THERMAL PROPERTIES OF MATTER

8

KIPS MULTIPLE CHOICE QUESTIONS

1. **All the bodies expand ---------- on heating:**

a) Variable b) Constantly c) Uniformly d) All of them

2. **Temperature is the:**

a) Mass contained by the body b) Force of the molecules of body

c) Degree of hotness or coldness of the body d) none of above

3. **The SI unit of temperature is:**

a) ^{o}C b) ^{o}F c) K d) ^{o}K

4. **Temperature of 30 ^{o}C in Fahrenheit is:**

a) 86 ^{o}F b) 80 ^{o}F c) 30 ^{o}F d) 90 ^{o}F

5. **Human normal body temperature of 37 ^{o}C in Fahrenheit is:**

a) 98. 6 ^{o}F b) 98 ^{o}F c) 100 ^{o}F d) None of above

6. **Boiling point of water in Fahrenheit is:**

a) 100 ^{o}F b) 273 ^{o}F c) 212 ^{o}F d) 373 ^{o}F

7. **Celsius equivalent of 0K is:**

a) -273 ^{o}C b) -459.4 ^{o}C c) 0 ^{o}C d) 100 ^{o}C

8. **Fahrenheit equivalent of 0K is:**

a) -273 ^{o}F b) -459.4 ^{o}F c) 0 ^{o}F d) 100 ^{o}F

9. **Heat is a type of ---------- energy:**

a) Kinetic b) Potential c) Mechanical d) None of above

10. **Linear expansion of a rod occur along ------------ dimension (s):**

a) One b) Two c) Three d) All

11. **The characteristic of unequal expansion of different metals is employed in a device known as:**

a) Thermometer b) Burner c) Calorimeter d) Thermostat

12. **Linear expansion depends on:**

a) Length of rod b) Change in temperature

c) Nature of material of rod d) All of above

13. **Thermostat works on the principle of:**

a) Unequal expansion of solids b) Pascal's law

c) Anomalous expansion of water d) Vaporization

14. **Thermostat is used in:**

a) Electric iron　b) Refrigerator　c) Fire alarm　d) All of above

15. **SI unit of Coefficient of linear & volume expansion is:**

a) m　b) K　c) K^{-1}　d) ^{o}C

16. **Volume expansion depends on:**

a) Volume of block　b) Change in temperature

c) Nature of material of block　d) All of above

17. **β = -------**

a) α　b) 2α　c) 3α　d) 5α

18. **There are ------ type (s) of expansion (s) take place in a liquid filled in a container:**

a) One　b) Two　c) Three　d) Four

19. **The liquid (s) used in thermometers is (are):**

a) Mercury　b) Alcohol　c) Water　d) Both a & b

20. **Ice is a (an):**

a) Good conductor　b) Bad conductor　c) Perfect Conductor　d) None

21. **The quantity of heat that causes 1K change in temperature in a substance of mass 1 Kg is called:**

a) Specific heat　b) Latent heat　c) Heat of exchange　d) None of above

22. **Unit of specific heat is:**

a) $Jkg^{-1}K$　b) $JkgK^{-1}$　c) $Jkg^{-1}K^{-1}$　d) J

23. **Which of the following has highest specific heat?**

a) Water　b) Ice　c) Mercury　d) Alcohol

24. **Specific heat of water is:**

a) 2100 $Jkg^{-1}K^{-1}$　b) 2500 $Jkg^{-1}K^{-1}$　c) 3200 $Jkg^{-1}K^{-1}$　d) 4200 $Jkg^{-1}K^{-1}$

25. **Climate of regions near sea shore remains moderate due to:**

a) Greater specific heat of water　b) Less specific heat of water

c) Low freezing point of water　d) High boiling point of water

26. **Cause of land and sea breeze is:**

a) Greater specific heat of water　b) Less specific heat of water

c) Low freezing point of water　d) High boiling point of water

27. **The device used to measure of the specific heat of an object is:**

a) Thermometer　b) Burner　c) Calorimeter　d) Thermostat

28. **Quantity of heat that one kilogram of a of solid into liquid is called:**

a) Specific heat
b) Latent heat of fusion
c) Latent heat of vaporization
d) All of above

29. **Quantity of heat that one kilogram of a of liquid into gas is called:**

a) Specific heat
b) Latent heat of fusion
c) Latent heat of vaporization
d) All of above

30. **Unit of latent heat is:**

a) $Jkg^{-1}K$
b) Jkg
c) J
d) Jkg^{-1}

31. **Latent heat of fusion of ice is:**

a) 2,260,000 Jkg^{-1}
b) 336,000 Jkg^{-1}
c) 3,260,000 Jkg^{-1}
d) None of above

32. **Latent heat of vaporization of water is:**

a) 2,260,000 Jkg^{-1}
b) 336,000 Jkg^{-1}
c) 3,260,000 Jkg^{-1}
d) None of above

ANSWER KEY

Q.No	Ans	Q.No	Ans	Q.No	Ans	Q.No	Ans
1	c	11	d	21	a	31	b
2	c	12	d	22	c	32	a
3	c	13	a	23	a		
4	a	14	d	24	d		
5	a	15	c	25	a		
6	c	16	d	26	a		
7	a	17	c	27	c		
8	b	18	c	28	b		
9	a	19	d	29	c		
[illegible]	a	20	b	30	d		

KIPS SHORT QUESTIONS

Q.1 Define heat.

Ans: Heat is the energy that is transferred from one body to the other in thermal contact with each other as a result of the difference of temperature.

Q.2 Define thermometry and temperature.

Ans:

Thermometry

"The art of measuring temperature is termed as thermometry."

Temperature

"Degree of coldness or hotness of the body is a measure of its temperature"

Q.3 Define internal energy.

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

Q.4 Define thermal equilibrium.

Ans: "According to the principle of thermometry, if two objects at different temperatures are joined together, after a certain time they attain the same temperature. This is known as the state of thermal equilibrium"

Q.5 Define thermometer.

Ans: "The instrument which is used to measure the temperature is called a thermometer"

Q.6 Write down the conversions of thermometer scales.

Ans: Conversion of one temperature scale to the other by the given formulae T_F, T_c, T_K representing the Fahrenheit, centigrade (Celsius) and Kelvin temperatures respectively.

Conversion of Celsius (centigrade) to Fahrenheit scale

$$T_F = \frac{9}{5} \times T_c + 32$$

Conversion of Fahrenheit to Celsius scale

$$T_c = \frac{5}{9}(T_F - 32)$$

Relationship between Kelvin and Celsius scales

$$T_k = T_c + 273$$

Q.7 Define specific heat?

Ans: "Specific heat of a substance is the amount of heat that required to raise the temperature of 1 kg mass of that substance through 1K".

Q.8 Define heat capacity.

Ans: Heat capacity of a body is the quantity of thermal energy absorbed by it for one Kelvin (1K) increases in its temperature.

Q.9 Define latent heat of fusion.

Ans: "Heat energy required to change unit mass of a substance from solid to liquid state at its melting point without change in the temperature is called its latent heat of fusion".

Q.10 Define latent heat of vaporization.

Ans: "The quantity of heat that changes unit mass of a liquid completely into gas at its boiling point without any change in its temperature is called its latent heat of vaporization"

Q.11 Define evaporation.

Ans: "Evaporation is the changing of a liquid into vapors (gaseous state) from the surface of the liquid without heating it".

Q.12 What is linear Expansion?

Ans: "If a thin rod is heated, there is a prominent increase in its length as compared to its cross-sectional area. The expansion along length or in one dimension is called linear expansion".

Q.13 What is volume expansion?

Ans: "Heating a block causes an increase in length, breadth and thickness, i.e., volume of the block increases that is known as volume expansion".

Volume of a solid also changes with the change in temperature and is called volume thermal expansion or cubical thermal expansion.

Q.14 Write down some consequences of thermal expansion.

Ans: The expansions of solids many damage bridges, railway tracks and roads as they are constantly subjected to temperature changes.

- Prevision is made during construction for expansion and contraction with temperature.
- Railway tracks buckled on a hot summer day due to expansion if gaps are not left between sections.

Q.15 Write down some applications of thermal expansion.

Ans: Thermal expansion is used in our daily life. In thermometers, thermal expansion is used in temperature measurements.

- To open the cap of a bottle that is tight enough, immerse it in hot water for a minute or so. Metal cap expands and becomes loose. It would now be easy to turn it to open.
- To join steel plates tightly together, red hot rivets are forced through holes in the plates as shown in figure. The end of hot rivet is then hammered. On cooling, the rivets contracts and bring the plates tightly griped.

Q.16 What do you know about bimetallic strip (thermostat)?

Ans: A bimetal strip consists of two thin strips of different metals such as brass and iron joined together as shown in figure. On heating the strip, brass expands more than iron. This unequal expansion causes bending of the strip.

Usage

Bimetal strips are used for various purposes.

- Bimetal thermometers are used to measure temperature especially in furnaces and ovens.
- Bimetal themio state switch is used to control the temperature of heater coil in an electric iron.

Q.17 Write down some examples of expansions of solids.

- Pipes passing through deserts and plains are curved to allow expansion and contraction due to change of season.
- While laying rail tracks gaps are left at joints so as to avoid damages caused by expansion or contraction.

Q.18 While constructing bridges, one end of the beam is placed on rollers. Explain why?

Ans: This is because the iron beam of the bridges expands due to heat in summer. The iron beams are frightened at one end, keeping the other moveable as provision for their expansion. In the absence of such provision, bridge may be damaged in summer due to heat.

Q.19 What is the difference between specific heat and latent heat of a material?

Specific heat	Latent heat
• Specific heat is the amount of heat required to raise the temperature of unit mass of a substance through one Kelvin. • Its unit is $Jkg^{-1}K^{-1}$.	• Latent heat is the amount of heat that is required to convert a unit mass from solid to liquid or liquid to gas at constant temperature. • It unit is Jkg^{-1}.

Q.20 Why temperature of a substance does not change while it is changing its state from solid to liquid?

Ans: When a substance is changing from solid to liquid state, the temperature of the substance remains the same. It is because the heat supplied to the substance is used to overcome the attractive force among the atoms or molecules of the solid and not to increase the temperature.

LONG QUESTIONS

8.2 THERMOMETER

Q.No.1 What is thermometer? Explain its different types.

Ans: "The instrument which is used to measure the temperature is called a thermometer"

Thermometric Substance

Some substances have property that changes with temperature. Substance that show change with temperature can be used as thermometric material. Common thermometers are generally made using some suitable liquid as thermometric material.

Properties of Thermometric Properties

A thermometric liquid should have the following properties:

- It should be visible
- It should have uniform thermal expansion
- It should have a low freezing point
- It should have high boiling point
- It should not wet glass
- It should be a good conductor of electricity
- It should have small specific heat capacity

Liquid – In – glass Thermometer

A liquid – in – glass thermometer has a bulb with a long capillary tube of uniform and fine bore. A suitable liquid is filled in the bulb. When the bulb contacts a hot object, the liquid in it expands and rises in the tube. The glass stem of a thermometer is thick and acts as a cylindrical lens. This makes it easy to see the liquid level in the glass tube.

Mercury Liquid – in – Glass Thermometer

Mercury freezes at -39 °C and boils at 357 °C. It has all the thermometric properties listed above. Thus mercury is one of the most suitable thermometric materials. Mercury – in – glass thermometers are widely used in laboratories, clinics and houses to measure temperatures in range from -10 °C to 150 °C.

Reference points

A thermometer has a scale on its stem. This scale has two fixed points.

Lower Fixed Point

The lower fixed point is marked to show the position of liquid in the thermometer when it is placed in ice.

Upper Fixed Point

The upper fixed point is marked to show the position of liquid in the thermometer when it is placed in stem at standard pressure above boiling water.

Scales of Temperature

The distance between two reference points is divided in different divisions. A scale is marked on the temperature. The temperature of the body in contact with the thermometer can be read on that scale.

Types of Temperature Scale

There are three types of temperature scale.

(i) Celsius scale or centigrade scale

(ii) Fahrenheit scale

(iii) Kelvin scale

Fahrenheit and centigrade or Celsius scales are used to measure temperatures in ordinary life while Kelvin scale is in practice for scientific purposes.

Celsius scale

On Celsius scale, for water the interval between lower and upper fixed point is divided into 100 equal divisions. The lower fixed point is marked as 0 °C and the upper fixed point is marked as 100 °C.

Fahrenheit scale

On Fahrenheit scale, the interval between lower and upper fixed points is divided into 180 equal divisions. The lower fixed point is marked as 32 °C and the upper fixed point is marked as 212 °C.

Kelvin scale

In SI units, the unit of temperature is Kelvin (K) and its scale is called Kelvin scale of temperature. The interval between the lower and upper fixed points is divided into 100 equal divisions. Thus a change in 1°C is equal to a change of 1 K. the lower fixed point on the scale corresponds to 273 K and the upper fixed point is referred as 373 K. The zero on this scale is called the absolute zero and is equal to – 273 °C.

Q.No.2 What is specific heat? Explain with examples and derive its mathematical formula.

Ans: "Specific heat of a substance is the amount of heat that required to raise the temperature of 1 kg mass of that substance through 1K".

Explanation

Generally, when a body is heated, its temperature increases. Increase in the temperature of a body is found to be proportional to the amount of heat absorbed by it.

Mathematical Form

It has also been observed that the quantity of heat ΔQ required to raise the temperature ΔT of a body is proportional to the mass m of the body.

Thus $\Delta Q \propto m \Delta T$

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

Here ΔQ is the amount of heat absorbed by the body and c is the constant of proportionality called the specific heat capacity or simply specific heat.

So $$c = \frac{\Delta Q}{m\Delta T}$$

Unit

In SI units, mass m is measured in kilogram (kg), heat ΔQ is measured in joule (J) and temperature increases. ΔT is taken in Kelvin (K). So, SI unit of specific heat $Jkg^{-1}K^{-1}$.

Q.No.3 Explain the importance of large specific heat capacity of water.

Ans: Specific heat of water is 4200 $Jkg^{-1}K^{-1}$ and of dry soil is about 810 $Jkg^{-1}K^{-1}$. As a result the temperature of soil would increase five times more than the same mass of water by the same amount of heat.

Water has a large specific heat capacity. For this reason, it is very useful in storing and carrying thermal energy due to its high specific heat capacity.

Examples

(i) The temperature of land rises and falls more rapidly than that of the sea. Hence, the temperature variations from summer to winter are much smaller at places near the sea than land far away from the sea. So climate of the regions near sea shore, like Karachi, remains moderate.

(ii) The cooling system of the automobiles uses water to carry large amount of heat is produced by its engine due to which its temperature goes on increasing. The engine would cease unless it is not cooled down. Water circulating around the engine maintains the temperature. Water absorbs unwanted thermal energy of the engine and dissipates heat through its radiator.

(iii) In central heating systems hot water is used to carry thermal energy through pipes from boiler to radiators. Theses radiators are fixed inside the house at suitable places.

Heat Capacity

Q.No.4 Define heat capacity. Derive its mathematical formula and write down an activity to explain it.

Ans: Heat capacity of a body is the quantity of thermal energy absorbed by it for one Kelvin (1K) increases in its temperature.

Mathematical Form

Thus, if the temperature of a body increases through ΔT on adding ΔQ amount of heat, then its heat capacity will be $\Delta Q/\Delta T$. putting the value of ΔQ, we get

$$\text{Heat capacity} = \frac{\Delta Q}{\Delta T} = \frac{mc\Delta T}{\Delta T}$$

$$\text{Heat capacity} = mc$$

The above equation shows that heat capacity of a body is equal to the product of its mass of the body and its specific heat capacity.

Example

Heat capacity of 5 kg of water is (5 kg x 4200 $Jkg^{-1}K^{-1}$) 21000 Jkg^{-1}. That is 5 kg of water needs 21000 joules of heat for every 1 K rise in its temperature. Thus, larger is the quantity of a substance, larger will be its heat capacity.

8.4 CHANGE OF STATE

Q.No.5 Explain with an activity the change of state.

Matter can be changed from one state to another. For such a change to occur, thermal energy is added to or from a substance.

Activity

Take a beaker and place it over a stand. Put small pieces of ice in the beaker and suspend a thermometer in the beaker to measure the temperature of ice.

Now place a burner under the beaker. The ice will start melting. The temperature of the mixture containing ice and water will not increase above 0 °C until all the ice melts and we get water at 0° C is further heated, its temperature will begin to increase above 0° C as shown in figure.

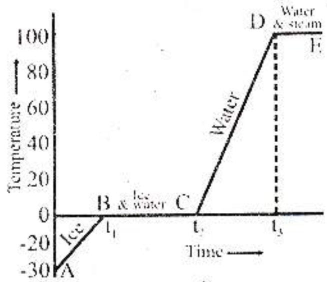

Figure 8.9: A graph of temperature and time showing change of state of ice into water and steam.

Part AB: On this portion of the curve, the temperature of ice increases from -30 °C to 0 °C.

Part BC: when the temperature of ice reaches 0 °C, the ice water mixture remains at this temperature until all the ice melts.

Part CD: The temperature of the substance gradually increases from 0 °C to 100 °C. the amount of energy so added is used up in increasing the temperature of water.

Part DE: At 100 °C water begins to boil and changes into steam. The temperature remains 100 °C until all the water changes into steam.

8.5 LATENT HEAT OF FUSION

Q.No.6 Define latent heat of fusion and write down its mathematical formula.

Ans: "Heat energy required to change unit mass of a substance from solid to liquid state at its melting point without change in the temperature is called its latent heat of fusion".

Mathematical Formula

It is denoted by H_f.

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

Or $\Delta Q_f = m\,H_f$

Latent Heat of Fusion of Ice

Ice changes at 0° C into water. Latent heat of fusion of ice is 3.36×10^5 Jkg^{-1}. That is; 3.36×10^5 joules heat is required to melt 1 kg of ice into water 0° C.

Experiment 8.1

Get a beaker, set it over a stand. Put small pieces of ice in it after hanging thermometer to note the temperature. Place a heat source under it and let the ice to melt. You will observe that temperature will not rise more than 0^0C until complete ice melts into water with a time gap.

The continued heat will rise temperature to 100^0C without repeat in time gap. Drawing graph, you can calculate the latent heat of fusion of ice with the data as given:

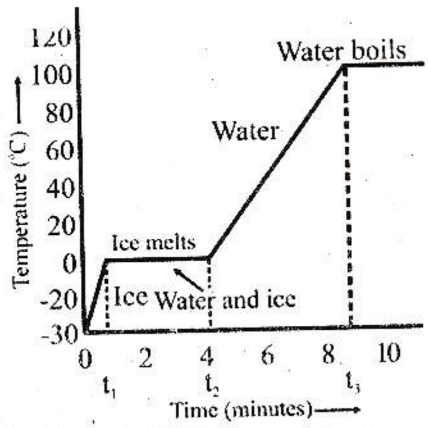

Figure 8.11: Temperature-time graph as ice changes into water that boils as heating continues.

Suppose the mass of ice =m

Measuring the time from the graph

Time taken by water to melt completely at 0° C = $t_f = t_2 - t_1$ =3.6 minutes

Time taken by water to heat from 0°C to 100° C = $t_o = t_3 - t_2$ = 4.6 minutes

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

Increase in the temperature of water $\Delta T = 100°\ C$

Heat required by water from 0° C to 100° C = ΔQ = ?

As we know that $\Delta Q = m\ c\ \Delta T$

$= m \times 4200 \times 100$

$= m \times 4.2 \times 10^3 \times 10^2$

$= 4.2 \times 10^5 \times m$ JKg^{-1}

To raise the temperature of the water from 0° C to 100° C, ΔQ is given to water. So the heat absorption rate of water in beaker can be given by

Rate of absorbing heat $= \Delta Q/t_o$

Since heat absorption in time $t_f = \Delta Q_f = (\Delta Q \times t_f)/t_o$

$= \Delta Q \times (t_f/t_o)$

As we know that $\Delta Q_f = m \times H_f$

$$m \times H_f = 4.2 \times 10^5 \times m \times (t_f/t_o)$$

$$H_f = 4.2 \times 10^5 \times (t_f/t_o)$$

Putting the values of t_f and t_o which can be found though graph

$$H_f = 4.2 \times 10^5 \times (3.6/4.6)\ JKg^{-1}$$

$$H_f = 3.29 \times 10^5\ JKg^{-1}$$

The latent heat of fusion of ice (H_f) found for above experiment is 3.29×10^5 JKg^{-1} however actual value is 3.36×10^5 JKg^{-1}.

8.6 LATENT HEAT OF VAPORIZATION

Q.No.7 Define latent heat of vaporization. Write its mathematical formula.

Ans: "The quantity of heat that changes unit mass of a liquid completely into gas at its boiling point without any change in its temperature is called its latent heat of vaporization"

Explanation

When heat is given to a liquid at its boiling point, its temperature remains constant. The heat energy given to liquid at its boiling point is used up in changing its state from liquid to gas without any increase in its temperature.

Mathematical Form

It is denoted by H_v

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

OR $\Delta Q_v = m H_v$

Latent Heat of Vaporization of Water

When water is heated, it boils at 100 °C under standard pressure. Its temperature remains 100°C until it is changed into steam. Its latent heat of vaporization is 2.26 x 106 Jkg-1. That is; one kilogram of water requires 2.26×10^6 joule heat to change it completely into gas (steam) at its boiling point.

Experiment 8.2

Water in the breaker takes to change completely into steam at its boiling point 100°C

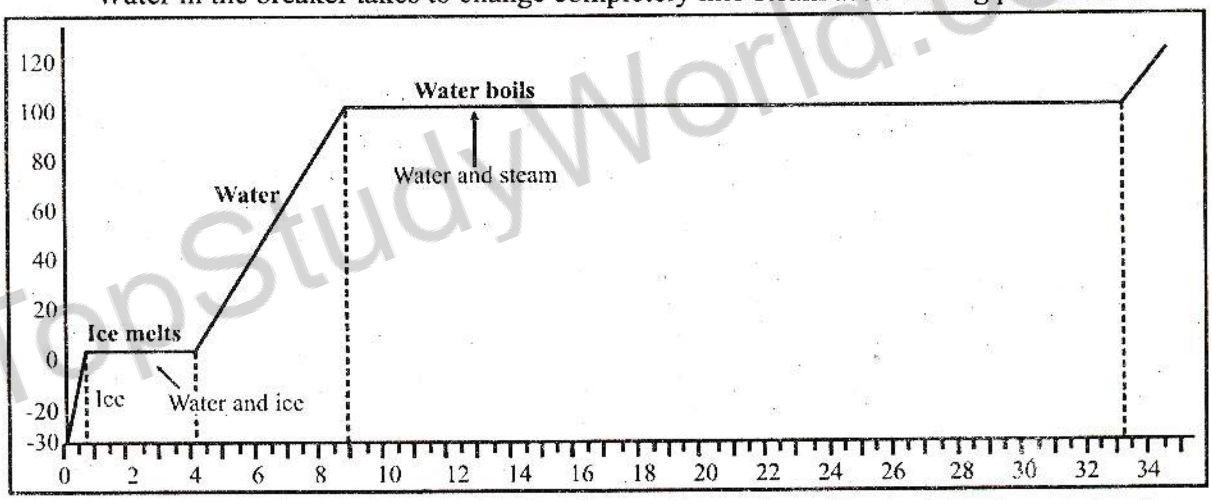

Figure: 8.12: Temperature-time graph as ice changes into water and water into steam on heating

Now take the boiling water of last experiment and heat till all water changes into steam. The time taken by boiled water to vaporize into steam is shown in graph. From graph, you can calculate the latent heat of vaporization of boiled water with the data as given:

Suppose: The mass of ice = m

Measuring the time from the graph

Time taken by water to heat from 0° C to 100° C = $t_o = t_3 - t_2$ = 4.6 minutes

Time taken by water to get changed into steam = $t_v = t_4 - t_3$ = 24.4 minutes

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

Increase in the temperature of water $\Delta T = 100^{\circ}\ C$

Heat required by water from 0° C to 100° C $= \Delta Q = m\ c\ \Delta T$

$$= m \times 4200 \times 100$$

$$= m \times 4.2 \times 10^{3} \times 10^{2}$$

$$= 4.2 \times 10^{5} \times m \quad JKg^{-1}$$

To raise the temperature of the water from 0° C to 100° C, ΔQ is given to water. So the heat absorption rate of water in beaker can be given by

Rate of absorbing heat $= \Delta Q/t_o$

Since heat absorption in time $t_v = \Delta Q_v = (\Delta Q \times t_v)/t_o$

$$= \Delta Q \times \left(\frac{t_v}{t_o}\right)$$

As we know that $\Delta Q_v = m \times H_v$

$$m \times H_v = 4.2 \times 10^{5} \times m \times (t_v/t_o)$$

$$H_v = 4.2 \times 10^{5} \times (t_v/t_o)$$

Putting the values of t_v and t_o which can be found though graph

$$H_f = 4.2 \times 10^{5} \times (24.4/4.6)\ JKg^{-1}$$

$$H_f = 2.23 \times 10^{6}\ JKg^{-1}$$

The latent heat of vaporization of boiled water (H_v) found for above experiment is $2.23 \times 10^{6}\ JKg^{-1}$ however actual value is $2.26 \times 10^{6}\ JKg^{-1}$.

8.7 THE EVAPORATION

Q.No.8 Define evaporation. On what factor speed of evaporation depend? Explain.

Ans: "Evaporation is the changing of a liquid into vapors (gaseous state) from the surface of the liquid without heating it".

Explanation

Take some water in a dish. The water in the dish will disappear after some time. It is because the molecules of water are in constant motion and possesses kinetic energy. Fast moving molecules escape out from the surface of water and goes into atmosphere.

Comparison of Boiling and Evaporation

Unlike boiling, evaporation takes place at all temperatures but only from the surface of a liquid. At boiling point, a liquid is changing into vapors not only from the surface but also within the liquid. These vapors are comes out of the boiling liquid as bubbles which breakdown on reaching the surface.

Example

Evaporation plays an important role in our daily life. We cloths dry up rapidly when spread.

Cooling Effect Produced by Evaporation

During evaporation fast moving molecules escape out from the surface of the liquid. Molecules that have lower kinetic energies are left behind. This lowers the average kinetic energy of the liquid molecules and the temperature of the liquid. Since temperature of a substance depends on the average kinetic energy of its molecules. Evaporation of perspiration helps to cool our bodies.

Dependence Factors

Evaporation takes place at all temperatures from the surface of a liquid. The rate of evaporation is affected by various factors.

Temperature

Why wet clothes dry up more quickly in summer than in winter? At higher temperature, more molecules of a liquid are moving with high velocities. Thus, more molecules escape from its surface. Thus, evaporation is faster at high temperature that at low temperature.

Surface Area

Why water evaporates faster when spread over large area? Large is the surface area of a liquid, greater number of molecules has the chance to escape from its surface.

Wind

Wind blowing over the surface of a liquid sweeps the liquid molecules that have just escaped out. This increases the chance for more liquid molecules to escape out.

Nature of the Liquid

Evaporation depends on the nature of the liquid. If we take spirit and water on our palm. As evaporation rate of spirit is greater than water, so we feel cooling effect due to evaporation of spirit.

8.8 THERMAL EXPANSION

Q.No.9 What is thermal expansion? Explain on the basis of kinetic molecular theory.

Ans: Most of the substances solids, liquids and gases expand on heating and contract on cooling.

Their thermal expansion and contractions are usually small and are not noticeable. However these expansions and contractions are important in our daily life.

Explanation on the basis of Kinetic Molecular Theory

The kinetic energy of the molecules of an object depends on its temperature. The molecules of a solid vibrate with large amplitude at high temperature than at low temperature. Thus, on heating, the amplitude of vibration of the atoms or molecules of an object increases. They push one another farther away as the amplitude of vibration increases. Thermal expansion results an increase in length, breadth and thickness of a substance.

Linear Thermal Expansion in Solids

Q.No.10 What is linear Expansion? On what factor it depend? Derive its mathematical formula.

Ans: "If a thin rod is heated, there is a prominent increase in its length as compared to its cross-sectional area. The expansion along length or in one dimension is called linear expansion".

Dependence

If we heat a metal rod the length of which is much larger than its thickness, then the increase in length depends on the following three factors:

(i) Length of thin rod.

(ii) Change in temperature.

(iii) Nature of material of the rod.

Mathematical form

Solids expand on heating and their expansion is nearly uniform over a wide range of temperature. Consider a metal rod of length L_o at certain temperature T_o. Let its length on heating to a temperature T becomes L. Thus

Increase in length of the rod = $\Delta L = L - L_o$

Increase in temperature = $\Delta T = T - T_o$

It is found that change in length ΔL of a solid is directly proportional to its original length L_o, and the change in temperature ΔT. that is;

$$\Delta L \propto L_o \Delta T$$

OR $$\Delta L = \alpha L_o \Delta T$$

OR $$L - L_o = \alpha L_o \Delta T$$

$$L = L_o(1 + \alpha \Delta T)$$

Coefficient of Linear Expansion

$$\alpha = \frac{\Delta L}{L_o \Delta T}$$

where α is the proportionality constant called co-efficient of linear expansion which depends on the nature of the material of the rod and it can be defined as:

"The fractional increase in its length per Kelvin rise in temperature which has unit K^{-1}"

OR

"If a rod of one meter length is heated through a temperature difference of 1K then the change in the length of the rod is called the co-efficient of linear expansion which has unit K^{-1}".

Volume Thermal Expansion

Q.No.11 What is volume expansion? On what factors it depend? Derive its mathematical formula.

Ans: "Heating a block causes an increase in length, breadth and thickness, i.e., volume of the block increases that is known as volume expansion".

Volume of a solid also changes with the change in temperature and is called volume thermal expansion or cubical thermal expansion.

Dependence

If we heat a block then increase in volume of the block depends on the following three factors:

(i) Original volume of block.

(ii) Change in temperature.

(iii) Nature of material of the block.

Mathematical form

Consider a solid of initial volume V_o at certain temperature T_o. On heating the solid to a temperature T, let its volume becomes V, then

Increase in volume of a solid = $\Delta V = V - V_o$

And Change in temperature = $\Delta T = T - T_o$

Like linear expansion, the change in volume ΔV is found to be proportional to its original volume V_o and change in temperature ΔT. Thus

$$V - V_o \propto V_o$$

And $$V - V_o \propto \Delta T$$

$$V - V_o \propto V_o \Delta T$$

$$V - V_o = \beta V_o \Delta T$$

$$V = V_o + \beta V_o \Delta T$$

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

Coefficient of Volume Expansion

Where β is the proportionality constant and is called the co-efficient of volume expansion.

$$\beta = \frac{\Delta V}{V_o \Delta T}$$

Thus, we can define the temperature coefficient of volume expansion as:

"The fractional change in its volume per Kelvin change in temperature".

OR

"If a block of one meter cube volume is heated through a temperature difference of 1K then the change in the volume of the block is called the co-efficient of linear expansion".

Its unit is also K^{-1}, but as compared to the co-efficient of linear expansion, it is three times greater.

$$\beta = 3\alpha$$

Consequences of Thermal Expansion

Q.No.12 Write down the consequences of thermal expansion.

Ans: The expansions of solids many damage bridges, railway tracks and roads as they are constantly subjected to temperature changes.

- Prevision is made during construction for expansion and contraction with temperature.
- Railway tracks buckled on a hot summer day due to expansion if gaps are not left between sections.
- Bridges made of steel girders also expands during the day and contract during night. They will bend if their ends are fixed. To allow thermal expansion, one end is fixed while the other one of the girder rests on rollers in the gap left for expansion. Overhead transmission lines are also given a certain amount of sag so that they contract in winter without snapping.

Applications of Thermal Expansion

Q.No.13 Write down the applications of thermal expansion.

Ans: Thermal expansion is used in our daily life. In thermometers, thermal expansion is used in temperature measurements.

- To open the cap of a bottle that is tight enough, immerse it in hot water for a minute or so. Metal cap expands and becomes loose. It would now be easy to turn it to open.
- To join steel plates tightly together, red hot rivets are forced through holes in the plates as shown in figure. The end of hot rivet is then hammered. On cooling, the rivets contracts and bring the plates tightly griped.
- Iron rims are fixed on wooden wheels of carts. Iron rims are heated. Thermal expansion allows them to slip over the wooden wheel. Water is poured on it to cool. The rim contracts and becomes tight over the wheel.

Bimetal Strip (Thermostat)

A bimetal strip consists of two thin strips of different metals such as brass and iron joined together as shown in figure. On heating the strip, brass expands more than iron. This unequal expansion causes bending of the strip as shown in figure.

Usage

Bimetal strips are used for various purposes.

- Bimetal thermometers are used to measure temperature especially in furnaces and ovens.
- Bimetal strips are also used in thermo states.
- Bimetal thermo state switch is used to control the temperature of heater coil in an electric iron.

Thermal Expansion of Liquids

Q.No.14 Explain the thermal expansion of liquid.

Ans: The molecules of liquids are free to move in all directions within the liquid. On heating a liquid, the average amplitude of vibration of its molecules increases. The molecules push each other and need more space to occupy. This accounts for the expansion of the liquid when heated. The thermal expansion in liquids is greater than solids due to the weak forces between their molecules. Therefore, the coefficient of volume expansion of liquids is greater than solids.

No Definite Shape of Liquids

Liquids have no definite shape of their own. A liquid always attains shape of the container in which it is poured. Therefore, when a liquid is heated, both liquid and the container undergo a change in their volume.

Activity

Take a long-necked flask. Fill it with some colored liquid up to mark A on its neck as shown in figure. Now start heating the flask from bottom. The liquid level first falls to B and then rises to C.

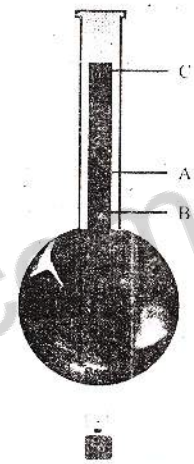

Figure 8.21: Real and apparent expansion of liquid.

Relation between expansions

We observe that there are two types of expansions appear as a result of heating a liquid in any container.

(i) Real expansion

(ii) Apparent expansion

In the given figure, real expansion is from B to C whereas A to C is apparent expansion. AB shows the expansion of the flask, whereas BC represents the real expansion of the liquid. Real expansion of the liquid is equal to the volume difference between A and C in addition to the volume expansion of the flask.

It can be seen that real expansion is comparatively greater than apparent expansion and they are related as follows:

Real expansion of liquid = Apparent expansion of liquid + Expansion of the flask

$$BC = AC + AB$$

The expansion of the volume of a liquid taking into consideration the expansion of the container also, is called the real expansion of the liquid.

Coefficients of volume expansions

The real rate of volume expansion β_r of a liquid is defined as the actual change in unit volume of a liquid for 1K (or 1 ^oC) rise in its temperature. The real rate of volume expansion β_r is always greater than the rate of volume expansion β_a by an amount equal to the rate of volume expansion of the container β_g.

Thus $\beta_r = \beta_a + \beta_g$

It should be noted that different liquids have different coefficients of volume expansion.

Coefficients of liquid expansion

In accordance with the apparent and real expansions of the liquids, their coefficient of expansion are also measured in two ways:

(i) Coefficient of apparent expansion

(ii) Coefficient of real expansion

MINI EXERCISE

(1) Which of the following substances have greater average kinetic energy of its molecules at 10°C?

(a) steel **(b)** copper **(c)** Water **(d)** Mercury

Ans. Copper

(2) Every thermometer makes use of some property of a material that varies with temperature. Name the property used in:

(a) Strip thermometers

(b) Mercury thermometers

Ans. **(a)** In strip thermometers, colour variation is used.

(b) Uniform thermal expansion of liquids is used in mercury thermometer.

(3) How specific heat differs from heat capacity?

Ans.

Specific Heat	Heat capacity
• Specific heat of a substance is the amount of heat required to raise the temperature of 1 kg mass of that substance through 1K. • Its unit is $Jkg^{-1}K^{-1}$	• Heat capacity of a body is the quantity of thermal energy absorbed by it for one Kelvin (1 K) increase in its temperature. • Its unit is JK^{-1}.

(4) Give two uses of cooling effect by evaporation.

Ans. **i.** Evaporation of perspiration helps to cool our body.

ii. It lowers the temperature of the body.

(5) How evaporation differs from vaporization?

Ans.

Evaporation	Vaporization
Evaporation is the changing of a liquid into vapours (gaseous state) from the surface of the liquid without heating it.	The process in which liquid converts into gas at its boiling point is called vaporization.

TEXTBOOK EXERCISE
QUESTIONS

8.1 Encircle the correct answer from the given choices.

i. Water freezes at:

a) 0 °F **b) 32 °F** c) -273 K d) 0 K

ii. Normal human body temperature is:

a) 15 °C **b) 37 °C** c) 37 °F d) 98.6 °F

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

a) Uniform thermal expansion b) low freezing point

c) small heat capacity **d) all of the above properties**

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

a) Copper b) ice **c) water** d) mercury

v. Which of the following material has large value of temperature coefficient of linear expansion?

a) Aluminum b) gold c) brass d) steel

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

a) $2 \times 10^{-5} K^{-1}$ **b) $6 \times 10^{-5} K^{-1}$** c) $8 \times 10^{-15} K^{-1}$ d) $8 \times 10^{-5} K^{-1}$

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

a) Low temperature of water **b) low specific heat of water**

c) less absorption of heat d) large specific heat of water

viii. Which of the following affects evaporation?

a) Temperature b) Surface area of the liquid

c) wind **d) all of the above**

8.2 Why does heat flow from hot body to cold body?

Ans: Molecules of hot body have greater kinetic energy than the molecules of cold body. Therefore, fast moving molecules give their energy to cold body. So we can say that heat flows from hot body to the cold body.

8.3 Define the term heat and temperature.

Ans: Heat

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

Temperature

Degree of coldness or hotness of the body is a measure of its temperature

8.4 What is meant by internal energy of a body?

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

8.5 How does heating affect the motion of molecules of a gas?

Ans: On heating the gas, the motion of the molecules becomes faster. So internal energy of the gas molecules increases.

8.6 What is thermometer? Why mercury is preferred as thermometric substance?

Ans: The instrument which is used to measure the temperature is called a thermometer. Mercury is preferred as thermometric substance because

- It has high boiling point
- It has low melting point
- It does not wet glass
- Good conductor
- Opaque
- Has low heat capacity

8.7 Explain the volumetric thermal expansion.

Ans: See Q. 11 Long Question

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

Ans: See Q. 2 'the method of mixture is used to find the specific heat of any solid'.

8.9 Define and explain latent heat of fusion.

Ans: See Q. 6 Long Question

8.10 Define latent heat of vaporization.

Ans: See Q. 7 Long Question

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

Ans: See Q. 8 Long Question

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

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

Result

Temperature in Fahrenheit = $T_f = 122\ ^oF$

8.2 Normal human body temperature is 98.6^0 F. Convert it into Celsius and Kelvin scale.

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

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

As we know that

$$T_K = C + 273$$

By putting the values, we have

$$T_K = 37 + 273 = 310\ K$$
$$T_K = 310\ K$$

Result

Temperature in Celsius = $T_c = 37\ ^oC$

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^o C to 20^0 C. If the thermal coefficient of linear expansion of aluminum is $2.5 \times 10^{-5}\ K^{-1}$.

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

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

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 $3.67 \times 10^{-3}\ K^{-1}$.

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

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

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.

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

$$\Delta T = T_2 - T_1$$
$$= (65-10)^\circ C$$
$$= 55^\circ C$$
$$= 55K$$

Required

Heat required = Q =?

Solution

As we know that

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

By putting the values, we have

$$\Delta Q = 0.5 \text{ x } 4200 \text{ x } 55$$
$$\Delta Q = 115500 \text{ J}$$

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 = ΔT = 90 – 20 = 70° C or K

Required

Heat required = Q = ?

Time = t = ?

Solution

As we know that

$$Q = cm\,\Delta T$$
$$Q = 0.2 \text{ x } 4200 \text{ x } 70$$
$$Q = 58800 \text{ J}$$

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 ice = 336000 Jkg^{-1}.

Given Data

Heat supplied to ice = ΔQ_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 $$m = \frac{\Delta Q}{H_f}$$

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 = Q = ?

Solution

As we know that heat of fusion (Q_1);

$Q_1 = m \times H_f$

$Q_1 = 0.1 \times 336000$

$Q_1 = 33600$ J

To increase temperature from 0° C to 10° C

The required heat (Q_2) for this change is;

$Q_2 = m\,c\,\Delta T$

$Q_2 = 0.1 \times 4200 \times 10$

$Q_2 = 4200$ J

For change of ice into water from -10° C to 0° C

The required heat (Q_3) for this change is;

$Q_3 = m\,c\,\Delta T$

$Q_3 = 0.1 \times 2100 \times 10$

Total heat (Q) is;

$Q = Q_1 + Q_2 + Q_3$

$Q = 33600 + 4200 + 2100$

$Q = 39900$ 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?

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 = $H_v = 2.26 \times 10^6$ 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 = $Q_v = 2.26 \times 10^5$ 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

As we know that

$$Q = m_1 \times H_v$$

$$Q = 0.005 \times 2.26 \times 10^6 \text{ J}$$

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

and

$$Q = m_2\, c\, \Delta T$$

$$Q = 0.5 \times 4200 \times (T - 10)$$

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

Comparing eq (i) & eq (ii)

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

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

$$5.4 = T - 10$$

$$T = 10 + 5.4 = 15.4^\circ \text{ C}$$

Result

Final temperature of water = T = 15.4° C