Part – I
Class –XI Physics
Chapter – 11 THERMAL PROPERTIES OF MATTER

Answer 1:

Kelvin and Celsius scales are related as:

$T_C = T_K - 273.15$ … (*i*)

Celsius and Fahrenheit scales are related as:

$T_F = \frac{9}{5}T_c + 32$ … (*ii*)

For neon:

$T_K = 24.57$ K

$\therefore T_C = 24.57 - 273.15 = -248.58°C$

$T_F = \frac{9}{5}T_c + 32$

$\frac{9}{5}(-248.58) + 32$

$= 415.44^{\circ} F$

For carbon dioxide:

$T_K = 216.55$ K

$\therefore T_C = 216.55 - 273.15 = -56.60°C$

$T_F = \frac{9}{5}(T_c) + 32$

$= \frac{9}{5}(-56.60) + 32$

$= -69.88^{\circ} C$

Answer 2:

Triple point of water on absolute scale A, $T_1 = 200$ A

Triple point of water on absolute scale B, $T_2 = 350$ B

Triple point of water on Kelvin scale, $T_K = 273.15$ K

The temperature 273.15 K on Kelvin scale is equivalent to 200 A on absolute scale A.

$T_1 = T_K$

200 A = 273.15 K

$\therefore A = \frac{273.15}{200}$

The temperature 273.15 K on Kelvin scale is equivalent to 350 B on absolute scale B.

$T_2 = T_K$

350 B = 273.15

$\therefore B = \frac{273.15}{350}$

T_A is triple point of water on scale A.

T_B is triple point of water on scale B.

$$\therefore = \frac{273.15}{200} \times T_A = \frac{273.15}{350} \times T_B$$

$$T_A = \frac{200}{350} T_B$$

Therefore, the ratio $T_A : T_B$ is given as 4: 7.

Answer 3:

It is given that:

$R = R = R_0 \left[\mathbf{1} + \boldsymbol{\alpha} \left(T - T_o \right) \right] \ldots (i)$

Where,

R_0 *and* T_0 are the initial resistance and temperature respectively

R and T are the final resistance and temperature respectively

α is a constant

At the triple point of water, T_0 = 273.15 K

Resistance of lead, R_0 = 101.6 Ω

At normal melting point of lead, T = 600.5 K

Resistance of lead, R = 165.5 Ω

Substituting these values in equation (i), we get:

$$R = R_0 \left[1 + a \left(T - T_o \right) \right]$$

$$165.5 = 101.6 \left[1 + a \left(600.5 - 273.15 \right) \right]$$

$$1.629 = 1 + a \left(327.35 \right)$$

$$\therefore a = \frac{0.629}{327.35} = 1.92 \times 10^{-3} K^{-1}$$

For resistance, R_1 = 123.4 Ω

$$R = R_0 \left[1 + a \left(T - T_o \right) \right]$$

Where, T is the temperature when the resis tan ce of lead is 123.4 Ω

$$123.4 = 101.6 \left[1 + 1.92 \times 10^{-3} \left(T - 273.15 \right) \right]$$

$$1.214 = 1 + 1.92 \times 10^{-3} \left(T - 273.15 \right)$$

$$\frac{0.214}{1.92 \times 10^{-3}} = T - 273.15$$

$$\therefore T = 384.61 K$$

Answer 4:

(a) The triple point of water has a unique value of 273.16 K. At particular values of volume and pressure, the triple point of water is always 273.16 K. The melting point of ice and boiling point of water do not have particular values because these points depend on pressure and temperature.

(b) The absolute zero or 0 K is the other fixed point on the Kelvin absolute scale.

(c) The temperature 273.16 K is the triple point of water. It is not the melting point of ice. The temperature 0°C on Celsius scale is the melting point of ice. Its corresponding value on Kelvin scale is 273.15 K.

Hence, absolute temperature (Kelvin scale) T, is related to temperature tc, on Celsius scale as:

$t_c = T - 273.15$

(d) Let *T*F be the temperature on Fahrenheit scale and T_K be the temperature on absolute scale. Both the temperatures can be related as:

$$\frac{T_F - 32}{180} = \frac{T_K - 273.15}{100} \quad \text{........(i)}$$

Let T_{F1} be the temperature on Fahrenheit scale and T_{K1} be the temperature on absolute scale. Both the temperatures can be related as:

$$\frac{T_{F1} - 32}{180} = \frac{T_{K1} - 273.15}{100} \quad \text{..........(ii)}$$

It is given that:

$T_{K1} - T_K = 1\ K$

Subtracting equation (*i*) from equation (*ii*), we get:

$$\frac{T_{F1} - T_F}{180} = \frac{T_{K1} - T_K}{100} = \frac{1}{100}$$

$$T_{F1} - T_F = \frac{1 \times 180}{100} = \frac{9}{5}$$

Triple point of water = 273.16 K

$\therefore$Triple point of water on absolute scale = $273.16 \times \frac{9}{5}$ = 491.69

Answer 5:

(a) Triple point of water, *T* = 273.16 K.

At this temperature, pressure in thermometer A, $P_A = \mathbf{1.250 \times 10^5}$ **Pa**

Let T_1 be the normal melting point of sulphur.

At this temperature, pressure in thermometer A, $P_B = \mathbf{1.797 \times 10^5}$ **Pa**

According to Charles' law, we have the relation:

$$\frac{P_A}{T} = \frac{P_1}{T_1}$$

$$\therefore T_1 = \frac{P_1 T}{P_A} = \frac{1.797 \times 10^5 \times 273.16}{1.250 \times 10^5}$$

= 392.69 K

Therefore, the absolute temperature of the normal melting point of sulphur as read by thermometer A is 392.69 K.

At triple point 273.16 K, the pressure in thermometer B, $P_B = 0.200 \times 10^5\ Pa$

At temperature T_1, the pressure in thermometer B, $P_2 = 0.287 \times 10^5\ Pa$

According to Charles' law, we can write the relation:

$$\frac{P_B}{T} = \frac{P_1}{T_1}$$

$$\frac{0.200 \times 10^5}{273.16} = \frac{0.287 \times 10^5}{T_1}$$

$$\therefore T_1 = \frac{0.287 \times 10^5}{0.200 \times 10^5} \times 273.16 = 391.98 K$$

Therefore, the absolute temperature of the normal melting point of sulphur as read by thermometer B is 391.98 K.

(b) The oxygen and hydrogen gas present in thermometers A and B respectively are not perfect ideal gases. Hence, there is a slight difference between the readings of thermometers A and B.

To reduce the discrepancy between the two readings, the experiment should be carried under low pressure conditions. At low pressure, these gases behave as perfect ideal gases.

Answer 6:

Length of the steel tape at temperature T = 27°C, l = 1 m = 100 cm

At temperature T_1 = 45°C, the length of the steel rod, l_1 = 63 cm

Coefficient of linear expansion of steel, α = $\mathbf{1.20\times10^{-5}\ K^{-1}}$

Let l_2 be the actual length of the steel rod and l' be the length of the steel tape at 45°C.

$$l' = l + al\left(T_1 - T\right)$$

$$\therefore l' = 100 + 1.20\times10^{-5}\times100\left(45-27\right)$$

= 100.0216 cm

Hence, the actual length of the steel rod measured by the steel tape at 45°C can be calculated as:

$$l_2 = \frac{100.0216}{100}\times63 = 63.0136 \text{ cm}$$

Therefore, the actual length of the rod at 45.0°C is 63.0136 cm. Its length at 27.0°C is 63.0 cm.

Answer 7:

The given temperature, T = 27°C can be written in Kelvin as:

27 + 273 = 300 K

Outer diameter of the steel shaft at T, d_1 = 8.70 cm

Diameter of the central hole in the wheel at T, d_2 = 8.69 cm

Coefficient of linear expansion of steel, $\boldsymbol{\alpha}_{\textbf{steel}} = 1.20\times10^{-5}\ K^{-1}$

After the shaft is cooled using 'dry ice', its temperature becomes T_1.

The wheel will slip on the shaft, if the change in diameter, Δd = 8.69 – 8.70

= – 0.01 cm

Temperature T_1, can be calculated from the relation:

$$\Delta d = d_1 \boldsymbol{\alpha}_{\textbf{steel}}\left(T_1 - T\right)$$

$$0.01 = 8.70\times1.20\times10^{-5}\ \left(T_1 - 300\right)$$

$$\left(T_1 - 300\right) = 95.78$$

$$\therefore T_1 = 204.21 \text{ K}$$

= 204.21–273.16

= –68.95°C

Therefore, the wheel will slip on the shaft when the temperature of the shaft is -69°C.

Answer 8: Initial temperature, T_1 = 27.0°C

Diameter of the hole at T_1, d_1 = 4.24 cm

Final temperature, T_2 = 227°C

Diameter of the hole at $T_2 = d_2$

Co-efficient of linear expansion of copper, $\alpha_{Cu} = 1.70 \times 10^{-5}\ K^{-1}$

For co-efficient of superficial expansion β, and change in temperature ΔT, we have the relation:

$$\frac{Change\,in\,area\,(\triangle A)}{Original\,area\,(A)} = \beta \triangle T$$

$$\frac{\left(\pi \frac{d_2^2}{4} - \pi \frac{d_1^2}{4}\right)}{\left(\pi \frac{d_1^2}{4}\right)} = \frac{\triangle A}{A}$$

$$\therefore \frac{\triangle A}{A} = \frac{d_2^2 - d_1^2}{d_1^2}$$

But $\beta = 2a$

$$\therefore \frac{d_2^2 - d_1^2}{d_1^2} = 2a \triangle T$$

$$\frac{d_2^2}{d_1^2} - 1 = 2a(T_2 - T_1)$$

$$\frac{d_2^2}{d\,(4.24)^2} = 2 \times 1.7 \times 10^{-5}(227 - 27) + 1$$

$$d_2^2 = 17.98 \times 1.0068 = 18.1$$

$$\therefore d_2 = 4.2544\,cm$$

Change in diameter = $d_2 - d_1 = 4.2544 - 4.24 = 0.0144$ cm

Hence, the diameter increases by 1.44×10^{-2} cm.

Answer 9: Initial temperature, T_1 = 27°C

Length of the brass wire at T_1, l = 1.8 m

Final temperature, T_2 = –39°C

Diameter of the wire, d = 2.0 mm = 2×10^{-3} m

Tension developed in the wire = F

Coefficient of linear expansion of brass, α= $2.0 \times 10^{-5}\ K^{-1}$

Young's modulus of brass, Y = $0.91 \times 10^{11}\ Pa$

Young's modulus is given by the relation:

$$Y = \frac{Stress}{Strain} = \frac{\frac{F}{A}}{\frac{\triangle L}{L}}$$

$$\triangle L = \frac{F \times L}{A \times Y} \quad \text{..............(i)}$$

Where,

F = Tension developed in the wire
A = Area of cross-section of the wire.
ΔL = Change in the length, given by the relation:
$\Delta L = \alpha L\left(T_2 - T_1\right)$ ... (ii)
Equating equations (i) and (ii), we get:

$$aL\left(T_2 - T_1\right) = \frac{FL}{\pi\left(\frac{d}{2}\right)^2 \times Y}$$

$$F = a\left(T_2 - T_1\right)\pi\left(\frac{d}{2}\right)^2$$

$$F = 2\times10^{-5}\times(-39-27)\times3.14\times0.91\times10^{11}\times\left(\frac{2\times10^{-3}}{2}\right)^2$$

$$= -3.8\times10^2\ N$$

$3.8\times10^2\ N$
(The negative sign indicates that the tension is directed inward.)
Hence, the tension developed in the wire is $3.8\times10^2\ N$.

Answer 10:

Initial temperature, T_1 = 40°C
Final temperature, T_2 = 250°C
Change in temperature, $\Delta T = T_2 - T_1$ = 210°C
Length of the brass rod at T_1, l_1 = 50 cm
Diameter of the brass rod at T_1, d_1 = 3.0 mm
Length of the steel rod at T_2, l_2 = 50 cm
Diameter of the steel rod at T_2, d_2 = 3.0 mm
Coefficient of linear expansion of brass, α_1 = $\mathbf{2.0\times10^{-5}\,K^{-1}}$
Coefficient of linear expansion of steel, α_2 = $\mathbf{1.2\times10^{-5}\ K^{-1}}$
For the expansion in the brass rod, we have:

$$\frac{Change\,in\,area\left(\Delta A\right)}{Original\,area\left(A\right)} = a_1 \Delta T$$

$$\therefore \Delta l_1 = 50\times\left(2.1\times10^{-5}\right)\times210$$

= 0.2205 cm
For the expansion in the steel rod, we have:

$$\frac{Change\,in\,area\left(\Delta A\right)}{Original\,area\left(A\right)} = a_2 \Delta T$$

$$\therefore \Delta l_2 = 50\times\left(2.1\times10^{-5}\right)\times210$$

= 0.126 cm
Total change in the lengths of brass and steel,
$\Delta l = \Delta l_1 + \Delta l_2$
= 0.2205 + 0.126

= 0.346 cm

Total change in the length of the combined rod = 0.346 cm

Since the rod expands freely from both ends, no thermal stress is developed at the junction.

Answer 11:

Coefficient of volume expansion of glycerin, α_V = $\mathbf{49\times10^{-5}K^{-1}}$

Rise in temperature, ΔT = 30°C

Fractional change in its volume = $\frac{\Delta V}{V}$

This change is related with the change in temperature as:

$$\frac{\Delta V}{V} = a_v \Delta T$$

$$V_{T_2} - V_{T_1} = V_{T_1} a_v \Delta T$$

$$\frac{m}{\rho_{T_2}} - \frac{m}{\rho_{T_1}} = \frac{m}{\rho_{T_1}} a_v \Delta T$$

Where,

m = Mass of glycerine

ρ_{T_1} = Initial density at T_1

ρ_{T_2} = Final density at T_2

$$\frac{\rho_{T_1} - \rho_{T_2}}{\rho_{T_2}} a_v \Delta T$$

Where,

$\frac{\rho_{T_1} - \rho_{T_2}}{\rho_{T_2}}$ = Fractional change in density

∴Fractional change in the density of glycerin = $49\times10^{-5}\times30 = 1.47\times10^{-2}$

Answer 12:

Power of the drilling machine, P= 10 kW = $10\times10^3\ W$
Mass of the aluminum block, m= 8.0 kg = $8\times10^3\ g$
Time for which the machine is used, t= 2.5 min = 2.5× 60 = 150 s
Specific heat of aluminium, c= 0.91 J $\mathbf{g}^{-1}\mathbf{K}^{-1}$
Rise in the temperature of the block after drilling = δT
Total energy of the drilling machine = P_t
= $10\times10^3\times150$
= $1.5\times10^6 J$
It is given that only 50% of the power is useful.
Useful energy, $\triangle Q=\frac{50}{100}\times1.5\times10^6=7.5\times10^5 J$
But $\triangle Q=mc\triangle T$
$\therefore\triangle T=\frac{\triangle Q}{mc}$
$=\frac{7.5\times10^5}{8\times10^3\times0.91}$
$=103^\circ C$
Therefore, in 2.5 minutes of drilling, the rise in the temperature of the block is 103°C.

Answer 13:

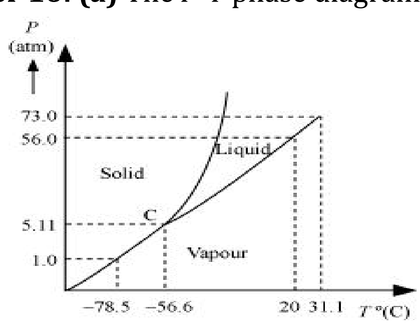
Mass of the copper block, m = 2.5 kg = 2500 g
Rise in the temperature of the copper block, $\Delta\theta$ = 500°C
Specific heat of copper, C = 0.39 J $\mathbf{g}^{-1}$ C^{-1}
Heat of fusion of water, L = 335 J g^{-1}
The maximum heat the copper block can lose, $Q = mC\Delta\theta$
= 2500 × 0.39 × 500
= 487500 J
Let m_1 g be the amount of ice that melts when the copper block is placed on the ice block.
The heat gained by the melted ice, $Q = m_1L$
$\therefore m_1=\frac{Q}{L}=\frac{487500}{335}=1455.22\ g$
Hence, the maximum amount of ice that can melt is 1.45 kg.

Answer 14: Mass of the metal, m = 0.20 kg = 200 g
Initial temperature of the metal, T_1 = 150°C
Final temperature of the metal, T_2 = 40°C
Calorimeter has water equivalent of mass, m' = 0.025 kg = 25 g
Volume of water, V = 150 cm^3

Mass (M) of water at temperature T = 27°C:
150 × 1 = 150 g
Fall in the temperature of the metal:
$\Delta T = T_1 - T_2 = 150 - 40 = 110°C$
Specific heat of water, C_w = 4.186 J/g/°K
Specific heat of the metal = C
Heat lost by the metal, $\theta = mC\Delta T$ ... (i)
Rise in the temperature of the water and calorimeter system:
$\Delta T'' = 40 - 27 = 13°C$
Heat gained by the water and calorimeter system:
$\Delta\theta'' = m_1 C_w \Delta T'$
$= (M + m') C_w \Delta T'$ ... (ii)
Heat lost by the metal = Heat gained by the water and calorimeter system
$mC\Delta T = (M + m')\ C_w \Delta T'$
200 × C × 110 = (150 + 25) × 4.186 × 13
$$\therefore C = \frac{175 \times 4.186 \times 13}{110 \times 200} = 0.43\, J\ g^{-1} K^{-1}$$
If some heat is lost to the surroundings, then the value of C will be smaller than the actual value.

Answer 15: The gases listed in the given table are diatomic. Besides the translational degree of freedom, they have other degrees of freedom (modes of motion).
Heat must be supplied to increase the temperature of these gases. This increases the average energy of all the modes of motion. Hence, the molar specific heat of diatomic gases is more than that of monatomic gases.
If only rotational mode of motion is considered, then the molar specific heat of a diatomic $gas = \frac{5}{2}R$
$$\frac{5}{2} \times 1.98 = 4.95\, cal\ mol^{-1} K^{-1}$$
With the exception of chlorine, all the observations in the given table agree with $\left(\frac{5}{2}R\right)$. This is because at room temperature, chlorine also has vibrational modes of motion besides rotational and translational modes of motion.

Answer 16: (a) The P-T phase diagram for CO_2 is shown in the following figure.



C is the triple point of the CO_2 phase diagram. This means that at the temperature and pressure corresponding to this point (i.e., at -56.6°C and 5.11 atm), the solid, liquid, and vaporous phases of CO_2 co-exist in equilibrium.

(b) The fusion and boiling points of CO_2 decrease with a decrease in pressure.

(c) The critical temperature and critical pressure of CO_2 are 31.1°C and 73 atm respectively. Even if it is compressed to a pressure greater than 73 atm, CO_2 will not liquefy above the critical temperature.

(d) It can be concluded from the *P*-*T* phase diagram of CO_2 that:

(a) CO_2 is gaseous at -70°C, under 1 atm pressure

(b) CO_2 is solid at -60°C, under 10 atm pressure

(c) CO_2 is liquid at 15°C, under 56 atm pressure

Answer 17:

(a) No

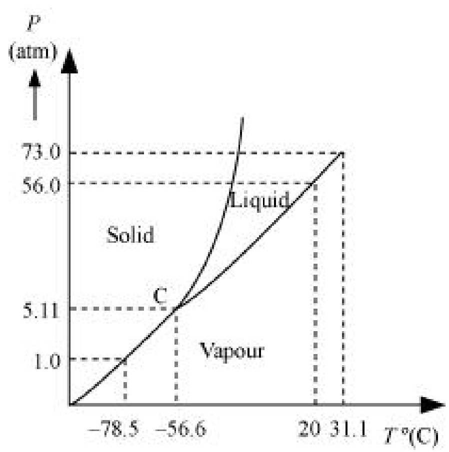
(b) It condenses to solid directly.

(c) The fusion and boiling points are given by the intersection point where this parallel line cuts the fusion and vaporisation curves.

(d) It departs from ideal gas behaviour as pressure increases.

Explanation:

(a) The *P*-*T* phase diagram for CO_2 is shown in the following figure.



At 1 atm pressure and at -60°C, CO_2 lies to the left of -56.6°C (triple point C). Hence, it lies in the region of vaporous and solid phases.

Thus, C CO_2 condenses into the solid state directly, without going through the liquid state.

(b) At 4 atm pressure, CO_2 lies below 5.11 atm (triple point C). Hence, it lies in the region of vaporous and solid phases. Thus, it condenses into the solid state directly, without passing through the liquid state.

(c) When the temperature of a mass of solid CO_2 (at 10 atm pressure and at -65°C) is increased, it changes to the liquid phase and then to the vaporous phase. It forms a line parallel to the temperature axis at 10 atm. The fusion and boiling points are given by the intersection point where this parallel line cuts the fusion and vaporisation curves.

(d) If $\mathbf{CO_2}$ is heated to 70°C and compressed isothermally, then it will not exhibit any transition to the liquid state. This is because 70°C is higher than the critical temperature of $\mathbf{CO_2}$. It will remain in the vapour state, but will depart from its ideal behaviour as pressure increases.

Answer 18:

Initial temperature of the body of the child, T_1 = 101°F

Final temperature of the body of the child, T_2 = 98°F

Change in temperature, $\Delta T = \left[(101-98)\times\frac{5}{9}\right]$°C

Time taken to reduce the temperature, t = 20 min

Mass of the child, m = 30 kg = $30\times10^3\ g$

Specific heat of the human body = Specific heat of water = c

= 1000 cal/kg/ °C

Latent heat of evaporation of water, L = 580 cal g^{-1}

The heat lost by the child is given as:

$\Delta\theta = mc\Delta T$

$= 30\times1000\times(101-98)\frac{5}{9}$

= 50000 cal

Let m_1 be the mass of the water evaporated from the child's body in 20 min.

Loss of heat through water is given by:

$\Delta\theta = m_1 L$

$\therefore m_1 = \frac{\Delta\theta}{L}$

= $\frac{50000}{580} = 86.2g$

∴Average rate of extra evaporation caused by the drug $= \frac{m_1}{t}$

$= \frac{86.2}{200} = 4.3\,g\,/\,\text{min}$

Answer 19:

Side of the given cubical ice box, s= 30 cm = 0.3 m

Thickness of the ice box, l= 5.0 cm = 0.05 m

Mass of ice kept in the ice box, m= 4 kg

Time gap, t = 6 h = 6 × 60 × 60 s

Outside temperature, T= 45°C

Coefficient of thermal conductivity of thermacole, K= $\mathbf{0.01\ J\ s^{-1}m^{-1}K^{-1}}$

Heat of fusion of water, L= $335\times10^3\ J\ kg^{-1}$

Let m'be the total amount of ice that melts in 6 h.

The amount of heat lost by the food:

$$\theta = \frac{KA(T-0)t}{l}$$
Where,
A= Surface area of the box = $6s^2 = 6\times(0.3)^2 = 0.54\ m^3$
$$\theta = \frac{0.01\times0.54\times(45)\times6\times60\times60}{0.05} = 104976J$$
But $\theta = m'L$
$$\therefore m' = \frac{\theta}{L}$$
$$= \frac{104976}{335\times10^3} = 0.313\,kg$$
Mass of ice left = 4 – 0.313 = 3.687 kg
Hence, the amount of ice remaining after 6 h is 3.687 kg.

Answer 20:

Base area of the boiler, A = 0.15 m^2
Thickness of the boiler, l = 1.0 cm = 0.01 m
Boiling rate of water, R= 6.0 kg/min
Mass, m = 6 kg
Time, t = 1 min = 60 s
Thermal conductivity of brass, K= $10^9\ J\ s^{-1}m^{-1}\ K^{-1}$
Heat of vaporisation, L= $2256\times10^3 J\ kg^{-1}$
The amount of heat flowing into water through the brass base of the boiler is given by:
$$\theta = \frac{KA(T_1-T_2)t}{l} \quad \text{............(i)}$$
Where,
T_1 = Temperature of the flame in contact with the boiler
T_2 = Boiling point of water = 100°C
Heat required for boiling the water:
θ = mL … (ii)
Equating equations (i) and (ii), we get:
$$\therefore ml = \frac{KA(T_1-T_2)t}{l}$$
$$T_1 - T_2 = \frac{mLl}{KAt}$$
$$= \frac{6\times2256\times10^3\times0.01}{109\times0.15\times60}$$
= 137.98°C
Therefore, the temperature of the part of the flame in contact with the boiler is 137.98°C.

Answer 21:

(a) A body with a large reflectivity is a poor absorber of light radiations. A poor absorber will in turn be a poor emitter of radiations. Hence, a body with a large reflectivity is a poor emitter.

(b) Brass is a good conductor of heat. When one touches a brass tumbler, heat is conducted from the body to the brass tumbler easily. Hence, the temperature of the body reduces to a lower value and one feels cooler.

Wood is a poor conductor of heat. When one touches a wooden tray, very little heat is conducted from the body to the wooden tray. Hence, there is only a negligible drop in the temperature of the body and one does not feel cool.

Thus, a brass tumbler feels colder than a wooden tray on a chilly day.

(c) An optical pyrometer calibrated for an ideal black body radiation gives too low a value for temperature of a red hot iron piece kept in the open.

Black body radiation equation is given by:

$$E = \sigma\left(T^4 - T_0^4\right)$$

Where,

E = Energy radiation

T = Temperature of optical pyrometer

T_o = Temperature of open space

σ = Constant

Hence, an increase in the temperature of open space reduces the radiation energy.

When the same piece of iron is placed in a furnace, the radiation energy, $E = \sigma T^4$

(d) Without its atmosphere, earth would be inhospitably cold. In the absence of atmospheric gases, no extra heat will be trapped. All the heat would be radiated back from earth's surface.

(e) A heating system based on the circulation of steam is more efficient in warming a building than that based on the circulation of hot water. This is because steam contains surplus heat in the form of latent heat (540 cal/g).

Answer 22:

According to Newton's law of cooling, we have:

$$-\frac{dT}{dt} = K\left(T - T_0\right)$$

$$\frac{dT}{K\left(T - T_0\right)} = -Kdt$$

Where,

Temperature of the body = T

Temperature of the surroundings = T_0 = 20°C

K is a constant

Temperature of the body falls from 80°C to 50°C in time, t = 5 min = 300 s

Integrating equation (i), we get:

$$\int_{50}^{80} \frac{dT}{K\left(T - T_0\right)} = -\int_{0}^{300} Kdt$$

$$\left[\log_e\left(T - T_0\right)\right]_{50}^{80} = -K\left[t\right]_0^{300}$$

$$\frac{2.3026}{K}\log_{10}\frac{80-20}{50-20}=-300$$

$$\frac{2.3026}{K}\log_{10}2=-300$$

$$\frac{-2.3026}{K}\log_{10}2=K \quad \text{.......(ii)}$$

The temperature of the body falls from 60°C to 30°C in time = t'

Hence, we get:

$$\frac{-2.3026}{t'}\log_{10}\frac{60-20}{30-20}=-t'$$

$$\frac{-2.3026}{t'}\log_{10}4=K \quad \text{.............(iii)}$$

Equating equations (*ii*) and (*iii*), we get:

$$\frac{-2.3026}{t'}\log_{10}4=\frac{-2.3026}{300}\log_{10}2$$

$$\therefore t'=300\times2=600\,s=10\,\text{min}$$

Therefore, the time taken to cool the body from 60°C to 30°C is 10 minutes.