Heat

Heat

If is a form of energy which causes in us the sensation of hotness of coldness.

For example, if we dip our finger in hot water we have a sensation of hotness. Similarly, if we touch a block of ice, the sensation is that of coldness. In the former case the heat energy has moved into the finger, while in the later case it has moved out of the finger. Thus, hotness or coldness basically indicates whether heat energy is flowing into our body or out of it.

The amount of heat energy present in a body is determined by the total sum of the kinetic energy and potential energy of its molecules.

Unit of Heat Energy

S.I. unit heat is joule (J). However, a more common unit of heat is calorie.

❖ The quality of heat energy required to raise the temperature of 1 g of water through 1 ^{0}C (14.5^{0}C to 15.5^{0}C) is called one calorie.

1 calorie = 4.2 Joules

❖ The bigger unit of heat is kilocalorie.

The quantity of heat energy required to raise the temperature of 1 kg of water through 1 ^{0}C is called one kilocalorie.

1 kilocalorie = 1000 calories = 4.2×10^3 J

Temperature

It is the effect of heat energy which determines the thermal state of a given substance. In other words, it is a measure of the degree of hotness of coldness of a substance. If a body is at a higher temperature than its surroundings, it means that heat energy will flow out of the body. Similarly, if a body is at a lower temperature than its surroundings, it means that heat energy will flow into the body.

Different Types of Temperature Scales

The Kelvin temperature scale is also known as thermodynamic scale. The S.I. unit of temperature is Kelvin and is defined as (1/273.16) of the temperature of the triple point of water. The triple point of water is that point where the three phases of water, the solid, the liquid and the gas, can coexist in equilibrium.

In addition ot Kelvin temperature scale, there are other temperature scales also like Celsius, Fahrenheit, Reaumer. Temperature on one scale can be converted into other scale by using the following identity:

$$\frac{\text{Reading on any scale} - \text{lower fixed point}(L.F.P.)}{\text{Upper fixed point}(U.F.P.) - \text{lower fixed point}(L.F.P.)}$$

$$\frac{C-0}{100-0} = \frac{F-32}{212-32} = \frac{R-0}{80-0} = \frac{K-273.15}{373.15-273.15}$$

$$\frac{C}{5} = \frac{F-32}{9} = \frac{R}{4} = \frac{K-273}{5}$$

S. No.	Name of the Scale	Symbol for each degree	Lower fixed point(L.F.P.)	Upper fixed point(U.F.P.)	Namber of division on the scale
1	Celsius	^{0}C	0^0C	100^0C	100
2	Fahrenheit	^{0}F	32^0F	212^0F	180
3	Reaumer	^{0}R	0^0R	80^0R	80
4	Kelvin	K	273.15 K	373.15 K	100

Specific Heat Capacity

The specific heat capacity of a substance is the amount of energy (in joule) that is needed to raise the temperature of 1 kg of the substance by 1^{0}C.

Specific heat of water = 1 cal/gm^{0}C = 4200 J/kg^{0}C.

Specific heat of ice = 0.5 cal/gm^{0}C = 2100 J/kg^{0}C

The quantity of heat gained or lost by a body depends on:

(1) The mass of the substance (m)

(2) the nature of the substance (specific heat-capacity or specific heat)

(3) The rise or fall in temperature of the substance (Δt). Thus, if Q is the amount of heat gained or lost by a body of mass m, specific heat capacity s and rise or fall of temperature is Δt, then Q = m × s × Δt

❖Heat capacity (J/^{0}C) = specific heat (J/kg^{0}C) × mass capacity (kg)

❖ The heat capacity of a substance is the amount of heat needed to raise the temperature of the substance by 1^{0}C. The unit of heat capacity is J/^{0}C.

Principle of Mixture (Calorimetry)

If heat is not being used in any other cause, the amount of heat lost by a body always equals to the amount of heat gained by another body. Hence,

Heat gained = Heat lost

This is called the principle of mixture.

Illustrations

1. The quantity of heat required to rose the temperature of 2000 g of water from 10^{0}C to 50^{0}C is [take specific heat of water as 1 calorie/g^{0}C]:

SoI. Heat required, Q = msΔt

Where, m = mass of water = 2000 g

S = specific heat of water = 1 calorie/g $\times^0$C

Δt = rise in temperature = (50 – 10)^{0}C = 40^{0}C

Q = 2000 × 1 × 40 = 80.000 Calorie

Q = 80 Kilocalorie

2. Find the value of 5^{0}C in ^{0}F and K scale respectively.

Sol. Relation between Celsius and Fahrenheit scale

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

So corresponding value of 5^{0}C in Fahrenheit scale is

$$\frac{5}{5} = \frac{F - 32}{9} \Rightarrow F = 41^0 F$$

Relation between Celsius and Kelvin scale

T(K) = T (^{0}C) + 273 = 5 + 273 = 278 K

Change of State (Melting, Boiling and Vaporization)

When a solid changes into liquid state at constant temperature, the melting or fusion takes place. When a liquid rapidly changes into its vapours at constant temperature, the boiling or vaporization takes place. The constant temperature at which a solid starts changing into liquid state is called melting point.

Conversely, the constant temperature at which a liquid changes into solid state is called solidification point. Numerical value of melting point or solidification point is same.

Eg.: Melting point of ice is 0^{0}C and freezing point of water is also 0^{0}C.

The constant temperature at which a liquid rapidly changes into its gaseous state is called its boiling point. Conversely, the constant temperature at which a gas changes into liquid state is called liquefaction point. Numerical value of boiling point or liquefaction point is same.

Eg.: Boiling point of water is 100^{0}C and liquefaction point of steam is also 100^{0}C.

(a) Condensation: Condensation is a process in which vapours turm into liquid at its liquefaction point.

(b) Sublimation: Sublimation is a process in which solid changes into vapours without undergoing the liquid state.

Latent Heat

The latent heat of a substance is that heat which changes the physical state of the substance but does not rise its temperature. Latent heat is of two types:

(i) Latent heat of melting (ii) Latent heat of vaporisation

❖ The latent heat of fusion or melting of a substance is the amount of the heat required to convert a unit mass of the substance from the solid state to the liquid state without change of temperature.

❖ The latent heat of vaporization of a substance is the amount of heat required to convert a unit mass of the substance from the liquid state to the vapour state without changing the temperature.

Its unit is calorie/g or kilocalorie/kg or Joule/kg. Its S.I. unit is J/kg. The latent heat of vaporisation is 540 kilocalorie/kg or 2.268 × 10^6 joule heat is required to convert 1 kg of water at 100^{0}C into 1 kg of steam at 100^{0}C.

The amount of thermal energy required to change the state of substance is given by the following formula:

Q = m × L

Where, $\rightarrow$mass of the substance

L $\rightarrow$latent heat of the substance

3. Calculate the quantity of heat required to convert 10 kg of ice at 0^{0}C to water at 50^{0}C. Specific heat of water is 4200 J/kg ^{0}C.

Sol. Firstly 10 kg ice at 0^{0}C convert into 0^{0}C water, which requires heat

Q_1 = ml = 10 × 80 × 4.2 = 3360 J.

Now heat required to rise temperature of water from 0^{0}C to 50^{0}C is,

Q_2 = msΔT = 10 × 4.2 × 50 = 2100 KJ

Total heat, Q = Q_1 + Q_2 = 3360 + 2100 = 5460 KJ

Difference Between Evaporation and Boiling

Evaporation	Boiling
1. The process in which a liquid changes into vapours at all temperature is called evaporation.	**1.** The process in which the vapour pressure of a liquid becomes equal to the atmospheric pressure, is
2. It takes place at ass temperatures.	**2.** It takes place at a particular temperature..
3. It is a slow and invisible process.	**3.** It is rapid and visible process.
4. It takes place only on the surface of liquids.	**4.** It takes place throughout the liquid.
5. It produces cooling effect.	**5.** It does not produce any cooling effect.
6. During the process there is a variation in the temperature	**6.** During this process there is no change in the temperature

❖ Evaporation is a process of gradual loss of molecules having very high energy. From the upper surface of a liquid at any temperature.

❖ The temperature at which a substance changes its state from liquid to gas is called its boiling point.

Thermal Expansion of Substance

When an object is heated it expands, it is called thermal expansion.

(a) Thermal expansion of Solid:

❖ The coefficient of linear expansion (a), superficial (area) expansion (β) and volume expansion (γ) are defined by the relations:

$$\frac{\Delta \ell}{\ell} = \alpha \Delta T \; , \; \frac{\Delta A}{A} = \beta \Delta T \; , \; \frac{\Delta V}{V} = \gamma \Delta T$$

Here, $\Delta \ell$, ΔV denote the change in length ℓ, change in area A and change in volume V.

Relations between α, β *and* γ:

$\beta = 2\alpha, \gamma = 3\alpha$

$\alpha : \beta : \gamma = 1 : 2 : 3$

- ❖ For metal sphere, the volume of cavity increases on heating.
- ❖ For metal ring, diameter of ring increases on heating.

(b) Thermal Expansion of liquid:

Liquid expand more than solids on heating.

Real expansion of liquid = Apparent expansion of liquid + Volume expansion of glass

So,

$\gamma_r = \gamma_\alpha + \gamma_g$

$\gamma_r \rightarrow Coefficien\,t \; of \; real \exp ansion \; of \; lequid$

$\gamma_\alpha \rightarrow Coefficien\,t \; of \; apparent \exp ansion \; of \; liquid$

$\gamma_g \rightarrow coefficien\,t \; of \; volume \exp ansion \; of \; glass$

$\because \gamma_g = 3\alpha_g$

So, $\gamma_r = \gamma_\alpha + 3\alpha_g$

$\gamma_\alpha = \gamma_r - 3\alpha_g$

α_g is coefficient of linear expansion of glass.

Case-I. If $\gamma_r > 3\alpha_g$, then liquid level will go up on heating.

Case-II. If $\gamma_r = 3\alpha_g$ then liquid level will not change on heating.

Case-III. If $\gamma_r > 3\alpha_g$ then liquid level will go down on heating.

(c) Thermal Expansion of Gases:

Gases expand more than liquids on heating.

Transfer of Heat

Heat transfer always occurs from regions of higher temperature to regions of lower temperature, so that two objects isolated from their surroundings gradually approach a common temperature.

Heat is transferred by three methods:

(i) conduction (ii) convection (iii) Radiation

- ❖ In conduction, heat is transferred between neighbouring parts of a body through molecular collisions, without any flow of matter.
- ❖ Convection involves low of matter within a fluid due to unequal temperatures of its parts. A hot bar placed under a running tap loses heat by conduction between the surface of the bar and water and not by convection within water.
- ❖ Radiation is the transmission of heat as electromagnetic waves. Radiant heat travels with the speed of light. It requires no medium.
- ❖ Pendulum clock loses time in summer and gains time in winter. If a pendulum clock is giving correct time when time period is T, if T increases, clock becomes slow and if T decreases, clock becomes fast.
- ❖ The relative humidity of air at given temperature is the ratio of mass of water vapour actually present in a certain volume of air to the mass of water vapour required to saturate the same volume of air at the same temperature, multiplied by 100.

4. Tow liquid have the densities in the ratio of 1 : 2 and specific heats in the ratio of 2 : 1. Find the ratio of thermal capacity of equal volume of those liquids.

Sol. The ratio of density of liquids,

$$\frac{d_1}{d_2} = \frac{1}{2}$$

Ratio of specific heats of both liquids,

$$\frac{s_1}{s_2} = \frac{2}{1}$$

Heat capacity of first liquid,

$Q_1 = Vd_1s_1$

Heat capacity of second liquid,

$Q_2 = Vd_2s_2$

So, $\dfrac{Q_1}{Q_2} = \dfrac{d_1 s_1}{d_2 s_2} = \dfrac{1}{2} \times \dfrac{2}{1} = \dfrac{1}{1}$

5. Find the amount of heat required to convert 1g of ice (specific 0.5 cal g^{-1} $0C^{-1}$) at – 10^0C to steam at 100^0C.

Sol. Heat required to convert 1g of ice at 10^0C to steam at 100^0C.

= Heat required to convert ice at – 10^0C $\rightarrow$ice at 0^0C$\rightarrow$water at 0^0C $\rightarrow$water at 100^0C $\rightarrow$steam at 100^0C + 1 × 0.5 [0-(-10)] + 1 × 80 + 1 × 1 (100-0) + 1 × 540 = 5 + 80 + 100 + 540 = 725 cal.

EXERCISE

1. The normal temperature of human body is:

(A) 37^0C (B) 38^0C
(C) 35^0C (D) 25^0C

2. At what temperature, Fahrenheit and degree Celsius scale measure same temperature:

(A) -40^0 (B) 40^0
(C) 100^0 (D) 0^0

3. Two holes of unequal diameters d_1 and d_2 ($d_1 > d_2$) are made in a metal sheet. If the sheet is heated:

(A) Both d_1 and d_2 will decrease
(B) Both d_1 and d_2 will increase
(C) d_1 will increase d_2 will decrease
(D) d_1 will decrease, d_2 will increase

4. The saturated vapour pressure s water at 100^0C is:

(A) 750 mm of Hg (B) 760 mm of Hg
(C) 76 mm of Hg (D) 7.6 mm of Hg

5. Two identical rectangular strips one of copper and other of steel are riveted together to form a bimetallic strip. $((\alpha_{copper} > \alpha_{steel})$. On heating, this strip will:

(A) remains straight
(B) bend with copper on convex side

(C) bend with steel on convex side
(D) get twisted

6. One gram of ice at 0^0C is added to 5 grams of water at 10^0C. It the latent heat of ice be 80 cal/gm, then the final temperature of the mixture is:
(A) 5^0C (B) 0^0C
(C) -5^0C (D) none of the above

7. If water at 00C, kept in a container with an open top, is placed in a large evacuated chamber:
(A) all the water will vaporize
(B) all the water will freeze
(C) part of the water will vaporize and the rest will freeze
(D) ice, water and water vapour will be formed and reach equilibrium at the triple point

8. If 40 g of water at 100^0C is mixed with 150 g of water and mixture temperature becomes 50^0C. Find initial temperature of cold water:
(A) 36.66^0C (B) 32^0C
(C) 25^0C (D) 46.66^0C

9. Absolute zero corresponds to:
(A) -273 K (B) -273^0C
(C) 273^0 F (D) None of these

10. Unit of relative humidity is:
(A) kg/m (B) g/cm
(C) kg/wt (D) none of these

11. We feel most comfortable at relative humidity:
(A) <50% (B) 50%
(C) > 50% (D) 100%

12. In which method of transfer of heat, particle of medium actually moves?
(A) Radiation (B) Convection
(C) Conduction (D) All of these

13. Which is the fastest method of transfer of heat?
(A) Radiation
(B) Convection
(C) All are equally fast
(D) All are equally fast

14. Conduction cannot takes place in:
(A) copper (B) iron
(C) aluminium (D) vacuum

15. A graph is plotted taking ^0C along the Y-axis and ^0F along the X-axis. It is a/an:
(A) straight line (B) parabofa
(C) ellipse (D) circle

16. When two object are in thermal contact, the heat is transferred by:
(A) conduction (B) convection
(C) radiation (D) none of these

17. Two bodies are in thermal equilibrium if they have same :
(A) temperature (B) amount of heat
(C) specific heat (D) thermal capacity

18. 2000 J of energy is needed to heat 1 kg of paraffin through 1^0C. How much energy is needed to heat 10 kg of paraffin through 2^0C?
(A) 4000 J (B) 10.000 J
(C) 20,000 J (D) 40,000 J

19. In hot water bottles, water is used because:
(A) Its specific heat is low
(B) Its specific heat is high
(C) It is cheap
(D) It is easily available

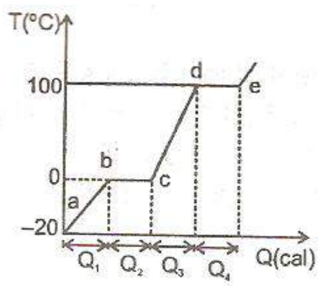
20. Heat capacity equal to:
(A) mass × specific heat capacity
(B) mass/specific heat capacity
(C) specific heat capacity/mass
(D) none of these

21. When air is saturated, it cannot hold:
(A) more water vapour (B) more air
(C) more carbon dioxide (D) more oxygen

22. The ratio between γ, β and α is:
(A) 1 : 2: 3 (B) 3 : 2 : 1
(C) 1 : 3 : 2 (D) 2 : 1 : 3

23. A piece of ice at 0^0C is added to vessel containing water at 0^0C, then:
(A) all of the ice will melt
(B) same ice will melt
(C) no ice will melt
(D) the temperature will decrease further

24. Figure shows the temperature variation when heat is added continuously to a specimen of ice (1g) at -20^0C. Specific heat of ice is 0.53 cal/g ^0C. Mark the correct options according to terms in column I and column II:



Column I	**Column II**
(i) Q_1 (cal)	(p) 80
(ii) Q_2 (cal)	(q) 540
(iii) Q_3 (cal)	(r) 100
(iv) Q_4 (cal)	(s) 10.6

(A) (i) $\rightarrow$s (ii) $\rightarrow$p, (iii) $\rightarrow$r, (iv) $\rightarrow$q
(B) (i) $\rightarrow$ r (ii) $\rightarrow$p, (iii) $\rightarrow$ r, (iv) $\rightarrow$ q
(C) (i) $\rightarrow$ s (ii) $\rightarrow$ q, (iii) $\rightarrow$ r, (iv) $\rightarrow$ p
(D) (i) $\rightarrow$ p (ii) $\rightarrow$ s, (iii) $\rightarrow$ r, (iv) $\rightarrow$ q

25. By the effect of heat, a magnet:
(A) loses its magnetic property
(B) becomes strong magnet
(C) becomes temporary magnet
(D) none of the above

26. Expansion of a substance is :
(A) directly proportional to rise in the temperature
(B) inversely proportional to rise in the temperature
(C) independent of rise in temperature
(D) can not say

27. Per 0C is unit of:
(A) α (B) β
(C) γ (D) all of these

28. Clock's pendulum is made of invar because:
(A) It is light in weight
(B) It is easily available
(C) Its coefficient of linear expansion is low
(D) It is cheaply available

Direction (29 to 30): Each questions contains Statement (Assertion) and Statement (Reason). Each question has 4 choices (I), (II), (III) and (IV) out of which only one is correct.

(I) Statement is true, Statement is true, Statement is a correct explanation for Statement
(II) Statement is true, Statement is true, Statement is Not a correct explanation for Statement
(III) Statement is true, Statement is false.
(IV) Statement is false, Statement is true.

29. **Statement:** The bulb of one thermometer is spherical while that of the other is cylindrical. Both have equal amount of mercury. The response of the cylindrical bulb thermometer will be quicker.
Statement: Heat conduction in a body is directly proportional to cross-sectional area.
(A) I (B) II (C) III (D) IV

30. **Statement:** The steam at 100^0C causes more severe burn to human body than the water at 100^0C
Statement: The steam has greater internal energy due to latent heat of vaporization.
(A) I (B) II (C) III (D) IV

31. The specific heat of four bodies P, Q, R, S of equal masses are 0.1, 0.2, 0.3, 0.4 kilo calorie/kg ×0C respectively. Temperature of which body will increase highest on giving equal amount of heat?
(A) P (B) Q
(C) R (D) S

32. On giving 100 kilo calorie heat to 5 kg. of water at 20^0C, the temperature of water will be :
(A) 25^0C (B) 30^0C
(C) 40^0C (D) 45^0C

33. On a thermometer the freezing point of water is at 20 degree and boiling point is at 160^0 degrees. If the temperature of a liquid on Celsius scale is 60^0 C, then the temperature of the same liquid recorded by this thermometer in degrees will be:
(A) 84 (B) 96
(C) 104 (D) 120

34. At what temperature, the density on pure water is maximum?
(A) 0^0C (B) -40^0C
(C) 4^0C (D) 2^0C

35. The body temperature of a person is 990 F then what is equivalent temperature in Celsius?
(A) 114.6^0 C (B) 72.8^0 C
(C) 37.2^0C (D) 36.6^0 C

36. How much heat is required to raise the temperature of 15 kg of water by 15^0 C?
(A) 22.5 kilo calorie (B) 225 Joule
(C) 225 kilo calorie (D) 30 kilo calorie

37. A beaker is completely filled with water at 4^0 C. When it is cooled further to 1^0 C, then:
(A) the level of water decreases
(B) the water overflows
(C) the beaker shatters
(D) nothing happens

38. On raising the temperature, the mercury in a thermometer rises. This happens because:
(A) glass is a poor conductor of heat
(B) glass does not expand on heating
(C) mercury expands much more than glass
(D) mercury is a good conductor of heat

39. A test tube contains water with a piece of ice floating on the water surface . When the test tube is heated from below, ice melts rapidly. However, if the ice piece is sunk below the column of water by tying it to a weight and water is heated from above, ice does not melt even though water at the top starts boiling. From this observation we conclude that :
(A) Water is a good conductor as well as a bad convector of heat
(B) Water is a bad conductor as well as a bad convector of heat
(C) Water is a good conductor but a bad convector of heat
(D) Water is a bad conductor but a good convector of heat

ANSWER – KEY

HEAT

Q.	1	2	3	4	5	6	7	8	9	10
A.	A	A	B	B	B	B	C	A	B	D
Q.	11	12	13	14	15	16	17	18	19	20
A.	B	B	A	D	A	A	A	D	B	A
Q.	21	22	23	24	25	26	27	28	29	30
A.	A	B	C	A	A	A	D	C	A	A
Q.	31	32	33	34	35	36	37	38	39	
A.	A	C	C	C	C	C	B	C	D	