Chapter 5. Heat

Solution 1

PAGE NO-259:

(a)J/kg ^{o}C(b)2000 / (4 x 3) J/kg ^{o}C(c)AB and CD(d)Latent heat is emitted(e)The first time when temperature is constant represents change of state from solid to liquid and the second time temperature is constant represents change of state from liquid to vapour.

PAGE NO-260:

Solution 2

(a)Heat capacity of a body is the quantity of heat required to raise its temperature by 1^{o}C. It depends upon the mass and the nature of the body.Units: J/^{o}C or calorie/^{o}C(b)Change in temperature = (50-30) = 20^{o}C Amount of heat required, Q = m x C x ?T = 0.5 x 4200 x 20 = 42000 J

Solution 3

(a)This means that 390 J of heat is required to raise the temperature of 1kg of copper by 1^{o}C.(b)Change in temperature = (100-30) = 70^{o}C = 70 KAmount of heat given out, Q = m x C x T = 0.6 x 900 x 70 = 37800 J

Solution 4

a) Principle of Calorimeter:

When a hot body is mixed or kept in contact with a cold body, there is a transfer of heat from hot body to cold body such that

Total heat gained by colder body = Total heat lost by the hot body,

if there is no loss of heat to the surroundings.

One calorie is the quantity of heat required to raise the temperature of 1 g of water by 1°C.

1 calorie = 4.186 joule

One kilocalorie is the quantity of heat required to raise the temperature of 1 kg of water by 1°C.

1 kcal = 4.186×10^3 joule

b) Let the final temperature of the mixture be θ°C.

Heat lost by hot water = Heat gained by cold water

$0.4 \times C \times (80 - \theta) = 1 \times C \times (\theta - 20)$

or, $32 - 0.4\theta = \theta - 20$

or, $\theta = 37.14°C$

c) m = 360 g = 0.36 kg

Change in temperature, $\Delta T = (100\text{-}40)°C = 60°C = 60$ K

Amount of heat required, $Q = m \times C \times \Delta T$

$= 0.36 \times 4200 \times 60 = 90720$ J

Time taken = 5 min = 300 sec

Rate of heat supplied = $\frac{Q}{t} = \frac{90720}{300} = 302.4$ J/s

Solution 5

Let the specific heat of the solid be C.

Heat lost by solid = Heat gained by water

$0.08 \times C \times (80-30) = 0.4 \times 4200 \times (30-10)$

$$\text{or}, C = \frac{0.4 \times 4200 \times 20}{0.08 \times 50} = 8400\,\text{J kg}^{-1}\text{K}^{-1}$$

Solution 6

Let the mass of water be m.

Heat lost by mercury = Heat gained by water

$0.2 \times 140 \times (100-25) = m \times 4200 \times (25-20)$

$$\text{or}, m = \frac{0.2 \times 140 \times 75}{4200 \times 5} = 0.1\,\text{kg} = 100\,\text{g}$$

Solution 7

Specific heat of copper = 390 J $kg^{-1}K^{-1}$

Let the initial temperature of copper be t.

Heat lost by copper = Heat gained by water

$1 \times 390 \times (t-40) = 2 \times 4200 \times (40-15)$

$$\text{or}, t - 40 = \frac{2 \times 4200 \times 25}{390} = 538.46$$

$$\text{or}, t = 578.46^\circ\text{C}$$

Solution 8

Heat lost by metal = Heat gained by calorimeter and oil

$m_3C_3(x-z) = m_1C_1(z-y) + m_2C_2(z-y)$

where, m_1C_1=32 J/°C

m_2=100 g

y=30 °C

m_3=80 g

C_3=0.12 J/g°C

x=90°C

z=35°C

$$\Rightarrow 80 \times 0.12 \times (90 - 35) = 32 \times (35 - 30) + 100 \times C_2 \times (35 - 30)$$

$$\Rightarrow 528 = 160 + 500C_2$$

$$\Rightarrow C_2 = 0.736\,\text{J/g}^\circ\text{C}$$

Solution 9

a)

i. Latent heat is the amount of hidden heat supplied to or extracted from the substance to change its state without any change of temperature.

ii. Latent heat of fusion of ice is the amount heat absorbed by ice at 0°C to convert into water at 0°C.

b) Amount of heat required to convert ice from -10°C to 0°C = m x C x θ

= 40 x 2.1 x 10 = 840 J

Amount of heat required to convert ice at 0°C to water at 0°C = mL

= 40 x 330 = 13200 J

Amount of heat required to convert water from 0°C to 20°C = = 40 x 4.2 x 20 = 3360 J

Total heat required during the process = 17400 J

Solution 10

a)

i. Specific latent heat is the amount of heat required to change the state of unit mass of a substance without change in temperature.

ii. Specific latent heat of fusion is the amount of heat required to change unit mass of a solid at its melting point into liquid at the same temperature.

b) It means that 1 kg of water at 100°C absorbs 2268 J of heat energy to convert into steam at 100°C.

c) Amount of heat given out while converting water from 50°C to 0°C = m x C x θ

= 100 x 4.2 x 50 = 21000 J

Amount of heat given out while converting water at 0°C to ice at 0°C = mL

= 100 x 330 = 33000 J

Amount of heat given out while converting ice from 0°C to -50°C = = 100 x 2.1 x 5 = 10500 J

Total heat required during the process = 64500 J

Solution 11

Heat given out by steam = Heat taken by ice

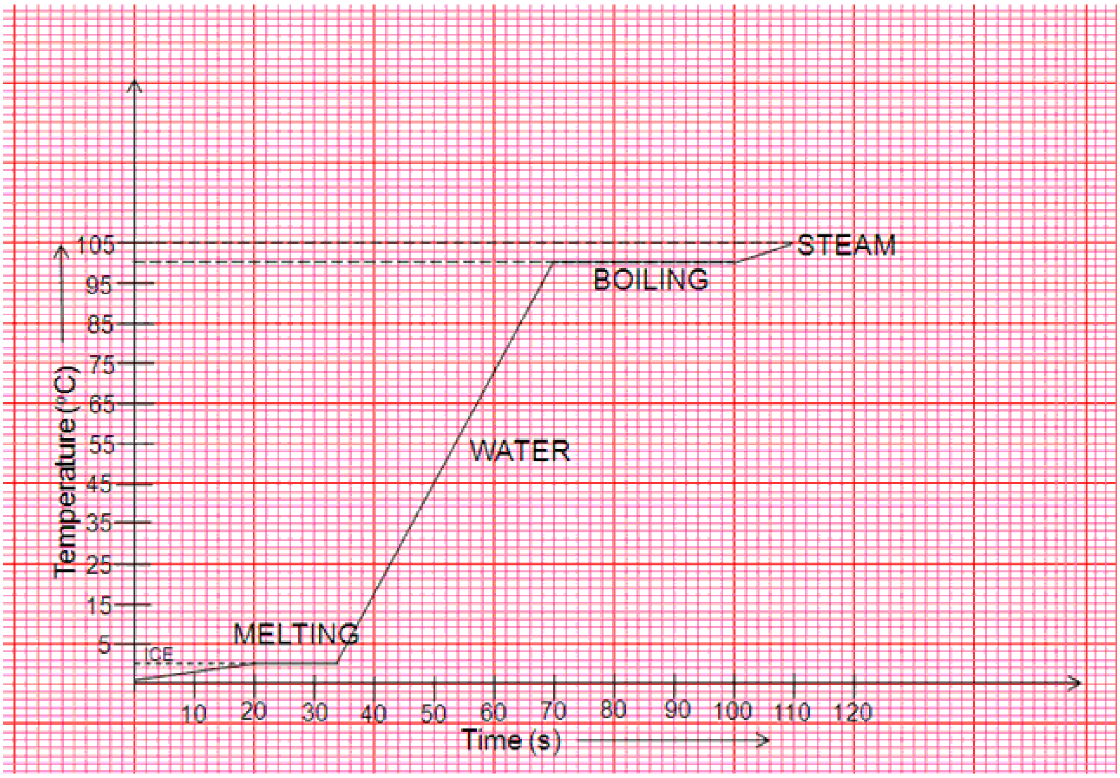
$m_1L_v + m_1 \times C \times \Delta T = m_2L_f$

$(1000 \times 2268) + (1000 \times 4.2 \times 100) = m_2 \times 336$

$$m_2 = \frac{2688000}{336} = 8000\text{ g}$$

8000 g of ice melts.

Solution 12



Solution 13

Let the final temperature of the mixture be t.

Heat gained by ice = Heat lost by water

$m_1L + m_1 \times C \times (t-0) = m_2 \times C \times (30-t)$

$(200 \times 336) + (200 \times 4.2 \times t) = 2000 \times 4.2 \times (30-t)$

$336 + 4.2t = 42(30-t)$

$t = 20°C$

Solution 14

(a) Melting point is 80°C

(b) Boiling point is 200°C.

(c) In 5 min, change in temperature = 50°C

$\frac{Q}{t} = 100\ J/s$

Heat supplied in 5 min, Q = $100 \times 30 = 3000\ J$

$Q = mC_s\Delta T$

$C_s = \frac{Q}{m\Delta T} = \frac{3000}{100 \times 50} = 0.6\ J/g\,°C$

(d) From 5 min to 18 min, heat supplied, $Q = 780 \times 100 = 78000\ J$

$Q = mL$

$78000 = 100 \times L$

$L = 780\ J/g$

(e) From 18 min to 40 min, change in temperature = 120°C

$\frac{Q}{t} = 100\ J/s$

Heat supplied in 22 min, Q = $100 \times 1320 = 132000\ J$

$Q = mC_L\Delta T$

$C_L = \frac{Q}{m\Delta T} = \frac{132000}{100 \times 120} = 11\ J/g\,°C$

PAGE NO-261:

Solution 15

Let the final temperature of the mixture be t.

Heat lost by lead = Heat gained by water

$m_1L + m_1 \times C_L \times (327-t) = m_2 \times C_w \times (t-20)$

$1 \times 27000 + 1 \times 130 \times (327-t) = 1 \times 4200 \times (t-20)$

$27000 + 42510 - 130t = 4200t - 84000$

$153510 = 4330t$

t=35.45°C

So, the final temperature of water is 35.45°C.

Solution 16

Let the mass of steam be m.

Heat lost by (steam at 100°C to condense into water at 100°C + 100°C water to convert into 40°C water = Heat gained by water to raise the temperature to 40°C

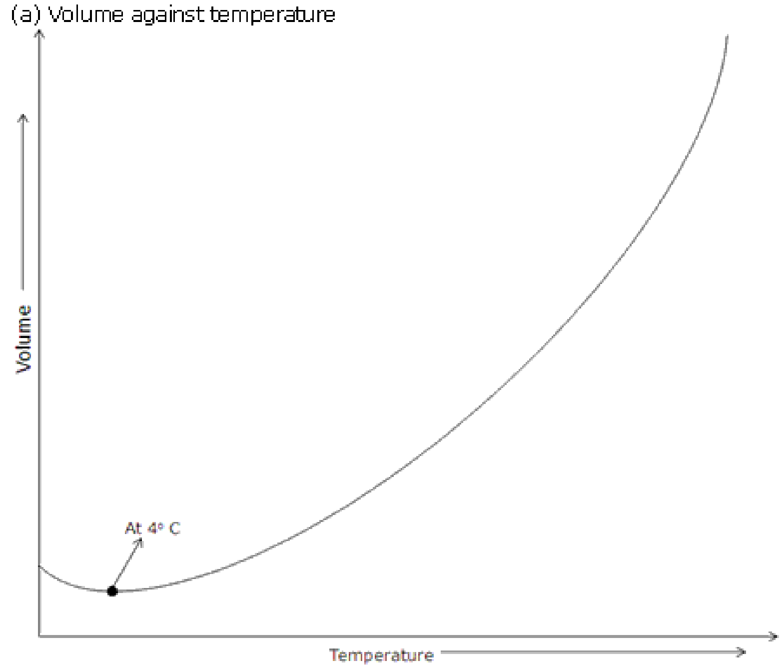
$m \times 2268 + m \times 4.2 \times (100-40) = 120 \times 4.2 \times (40-20)$

$m(2268 + 252) = 10080$

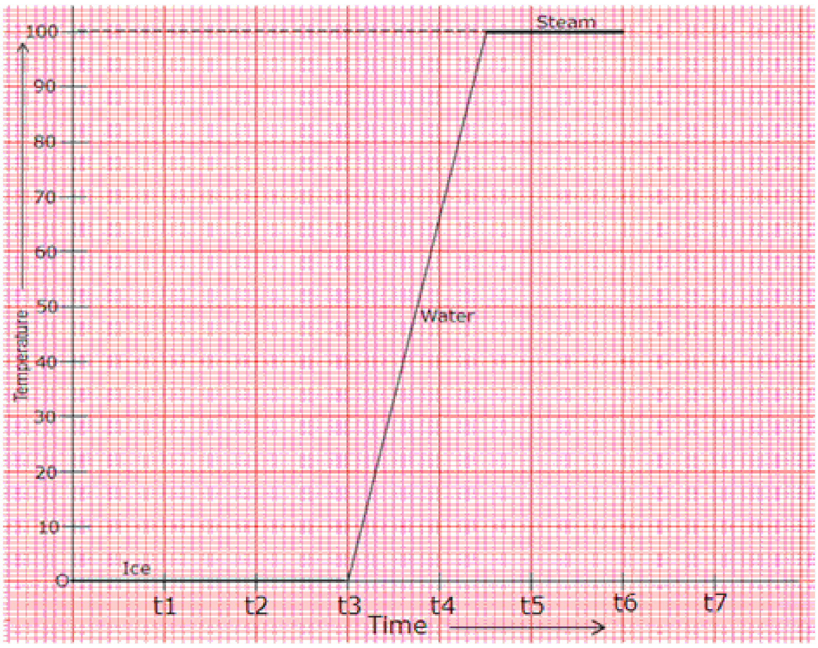
$m = 4\ g$

Solution 17

(a) Volume against temperature



(b) Temperature against time



Solution 18

(a) Ice melts under pressure. So, when the steel blades of the skates pressed on the ice, the ice melts. The water formed makes the skates slide easily over the ice, reducing friction. So, when we are skating on ice, we are skating on a thin film of water, which acts like lubricating oil. Nothing such happens in case of glass.

(b) Sand improves the friction between car tyres and the road, so cars don't skid on icy surfaces. Salt is spread so as to decrease the melting point of ice. Ice on the roads melt, making the roads less slippery.

(c) Steam burn is worse than a hot water burn because 1 g of steam gives out 540 calories of additional heat.

(d) Lumps of ice cool better than cold water because each gram of ice requires additional 80 calories of heat to get converted into water. Hence, cooling capacity of lumps of ice is more than cold water.

Solution 19

(a) Mass of water in the bucket = Density x Volume

= 1000 kg/m³ x 0.01 m³ = 10 kg

Let the mass of water that came out from the tap be m.

Heat lost by hot water = Heat gained by cold water

10 x 4200 x (80-50) = m x 4200 x (50-25)

300 = 25m

m=12 kg

12 kg of water came out of tap in 20 sec.

So, the rate at which cold water came out of the tap is $\frac{12}{20} = 0.6\text{kg/s} = 600\text{g/s}$

(b) In the above calculation we assumed that there is no loss of heat to the surroundings

Solution 20

Q = 650 J

m = 0.25 kg

ΔT = (35-15) = 20°C

Q = m x C x T

$$C = \frac{Q}{m \times \Delta T} = \frac{650}{0.25 \times 20} = 130\,\text{J/kg}^\circ\text{C}$$

Solution 21

Mass of calorimeter, m_1 = 57.5 g

Specific heat capacity of calorimeter, C_1 = 0.4 J/g°C

Mass of water taken, m_2 = 60 g

Specific heat capacity of water, C_2 = 4.2 J/g°C

Mass of iron nails, m_3 = 55 g

Specific heat capacity of iron = C_3

Initial temperature of iron nails, x = 100°C

Initial temperature of calorimeter + water, y = 12°C

Final temperature of the mixture, z = 20°C

Heat lost by iron nails = Heat gained by calorimeter and water

$m_3C_3(x-z) = m_1C_1(z-y) + m_2C_2(z-y)$

$$C_3 = \frac{(m_1C_1 + m_2C_2)(z-y)}{m_3(x-z)}$$

$$= \frac{(57.5 \times 0.4 + 60 \times 4.2)(20-12)}{55 \times (100-20)} = 0.5\ \text{J/g}^\circ\text{C}$$

Solution 22

Let the final temperature of the mixture be t.

Heat lost by lead = Heat gained by water

$m_1L + m_1 \times C_L \times (327\text{-}t) = m_2 \times C_W \times (t\text{-}20)$

1 x 27000 + 1 x 130 x (327-t) = 1 x 4200 x (t-20)

27000 + 42510 -130t = 4200t – 84000

153510 = 4330t

t=35.45°C

So, the final temperature of water is 35.45°C.

Solution 23

For water:
m = 120 g = 0.12 kg
ΔT = 10 K
C = 4200 J/kgK
Q = m x C x ΔT
= 0.12 x 4200 x 10
=5040 J
For oil:
Q = 5040 J
m = 60 g = 0.06 kg
ΔT = 40 K

$$C = \frac{Q}{m \times \Delta T}$$

$$= \frac{5040}{0.06 \times 40} = 2100\ J/kgK$$

Solution 24

Mass of lead block, m = 250 g
Change in temperature,ΔT = 327°C – 27°C = 300°C =300 K
C = 0.13 J/gK
Amount of heat required to raise the temperature to 327°C,
Q = m x C x ΔT
= 250 x 0.13 x 300 = 9750 J

Amount of heat required to completely melt the block upto its melting point
Q = m x L
= 250 x 26 = 6500 J

Solution 25

Amount of heat required to convert ice into steam is as given below:

(ice from -10°C to 0°C) = 0.1 x 2100 x 10 = 2100 J
(ice at 0°C to water at 0°C) = 0.1 x 336000 = 33600 J
(water from 0°C to 100°C) = 0.1 x 4200 x 100 = 42000 J
(water at 100°C to steam at 100°C) = 0.1 x 2260000 = 226000 J

Total amount of heat required = 2100 + 33600 + 42000 + 226000 = 30370 J

Solution 26

Heat given out during the following three stages:

1. Cooling water from 20°C to 0°C = $mC_1\theta_1$ = 100 x 4.2 x 20 = 8400 J
2. Water at 0°C freezes to form ice at 0°C = m x L = 100 x 336 = 33600 J
3. Cooling of ice at 0°C to -10°C =$mC_2\theta_2$ = 100 x 2.1 x 10 = 2100 J

Total quantity of heat given out = 44100 J

$$\text{Rate of heat extraction in watts} = \frac{44100}{73.5 \times 60} = 10\ W$$

Solution 27

Let the specific latent heat of metal is L.
Mass of molten metal = 150 g = 150 x 10^{-3} kg
Q = m x L
75000 = 150 x 10^{-3} x L

$$L = \frac{75000}{150 \times 10^{-3}} = 5 \times 10^5\ J/kg$$

Additional heat given out by metal in cooling upto -50°C
Q = m x C x ΔT
= 150 x 10^{-3} x 200 x 850 = 25500 J

Solution 28

Let the latent heat of fusion of ice be L.
Heat gained by ice at -16°C to convert to 0°C = Heat given out by 4 g of water to at 0°C to freeze into ice at 0°C
(40 x 2.1 x -16) = 4 x L
1344 = 4L
L = 336 J/g

Solution 29

$$\frac{Q}{t} = 7000 J/min$$

$$m = 5kg$$

$$\Delta T = 47 - 22 = 25^\circ C$$

$$C = 4200 J/kg^\circ C$$

$$Q = m \times C \times T$$

$$= 5 \times 4200 \times 25 = 525000 J$$

$$\text{Time taken} = \frac{525000}{7000} = 75 \min$$

Solution 30

Heat gained by ice at 0°C to convert to water at 0°C = Heat lost by water from 34°C to 0°C
17 x L = 40 x 4.25 x 34
17 L = 5780
L = 340 J/g

Solution 31

Heat gained by ice at 0°C to convert to water at 0°C = Heat lost by water to change the temperature from 35°C to 0°C
m x 336000 = 0.9 x 4200 x 35
m x 336000 = 132300
m = 0.39 kg

PAGE NO-262:

Solution 32

Steam at 100^{0}C will produce more severe burns because every gram of steam gives out 2260 J of heat energy while condensing. This much amount of heat is additional to the heat contained in one gram of boiling water.

Solution 33

Ice cream appears colder to mouth than water at 0^{0}C because it can extract approximately 80 cal/g (latent heat of fusion of ice)more heat from as compared to water at 0 ^{0}C.

Solution 34

Although both ice cubes and iced water are at 0oC but ice cubes cool more quickly because each gram of ice requires additional 80 calories of heat to get converted into water at the same temperature, i.e., at 0^{0}C. Hence, the cooling capacity of ice cubes is more than that of iced water.

Solution 35

Q = 10125 J
m = 4.5 g
Q = m x L
10125 = 4.5 x L

$$L = \frac{10125}{4.5} = 2250\,J/g$$

Specific latent heat of steam is 2250 J/g.

Solution 36

(i) SI unit of heat is joule.
(ii) 1 cal = 4.2 J
(iii) Whenever mechanical work is done, heat is produced.
(iv) Two bodies in contact are said to be in thermal equilibrium, if they have the same temperature.
(v) The normal temperature of a human body is 37°C.
(vi) SI unit of specific heat is $Jkg^{-1}C^{-1}$.
(vii) The amount of heat required to change the state of a physical substance without any change of temperature is called latent heat of the substance.
(viii) Ice at 0°C is colder than water at 0°C.
(ix) Steam at 100°C is hotter than water at 100°C.
(x) Evaporation causes cooling.

Solution 37

1 gram of ice at 0^oC requires 80 calories of heat to get converted into 1 gram of water at 0^oC. So, water has more heat.

Solution 38

1 gram of water at 100^oC requires 540 calories of heat to get converted into 1 gram of steam at 100^oC. So, steam has more heat.

Solution 39

1 gram of ice at 0^oC requires additional 80 calories of heat to get converted into water at 0^oC. Then, heat is provided to raise the temperature to 10^oC. Therefore, ice requires more heat than water and the additional heat is known as 'Latent heat of fusion of ice'.

Solution 40

Pressure cooker increases the pressure and hence the boiling point increases. So, the boiling point becomes greater than 373kelvin.