Chapter: 08

Thermal properties of matter

Exercise MCQs

1. Water freezes at:

Ⓐ 0^oF Ⓑ 32^oF Ⓒ $-273K$ Ⓓ $0K$

2. Normal human body temperature is:

Ⓐ 0^oC Ⓑ 37^oC Ⓒ 37^oF Ⓓ 98.6^oC

3. Mercury is used as thermometric material because it has:

Ⓐ uniform thermal expansion Ⓑ low freezing point
Ⓒ small heat capacity Ⓓ all the above properties

4. Which of the following material has large specific heat?

Ⓐ copper Ⓑ ice Ⓒ water Ⓓ mercury

5. Which of the following materials has a large value of temperature coefficient of linear expansion?

Ⓐ aluminium Ⓑ gold Ⓒ brass Ⓓ steel

6. What will be value of Q for a solid for which α has value of $2 \times 10^{-5}K^{-1}$?

Ⓐ $2 \times 10^{-5}K^{-1}$ Ⓑ $6 \times 10^{-5}K^{-1}$ Ⓒ $8 \times 10^{-15}K^{-1}$ Ⓓ $8 \times 10^{-5}K^{-1}$

7. A large water reservoir keeps the temperature of nearby land moderate due to:

Ⓐ low temperature of water Ⓑ specific heat of water
Ⓒ less absorption of heat Ⓓ large specific heat of water

8. Which of the following affects evaporation?

Ⓐ temperature Ⓑ wind
Ⓒ the surface area of the liquid Ⓓ all of the above

Answer Key:

1	(B)	5	(A)
2	(B)	6	(B)
3	(D)	7	(D)
4	(C)	8	(D)

Short Questions

1. Why does heat flow from a hot body to a cold body?

Ans: Heat flows from a hot body to a cold body to attain the condition of thermal equilibrium.

2. What is meant by the internal energy of a body?

Ans: Internal energy of a body:

The sum of kinetic energy and potential energy associated with the atoms, molecules, and particles of a body is called its internal energy.

3. Define the terms heat and temperature.

Ans: Heat:

Heat is the form of energy that is transferred from one body to another in thermal contact with each other as a result of the difference in temperature between them.

Temperature:

"The temperature of a body is the degree of hotness or coldness of a body".

4. How does heating affect the motion of molecules of a gas?

Ans: By heating the gas, its molecules get high kinetic energy and start to collide more randomly and the motion of gas molecules is increased by heating. So, the pressure and volume of gas molecules increase by heating.

5. Explain the volumetric thermal expansion.

Ans: Volumetric thermal expansion:

It is usually expressed as a fractional change in volume per unit temperature change.

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

6. What is a thermometer? Why mercury is preferred as a thermometric substance?

Ans: Thermometer:

A thermometer is a device which is used to measure the temperature of a body. Mercury is preferred as a thermometric substance due to the following properties.

Mercury as a thermometric substance:

- It is easily visible.
- It has uniform thermal expansion.
- It has a low freezing point and high boiling point.
- It has a small specific heat capacity.

7. Define specific heat. How would you find the specific heat of a solid?

Ans: Specific heat:

"The specific heat of a substance is the amount of heat required to raise the temperature of 1kg mass of that substance through 1K".

The specific heat of any substance can be found out by using the following formula:

$$c = \Delta Q\ m\Delta T$$

c is the specific heat capacity

ΔQ is the amount of heat absorbed by the body

m is the mass of the body

ΔT is the change in temperature

8. Define latent heat of vaporization.

Ans: Latent heat of vaporization:

"The quantity of heat that changes the unit mass of a liquid completely into the gas at its boiling point without any change in its temperature is called its latent heat of vaporization denoted by H_v".

Formula:

$$H_v = \frac{\Delta Qv}{m}$$

Unit:

$$Jkg^{-1}$$

9. Define and explain the latent heat of fusion.

Ans: Latent heat of fusion:

The latent heat of fusion is the amount of thermal energy, which must be absorbed for 1 mole of substance to change its state from solid to liquid without change in temperature, is called the latent heat of fusion.

Formula:

$$H_f = \frac{\Delta Qf}{m}$$

Unit:

Its SI unit is Jkg^{-1}.

10. What is meant by evaporation? On what factors the evaporation of a liquid depends? Explain how cooling is produced by evaporation.

Ans: Evaporation:

Evaporation is escaping out of fast-moving water molecules from the surface of a liquid without heating.

Factors:

(i) Temperature ii) Surface area

(iii) Wind iv) Nature of liquid

Cooling by evaporation:

During evaporation molecules having greater kinetic energy escape out from the surface of a liquid, while the molecules having lower kinetic energies are left behind. In this way, evaporation produces cooling by lowering the average kinetic energy and the temperature of molecules of a liquid.

Important Formulas

- $T_k = T^oC + 273$
- $^oF = 1.8^oC + 32$
- $V = V_o(1 + \beta\Delta T)$
- $L = L_o(1 + \alpha\Delta T)$
- $P = \frac{Q}{t}$
- $Q = mc\Delta T$
- $Q_f = mH_f$
- $Q_v = mH_v$
- $\Delta T = T - T_o$

Important Units

- Co-efficient of linear thermal expansion = α = K^{-1}
- Co-efficient of volume expansion = β = K^{-1}
- Specific heat capacity = c = $Jkg^{-1}K^{-1}$
- Latent heat of fusion = Hf = Jkg^{-1}
- Latent heat of vaporization = Hv = Jkg^{-1}
- Specific heat of water = c = $4200Jkg^{-1}K^{-1}$

Numerical

1. Temperature of water in a beaker is 50°C. What is its value in Fahrenheit scale?

Ans: Given data:

$T^{o}C = 50^{o}C$

To Find:

$^{0}F = ?$

Solution:

$^{0}F = 1.8^{0}C + 32^{0}$

$^{0}F = 1.8^{o} \times 50^{o} + 32^{0}$

$^{0}F = 90^{0} + 32^{0}$

$^{0}F = 122^{0}F$

2. Normal human body temperature is 98.6°F. Convert it into Celsius scale and Kelvin scale.

Ans: Given data:

$T^{o}F = 98.6^{o}F$

To Find:

$T^{0}F = ?$

$T_k = ?$

Solution:

$$T_k = 1.8T^0C + 32^0$$
$$98.6^0 - 32^0 = 1.8T^0C$$
$$66.6^0 = 1.8T^0C$$
$$T^0C = \frac{66.6}{1.8}$$
$$T^0C = 37^0C$$

Now

$$T_k = T^0C + 273$$
$$T_k = 37 + 273$$
$$\mathbf{T_k = 310K}$$

3. Calculate the increase in the length of an aluminum bar 2m long when heated form 0^o to 20^oC. If thermal coefficient of linear expansion of aluminium is $2.5 \times 10^{-5}K^{-1}$.

Ans: Given data:

Original length = $L_o = 2m$

$T_o = 0^0C = 0 + 273 = 273K$

$T^oC = 20^0C = 20 + 273 = 293K$

$T^0C = T - T_0$

$\Delta T = 293 - 273$

$\Delta T = 20K$

Co-efficient of linear expansion = $\propto = 2.5 \times 10^{-5}K^{-1}$

To Find:

Increase in length = ΔL = ?

Solution:

$$L = L_o(1 + \alpha\Delta T)$$
$$L = 2 \times (1 + 2.5 \times 10^{-5} \times 20)$$
$$L = 2 \times (1 + 0.0005)$$
$$L = 2.001m$$

Increase in length = $\Delta L = L - L_o$

Increase in length = $\Delta L = 2.001 - 2$

Increase in length = $\Delta L = 0.001m$ $\quad \therefore 1m = 100cm$

Increase in length = $\Delta L = 0.001 \times 100$

Increase in length = ΔL = 0.1cm

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

Ans: Given data:

Initial volume of air in balloon = $V_o = 1.2m^3$

Initial temperature = T_o = $15^0C = (15 + 273)K = 288K$

Final temperature = T = $40^0C = (40 + 273)K = 313K$

$\Delta T = T - T_0$

$\Delta T = 313 - 288$

$\Delta T = 25K$

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

To Find:

Final volume of gas = V = ?

Solution:

As we know that;

$V = V_o(1 + \beta\,\Delta T)$

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

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

$V = 1.2 \times (1.0917)$

$\mathbf{V = 1.3m^3}$

5. How much heat is required to increase the temperature of 0.5kg of water from 100^oC to 65^oC?

Ans: Given data:

$m = 0.5kg$

$T_o = 10^0C = (10 + 273)K = 283K$

$T = 65^0C = (65 + 273)K = 338K$

$\Delta T = T - T_0$

$\Delta T = 338 - 283$

$\Delta T = 55K$

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

To Find:

Heat = Q = ?

Solution:

As we know that;

$$Q = mc\Delta T$$

$$Q = 4200 \times 0.5 \times 25$$

$$\mathbf{Q = 115500J}$$

Required heat is 115500J

6. **An electric heater supplies heat at the rate of 1000 joule per second. How much time is required to raise the temperature of 200g of water from 20°C to 90°C?**

Ans: Given data:

$$\text{Power} = P = 1000J/sec$$

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

$$T_o = 20^0C = (20 + 273)K = 293K$$

$$T = 90^0C = (90 + 273)K = 363K$$

$$\Delta T = T - T_0$$

$$\Delta T = 363 - 293$$

$$\Delta T = 70K$$

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

To Find:

Time = t = ?

Solution:

As we know that;

$$Q = mc\Delta T$$

$$Q = 0.2 \times 4200 \times 70$$

$$Q = 58800J$$

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

$$1000 = \frac{48800}{t}$$

$$t = \frac{48800}{1000}$$

$$\mathbf{t = 58.8sec}$$

7. How much ice will melt by 50000J of heat? Latent heat of fusion of ice = 336000Jkg-1?

Ans: Given data:

$Q_f = 50,000J$

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

To Find:

Mass $= m = ?$

Solution:

As we know that;

$$Q_f = mH_f$$

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

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

$$m = 0.15kg$$

$$m = 0.15 \times 1000g$$

$$\mathbf{m = 150g}$$

8. Find the quantity of heat needed to melt 100g of ice at – 10°C at it no water at 10°C. (Note: Specific heat of ice is 2100Jkg-1K-1. The specific heat of water is 4200Jkg-1K-1. Latent heat of fusion of ice is 336000Jkg-1).

Ans: Given data:

Mass of ice $= 100g = 0.1kg$

Change in temperature of ice $= \Delta T = T - T_0$

Change in temperature of ice $= \Delta T = 0^oC - (-10^0C)$

Change in temperature of ice $= \Delta T = 10^0C$

Change in temperature of water $= \Delta T = 10^oC - 0^0C$

Change in temperature of water $= \Delta T = 10^0C$

Specific heat of ice $= 2100Jg^{-1}K^{-1}$

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

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

To Find:

Heat $= Q = ?$

Solution:

(i) Heat gained by ice from -10^0C to 0^0C =

$Q_1 = mc\Delta T$

$Q_1 = 0.1 \times 2100 \times 10$

$\mathbf{Q_1 = 2100\ J}$

(ii) Heat gained by ice to melt = $Q_2 = mt$

$Q_2 = 0.1 \times 3360000$

$\mathbf{Q_2 = 33600J}$

(iii) Heat required to raise temperature from 0^0C to 10^0C =

$Q_3 = mc\Delta T$

$Q_3 = 0.1 \times 4200 \times 10$

$\mathbf{Q_3 = 4200\ J}$

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

$Q = 2100 + 33600 + 4200$

$\mathbf{Q = 39900J}$

9. How much heat is required to change 100g of water at 100°C into steam? The latent heat of the vaporization of water is $2.26 \times 10^6 Jkg^{-1}$.

Ans: Given data:

Mass of water = 100g

$M = \frac{100}{1000} = 0.1kg$

$T = 100^0C$

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

To Find:

$Q_v = ?$

Solution:

As we know that;

$Q_v = mH_v$

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

$\mathbf{Q_v = 2.26 \times 10^5\ g}$

10. Find the temperature of water after passing 5g of steam at 100°C through 500g of water at 10°C. (Note: Specific heat of water is 4200$Jkg^{-1}K^{-1}$, Latent heat of vaporization of water Is $2.26 \times 10^6 Jkg^{-1}$).

Ans: Given data:

Mass of water $= m_1 = 500g = 0.5kg$

Mass of steam $= m_2 = 5g = 0.005kg$

Temperature of water $= T_1 = 10°C$

Temperature of steam $= T_2 = 100^0C$

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

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

To Find:

Final temperature of water $= T = ?$

Solution:

As we know that;

$$Q = m_1H_v$$

$$Q = 0.005 \times 2.26 \times 10^6$$

$$Q = 1.13 \times 10^4 \text{ ------------ (i)}$$

And

$$Q = m_2c\Delta T$$

$$Q = 0.005 \times 4200 \times (T - 10)$$

$$Q = 2100 \times (T - 10) \text{ ---------- (ii)}$$

Comparing equation (i) and (ii), we get

$$1.13 \times 10^4 = 2100 \times (T - 10)$$

$$\frac{1.13 \times 10^4}{2100} = (T - 10)$$

$$5.4 = (T - 10)$$

$$T = 10 + 5.4$$

$$T = 15.4^0C$$

Result:

Final temperature of water $= T = 15.4^0C$