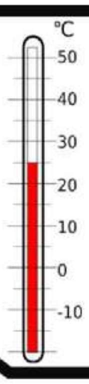

UNIT 8

THERMAL PROPERTIES OF MATTER

PROBLEMS

8.1 Temperature of the water in beaker is 50^0 C. What is its value in Fahrenheit?

Given Data

Temperature in Celsius = $T_c = 50^0$ C

Required

Temperature in Fahrenheit = T_f = ?

Solution

As we know that

$$F = \frac{9}{5}C + 32$$

By putting the values, we have

$$\frac{9}{5} \times 50 + 32$$
$$F = 90 + 32$$
$$F = 122\ ^{o}F$$

Result

Temperature in Fahrenheit = $T_f = 122\ ^{o}F$

8.2 Normal human body temperature is 98.6^0 F. Convert it into Celsius and Kelvin scale.
(GRW 2013, LHR 2013, 2015)

Given Data

Normal human Temperature in Fahrenheit = $T_f = 98.6^0$ F

Required

Temperature in Celsius = T_c = ?

Temperature in Kelvin = T_k = ?

Solution

As we know that

$$C = \frac{5}{9}(F - 32)$$

By putting the values, we have

$$C = \frac{5}{9}(98.6 - 32)$$
$$C = \frac{5}{9}(66.6)$$
$$C = 37\ ^{o}C$$

As we know that

$$T_K = C + 273$$

By putting the values, we have

$$T_K = 37 + 273 = 310\text{ K}$$
$$T_K = 310\text{ K}$$

Result

Temperature in Celsius = $T_c = 37\ ^{o}C$

Temperature in Kelvin = $T_k = 310$ K

8.3 Calculate the increase in length of an aluminium bar of 2m long when heated from 0^0 C to 20^0 C. If the thermal coefficient of linear expansion of aluminum is 2.5×10^{-5} K^{-1}.

Given Data

Length of aluminum bar = L_1 = 2 m
Initial temperature = $T_1 = 0^oC = (0 + 273)$ K = 273 K
Final temperature = $T_2 = 20^oC = (20 + 273)$ K = 293 K
Coefficient of linear expansion of aluminum = $\alpha = 2.5 \times 10^{-5}$ K^{-1}

Required

Increase in length = $L - L_o$ = ?

Solution

As we know that

$$L - L_o = \alpha L_o (T_2 - T_1)$$

By putting the values, we have

$$L - L_o = 2.5 \times 10^{-5} \times 2 \times (293 - 273)$$
$$L - L_o = 5 \times 10^{-5} (20)$$
$$L - L_o = 100 \times 10^{-5}$$
$$L - L_o = 1 \times 10^{-3} \text{ m} = 0.1 \text{ cm} = 1 \text{ mm}$$

Result

Increase in length = $L - L_o = 1 \times 10^{-3}$ m = 0.1 cm = 1 mm

8.4 A balloon contains 1.2 m^3 of air at 15^0 C. Find its volume at 40^0 C. Thermal coefficient of volume expansion of air is 3.67×10^{-3} K^{-1}.

Given Data

Initial volume of air in balloon = V_1 = 1.2 m^3
Initial temperature = $T_1 = 15^0$ C = (15 + 273) K = 288 K
Final temperature = $T_2 = 40^0$ C = (40 + 273) K = 313 K
Coefficient of volume expansion = $\beta = 3.67 \times 10^{-3}$ K^{-1}

Required

Final volume of gas = V_2 = ?

Solution

As we know that

$$V = V_o (1 + \beta(T_2 - T_1))$$

By putting the values, we have

$$V = 1.2 (1 + 3.67 \times 10^{-3} \times (313 - 288))$$
$$V = 1.2 (1 + 3.67 \times 10^{-3} (25))$$
$$V = 1.2 (1 + 91.75 \times 10^{-3})$$
$$V = 1.2 (1 + 0.091)$$
$$V = 1.2 + 0.108 = 1.308 = 1.3 \text{ m}^3$$

Result

Final volume of gas = V_2 = 1.3 m^3

8.5 How much heat is required to increase the temperature of 0.5 kg of water from 10^0 C to 65^0 C. (LHR 2014 GRW 2015)

Given Data

Mass of water = m = 0.5 kg
Initial temperature = $T_1 = 10^0$ C
Final temperature = $T_2 = 65^0$ C
Change in Temperature

$$\Delta T = T_2 - T_1$$
$$= (65 - 10)^o \text{ C}$$
$$= 55^o \text{C}$$
$$= 55\text{K}$$

Required

Heat required = Q =?

Solution

As we know that

$\Delta Q = mc\Delta T$

By putting the values, we have

$\Delta Q = 0.5 \times 4200 \times 55$

$\Delta Q = 115500$ J

Result

Heat required = Q = 115500 J

8.6 An electric heater supplies heat at the rate of 1000 joules per second. How much time is required to raise the temperature of 200 g of water from 20^0 C to 90^0 C?

Given Data

Rate of heat supplied by heat = P = 1000 Js^{-1}

Mass of water = m = 200 g = 0.2 kg

Specific heat of water = c = 4200J

Initial temperature = $T_1 = 20^0$ C

Final temperature = $T_2 = 90^0$ C

Change in temperature = $\Delta T = 90 - 20 = 70^o$ C = 70K

Required

Heat required = Q = ?

Time = t = ?

Solution

As we know that

$Q = cm\,\Delta T$

$Q = 0.2 \times 4200 \times 70$

$Q = 58800$ J

As we also know that

$P \times t = Q$

$t = Q/P$

$t = 588000/1000$

$t = 58.8$ s

Result

Heat required = Q = 58800 J

Time taken = t = 58.8 s

8.7 How much ice will melt by 50000 J of heat? Latent heat of fusion of (GRW 2013, 14) ice = 336000 Jkg^{-1}.

Given Data

Heat supplied to ice = $\Delta Q_f = 50000$ J

Latent heat of fusion of ice = $H_f = 336000$ Jkg^{-1}

Required

Mass of ice = m = ?

Solution

As we know that

$\Delta Q = m \times H_f$

So $m = \dfrac{\Delta Q}{H_f}$

By putting the values, we have

$$m = \frac{50000}{336000}$$

m = 0.15 kg = 150 g

Result

Mass of ice = m = 0.15 kg = 150 g

8.8 Find the quantity of heat needed to melt 100 g of ice at -10^0 C to 10^0 C.

Given Data

Mass of ice = m = 100 g = 0.1 kg
Specific heat of ice = 2100 $JKg^{-1}K^{-1}$
Specific heat of water = 4200 $JKg^{-1}K^{-1}$
Latent heat of fusion of ice = 336000 $JKg^{-1}K^{-1}$
Initial temperature of ice = T_1 = -10^0 C
Final temperature = T_2 = 10^0 C

Required

Heat required to raise the temperature of ice from –10°C to 10°C = Q = ?

Solution

Step-I Heat required to raise the temperature of ice from –10°C to 0°C = ΔQ_1 = ?

$T_1 = -10°C$
$T_2 = 0°C$
$\Delta T = 0°C-(-10)°C = 10°C = 10\ K$
$\Delta Q = cm\Delta T$
$\Delta Q_1 = 2100 \times 0.1 \times 10$
$\Delta Q_1 = 2100\ J$

Step-II Heat required to convert ice at 0°C into water at 0°C = ΔQ_2 =?

We know that

$\Delta Q = mL_f$

$\Delta Q_2 = 0.1 \times 336000$

$\Delta Q_2 = 33600\ J$

Step-III

Heat required to raise temperature water from 0°C to 10°C = ΔQ_3 =?

T1 = 0°C

T2 = 10°C

$\Delta T = 10°C - 0°C = 10°C = 10K$

We know that

$\Delta Q = cm\Delta T$

$\Delta Q_3 = 4200 \times 0.1 \times 10$

$\Delta Q_3 = 4200\ J$

Total heat required = Q = $\Delta Q_1 + \Delta Q_2 + \Delta Q_3$

Q = 2100+33600+4200

Q = 39900 J

Result

Heat required = Q = 39900 J

8.9 How much heat is required to change 100 g of water at 100^0 C into steam?

(LHR 2013, 2015)

Given Data

Mass of water = m = 100 g = 0.1 kg

Temperature of water = T_1 = 100^0 C

Temperature of steam = T_2 = 100^0 C

Latent heat of vaporization of water = H_v = 2.26 x 10^6 Jkg^{-1}

Required

Heat required = Q_v = ?

Solution

$Q_v = m \times H_v$

$Q_v = 0.1 \times 2.26 \times 10^6$ J

$Q_v = 2.26 \times 10^5$ J

Result

Heat required = Q_v = 2.26 x 10^5 J

8.10 Find the temperature of water after passing 5 g of steam at 100^0 C through 500 g of water at 10^0 C.

Given Data

Mass of water = m_1 = 500 g = 0.5 kg

Mass of steam = m_2 = 5 g = 0.005 kg

Temperature of water = T_1 = 10^0 C

Temperature of steam = T_2 = 100^0 C

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

Latent heat of vaporization of vaporization = H_v = 2.26 x 106 Jkg^{-1}

Required

Final temperature of water = T = ?

Solution

According to law of heat exchange

Heat lost by steam = Heat gain by water

$mH_v + cm\Delta T = cm\Delta T$

$(0.005)(2.26\times10^6) + (4200)(0.005)(100-T) = (4200)(0.5)(T-10)$

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

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

$11300+2100+21000 = 2100T+21T$

$344400 = 2121T$

$T = \dfrac{34400}{2121}$

$T = 16.2°C$

Result

Final temperature of water = T = 16.2°C