

NCERT SOLUTIONS
PHYSICS XI CLASS
CHAPTER - 11
THERMAL PROPERTIES OF MATTER

11.1 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.

Sol. For Neon

$$(i) \frac{C}{100} = \frac{K - 273.15}{100} ; K = 24.57 \text{ K}$$

$$\therefore C = 24.57 - 273.15 = -248.58^\circ\text{C}$$

$$\text{Also, } \frac{F - 32}{180} = \frac{K - 273.15}{100} \text{ or } \frac{F - 32}{180} = \frac{24.57 - 273.15}{100} \text{ or } F = -415.44^\circ\text{F}$$

$$\text{For CO}_2: \frac{C}{100} = \frac{K - 273.15}{100} \text{ or } C = 216.55 - 273.15 = -56.60^\circ\text{C}$$

$$\text{Also, } \frac{F - 32}{180} = \frac{216.55 - 273.15}{180} \text{ or } F = -69.88^\circ\text{F}$$

11.2 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 ?

Sol. Triple point of water on scale A = 200 A
 200 A = 273.16 K

$$\therefore 1A = \frac{273.16}{200} \Rightarrow \theta_a = \frac{273.16}{200} \times T_a$$

$$\text{Similarly, } \theta_b = \frac{273.16}{350} \times T_b$$

But $\theta_a = \theta_b$ as they represent triple point of water

$$\therefore \frac{273.16}{200} \times T_a = \frac{273.16}{350} \times T_b \Rightarrow \frac{T_a}{T_b} = \frac{4}{7}$$

11.3 The electrical resistance in ohms of a certain thermometer varies with temperature according to the approximate law: $R = R_0 [1 + \alpha (T - T_0)]$

The resistance is 101.6 Ω at the triple-point of water 273.16K, and 165.5 Ω at the normal melting point of lead (600.5 K). What is the temperature when the resistance is 123.4 Ω ?

Sol. Here $R = R_0 [1 + 5 \times 10^{-3} (T - T_0)]$

$$R_T = 101.6 \Omega, R_N = 165.5 \Omega, T_N = 600.5$$

Using above equation

$$R_0 [1 + 0.005 (600.5 - T_0)] = 165.5 \quad \dots\dots\dots (1)$$

$$R_0 [1 + 0.005 (273.16 - T_0)] = 101.6 \quad \dots\dots\dots (2)$$

Dividing eq. (2) by (1)

$$\frac{1 + 0.005 (273.16 - T_0)}{1 + 0.005 (600.5 - T_0)} = \frac{101.6}{165.5} \text{ or } T_0 = -50.33 \text{ K}$$

Substituting for T_0 in eq. (2)

$$R_0 [1 + 0.005 (273.16 - (-50.33))] = 101.6 \quad \text{or} \quad R_0 = 38.823 \Omega$$

The resistance at any unknown temperature T is 123.4 Ω .

$$\therefore 123.4 = 38.823 [1 + 5 \times 10^{-3} (T - (-50.33))]$$

$$123.4 = 38.823 + 38.823 \times 5 \times 10^{-3} (T + 50.33) \quad \text{or} \quad T = 385.3 \text{ K}$$

- 11.4** (a) The triple-point of water is a standard fixed point in modern 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 by $t_c = T - 273.15$. 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?

- Sol.** (a) The triple point of water has a unique value of 273.16K. 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 t_c , on Celsius scale as:

$$t_c = T - 273.15$$

- (d) There are 100 divisions on absolute scale while on Fahrenheit scale the same interval is divided into 180 divisions.

$$\therefore 1 \text{ div. on absolute scale} = \frac{180}{100} \text{ div. on Fahrenheit scale}$$

$$\therefore \text{Temperature of triple point on water (273.16 K)}$$

$$\text{On absolute scale having a degree equal to } 1.8 = 273.16 \times 1.8 = 491.69$$

- 11.5** 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	$1.250 \times 10^5 \text{ Pa}$	$0.200 \times 10^5 \text{ Pa}$
Normal melting point of sulphur	$1.797 \times 10^5 \text{ Pa}$	$0.287 \times 10^5 \text{ Pa}$

- (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?

- Sol.** (a) Let T be the melting point of sulphur.
For water triple point in $T_{tr} = 273.16 \text{ K}$

$$\text{For thermometer A: } T = \frac{P}{P_{tr}} \times 273.16 = \frac{1.797 \times 10^5}{1.250 \times 10^5} \times 273.16 = 392.69 \text{ K}$$

$$\text{For thermometer B: } T = \frac{0.287 \times 10^5}{0.200 \times 10^5} \times 273.16 = 391.98 \text{ K}$$

The difference in the two values is due to the fact that oxygen and hydrogen do not behave strictly as perfect gas.

- (b) To reduce the discrepancy between the two readings, the observation should be taken under such conditions when the gases approach ideal gas behaviour.

11.6 A steel tape 1m 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 = $1.20 \times 10^{-5} \text{ K}^{-1}$.

Sol. If l_1 and l_2 be the length of the steel take at temperature t_1 and t_2 °C then

$$\Delta t = 45 - 27 = 18^\circ\text{C}; \alpha = 1.20 \times 10^{-5}/^\circ\text{C}$$

Let $l_1 = 1 \text{ cm}$, Using relation $l_2 = l_1(1 + \alpha\Delta t)$

$$l_2 = 1[1 + 1.20 \times 10^{-5} \times 18] = 1.000216 \text{ cm.}$$

The size of the rod at 45°, is 63 cm.

$$\therefore \text{Actual length of the rod at } 45^\circ\text{C} = 63 \times 1.000216 = 63.0136 \text{ cm.}$$

The length of the rod, on a day when temperature is 27°C = $63 \times 1 = 63 \text{ cm}$.

11.7 A large steel wheel is to be fitted on to a shaft of the same material. At 275°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:

$$(\alpha_{\text{steel}} = 1.20 \times 10^{-5} \text{ K}^{-1})$$

Sol. Here, $T_1 = 300 \text{ K}$

$$\text{Length at temperature } T_1 = l_{T_1} = 8.70 \text{ cm.}$$

$$\text{Length at temperature } T_2 = l_{T_2} = 8.69 \text{ cm.}$$

$$\therefore \text{Change in length } l_{T_2} - l_{T_1} = l_{T_1} \times (T_2 - T_1)$$

$$\text{or } 8.69 - 8.70 = 8.70 \times (1.20 \times 10^{-5}) \times (T_2 - 300)$$

$$\text{or } T_2 - 300 = \frac{0.01}{8.70 \times 1.2 \times 10^{-5}} = 95.8 \text{ or } T_2 = 300 - 95.8 = 204.2 \text{ K} = -68.8^\circ\text{C}$$

11.8 A hole is drilled in a copper sheet. The diameter of the hole is 4.24 cm at 27°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 = $1.70 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$.

Sol. Here $D_1 = 4.24 \text{ cm}$, $t_1 = 27^\circ\text{C}$, $t_2 = 227^\circ\text{C}$,

$$\therefore \Delta t = 200^\circ\text{C}, \alpha = 1.70 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$$

$$\text{From formula, } \Delta D = D_1 \alpha \Delta t = 4.24 \times 1.70 \times 10^{-5} \times 200 = 1.44 \times 10^{-2} \text{ cm.}$$

11.9 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 = $2.0 \times 10^{-5} \text{ K}^{-1}$;

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

Sol. Here, $L_1 = 1.8 \text{ m}$, $t_1 = 27^\circ\text{C}$, $t_2 = -39^\circ\text{C}$, $r = 1 \text{ mm} = 10^{-3} \text{ m}$, $\alpha = 2 \times 10^{-5}/^\circ\text{C}$,

$$Y = 0.1 \times 10^{11} \text{ Nm}^{-2}$$

From formula, $Y = \frac{F.L}{a.\Delta L}$, where ΔL is change in length and is given by $\Delta L = L \alpha \Delta t$

$$\therefore Y = \frac{F.L}{a.L\alpha \Delta T} \text{ or } F = Y.a \alpha \Delta t$$

$$F = 0.91 \times 10^{11} \times 3.14 (10^{-3})^2 \times 2 \times 10^{-5} \times (27 - (-39)) = 0.91 \times 3.14 \times 66 \times 2 = 3.8 \times 10^2 \text{ N}$$

11.10 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 = $2.0 \times 10^{-5} \text{ K}^{-1}$, steel = $1.2 \times 10^{-5} \text{ K}^{-1}$).

Sol. Here $l_1 = 50\text{cm}$, $\alpha_1 = 2.10 \times 10^{-5} / ^\circ\text{C}$

$$\Delta t = (250 - 40) = 210^\circ\text{C}, \quad \alpha_2 = 1.2 \times 10^{-5} / ^\circ\text{C}$$

$$\text{Change in length, } \Delta L_1 = L_1 \alpha_1 \Delta t = 50 \times 2.10 \times 10^{-5} \times 210 = 0.22 \text{ cm.}$$

$$\text{Similarly, } \Delta L_2 = L_2 \alpha_2 \Delta t = 50 \times 1.2 \times 10^{-5} \times 210 = 0.126 \text{ cm.}$$

$$\therefore \text{ Total change in length } \Delta L = \Delta L_1 + \Delta L_2 = 0.22 + 0.126 = 346 \text{ cm.}$$

11.11 The coefficient of volume expansion of glycerine is $49 \times 10^{-5} \text{ } ^\circ\text{C}^{-1}$. What is the fractional change in the density for a 30°C rise in temperature.

Sol. Here, $\gamma = 49 \times 10^{-5} / ^\circ\text{C}$, $\Delta t = 30^\circ\text{C}$

$$V' = V(1 + \gamma t) = V(1 + 49 \times 10^{-5} \times 30) = V(1 + 1470 \times 10^{-5}) = 1.01470 V$$

$$\text{Now density, } \rho = \frac{M}{V} \text{ and } \rho' = \frac{M}{V'} = \frac{M}{1.0147V} \text{ or } \rho' = \frac{1}{1.0147} \rho$$

$$\therefore \text{ Fractional change in density } = \frac{\rho - \rho'}{\rho} = \frac{\left(\rho - \frac{1}{1.0147} \rho\right)}{\rho} = \frac{(1.014 - 1)}{1.014} = 0.0138$$

11.12 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 = $0.91 \text{ Jg}^{-1}\text{ } ^\circ\text{C}^{-1}$.

Sol. Here, $P = 10 \text{ kW} = 10^4 \text{ W}$, $m = 8.0 \text{ kg} = 8.0 \times 10^3 \text{ g}$
 $t = 2.5 \text{ min} = 2.5 \times 60 = 150\text{s}$, Sp. heat = $0.91 \text{ J/g}^\circ\text{C}$

$$\therefore Q = P \times t = 10^4 \times 150 = 15 \times 10^5 \text{ J}$$

$$\text{Heat absorbed by block} = 15 \times 10^5 \times \frac{50}{100} = 7.5 \times 10^5 \text{ J}$$

$$\therefore \text{ From formula, } \Delta Q = ms \Delta t$$

$$\Delta t = \frac{\Delta Q}{m.s} = \frac{7.5 \times 10^5}{8 \times 10^3 \times 0.91} \approx 103^\circ\text{C}$$

11.13 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 maximum amount of ice that can melt?

(Specific heat of copper = $0.39 \text{ J/g}^\circ\text{C}$,
 heat of fusion of water = 335 Jg^{-1})

Sol. Here, $M = 2.5 \text{ kg} = 2500 \text{ g}$, $\Delta t = 500 - 0 = 500^\circ\text{C}$, $s = 0.39 \text{ J/g}^{-1}\text{ } ^\circ\text{C}^{-1}$, $L = 335 \text{ Jg}^{-1}$
 Let m mass of ice melts.

$$\text{So, } mL = Ms\Delta t \text{ or } m = \frac{Ms\Delta t}{L} = \frac{2500 \times 0.39 \times 500}{335} = 1455\text{g} = 1.46 \text{ kg}$$

11.14 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.

Sol. Here mass of metal block, $m = 0.20 \text{ kg} = 200\text{g}$

$$\text{Fall in temperature of metal } \Delta t = 150 - 40 = 110^\circ\text{C}$$

$$\text{Value of water } M_w = 150 \text{ cc} = 150\text{g}$$

Water equivalent of calorimeter $w = 0.025 \text{ kg} = 25\text{g}$

Rise in the temperature of water and calorimeter $\Delta t' = 40 - 27 = 13^\circ\text{C}$

According to principle of calorimetry, Heat given = Heat taken

$$ms\Delta t = (m_w + w) s_w \Delta t'$$

$$\therefore s = \frac{(150 + 25) \times 1 \times 13}{200 \times 110} = \frac{175 \times 13}{200 \times 110} = 0.103 \text{ cal g}^{-1} \text{ } ^\circ\text{C}^{-1}$$

If heat losses to the surroundings are not negligible then value of S will be less than its actual value.

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

Gas	Molar specific heat (C_v) ($\text{cal mol}^{-1} \text{ K}^{-1}$)
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 monatomic gases. Typically, molar specific heat of a monatomic gas is 2.92 cal/mol K . Explain this difference. What can you infer from the somewhat larger (than the rest) value for chlorine?

Sol. 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.

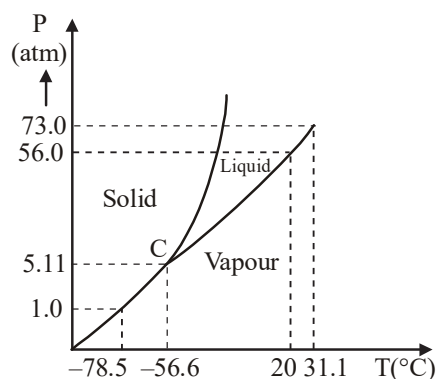
If only rotational mode of motion is considered, then the molar specific heat of a diatomic gas

$$= \frac{5}{2} R = \frac{5}{2} \times 1.98 = 4.95 \text{ cal mol}^{-1} \text{ K}^{-1}.$$

With the exception of chlorine, all the observations in the given table agree with $(5/2) R$. This is because at room temperature, chlorine also has vibrational modes of motion besides rotational and translational modes of motion.

11.16 Answer the following questions based on the P-T phase diagram of carbon dioxide:

- At what temperature and pressure can the solid, liquid and vapour phases of CO_2 coexist in equilibrium?
- What is the effect of decrease of pressure on the fusion and boiling point of CO_2 ?
- What are the critical temperature and pressure for CO_2 ? What is their significance?
- Is CO_2 solid, liquid or gas at (a) -70°C under 1 atm, (b) -60°C under 10 atm, (c) 15°C under 56 atm?



Sol. (a) The P-T phase diagram for CO_2 is shown in the given 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.

- The fusion and boiling points of CO_2 decrease with a decrease in pressure.
- 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.
- It can be concluded from the P-T phase diagram of CO_2 that:

- (1) CO₂ is gaseous at -70°C, under 1 atm pressure
- (2) CO₂ is solid at -60°C, under 10 atm pressure
- (3) CO₂ is liquid at 15°C, under 56 atm pressure

11.17 Answer the following questions based on the P – T phase diagram of CO₂:

- (a) CO₂ at 1 atm pressure and temperature - 60 °C is compressed isothermally. Does it go through a liquid phase?
- (b) What happens when CO₂ at 4 atm pressure is cooled from room temperature at constant pressure?
- (c) Describe qualitatively the changes in a given mass of solid CO₂ at 10 atm pressure and temperature -65 °C as it is heated up to room temperature at constant pressure.
- (d) CO₂ is heated to a temperature 70 °C and compressed isothermally. What changes in its properties do you expect to observe?

- Sol.**
- (a) Since the temperature -60°C lies to the left of 56.6°C on the curve i.e. lies in the region of vapour and solid phase, so carbon dioxide will condense directly into solid without becoming liquid.
 - (b) Since the pressure 1 atm is less than 5.11 atm, the carbon dioxide will directly condense into solid without becoming liquid.
 - (c) When a solid CO₂ at 10 atm pressure and -65°C temperature is heated, it is first converted into a liquid. A further increase in temperature brings it into the vapour phase. At P = 10 atm, if a horizontal line is drawn parallel to the T-axis, then the points of intersection of this line with the fusion and vaporisation curve will give the fusion and boiling points of CO₂ at 10 atm.
 - (d) Since 70°C is higher than the critical temperature of CO₂, so the CO₂ gas cannot be converted into liquid state on being compressed isothermally at 70°C. It will remain in the vapour state. However, the gas will depart more and more from its perfect gas behaviour with the increase in pressure.

11.18 A child running a temperature of 101°F is given an antipylin 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 min, what is the average rate of extra evaporation by the drug. Assume the evaporation mechanism to be the only way to 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.

Sol. Here, Fall in the temperature of child = 101 – 98 = 3°F = $\frac{5}{9} \times 3 = \frac{5}{3}$ °C

$$m = 30 \text{ kg, } S = 1000 \text{ cal kg}^{-1} \text{ } ^\circ\text{C}^{-1}$$

$$\text{Heat lost by child, } \Delta Q = ms \Delta T = 30 \times \frac{5}{3} \times 1000 = 5 \times 10^4 \text{ cal}$$

Let m is the mass of water evaporated in 20 min. Then

$$\Delta Q = m'L \quad \text{or} \quad m' = \frac{\Delta Q}{L} = \frac{5 \times 10^4}{580} = 86.2 \text{ g}$$

$$\therefore \text{Rate of evaporation} = \frac{86.2}{20} = 4.31 \text{ g min}^{-1}$$

11.19 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 co-efficient of thermal conductivity of thermacole is 0.01 J s⁻¹ m⁻¹ K⁻¹. [Heat of fusion of water = 335 × 10³ J kg⁻¹]

Sol. Here, $l = 5.0 \text{ cm} = 5 \times 10^{-2} \text{ m}$

$$t = 60 \times 60 \times 60 \text{ sec, } \theta_1 - \theta_2 = 45^\circ\text{C, } k = 0.01 \text{ J s}^{-1} \text{ m}^{-1} \text{ K}^{-1}.$$

Surface area of all the six faces = $6(\text{side})^2 = 6(0.3 \times 0.3) = 0.54 \text{ m}^2$.

Let m mass of ice will melt.

$$\therefore Q = mL \quad \text{or} \quad mL = \frac{KA(\theta_1 - \theta_2)t}{\ell} \quad \text{or} \quad m = \frac{KA(\theta_1 - \theta_2)t}{L \times \ell}$$

$$\text{or} \quad m = \frac{0.01 \times 0.54 \times 45 \times 6 \times 60 \times 60}{335 \times 10^3 \times 5 \times 10^{-2}} = 0.313 \text{ kg}$$

Mass of the ice left in the box = $4.0 - 0.313 = 3.687 \text{ kg}$.

11.20 A brass boiler has a base area of 0.15 m^2 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 = $109 \text{ Js}^{-1}\text{m}^{-1}\text{C}^{-1}$. ($L = 2256 \times 10^3 \text{ J kg}^{-1}$)

Sol. Here $A = 0.15 \text{ m}^2$, $\ell = 1.0 \times 10^{-2} \text{ m}$

$$\frac{m}{t} = \frac{6 \text{ kg}}{\text{min}} = \frac{6 \text{ kg}}{60 \text{ sec}} = \frac{1 \text{ kg}}{10 \text{ sec}}$$

$$K = 109 \text{ Js}^{-1}\text{m}^{-1}\text{C}^{-1}, L = 2256 \times 10^3 \text{ J kg}^{-1}, \theta_2 = 100^\circ\text{C}$$

$$\text{From formula, } Q = \frac{KA(\theta_1 - \theta_2)t}{\ell}$$

This heat supplied to the water is used in boiling it.

Let temperature of the part of the flame in contact with boiler is θ_1 .

$$\therefore mL = \frac{KA(\theta_1 - \theta_2)t}{\ell} \quad \text{or} \quad \theta_1 - \theta_2 = \frac{mL\ell}{KA t}$$

$$\text{or} \quad \theta_1 = \left(\frac{m L \ell}{t A K} \right) + \theta_2 = \frac{1}{10} \times \frac{2256 \times 10^3 \times 1 \times 10^{-2}}{109 \times 0.15} + 100 = 137.9 + 100 = 237.9^\circ$$

11.21 Explain why:

- a body with large reflectivity is a poor emitter.
- a brass tumbler feels much colder than a wooden tray on a chilly day.
- 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.
- the earth without its atmosphere would be inhospitably cold
- heating systems based on circulation of steam are more efficient in warming a building than those based on circulation of hot water.

Sol. (a) A poor absorber is a poor radiator. But a poor absorber is a good reflector. Hence "a body with large reflectivity is a poor emitter."

(b) Brass is a good conductor and absorbs body heat when we touch it by our hand. On the other hand, wood is bad conductor. So brass tumbler feels much colder than a wooden tray on a chilly day.

(c) In case, red hot iron piece is in oven, the temperature is given by $E = \sigma T^4$. But if it is in the open having temperature T_0 , then energy radiated per unit area per second is $E = \sigma (T^4 - T_0^4)$. It gives too low value for temperature.

(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) The amount of heat contained by steam at 100° is more than that in water at the same temperature. Latent heat of vaporisation of water is 540 cal/g . Thus, one gram of steam has 540 calories more heat than water at the same temperature. Hence heating system based on circulation of steam is more efficient.

11.22 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 .

Sol. Here, $\theta_1 = 80^{\circ}\text{C}$, $\theta_2 = 50^{\circ}\text{C}$, $\theta_0 = 20^{\circ}\text{C}$

$$\therefore \theta = \frac{\theta_1 + \theta_2}{2} = \frac{80 + 50}{2} = 65^{\circ}\text{C}; \quad t = 5 \text{ minutes}$$

$$\therefore \frac{(\theta_1 - \theta_2)}{t} = K(\theta - \theta_0) \quad ; \quad \frac{80 - 50}{5} = K(65 - 20)$$

$$\frac{30}{5} = K \times 45 \quad \text{or} \quad K = \frac{30}{5} \times \frac{1}{45} = \frac{6}{45}$$

In second case $\theta_1 = 60^{\circ}\text{C}$, $\theta_2 = 30^{\circ}\text{C}$,

$$\therefore \theta = \frac{60 + 30}{2} = 45^{\circ}\text{C}$$

$$\therefore \frac{(\theta_1 - \theta_2)}{t} = K(\theta - \theta_0) \quad \text{or} \quad \frac{60 - 30}{t} = \frac{6}{45}(45 - 20)$$

$$\text{or} \quad \frac{30}{t} = \frac{6}{45} \times 25 \quad \text{or} \quad t = \frac{30 \times 45}{6 \times 25} = 9 \text{ min.}$$