Chapter Calorimetry

Day - 1

Amount of heat given or taken

If temperature is changing but state (Solid, liquid, gas) remains unchanged $Q = ms\Delta T$

Here,

Q is amount of heat

m is mass of substance

ΔT is change in temperature

And s is specific heat

$Q = mL$

If temperature is not changing but state (Solid, liquid, gas) must be change

Here,

m is mass

Some standard values

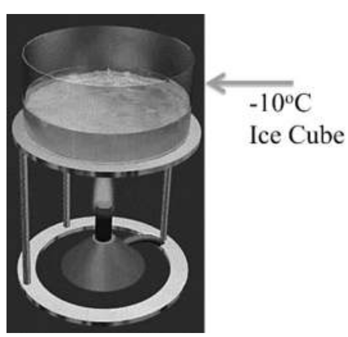
S for water = 1 if m is in gram

S for ice = 0.5 if m is in gram

$$\left.\begin{aligned}\text{L for ice} &= 78 \\ &\approx 80\end{aligned}\right\} \text{if m is in gram}$$

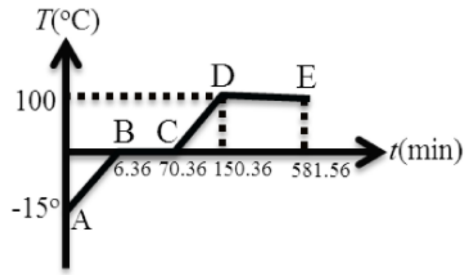
$$\left.\begin{aligned}L \text{ for steam} &= 536 \\ &\approx 540\end{aligned}\right\} \text{if m is in gram}$$

CALORIMETRY



Example:- How much heat is required to convert 8 gm of ice at – 15 ^oC to steam at 100 ^oC if heat is supplied at a constant rate of q =10 cal/min then plot temperature versus time graph .(Given c_{ice} = 0.53 cal/g ^oC , L_f = 80 cal/ gm , and L_v =539 cal/gm and c_{water}= 1 cal/gm ^oC

Solution:



From A to B

(i) temperature of ice will increase from -15^oC to 0^oC

(ii) $t_{AB} = \frac{\text{Total heat required}}{\text{Heat supplied per minute}} = \frac{Q_1}{q}$

$$= \frac{63.6}{10} = 6.36 \text{ min}$$

(iii) Between A and B we will get only ice.

From B to C

(i) Temperature of (ice + water) mixture will remain constant at 0^oC.

(ii) $t_{BC} = \frac{Q_2}{q} = \frac{640}{10} = 64 \text{ min}$

$$\therefore\ t_{Total} = t_{AB} + t_{BC} = 70.36 \text{ min}$$

From C to D

(i) Temperature of water increase from 0^oC to 100^oC

(ii) $t_{CD} = \frac{Q_3}{q} = \frac{800}{10} = 80 \text{ min}$

$$\therefore\ t_{Total} = t_{AB} + t_{BC} + t_{CD} = 150.36 \text{ min}$$

(iii) Between C and D we will get only water.

From D to E

(i) Temperature of (water + steam) mixture will remain constant at 100^oC.

(ii) $t_{DE} = \frac{Q_4}{q} = \frac{4312}{10} = 431.2 \text{ min}$

$$\therefore\ t_{Total} = t_{AB} + t_{BC} + t_{CD} + t_{DE} = 581.56 \text{ min}$$

(iii) Between D and A we will get both water and steam.

The corresponding graph is as shown is as shown in Fig. given above.

Example:- The temperature of equal masses of three different liquids A, B and C are 12°C, 19°C and 28°C respectively. The temperature when A and B are mixed is 16°C and when B and c are mixed it is 23°C. what should be the temperature when A and C are mixed?

Solution: Let m be the mass of each liquid and S_A, S_B, S_C specific heats of liquids A, B, and C respectively. When A and B are mixed. The final temperature is 16°C.

$$\therefore \quad \text{Heat gained by A} = \text{Heat lost by B}$$

$$\text{i.e.,} \quad ms_A(16-12) = ms_B(19-16)$$

$$\text{i.e.,} \qquad s_B = \frac{4}{3}s_A$$

When B and C are mixed.

Heat gained by B = Heat lost by C

$$\text{i.e.,} \quad ms_B(23-19) = ms_C(28-23)$$

From Eqs. (i) and (iii), $S_C = \frac{4}{5} \times \frac{4}{3} S_A = \frac{16}{15} S_A$

When A and C are mixed, left the final temperature be θ

Heat gained by A = Heat lost by C

$$ms_A(\theta - 12) = ms_C(28-\theta)$$

$$\text{i.e.,} \quad \theta - 12 = \frac{16}{15}(28-\theta)$$

By solving, we get

$$\theta = \frac{628}{31} = 20.26^oC$$

Example:- In an insulated vessel, 0.05 kg steam at 373 K and 0.45 kg of ice at 253 K are mixed. Find the final temperature of the mixture (in kelvin). (JEE Adv. 2006)

Given, , $L_{fusion} = 80\frac{cal}{g} = 336\ J/g$

$$L_{vaporization} = 540 cal/g = \ 2268 J/g$$

$$s_{ice} = 2100\frac{J}{kg} - K = 0.5\ cal/g - K$$

$$\text{and} \qquad s_{water} = 4200\frac{J}{kg} - K = 1\frac{Cal}{g} - K$$

Solution: $0.05\text{ kg steam at 373 K} \xrightarrow{Q_1} 0.05\text{ kg water at 373 K}$

$$0.05\text{ kg water at 373 K} \xrightarrow{Q_2} 0.05\text{ kg water at 273 K}$$

$$0.45\text{ Kg ice at 253 k} \xrightarrow{Q_3} 0.45\text{ kg ice at 273 K}$$

$$0.45\text{ kg ice at 273 K} \xrightarrow{Q_4} 0.45\text{ kg water at 273 K}$$

$Q_1 = (50)(540) = 27{,}000\text{ cal}$ = 27 k cal.

$$Q_2 = (50)(1)(100) = 5000 cal = 5\text{ k cal}$$

$$Q_3 = (450)(0.5)(20) = 4500\text{ cal} = 4.5\text{ k cal}$$

$Q_4 = (450)(80) = 36000 \text{ cal} = 36 \text{ k cal}$

Now, since $Q_1 + Q_2 > Q_3$ but $Q_1 < Q_2 < Q_3 + Q_4$ ice will come to 273 K from 253 K, but whole ice will not melt. Therefore, temperature of the mixture is 273 K.

Ex. 22.7. An ice cube of mass 0.1 kg at 0^oC is placed in an isolated container which is at 227^oC. The specific heat s of the container varies with temperature T according to the empirical relation s = A + BT, where A = 100 cal /kg-K and B = 2 x 10^{-2} cal/kg-K^2. If the final temperature of the container is 27^oC, determine the mass of the container. (JEE Adv. 2001)

(Latent heat of fusion for water = 8 x 10^4 cal/kg, specific heat of water =10^3 cal/kg -K)

Solution: Let m be the mass of the container.

Initial temperature of container,

$$T_i = (227 + 273) = 500 \text{ K}$$

And final temperature of container,

$$T_f = (27 + 273) = 300 \text{ K}$$

Now, heat gained by the ice cube = heat lost by the container

$$\therefore \quad (0.1)(8 \times 10^4) + (0.1)(10^3)(27) = -m \int_{500}^{300} (A + BT)\, dT$$

$$\text{or} \quad 10700 = -m \left[AT + \frac{BT^2}{2} \right]_{500}^{300}$$

After substituting the values of A and B and the proper limits, we get

$$m = 0.495 \text{ kg}$$

Day 2 and Day 3 Main & Advance Questions

Please watch videos for the questions and also practice online assignments