CHAPTER TWELVE

LATENT HEAT

The latent of vaporization:

- This is the quantity of heat which is required to change the whole mass of a substance from the liquid to the vapour state, at its boiling point without a change in temperature.
- When water is heated, its temperature rises steadily until it reaches 100^0C which is its boiling point.
- It then starts to boil and once it starts boiling, its temperature remains constant at 100^0C.
- But at the same time, heat is being steadily absorbed by the water from the source of heating such as a heater or a burner.
- This heat which goes into the water but does not cause a change in its temperature, is the energy needed to convert the water from the liquid state into the vapour state and is called the latent heat of vapourization.
- But the amount of heat which is needed to convert a unit mass, (1kg) of a liquid into vapour as its boiling point (constant temperature), is called the specific latent heat of vapourization.
- For example, experiment shows that 2260000J is required to convert 1kg of water at its boiling point into steam at the same temperature, and this is what is referred to as the specific latent heat of steam.
- When the steam condenses to form water, this latent heat is given out.
- Because steam contains more or additional heat as compared to boiling water, a scald from steam does more harm than one from boiling water.
- The S.I unit of specific latent heat of vaporization is the joule per kilogram (J/kg).
- However kJ/kg or MJ/kg may be used instead.
- 1kJ = 1000J and 1MJ = 1000000J.
- For example, the specific latent heat of vaporization of water is 2260kJ/kg, or 2.26MJ/kg.

- The latent heat of vaporization = ml, where m = mass and l = the specific latent heat of vaporization.

(Q1) Calculate the amount of heat needed to change 5kg of a substance into the vapour state at its boiling point. [Take the specific latent heat of vaporization of the substance = 2J/kg].

N/B: Since the mass of the substance is given in kg and the latent heat of vaporization is given in J/kg, we therefore solve the question without doing any conversion.

Soln:

Mass = m = 5kg.
Specific latent heat of vaporization = l = 2J/kg.
The amount of heat needed is the latent heat of vaporization = $m \times l = 5 \times 2 = 10$J.

(Q2) The mass of a body is 1.5kg and its specific latent heat of vaporization is 2260J/g. Determine the amount of heat which will be needed to change this liquid into the vapour state at its boiling point.

N/B: Since the mass is given in kg and the specific latent heat is given in J/g, we must first convert the 1.5kg into grams.

Soln:

m = 1.5kg = 1500g.

L = 2260J/g.

The amount of heat needed = ml = 1500×2260

= 3390000J = 3390kJ.

(Q3) A liquid of mass 20kg is at a temperature of 10^0C, and has a boiling point of 50^0c. Determine the amount of heat which will be needed to evaporate the whole liquid. [The specific latent heat of vaporization of the liquid = 2J/kg, and the specific heat capacity of the liquid = 4J/kg^{0}C].

Soln:

(a)- First the liquid will be heated from its initial temperature of 10^0C to its boiling point of 50^0c.

- The amount of heat needed in this case, is the heat capacity where m = 20kg and

c = specific heat capacity of the liquid = $4J/kg^0c$.

Amount of heat needed = m x c x $\triangle\theta$ = $20 \times 4 \times 40$ = 3200J.

(b)- At the boiling point, the temperature remains constant and the liquid changes into the vapour state.

- The amount of heat needed is the latent heat of vaporization = ml or $m \times l$,

where m = mass = 20kg and l = the specific latent heat of vaporization.

=> The amount of heat needed = ml = 20×2 = 40J.

The amount of heat needed to change the liquid from 10^0c into the vapour state

= 3200 + 40 = 3240J or 3.24kJ.

(Q4) 116360J of heat was needed in order to evaporate a certain amount of water, whose temperature was 20^0c. Calculate the mass of the water which was evaporated. [Boiling point of water = 100^0c, specific latent heat of steam = 2260J/g, the specific heat capacity of water = $4.2J/g^0c$].

Soln:

(a)Let m = the mass of water. The water first heats from 20^0c to its boiling point of 100^0C.

The amount of heat needed to do this = $m \times c \times \triangle\theta$

= $m \times 4.2 \times (100 - 20)$

= $m \times 4.2 \times 80$ = 336m.

(b) The amount of heat needed to convert the water at its boiling point into steam = ml = m $\times$ 2260 = 2260m.

(c)The total amount of heat needed to convert the water from 20^0C into vapour = 336m + 2260m = 2596m.

Since the amount of heat needed to convert the water from 20^0c into water vapour = 116360J, then 2596m = 116360,

=> m = $\frac{116360}{2596} = 45g.$

N/B: - Since both the specific heat capacity of water i.e. 4.2J/g^0C and the specific latent heat of steam i.e. 2260J/g are both given is grams, our answer must be in grams but not in kg.

- The amount of heat generated within an electrical heating device or a material heating device or a material is given by heat generated = IVt, where I = current in amperes, V = the P.d or the potential difference in volts and t = time in seconds.
- Also, the amount of heat generated is also given by heat generated = I^2Rt, where I = current in amperes, R = the resistance in ohm (Ω), and t = time in seconds.

(Q5) All the heat generated in a 5Ω resistor by a current of 2A flowing for 30 seconds, was used to evaporate 5g of a liquid at its boiling point. Calculate the specific latent heat of the liquid.

Soln:

The heat generated within the 5Ω resistor = I^2Rt, where I = 2A, R = 5Ω and t = 30 seconds.

=> The heat generated = $2^2 \times 5 \times 30$ = 600J.

- This was the amount of heat, which was used to evaporate the 5g of the liquid at its boiling point.

- Also since the liquid is already at its boiling point, only the latent heat of vaporization will be needed for this change to occur.

=> Amount of heat needed = ml = 5 $\times$ l = 5l, where l = the specific heat of vaporization.

Since the amount of heat needed = 600J, => 5l = 600,

=> l = $\frac{600}{5} = 120\text{J}/g$.

N/B: The latent heat of vaporization of a substance is the amount of heat needed, to convert the whole substance from the liquid state into the vapour state, at its boiling point.
-Latent heat of vaporization = ml, where m = mass of the substance and l = its specific heat of vaporization.

Example : If 4220 J of heat was used to evaporate 5kg of a liquid at its boiling point into the vapour state, determine the specific heat of vaporization of the liquid.

Soln:

Latent heat of vaporization = 4220J.

Mass = m = 5kg.

Specific heat of vaporization = l =?

Since latent heat of vaporization = ml, => 4220 = 5l => l = $\frac{4220}{5} = 884$.

=> The specific latent heat of vaporization of the liquid = 884J/kg.

(Q6) 50g of steam was condensed into liquid which was then allowed to cool from 100^0C to 30^0c. Determine the amount of heat given out. [Specific latent heat of steam = 2260J/g, the specific heat capacity of water = 4.2J/g^{0}C].

Soln:
(a)The steam first condenses into liquid and the heat given out = the latent heat of vaporization = ml = 50 $\times$ 2260 = 113000J.

(b)The condensed steam or the liquid then cools from 100^0c to 30^0C, and the heat given out = m $\times$ c $\times \Delta\theta$ = 50 $\times$ 4.2 $\times$ (100 – 30) = 50 $\times$ 4.2 $\times$ 70 = 14700J.

Amount of heat therefore given out = 113000 + 14700 = 128KJ.

(Q7) 0.05kg of steam which was contained in a can, was allowed to cool to a temperature of 20^0C. Calculate the amount of heat given out by the steam and the can. [specific latent heat of steam = 2260J/g, specific heat capacity of water = $4.2J/g^0C$, thermal heat capacity of the can = $4J/^0c$].

N/B: Since the mass is in kg, and the specific latent heat of vapourization as well as the specific heat capacity are associated with grams, then the mass in kilogram must be converted into grams.

Soln:

Mass of steam = 0.05kg = 0.05×1000 = 50g.

The temperature of steam = 100^0c.

Since the steam was contained within the can => the initial temperature of the can = 100^0C.

(a) The steam first condenses into water, and the heat given out is the latent heat of vaporization = ml = 50×2260 = 113000J.

(b) The heat given out by the condensed steam (water) cooling from 100^0C to 20^0C

$= m \times c \times \triangle\theta = 50 \times 4.2 \times (100 - 20)$
$= 50 \times 4.2 \times 80 = 16800J.$

(c) The heat given out by the can in cooling from 100^0c to 20^0c = thermal heat capacity $\triangle\theta = 4 \times (100 - 20) = 4 \times 80 = 320J.$

Therefore the total heat given out by the steam and the can = 113000 + 16800 + 320 = 130120J or 130kJ.

The latent heat fusion:

- Just as latent heat is taken in when water changes from the liquid state into the vapour state at a constant temperature, almost a similar thing happens when water changes into ice at a constant temperature.
- The latent heat of fusion is the amount of heat, which is needed to change a substance from the liquid state into the solid state, or from the solid state into the liquid state at a

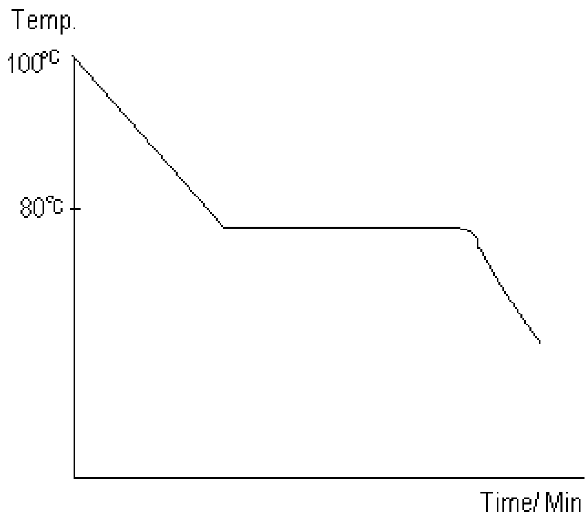
constant temperature.

- The specific latent heat of fusion of a substance is the amount of heat, which is needed to convert a unit mass (1kg) of it, from either the solid into the liquid state, or from the liquid into the solid state, at a constant temperature (I.e. the freezing or the melting point).

- For example, latent heat of fusion is absorbed or needed in order to convert ice at 0^0C into water at the same temperature.
- Likewise when water at 0^0C freezes into ice, the same quantity of heat (i.e. the latent heat of fusion), is needed.
- Other substances apart from water also absorb latent heat of fusion when they melt.
- They also give out this latent heat when they solidify.
- The latent heat of fusion = ml, where m = the mass and l = the specific latent heat of fusion.
- Its unit is J/kg, kJ/kg or MJ/kg.

The determination of the melting point of a substance, from a cooling curve:

- The latent heat given out when a molten substance freezes into the solid state, can be investigated by using the following experiment with naphthalene.
- A test tube containing naphthalene is held vertically by a clamp and a stand.
- The naphthalene is then gently heated by a very small flame until it melts.
- A thermometer is inserted into the naphthalene, and the heating continued till the temperature gets to around 100^{0c}.
- The Bunsen flame is then removed and readings of the thermometer are taken at small interval as the tube and its contents cooling.
- It will be noticed that when the freezing point or what is the same as the melting point of the naphthalene is reached (i.e. 80^0C), the temperature remains constant until all the naphthalene has solidified, and after all the naphthalene has solidified, the temperature then begins to fall continuously.



- The temperature changes can be illustrated, by plotting a graph of temperature against time.
- The flat portion or the straight line portion of the graph represents the time during which the naphthalene was solidifying.
- At this stage, i.e. 80^0C, the temperature becomes constant even though heat is being lost or gained by the naphthalene.
-This heat being lost or gained which does not cause a change in temperature is what is referred to as the latent heat of fusion.
- And it only causes a change of state of the substance (i.e. either from the liquid into the solid state or from the solid into the liquid state), without causing an increase or decrease in temperature of the substance.
- The flat portion or the straight line portion of the curve gives us the melting point of the substance (naphthalene).

(Q1) A substance of mass 2kg is solid in state, even though it is at its melting point. Determine the amount of heat needed to melt it. [The specific latent heat fusion of the substance = 10J/kg].

Soln:

Since the substance is at its melting point, then the amount of heat needed to melt it = the latent heat of fusion = ml = $2 \times 10 = 20$J.

(Q2) The specific latent heat of fusion of ice is given as 336J/g.

(a) Explain what this statement means.
(b) Determine the amount of heat, which will be needed to melt 5g of ice into water.

Soln:

(a) This means that the amount of heat needed to convert 1kg of ice into water at a constant temperature of 0^0C, is 336J.
(b) Mass = m = 5g.

Specific latent heat of fusion = l = 336J.

Amount of heat needed = ml = 5 x 336 = 1680J = 1.68KJ.