CHAPTER 10 THERMAL PROPERTIES OF MATTER

Question 1. The triple points of neon and carbon dioxide are 24.57 K and 216.55 K respectively. Express these temperatures on the Celsius and Fahrenheit scales.
Answer: The relation between kelvin scale and Celsius scale is $T_K - 273.15 = T_C$ => $T_C = T_K - 273.15$

For neon, $T_K = 24.57$ K

∴ $T_C = 24.57 - 273.15 = -248.58$ °C

For CO_2, $T_K = 216.55$ K

∴ $T_C = 216.55 - 273.15 = -56.60$ °C

Also, the relation between Kelvin scale and Fahrenheit scale is

$$\frac{T_K - 273.15}{100} = \frac{T_F - 32}{180}$$

∴ $T_F = \frac{9}{5}(T_K - 273.15) + 32$

Now, for neon, $T_K = 24.57$ K

∴ $T_F = \frac{9}{5}[24.57 - 273.15] + 32 = -415.44$ °F

For CO_2, $T_K = 216.55$ K

∴ $T_F = \frac{9}{5}[216.55 - 273.15] + 32 = -69.88$ °F

Question 2. Two absolute scales A and B have triple points of water defined to be 200 A and 350 B. What is the relation between T_A and T_B ?
Answer: As we know, triple point of water on absolute scale = 273.16 K, Size of one

degree of kelvin scale on absolute scale A

$$= \frac{273.16}{200}$$

Value of temperature T_A on absolute scale A

$$= \frac{273.16}{200} T_A$$

Value of temperature T_B on absolute scale B

$$= \frac{273.16}{350} T_B$$

Since T_A and T_B represent the same temperature,

$$\therefore \quad \frac{273.16}{200} T_A = \frac{273.16}{350} T_B$$

or $\qquad T_A = \frac{200}{350} T_B = \frac{4}{7} T_B.$

Question 3. The-electrical resistance in ohms of a certain thermometer varies with temperature according to the approximate law: R = R₀ [1 + α (T − T₀)].
The resistances is 101.6 Ωat the triple-point of water 273.16 K, and 165.5 Ωat the normal melting point of lead (600.5 K). What is the temperature when the resistance is 123.4 Ω ?
Answer: Here, $R_0 = 101.6\ \Omega$; $T_0 = 273.16$ K Case (i) $R_1 = 165.5\ \Omega$; $T_1 = 600.5$ K, Case (ii) $R_2 = 123.4$, $T_2 = ?$
Using the relation $R = R_0[1 + \alpha (T - T_0)]$
Case (i) $165.5 = 101.6 [1 + \alpha (600.5 - 273.16)]$

$$\alpha = \frac{165.5 - 101.6}{101.6 \times (600.5 - 273.16)} = \frac{63.9}{101.6 \times 327 \times 34}$$

Case (ii) $\qquad 123.4 = 101.6 [1 + \alpha (T_2 - 273.16)]$

or $\qquad 123.4 = 101.6 \left[1 + \frac{63.9}{101.6 \times 327.34}(T_2 - 273.16)\right]$

$$= 101.6 + \frac{63.9}{327.34}(T_2 - 273.16)$$

or $\qquad T_2 = \frac{(123.4 - 101.6) \times 327.34}{63.9} + 273.16 = 111.67 + 273.16$

$$= \textbf{384.83 K}$$

Question 4. Answer the following:
(a) The triple-point of water is a standard fixed point in modem thermometry. Why ? What is wrong in taking the melting point of ice and the boiling point of water as standard fixed points (as was originally done in the Celsius scale) ?

(b) There were two fixed points in the original Celsius scale as mentioned above which were assigned the number 0 °C and 100 °C respectively. On the absolute scale, one of the fixed points is the triple-point of water, which on the Kelvin absolute scale is assigned the number 273.16 K. What is the other fixed point on this (Kelvin) Scale ?

(c) The absolute temperature (Kelvin scale) T is related to the temperature t_c on the Celsius scale $t_c = T - 273.15$

Why do we have 273.15 in this relation, and not 273.16 ?

(d) What is the temperature of the triple-point of water on an absolute scale whose unit interval size is equal to that of the Fahrenheit scale ?

Answer: (a) Triple point of water has a unique value i.e., 273.16 K. The melting point and boiling points of ice and water respectively do not have unique values and change with the change in pressure.

(b) On Kelvin's absolute scale, there is only one fixed point, namely, the triple-point of water and there is no other fixed point.

(c) On Celsius scale 0 °C corresponds to the melting point of ice at normal pressure and the value of absolute temperature is 273.15 K. The temperature 273.16 K corresponds to the triple point of water.

(d) The Fahrenheit scale and Absolute scale are related as

$$\frac{T_F - 32}{180} = \frac{T_K - 273}{100} \qquad \qquad ...(i)$$

For another set of temperature T'_F and T'_K,

$$\frac{T'_F - 32}{180} = \frac{T'_K - 273}{100} \qquad \qquad ...(ii)$$

Subtracting (i) from (ii)

$$\frac{T'_F - T_F}{180} = \frac{T'_K - T_K}{100}$$

$$\therefore \qquad T'_F - T_F = \frac{180}{100}(T'_K - T_K) \qquad ,$$

For $\qquad T'_K - T_K = 1\ K,$

$$T'_F - T_F = \frac{180}{100}$$

$\therefore$ For a temperature of triple point i.e., 273.16 K, the temperature on the new scale is

$$= 273.16 \times \frac{180}{100} = 491.688.$$

Question 5. Two ideal gas thermometers A and B use oxygen and hydrogen respectively. The following observations are made:

Temperature	Pressure thermometer A	Pressure thermometer B
Triple-point of water	1.250×10^5 Pa	0.200×10^5 Pa
Normal melting point of sulphur	1.797×10^5 Pa	0.287×10^5 Pa

(a) What is the absolute temperature of normal melting point of sulphur as read by thermometers A and B ?

(b) What do you think is the reason behind the slight difference in answers of thermometers A and B ? (The thermometers are not faulty). What further procedure is needed in the experiment to reduce the discrepancy between the two readings ?

Answer:

(a) Let T be the melting point of sulphur.

For thermometer A

$$P_{tr} = 1.250 \times 10^5 \text{ Pa}; \quad P = 1.797 \times 10^5 \text{ Pa}$$

Now,

$$T_A = T_{tr} \times \frac{P}{P_{tr}}$$

$$T_A = 273.16 \times \frac{1.797 \times 10^5}{1.250 \times 10^5} \text{ K} = 392.69 \text{ K}$$

For thermometer B

$$P_{tr} = 0.200 \times 10^5 \text{ Pa}; \quad P = 0.287 \times 10^5 \text{ Pa}$$

$$T_B = T_{tr} \times \frac{P}{P_{tr}} = \frac{273.16 \times 0.287 \times 10^5}{0.200 \times 10^5} \text{ K}$$

$$= 391.98 \text{ K}$$

(b) The value of the melting point of sulphur found from the two thermometers differ slightly due to the reason that in practice, the gases do not behave strictly as perfect gases i.e., gases are not perfectly ideal.

To reduce the discrepency, readings should be taken for lower and lower pressures and the plot between temperature measured versus absolute pressure of the gas at triple point should be extrapolated to obtain the temperature in the limit pressure tends to zero (if P —> 0), when the gases approach ideal gas behaviour.

Question 6. A steel tape 1 m long is correctly calibrated for a temperature of 27.0 °C. The length of a steel rod measured by this tape is found to be 63.0 cm on a hot day when the temperature is 45.0 °C. What is the actual length of the steel rod on that day ? What is the length of the same steel rod on a day when the temperature is 27.0 °C ? Coefficient of linear expansion of steel = 1.20 x 10^{-1}K^{-1}.

Answer: On a day when the temperature is 27 °C, the length of 1 cm division on the steel tape is exactly 1 cm, because the tape has been calibrated for 27 °C.When the temperature rises to 45 °C (that is, $\Delta T = 45 - 27 = 18$ °C), the increase in the length of 1 cm division is $\Delta l = \alpha l \Delta T = (1.2 \times 10^{-5} \text{C}^{-1}) \times 1 \text{ cm} \times 18$ °C = 0.000216 cm Therefore,

the length of 1 cm division on the tape becomes 1.000216 cm at 45 °C. As the length of the steel rod is read to be 63.0 cm on the steel tape at 45 °C, the actual length of the rod at 45 °C is 63.0 x 1.000216 cm = 63.0136 cm The length of the same rod at 27 °C is 63.0 cm, because 1 cm mark on the steel tape is exactly 1 cm at 27 °C.

Question 7. A large steel wheel is to befitted on to a shaft of the same material. At 27 °C, the outer diameter of the shaft is 8.70 cm and the diameter of the central hole in the wheel is, 8.69 cm. The shaft is cooled using 'dry ice'. At what temperature of the shaft does the wheel slip on the shaft ? Assume coefficient of linear expansion of the steel to be constant over the required temperature range α_{steel}= 1-20 x 10^{-5}K^{-1}.

Answer:

Here at temperature T_1 = 27 °C, diameter of shaft D_1 = 8.70 cm

Let at temperature T_2, the diameter of shaft changes to D_2 = 8.69 cm and for steel

$$\alpha = 1.20 \times 10^{-5} \text{ K}^{-1} = 1.20 \times 10^{-5} \text{ °C}^{-1}$$

$\because$ Change in diameter $\Delta D = D_2 - D_1 = D_1 \times \alpha \times (T_2 - T_1)$

$\therefore$ $8.69 - 8.70 = 8.70 \times 1.20 \times 10^{-5} \times (T_2 - 27)$

$\Rightarrow$ $T_2 = 27 - \dfrac{0.01}{8.70 \times 1.20 \times 10^{-5}} = 27 - 95.8 = -68.8$ °C   or -69 °C.

Question 8. A hole is drilled in a copper sheet. The diameter of the hole is 4.24 cm at 27.0 °C. What is the change in the diameter of the hole when the sheet is heated to 227 °C ? Coefficient of linear expansion of copper = 1.70 x 10^{-5}K^{-1}.

Answer:

In this problem superficial expansion of copper sheet will be involved on heating.

Here, area of hole at 27° C, $A_1 = \dfrac{\pi D_1^2}{4} = \dfrac{\pi}{4} \times (4.24)^2$ cm^2

If D_2 cm is the diameter of the hole at 227 °C, then area of the hole at 227 °C,

$$A_2 = \dfrac{\pi D_2^2}{4} \text{ cm}^2$$

Coefficient of superficial expansion of copper is,

$$\beta = 2\,\alpha = 2 \times 1.70 \times 10^{-5} = 3.4 \times 10^{-5} \text{ °C}^{-1}$$

Increase in area $= A_2 - A_1 = \beta A_1 \Delta T$ or $A_2 = A_1 + \beta A_1 \Delta T = A_1 (1 + \beta \Delta T)$

$$\dfrac{\pi D_2^2}{4} = \dfrac{\pi}{4} (4.24)^2 [1 + 3.4 \times 10^{-5} (228 - 27)]$$

$\Rightarrow$ $D_2^2 = (4.24)^2 \times 1.0068$

or $D_2 = 4.2544$ cm

Change in diameter $= D_2 - D_1 = 4.2544 - 4.24 = 0.0144$ cm.

Question 9. A brass wire 1.8 m long at 27 °C is held taut with little tension between two rigid supports. If the wire is cooled to a temperature of − 39 °C, what is the

tension developed in the wire, if its diameter is 2.0 mm ? Co-efficient of linear expansion of brass = 2.0 x 10^{-5}K^{-1}; Young's modulus of brass = 0.91 x 10^{11} Pa

Ans.

Here,

$l = 1.8$ m,

$\Delta t = (-39 - 27)$ °C $= -66$ °C

$\alpha = 2.0 \times 10^{-5}$ K^{-1}

$Y = 0.91 \times 10^{11}$ Pa

$A = \dfrac{\pi D^2}{4} = \dfrac{22}{7} \times \dfrac{1}{4} (2 \times 10^{-3})^2$ m^2

Now,

$Y = \dfrac{Fl}{A\Delta l} \Rightarrow \Delta l = \dfrac{Fl}{AY}$ or $l\alpha \Delta t = \dfrac{Fl}{AY}$

or

$F = -YA\alpha\Delta t$

or

$F = -0.91 \times 10^{11} \times \dfrac{22}{7} \times \dfrac{1}{4}(2 \times 10^{-3})^2 \times 2.0 \times 10^{-5} \times 66$ N

$= -3.77 \times 10^2$ N.

Question 10. A brass rod of length 50 cm and diameter 3.0 mm is joined to a steel rod of the same length and diameter. What is the change in length of the combined rod at 250 °C, if the original lengths are at 40.0 °C ? Is there a 'thermal stress' developed at the junction ? The ends of the rod are free to expand (Co-efficient of linear expansion of brass = 2.0 x 10^{-5} °C^{-1}, steel = 1.2 x 10^{-5} °C^{-3}.

Ans.

Here, $l_{brass} = l_{steel} = 50$ cm, $d_{brass} = d_{steel} = 3$ mm $= 0.3$ cm, $\Delta l_{brass} = ?$, $\Delta l_{steel} = ?$

$\Delta T = 250 - 40 = 210$ °C.

$\alpha_{brass} = 2 \times 10^{-5}$ °C^{-1} and $\alpha_{steel} = 1.2 \times 10^{-5}$ °C^{-1}

Now

$\Delta l_{brass} = \alpha_{brass} \times l_{brass} \times \Delta T$

$= 2 \times 10^{-5} \times 50 \times 210 = 0.21$ cm

Now

$\Delta l_{steel} = \alpha_{steel} \times l_{steel} \times \Delta T$

$= 1.2 \times 10^{-5} \times 50 \times 210$

$= 0.126$ cm ≈ 0.13 cm

∴ Total change in length, $\Delta l = \Delta l_{brass} + \Delta l_{steel} = 0.21 + 0.13 = 0.34$ cm

Since the rod is not clamped at its ends, no thermal stress is developed at the junction.

Question 11. The coefficient of volume expansion of glycerine is 49 x 10^{-5}K^{-1}. What is the fractional change in its density for a 30 °C rise in temperature ?

Ans.

Here, $\gamma = 49 \times 10^{-5} \, °C^{-1}, \quad \Delta T = 30 \, °C$

As $V = V + \Delta V = V(1 + \gamma \, \Delta T)$

∴ $V' = V(1 + 49 \times 10^{-5} \times 30) = 1.0147 \, V$

Since $\rho = \dfrac{m}{V}, \quad \rho'' = \dfrac{m}{V'} = \dfrac{m}{1.0147V} = 0.9855 \, \rho$

Fractional change in density $= \dfrac{\rho - \rho'}{\rho}$

$$= \dfrac{\rho - 0.9855 \, \rho}{\rho} = 0.0145.$$

Question 12. A 10 kW drilling machine is used to drill a bore in a small aluminium block of mass 8.0 kg. How much is the rise in temperature of the block in 2.5 minutes, assuming 50% of power is used up in heating the machine itself or lost to the surroundings? Specific heat of aluminium = 0.91 J g^{-1} K^{-1} .

Answer: Power = 10 kW = 10^4 W

Mass, m=8.0 kg = 8 x 10^3 g

Rise in temperature, $\Delta T = $?

Time, $t = 2.5$ min $= 2.5 \times 60 = 150$ s

Specific heat, $C = 0.91 \, Jg^{-1} \, K^{-1}$

Total energy $=$ Power $\times$ Time $= 10^4 \times 150$ J

$= 15 \times 10^5$ J

As 50% of energy is lost,

∴ Thermal energy available,

$$\Delta Q = \frac{1}{2} \times 15 \times 10^5 = 7.5 \times 10^5 \text{ J}$$

Since $\Delta Q = mc\Delta T$

∴ $\Delta T = \dfrac{\Delta Q}{mc} = \dfrac{7.5 \times 10^5}{8 \times 10^3 \times 0.91} = 103° \text{ C.}$

Question 13. A copper block of mass 2.5 kg is heated in a furnace to a temperature of 500°C and then placed on a large ice block. What is the maximum amount of ice that can melt? Specific heat of copper is 0.39 Jg^{-1}°C^{-1}. Heat of fusion of water = 335 Jg^{-1}.

Answer:

Here, mass of copper block, m = 2.5 kg = 2500 g
Fall in temperature, ΔT = 500 − 0 = 500°C
Specific heat of copper, c = 0.39 J g^{-1} °C^{-1}
Latent heat of fusion, L = 335 J g^{-1}
Let the mass of ice melted be m'

As, Heat gained by ice = Heat lost by copper

$\therefore$ $$m' L = mc \Delta T$$

$$m' = \frac{mc \Delta T}{L}$$

$$m' = \frac{2500 \times 0.39 \times 500}{335} = 1500 \text{ g} = 1.5 \text{ kg}$$

Question 14. In an experiment on the specific heat of a metal, a 0.20 kg block of the metal at 150°C is dropped in a copper calorimeter (of water equivalent 0.025 kg) containing 150 cm³ of water at 27 °C. The final temperature is 40° C. Compute the specific heat of the metal. If heat losses to the surroundings are not negligible, is your answer greater or smaller than the actual value for specific heat of the metal?

Answer: Mass of metal block, m = 0.20 kg = 200 g

Fall in the temperature of metal block,

ΔT = (150 − 40) °C = 110 °C

If C be the specific heat of metal, then heat lost by the metal block = 200 x C x 110 cal Volume of water = 150 cm³

mass of water = 150 g

Increase in temperature of water = (40 − 27) °C = 13°C

Heat gained by water = 150 x 13 cal Water equivalent of calorimeter, w = 0.025 kg = 25g

Heat gained by calorimeter,

$$= w \times \text{increase in temperature of calorimeter}$$
$$= 25 \times 13 \text{ cal}$$

Heat lost by metal block

$$= \text{Heat gained by water + Heat gained by calorimeter}$$
$$200 \times C \times 110 = (150 + 25) \, 13$$

$$C = \frac{175 \times 13}{200 \times 110} = 0.1 \text{ Cal g}^{-1} \text{ °C}^{-1} = 0.43 \text{ Jg}^{-1} \text{ K}^{-1}$$

If heat is lost to the surroundings, C will be smaller than the actual value.

Question 15. Given below are observations on molar specific heats at room temperature of some common gases.

Gas	Molar specific heat (C_v) (cal mol^{-1} K^{-1})
Hydrogen	4.87
Nitrogen	4.97
Oxygen	5.02
Nitric oxide	4.99
Carbon monoxide	5.01
Chlorine	6.17

The measured molar specific heats of these gases are markedly different from those for mono atomic gases. Typically, molar specific heat of a mono atomic gas is 2.92 cal/mol K. Explain this difference. What can you infer from the somewhat larger (than the rest) value for chlorine ?

Answer: The gases which are listed in the above table are diatomic gases and not mono atomic gases. For diatomic gases, molar specific heat =5/2 R = 5/2 x 1.98 = 4.95, which agrees fairly well with all observations listed in the table except for chlorine. A mono atomic gas molecule has only the translational motion. A diatomic gas molecule, apart from translational motion, the vibrational as well as rotational motion is also possible. Therefore, to raise the temperature of 1 mole of a diatomic gas through 1°C, heat is to be supplied to increase not only translational energy but also rotational and vibrational energies. Hence, molar specific heat of a diatomic gas is greater than that for mono atomic gas. The higher value of molar specific heat of chlorine as compared to hydrogen, nitrogen, oxygen etc. shows that for chlorine molecule, at room temperature vibrational motion also occurs along with translational and rotational motions, whereas other diatomic molecules at room temperature usually have rotational motion apart from their translational motion. This is the reason that chlorine has somewhat larger value of molar specific heat.

Question 16. A child running a temperature of 101°F is given an antipyrin (i.e., a medicine that lowers fever) which causes an increase in the rate of evaporation of sweat from his body. If the fever is brought down to 98° F in 20 minutes, what is the average rate of extra evaporation caused by the drug ? Assume the evaporation mechanism to be the only way by which heat is lost. The mass of the child is 30 kg. The specific heat of human body is approximately the same as that of water, and latent heat of evaporation of water at that temperature is about 580 cal g^{-1}.

Answer:

Decrease of temperature, Δt

$$= 101^\circ \ F - 98^\circ \ F = 3^\circ \ F = 3 \times \frac{5}{9}^\circ C = 1.67^\circ C$$

specific heat of water $= 1000$ cal kg^{-1} $^\circ$C^{-1}

latent heat of vaporisation, $L = 580 \times 10^3$ cal kg^{-1}

heat lost

$$= 30 \text{ kg} \times 1000 \text{ cal kg}^{-1} \ ^\circ C^{-1} \times 1.67 \ ^\circ C = 50100 \text{ cal}$$

If m' be the mass of water evaporated, then

$$m' = \frac{50100 \text{ cal}}{580 \times 10^3 \text{ cal kg}^{-1}} = 0.086 \text{ kg}$$

This much water has taken 20 minutes to evaporate.

So, rate of evaporation $= \dfrac{0.086 \text{ kg}}{20 \text{ min}} = \dfrac{86 \text{ g}}{20 \text{ min}}$

$$= 4.3 \text{ g min}^{-1}.$$

Question 17. A 'thermacole' icebox is a cheap and efficient method for storing small quantities of cooked food in summer in particular. A cubical icebox of side 30 cm has a thickness of 5.0 cm. If 4.0 kg of ice is put in the box, estimate the amount of ice remaining after 6 h. The outside temperature is 45°C, and coefficient of thermal conductivity of thermacole is 0.01 Js^{-1} m^{-1} °C^{-1} [Heat of fusion of water = 335 x 10^3 J kg^{-1}].

Answer: Each side of the cubical box (having 6 faces) is 30 cm = 0.30 m. Therefore, the total surface area' of the icebox exposed to outside air is A = 6 x (0.30 m)^2 = 0.54 m^2. The thickness of the icebox is d = 5.0 cm = 0.05 m, time of exposure t = 6h = 6 x 3600 s and temperature difference $T_1 - T_2$ = 45°C − 0°C = 45°C.

∴ Total heat entering the icebox in 6 h is given by

$$Q = \frac{KA\,(T_1 - T_2)\,t}{d}$$

$$= \frac{0.01 \text{ Js}^{-1} \text{ m}^{-1} \text{ C}^{-1} \times 0.54 \text{ m}^2 \times 45^\circ C \times (6 \times 3600 \text{ s})}{0.05 \text{ m}}$$

$$= 1.05 \times 10^5 \text{ J}$$

Suppose a mass m of ice melts with this heat. Then $Q = mL$, where L is tatent heat of fusion of water. Thus,

$$1.05 \times 10^5 \text{ J} = m \ (335 \times 10^3) \ \text{Jkg}^{-1}$$

or $$m = \frac{1.05 \times 10^5 \text{J}}{335 \times 10^3 \text{J kg}^{-1}} = 0.313 \text{ kg}$$

The initial mass of ice in the box is 4.0 kg. Therefore,the ice remaining in the box after 6 h is

$$= (4.0 - 0.313) \text{ kg}$$
$$= 3.687 \text{ kg}.$$

Question 18. A brass boiler has a base area 0.15 m² and thickness 1.0 cm. It boils water at the rate of 6.0 kg/ min when placed on a gas stove. Estimate the temperature of the part of the flame in contact with the boiler. Thermal conductivity of brass = 10⁹ Js⁻¹ m⁻¹ K⁻¹.(Heat of vaporization of water = 2256 x 10³ J kg⁻¹)

Answer:

Here, $$K = 109 \text{ Js}^{-1} \text{ m}^{-1} \text{K}^{-1}$$
$$A = 0.15 \text{ m}^2$$
$$d = 1.0 \text{ cm} = 10^{-2} \text{ m}$$
$$T_2 = 100° \text{ C}$$

Let T_1 = temperature of the part of the boiler in contact with the stove.
If Q be the amount of heat flowing per second through the base of the boiler, then

$$Q = \frac{KA \ (T_1 - T_2)}{d}$$

or $$Q = \frac{109 \times 0.15 \times (T_1 - 100)}{10^{-2}}$$

$$= 1635 \ (T_1 - 100) \text{ Js}^{-1} \qquad \qquad ...(i)$$

Also heat of vaporisation of water

$$L = 2256 \times 10^3 \text{ J kg}^{-1}$$

Rate of boiling of water in the boiler,

$$M = 6.0 \text{ kg min}^{-1} = \frac{6.0}{60} = 0.1 \text{ kg}^{-1} \text{ s}.$$

∴ Heat received by water per second, $Q = ML$

$$\Rightarrow \qquad Q = 0.1 \times 2256 \times 10^3 \text{ Js}^{-1} \qquad \qquad ...(ii)$$

∴ From eqn. (i) and (ii), we get

$$1635 \ (T_1 - 100) = 2256 \times 10^2$$

or $$T_1 - 100 = \frac{2256 \times 10^2}{1635} = 138$$

$$T_1 = 138 + 100 = 238°\text{C}.$$

Question 19. Explain why:
(a) a body with large reflectivity is a poor emitter.

(b) a brass tumbler feels much colder than a wooden tray on a chilly day.
(c) an optical pyrometer (for measuring high temperatures) calibrated for an ideal black body radiation gives too low a value for the temperature of a red hot iron piece in the open, but gives a correct value for the temperature when the same piece is in the furnace.
(d) the earth without its atmosphere would be inhospitably cold.
(e) heat systems based on circulation of steam are more efficient in warming a building than those based on circulation of hot water.
Answer: (a) According to Kirchh off's law of black body radiations, good emitters are good absorbers and bad emitters are bad absorbers. A body with large reflectivity is a poor absorber of heat and consequently, it is also a poor emitter.
(b) Brass is a good conductor of heat, while wood is a bad conductor. When we touch the brass tumbler on a chilly day, heat starts flowing from our body to the tumbler and we feel it cold. However, when the wooden tray is touched, heat does not flow from our hands to the tray and we do not feel cold.
(c) An optical pyrometer is based on the principle that the brightness of a glowing surface of a body depends upon its temperature. Therefore, if the temperature of the body is less than 600°C, the image formed by the optical pyrometer is not brilliant and we do not get the reliable result. It is for this reason that the pyrometer gives a very low value for the temperature of red hot iron in the open.
(d) The lower layers of earth's atmosphere reflect infrared radiations from earth back to the surface of earth. Thus the heat radiation received by the earth from the sun during the day are kept trapped by the atmosphere. If atmosphere of earth were not there, its surface would become too cold to live.
(e) Steam at 100°C possesses more heat than the same mass of water at 100°C. One gram of steam at 100°C possesses 540 calories of heat more than that possessed by 1 gm of water at 100°C. That is why heating systems based on circulation of steam are more efficient than those based on circulation of hot water.

Question 20. A body cools from 80 °C to 50°C in 5 minutes. Calculate the time it takes to cool from 60 °C to 30°C. The temperature of the surroundings is 20 °C.

Answer:

According to Newton's law of cooling, the rate of cooling is proportional to the difference in temperature.

Here average of 80 °C and 50 °C = 65 °C

Temperature of surroundings = 20°C

∴ Difference = 65 – 20 = 45 °C

Under these conditions, the body cools 30°C in time 5 minutes

∴ $\dfrac{\text{Change in temp.}}{\text{Time}} = K\,\Delta T$

or $\dfrac{30}{5} = K \times 45°$ ...(i)

The average of 60°C and 30°C is 45°C which is 25°C (45 – 20) above the room temperature and the body cools by 30°C (60 – 30) in a time t (say)

∴ $\dfrac{30}{t} = K \times 25$ ...(ii)

where K is same for this situation as for the original.

Dividing eqn. (i) by (ii), we get

$$\dfrac{30/5}{30/t} = \dfrac{K \times 45}{K \times 25}$$

or $\dfrac{t}{5} = \dfrac{9}{5}$

⇒ $t = 9$ min.