 1000$ Cal. $\quad = 5400$ Cal.

Again,

∴ Total heat required (Q) $= Q_1 + Q_2 + Q_3 + Q_4$

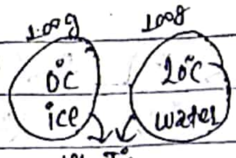
$= (50 + 800 + 1000 + 5400)$ Cal

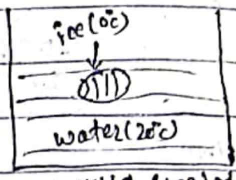
$= 7250$ Cal

$= 30450\ J$ #

Q.3[A] What is the result of mixing 100g of ice at 0°c into 100g of water at 20°c in an iron vessel of mass 100g?

A Sol^n:- $S_v = 0.1$ cal/gm°c.





Iron vessel (100g) at 20°c

According to principle of Calorimetry,
Heat loss = Heat gain

or, $m_w S_w(20-T) + m_v S_v(20-T) = m_i L_f + m_i S_w(T-0)$

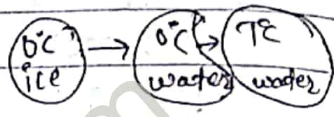
or, $[(100\times1)+(100\times0.1)](20-T) = 100(80) + 100(1)(T)$

or, $110(20-T) = 8000 + 100T$

or, $2200 - 110T = 8000 + 100T$

or, $-5800 = 210T$

$\Rightarrow \boxed{T = -27.6°c}$



So, Heat loss by water & vessel at 0°c,
= Heat gain by ice at 0°c

or, $110(20-0) = m.80$

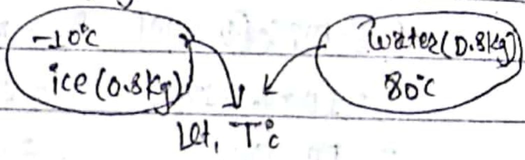
$\Rightarrow \boxed{m = 27.5\ gm}$ of ice at 0°c

It shows that, all amount of ice does not melt.
therefore, resulting temp^r must be 0°c.

Hence, resulting mixture contains (100+27.5)gm = 127.5gm of water & (100−27.5)gm = 72.5gm of ice.

Q.3[B] Find the result of mixing 0.8kg of ice at −10°c with 0.8kg of water at 80°c?

A Sol^n:- Now,



According to principle of Calorimetry;
Heat loss = Heat gain

or, $m_w S_w(80-T) = m_i S_i[0-(-10)] + m_i S_w(T-0) + m_i L_f$

or, $0.8\times4200(80-T) = 0.8\times2100(10) + 0.8\times4200\times T + 0.8\times80\times4.2\times1000$

or, $268800 - 3360T = 16800 + 3360T + 268800$

or, $-16800 = 6720T$

$\Rightarrow \boxed{T = -2.5°c}$ It shows that, ice does not completely melt. It should be 0°c.

then, Heat loss = Heat gain (at 0°c)

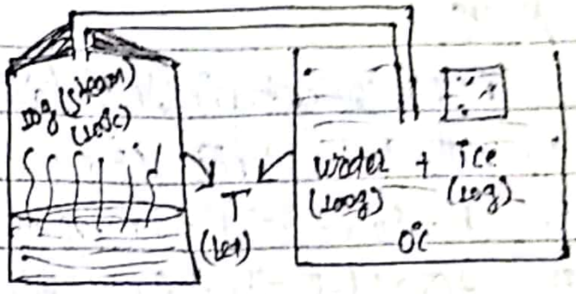
or, $16800 + mL_f = 268800 + 3360(0)$

$\Rightarrow m = 0.75$ Kg

$\therefore$ water = (0.75+0.8) Kg = 1.55 Kg & ice = (0.8−0.75) Kg = 0.05 Kg

Q.3[C] 10g of steam at 100°C is passed into a mixture of 100g of water & 10g of ice at 0°C. Find the resulting temperature of the mixture?

★ Sol^n :-



According to principle of Calorimetry,

⇒ Heat gain = Heat loss

or, $m_w s_w (T-0) + m_i L_f + m_i s_w (T-0) = m_s L_v + m_s s_w (100-T)$

or, $100\times 1(T) + (10\times 80) + 10\times 1(T) = (10\times 540) + 10\times 1\times(100-T)$

or, $100T + 800 + 10T = 5400 + 1000 - 10T$

0°C ice → 0°C water → T°C water

or, $120T = 5600$

⇒ $\boxed{T = 46.67°C}$ Which is resultant temperature.

Q.3[D] What is the result of mixing 10gm of ice at 0°C into 15gm of water at 20°C in a vessel of mass 100g and specific heat 0.09?

★ Sol^n :- Heat loss = Heat gain

0°C ice (10 gm) → T (say) ← 20°C water (15 gm)

or, $m_v s_v (20-T) + m_w s_w (20-T) = m_i L_f + m_i s_w (T-0)$

or, $15\times 1(20-T) + 100\times 0.09\times(20-T) = (10\times 80) + (10\times 1\times T)$

or, $[9+15](20-T) = 800 + 10T$

or, $480 - 24T = 800 + 10T$

or, $-320 = 34T$

⇒ $\boxed{T = -9.41°C}$

It shows that ice does not melt completely. It should be 0°C.

If resultant temperature is 0°C then,

Heat loss by water & vessel = Heat gain by ice

or, $m_w s_w (20-0) + m_v s_v (20-0) = m L_f$

or, $15\times 1(20) + (100\times 0.09\times 20) = m\times 80$

⇒ $m = 6$ gm.

Hence, water must be (15+6) = 21 gm & ice must be (10−6) = 4 gm then ice will be fully melt.

Q.3[E] What is the result of mixing 100g of ice at 0°C and 100g of water at 100°C.
[$L_f = 336 \times 10^3\ JK^{-1}$, $S_w = 4200\ J/kg°C$]

★ Solⁿ:-

0°C ice (100 gm) → T°C (say) ← 100°C water (100 gm)

Now, According to principle of Calorimetry;

⇒ Heat loss = Heat gain,

or, $m_w S_w (100 - T) = m_i L_f + m_i S_w (T - 0)$

or, $100 \times 1 (100 - T) = (100 \times 80) + (100 \times 1 \times T)$

or, $10000 - 100T = 8000 + 100T$

or, $2000 = 200T$

⇒ $\boxed{T = 10°C}$ Hence, ice will be completely melt at resulting tempʳ 10°C.#

Q.4[A] A substance takes 3 minutes in cooling from 50°C to 45°C and takes 5 minutes in cooling 45°C to 40°C. What is the temperature of surroundings?

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★ Solⁿ:- We know,

According to Newton's law of cooling;

$$\frac{d\theta}{dt} = -K(T - T_s)$$

or, $$\frac{(50-45)}{3} = -K(50 - T_s) \quad \text{——(i)}$$

& $$\frac{(45-40)}{5} = -K(45 - T_s) \quad \text{——(ii)}$$

dividing eqⁿ (i) by (ii)

or, $$\frac{5/3}{5/5} = \frac{(50 - T_s)}{45 - T_s}$$

or, $$\frac{5}{3} = \frac{50 - T_s}{45 - T_s}$$

or, $225 - 5T_s = 150 - 3T_s$

or, $75 = 2T_s$

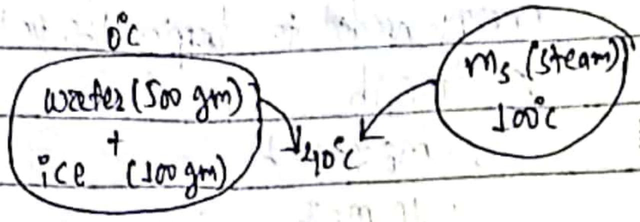
⇒ $\boxed{T_s = 37.5°C}$

Hence,
Temperature of surroundings is 37.5°C.#

Q.5[A] A mixture of 500g water and 100g ice at 0°c is kept in a copper calorimeter of mass 200g. How much steam from the boiler be passed to the mixture so that the temperature of the mixture reaches to 40°c?

Sol^n: -

$0°c$ → $0°c$ → $40°c$
ice water water



Here, Heat gain = Heat loss

or, $(m_w s_w + m_c s_c)(40-0) + m_i L_f + m_i s_w(40-0) = m_s L_v + m_s s_w(100-40)$

or, $(0.5\times4200 + 0.2\times390)40 + (0.1\times336000) + (0.1\times4200\times40) = m_s[226800 + (4200\times60)]$

or, $87120 + 33600 + 16800 = m_s(252000)$

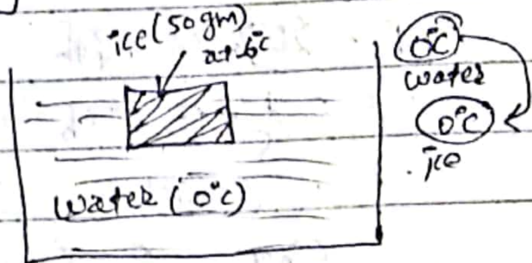
⇒ $\boxed{m_s = 54.57 \text{ gm}}$

Hence, 54.57 gm of steam were passed to the mixture.

Q.5[B] 50 gm of ice at -6°c is dropped into water at 0°c. How many grams of water freeze? [sp heat of ice = 2000 J kg^{-1}°c^{-1}]

Sol^n: -

$-6°c$ → $0°c$ →
ice ~~water~~ ice



Here,

Heat gain = Heat loss

or, $m_i s_i[0-(-6)] + \ldots = m_w L_f$

or, $0.05\times2000(6) = m_w(336000)$

⇒ $m_w = \frac{600}{336000} = 1.785$ kg will freeze.

Q.6[A] From what height should a block of ice be dropped in order that it may melt Completely?

Sol^n:-

then, $0^\circ C \rightarrow 0^\circ C$
ice → water

Energy needed to dropping the ice block,

$E_1 = m_i g h$
$= m_i \times 10 \times h$
$= 10\, m_i h$

$E_2 = m_i L_f$
$= m_i \times 336000$

Ice will be melt completely, when $E_1 = E_2$

or, $10\, m_i h = m_i \cdot 336000$

$\Rightarrow \boxed{h = 33600\ m}$

Hence, from 33600 m height ice will be melt.

Q.6[B] From what height a block of ice be dropped in order that it may completely melt. It is assumed that 20% of energy of fall is retained by ice. [$L = 80$ cal/gm]

Sol^n:-

$E_1 = 20\%$ of $m_i g h$
$= \frac{1}{5} \times m_i \times 10 \times h$
$= 2\, m_i h$

& $E_2 = m_i L_f$
$= m_i \times 336000$

Since, $E_1 = E_2$ [$\because$ ice will be melt completely]

or, $2\, m_i h = 336000\, m_i$

$\Rightarrow \boxed{h = 168000\ m}$

Hence, from 168000 m height ice will be melt completely.

Evaporation or perspiration is an important mechanism for temperature control of warm-blooded animals. What mass of water must evaporate from the surface of an 80 kg human body to cool it by 1°C? The specific heat capacity of the human body is approximately 0.1 cal gm^{-1} $°C^{-1}$ and L_v of water at the body temperature is 577 cal/gm?

Sol^n:-

$Q_1 = m s \Delta t$
$= 80 \times 1000 \times 0.1 \times (1)$
$= 8000 J$

$Q_2 = m_w L_v$
$= m_w \times 577$

Here, $Q_1 = Q_2$ [∵ Heat loss = Heat gain]

or, $m_w \times 577 = 8000$

$\Rightarrow m_w = 13.86$ gm $= 0.0138$ kg

Hence, 0.0138 kg of water must evaporate. Ans