

## PROBLEMS

**8.1 Temperature of water in a beaker is  $50^{\circ}\text{C}$ , what is its value in Fahrenheit scale?**

**( $122^{\circ}\text{F}$ )**

**Solution:** Temperature in Celsius scale =  $C = 50^{\circ}\text{C}$

Temperature in Fahrenheit scale =  $F = ?$

$$F = 1.8C + 32$$

$$F = 1.8 \times 50 + 32 = 90 + 32$$

$$F = 122^{\circ}\text{F}$$

**8.2 Normal human body temperature is  $98.6^{\circ}\text{F}$ , convert it into Celsius scale and kelvin scale.**

**( $37^{\circ}\text{C}, 310\text{K}$ )**

**Solution:** Temperature in Fahrenheit scale =  $98.6^{\circ}\text{F}$

**(i)** Temperature in Celsius scale = ?

**(ii)** Temperature in Kelvin scale = ?

**(i)**  $F = 1.8C + 32$

$$1.8C = F - 32$$

$$1.8C = 98.6 - 32$$

$$1.8C = 66.6$$

$$C = \frac{66.6}{1.8} = 37^{\circ}\text{C}$$

**(ii)**  $T(\text{K}) = C + 273$

$$T(\text{K}) = 37 + 273$$

$$T(\text{K}) = 310\text{K}$$

**8.3 Calculate the increase in the length of an aluminum bar 2 m long when heated from 0°C to 20°C, if the thermal coefficient of linear expansion of aluminum is  $2.5 \times 10^{-5} K^{-1}$ . (0.1cm)**

**Solution:** Original length of rod =  $L_0 = 2\text{m}$

Initial temperature =  $T_0 = 0^\circ\text{C} = 0 + 273 = 273\text{ K}$

Final temperature =  $T = 20^\circ\text{C} = 20 + 273 = 293\text{ K}$

Change in temperature =  $\Delta T = T - T_0 = 293 - 273 = 20\text{ K}$

Coefficient of linear expansion of aluminum =  $\alpha = 2.5 \times 10^{-5} K^{-1}$

Increase in volume  $\Delta L = ?$

$$\Delta L = \alpha L_0 \Delta T$$

$$\Delta L = 2.5 \times 10^{-5} \times 20$$

$$\Delta L = 100 \times 10^{-5}$$

$$\Delta L = 0.001\text{ m} = 0.001 \times 100 = 0.1\text{cm}$$

**8.4 A balloon contains  $1.2\text{m}^3$  air at  $15^\circ\text{C}$ . Find its volume at  $40^\circ\text{C}$ . Thermal coefficient of volume expansion of air is  $3.67 \times 10^{-3} K^{-1}$ .**

**( $1.3\text{m}^3$ )**

**Solution:** Original volume =  $V_0 = 1.2\text{m}^3$

Initial temperature =  $T_0 = 15^\circ\text{C} = 15 + 273 = 288\text{ K}$

Final temperature =  $T = 40^\circ\text{C} = 40 + 273 = 313\text{ K}$

Change in temperature =  $\Delta T = T - T_0 = 313 - 288 = 25\text{ K}$

Coefficient of volume expansion of air  $\beta = 3.67 \times 10^{-3} K^{-1}$

Volume =  $V = ?$

$$V = V_0 (1 + \beta \Delta T)$$

$$V = 1.2 (1 + 3.67 \times 10^{-3} \times 25) = 1.2(1 + 91.75 \times 10^{-3})$$

$$= 1.2(1 + 0.09175) = 1.2 \times 1.09175$$

$$V = 1.3m^3$$

**8.5 How much heat is required to increase the temperature of 0.5 kg of water from 10°C to 65°C?  
(115500 J)**

**Solution:**

$$\text{Mass of water} = m = 0.5 \text{ kg}$$

$$\text{Initial temperature} = T_1 = 10^\circ\text{C} = 10 + 273 = 283 \text{ K}$$

$$\text{Final temperature} = T_2 = 65^\circ\text{C} = 65 + 273 = 338 \text{ K}$$

$$\text{Change in temperature} = \Delta T = T_2 - T_1 = 338 - 283 = 55 \text{ K}$$

$$\text{Heat} = \Delta Q = ?$$

$$\Delta Q = mc \Delta T$$

$$\Delta Q = 0.5 \times 2400 \times 55$$

$$\Delta Q = 115500 \text{ J}$$

**8.6 An electric heater supplies heat at the rate of 1000J per second. How much time is required to raise the temperature of 200 g of water from 20°C to 90°C?  
(58.8 s)**

**Solution:** Power =  $P = 1000 \text{ Js}^{-1}$

$$\text{Mass of water} = m = 200 \text{ g} = \frac{200}{1000} = 0.2 \text{ kg}$$

$$\text{Initial temperature} = T_2 = 20^\circ\text{C} = 20 + 273 = 293 \text{ K}$$

$$\text{Final temperature} = T_1 = 90^\circ\text{C} = 90 + 273 = 363 \text{ K}$$

$$\text{Change in temperature} = \Delta T = T_2 - T_1 = 363 - 293 = 70 \text{ K}$$

Specific heat of water =  $c = 4200 \text{ Jkg}^{-1} \text{ K}^{-1}$

Time =  $t = ?$

$$P = \frac{W}{t}$$

Or  $P = \frac{Q}{t}$

Or  $P \times t = Q$

Or  $P \times t = mc \Delta T$

Or  $t = \frac{mc \Delta T}{P}$

$$t = \frac{0.2 \times 4200 \times 70}{1000} = 58.8 \text{ s}$$

**8.7** How much ice will melt by 5000 J of heat? Latent heat of fusion of ice =  $336000 \text{ J kg}^{-1}$ .  
(149 g)

**Solution:** Amount of heat required to melt ice = 50000J

Latent heat of fusion of ice =  $336000 \text{ J kg}^{-1}$

Amount of ice =  $m = ?$

$$\Delta Q_f = m H_f$$

Or  $m = \frac{\Delta Q_f}{H_f}$

$$m = \frac{50000}{336000} = 0.1488 \text{ kg}$$

$$= 0.1488 \times 1000 = \frac{1488}{1000} \times 1000 = 148.8 \text{ g} \approx 149 \text{ g}$$

**8.8** Find the quantity of heat needed to melt 100g of ice at  $-10^\circ\text{C}$  into water at  $10^\circ\text{C}$ .

**(39900 J)**

**(Note: Specific heat of ice is  $2100 \text{ Jkg}^{-1} \text{ K}^{-1}$ , specific heat of water is  $4200 \text{ Jkg}^{-1} \text{ K}^{-1}$ , Latent heat of fusion of ice is  $336000 \text{ Jkg}^{-1}$ ).**

**Solution:** Mass of ice =  $m = 100 \text{ g} = \frac{100}{1000} = 0.1 \text{ kg}$

Specific heat of ice =  $c_1 = 2100 \text{ Jkg}^{-1} \text{ K}^{-1}$

Latent heat of fusion of ice =  $L = 336000 \text{ Jkg}^{-1}$

Specific heat of water =  $c = 4200 \text{ Jkg}^{-1} \text{ K}^{-1}$

Quantity of heat required =  $Q = ?$

**Case I:**

Heat gained by ice from  $-10^\circ\text{C}$  to  $0^\circ\text{C}$

$$Q_1 = mc \Delta T$$

$$Q_1 = 0.1 \times 2100 \times 10 = 2100 \text{ J}$$

**Case II:**

Heat required for ice to melt =  $Q_2 = mL$

$$= 0.1 \times 336000$$

$$Q_2 = 33600 \text{ J}$$

**Case III:**

Heat required to raise the temperature of water from  $0^\circ\text{C}$  to  $10^\circ\text{C}$

$$Q_3 = mc \Delta T$$

$$Q_3 = 0.1 \times 4200 \times 10 = 4200 \text{ J}$$

$$\text{Total heat required} = Q = Q_1 + Q_2 + Q_3$$

$$Q = 2100 + 33600 + 4200$$

$$Q = 39900 \text{ J}$$

**8.9 How much heat is required to change 100g of water at 100°C into steam? (Latent heat of vaporization of water is  $2.26 \times 10^6 \text{ Jkg}^{-1}$ . ( $2.26 \times 10^5 \text{ J}$ ))**

**Solution:** Mass of water =  $m = 100 \text{ g} = \frac{100}{1000} = 0.1 \text{ kg}$

Latent heat of vaporization of water =  $H_v = 2.26 \times 10^6 \text{ Jkg}^{-1}$

Heat required =  $\Delta Q_v = ?$

$$\Delta Q_v = mH_v$$

$$\begin{aligned} \Delta Q_v &= 0.1 \times 2.26 \times 10^6 = 0.226 \times 10^6 = \frac{226}{1000} \times 10^6 \\ &= 2.26 \times 10^{-1} \times 10^6 = 2.26 \times 10^5 \text{ J} \end{aligned}$$

**8.10 Find the temperature of water after passing 5 g of steam at 100°C through 500 g of water at 10°C. (16.2°C)**

(Note: Specific heat of water is  $4200 \text{ Jkg}^{-1} \text{ K}^{-1}$ , Latent heat of vaporization of water is  $2.26 \times 10^6 \text{ Jkg}^{-1}$ ).

**Solution:** Mass of steam =  $m_1 = 5 \text{ g} = \frac{5}{1000} \text{ kg} = 0.005 \text{ kg}$

Temperature of steam =  $T_1 = 100^\circ\text{C}$

Mass of water =  $m_2 = 0.5 \text{ kg}$

Temperature of water =  $T_2 = 10^\circ\text{C}$

Final temperature =  $T_3 = ?$

**Case I:**

Latent heat lost by steam =  $Q_1 = mL$

$$Q_1 = 0.005 \times 2.26 \times 10^6 = 11.3 \times 10^3 = 11300 \text{ J}$$

**Case II:**

Heat lost by steam to attain final temperature  $Q_2 = m_1 c \Delta T$

$$Q_2 = 0.005 \times 4200 \times (100 - T_3)$$

$$Q_2 = 21(100 - T_3)$$

**Case III:**

Heat gained by water  $Q_3 = m_2 c \Delta T$

$$Q_3 = 0.5 \times 4200 \times (T_3 - 10)$$

$$Q_3 = 2100(T_3 - 10)$$

According to the law of heat exchange.

Heat lost by stream = heat gained by water

$$Q_1 + Q_2 = Q_3$$

$$11300 + 21(100 - T_3) = 2100(T_3 - 10)$$

$$11300 + 2100 - 21T_3 = 2100T_3 - 21000$$

$$13400 + 21000 - 21T_3 = 2100T_3 - 21T_3$$

$$34400 = 2121T_3$$

$$T_3 = \frac{34400}{2121}$$

$$T_3 = 16.2 \text{ }^\circ\text{C}$$

