Unit 8

THERMAL PROPERTIES OF MATTER

Q1. Define the terms heat and temperature.

Ans: Heat:

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

Temperature:

Temperature of a body is the degree of hotness or coldness of the body.

Q2. Define the terms thermal conduct and thermal equilibrium.

Ans: Thermal conduct:

In heat transfer and thermodynamics, a thermodynamic system is said to be in thermal conduct with another system if it can exchange energy with it through the process of heat.

Thermal equilibrium:

Thermal equilibrium - When two objects A and B are in thermal contact and there is no net transfer of thermal energy from A to B or from B to A, they are said to be in thermal equilibrium.

Q3. Define the terms energy in transit and internal energy.

Ans: Energy in transit:

The form of energy that is transferred from a hot body to a cold body is called heat. Thus, Heat is therefore, called as the energy in transit.

Once heat enters a body, it becomes its internal energy and no longer exists as heat energy.

Internal energy:

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

Internal energy of a body depends on many factors such as the mass of the body, kinetic and potentials energies of molecules etc.

Q4. Differentiate between temperature and heat?

Ans: Heat:

Heat (symbol: Q) is energy. It is the total amount of energy (both kinetic and potential) possessed by the molecules in a piece of matter. Heat is measured in Joules.

Temperature:

Temperature (symbol: T) is not energy. It relates to the average (kinetic) energy of microscopic motions of a single particle in the system per degree of freedom. It is measured in Kelvin (K), Celsius (°C) or Fahrenheit (°F).

Explanation:

Heat is the total energy of molecular motion in a substance while temperature is a measure of the average of the molecular motion in a substance. Heat energy depends on the speed of the particles, the number of particles (the size or mass), and the type of particles in an object. Temperature does not depend on the size or type of object. For example, the temperature of a small cup of water might be the same as the temperature of a large tub of water. But the tub of water has more heat because it has more water and thus more total thermal energy.

Note: Temperature is not energy, but a measure of it. Heat is energy.

DO YOU KNOW?

The crocus flower is a natural thermometer. It opens when the temperature is precisely 23°C and closes when the temperature drops.

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

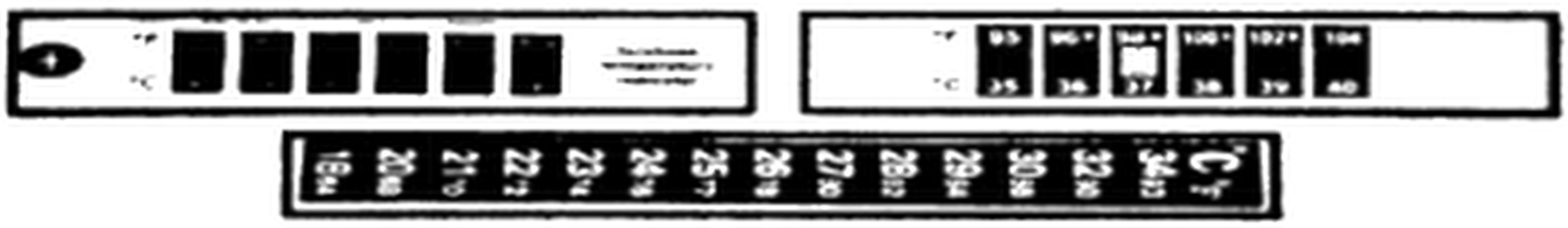
Ans: At 10°C water molecules have greater kinetic energy. Due to lesser intermolecular forces as compared to steel, copper and mercury.

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) strip thermometers:

Liquid-crystal thermometers use liquid crystals that change color in response to temperature changes. Mixture of liquid crystals are enclosed in separate partitions. Numbers on the partitions indicate temperatures according to the amount of heat present.



(b) mercury thermometers:

Mercury thermometers are based on the fact that materials (in this case, the liquid mercury) expands when heated.

Mercury has boiling point and less specific heat.

Note: Due to these properties' mercury is used in mercury thermometers. Since it is opaque, it is easy to see the capillary.

Q5. What is a thermometer? Why mercury is preferred as a thermometric substance?

Ans. See Q # 8.6 from Exercise.

Q6. Describe the feature of liquid-in-glass thermometer

OR

Describe the feature of mercury- in-glass thermometer

Ans. 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.

A mercury-in-glass thermometer

Mercury freezes at −39°C and boils at 357°C

Uses:

Thus, mercury is one of the most suitable thermometric material. Mercury-in-glass thermometer are widely used in laboratories, clinics and houses to measure temperature in the range from -10°C to 150°C.

Q7. What do you mean by lower and upper fixed points in thermometer?

Ans: Lower and upper fixed points:

A thermometer has a scale on its stem. The scale has two fixed points. The lower fixed point is marked to show the position of liquid in the thermometer when it is placed in ice.

Similarly, upper fixed points are m marked to show the position of liquid in the thermometer when it is placed in steam at standard pressure above boiling water.

Q8. Highlight the different scale of temperature from one scale to another (Fahrenheit, Celsius and Kelvin scales)

Ans. Scales of temperature:

A scale is marked on the thermometer. The temperature of the body in contact with the thermometer can be read on that scale. Three scales of temperature are in common in use. These are:

(i) Celsius scale or centigrade scale

(ii) Fahrenheit scale

(iii) Kelvin Scale

Celsius scale:

On Celsius scale, the interval between lower and upper fixed points is divided into 100 equal parts. 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 parts. The lower fixed point is marked as 32°F and the upper fixed point is marked as 212°F.

Kelvin scale:

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

	°C	**°F**	**K**
Boiling point of water	100	212	373
Freezing point of water	0	32	273

DO YOU KNOW?

Sun's core	15000000°C
Sun's surface	6000°C
Electric lamp	2500°C
Gas lamp	1580°C
Boiling water	100°C
Human body	37°C

Freezing water	0°C
Ice in freezer	-18°C
Liquid in oxygen	-180°C

Q9. How can you convert the temperature from one scale to another (Fahrenheit, Celsius and Kelvin Scales?)

Ans: Conversion of temperature from one scale into other temperature scale:

From Celsius to Kelvin scale:

The temperature (T) on Kelvin scale can be obtained by adding 273 in the temperature C on Celsius scale. Thus

$$T(K) = 273 + C \quad \ldots\ldots\ldots\ldots \text{(i)}$$

From Kelvin to Celsius scale:

The temperature on Celsius scale can be found by subtracting 273 in the temperature in Kelvin scale. Thus

$$C = T(K) - 273 \quad \ldots\ldots\ldots\ldots \text{(ii)}$$

From Celsius to Fahrenheit Scale:

Since 100 divisions on Celsius scale are equal to 180 divisions on Fahrenheit scale. Therefore, each division on Celsius scale is equal to 1.8 divisions on Fahrenheit scale. Moreover, 0°C corresponds to 32°F.

$$F = 1.8C + 32 \quad \ldots\ldots\ldots \text{(iii)}$$

Here F is the temperature on Fahrenheit scale and C is the temperature on Celsius scale.

DO YOU KNOW?

A clinical thermometer is used to measure, the temperature of human body. It has a narrow range from 35°C to 42°C. It has a constriction that prevents the mercury to return. Thus, its reading does not change until reset.

USEFUL INFORMATION

Specific heat of some common substances	
Substance	**Specific heat (Jk$g^{-1}K^{-1}$)**
Alcohol	2500.0
Aluminum	903.0
Bricks	900.0
Carbon	121.0
Clay	920.0
Copper	387.0
Ether	2010.0
Glass	840.0
Gold	128.0
Granite	790.0
Ice	2100.0
Iron	470.0

Lead	128.0
Mercury	138.6
Sand	835.0
Silver	235.0
Soil	810.0
Steam	2016.0
Tungsten	134.8
turpentine	1760.3
Water	4200.0
zinc	385.0

Q10. Define specific heat. How would you find the specific heat of a solid?

Ans: See Q # 8.8 from Exercise.

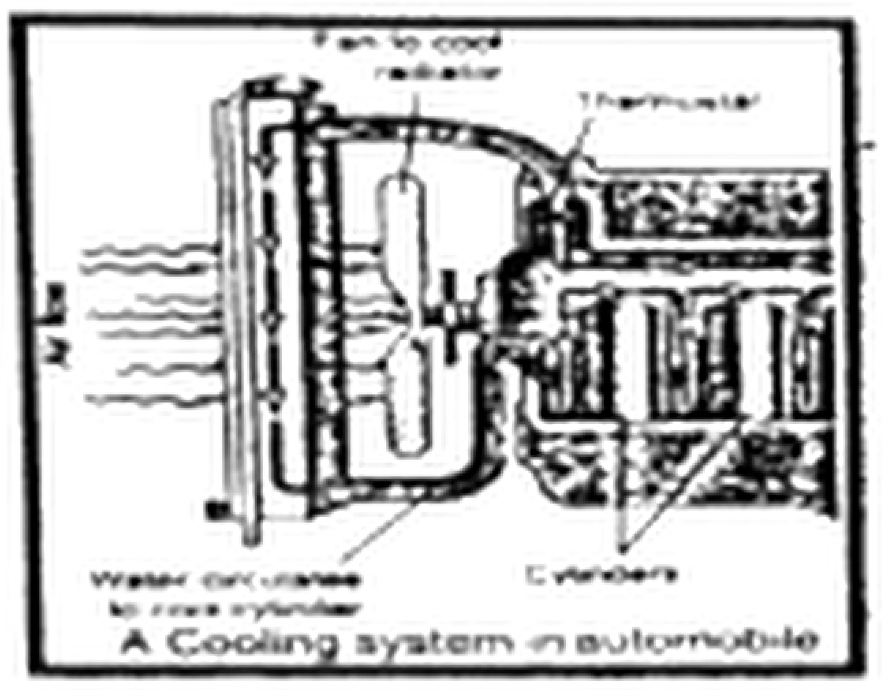
Q11. Describe the Importance of large specific heat capacity of water

Ans: Importance of large specific heat capacity of water:

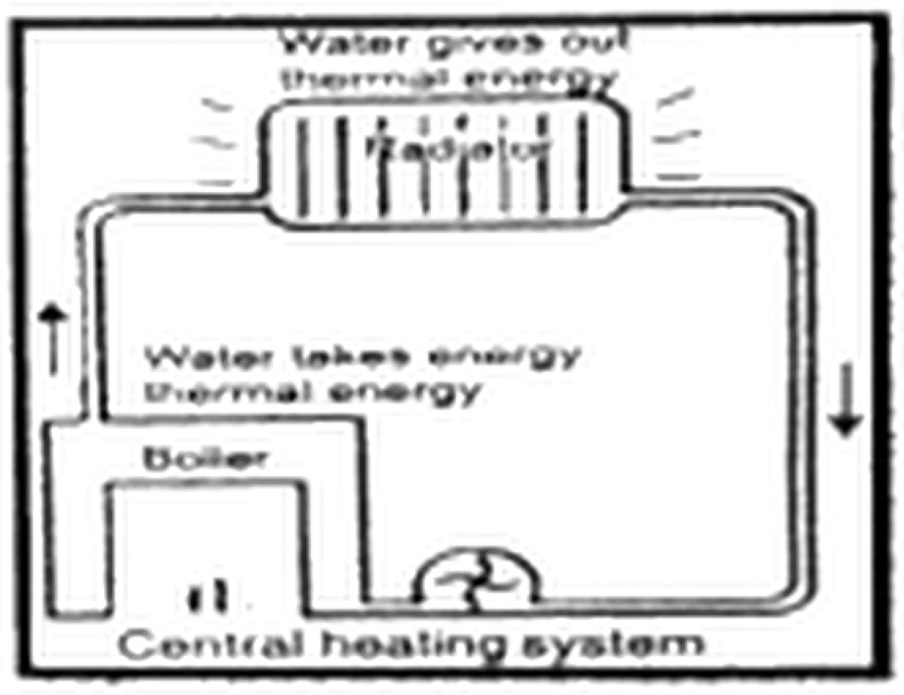
Specific heat of water is $4200\text{J}kg^{-1}K^{-1}$ and that of dry soil is about $810\text{J}kg^{-1}K^{-1}$. As a result the temperature of soil would increase five times more than the same mass of water the same amount of heat. Thus, the temperature of land rises and falls more rapidly than that 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.

Storing and carrying thermal energy:

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. The cooling system of automobiles uses water to carry away unwanted thermal energy. In an automobile, 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 by arrows in maintains its temperature. Water absorbs unwanted thermal energy of the engine and dissipates heat through its radiator.



A Cooling system in automobile



Central heating system

Central heating systems:

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

DO YOU KNOW?

The presence of large water reservoirs such as lakes and seas keep the climate of nearby land moderate due to the large heat capacity of these reservoirs.

Q12. Define heat capacity. How would you find the heat capacity of a solid?

Ans: Heat capacity:

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

If the temperature of a body increases through ΔT on adding ΔQ amount of heat, then its heat capacity will be $\frac{\Delta Q}{\Delta T}$. Putting the value of ΔQ. We get

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

$$\text{Heat capacity} = mc \;............\; (i)$$

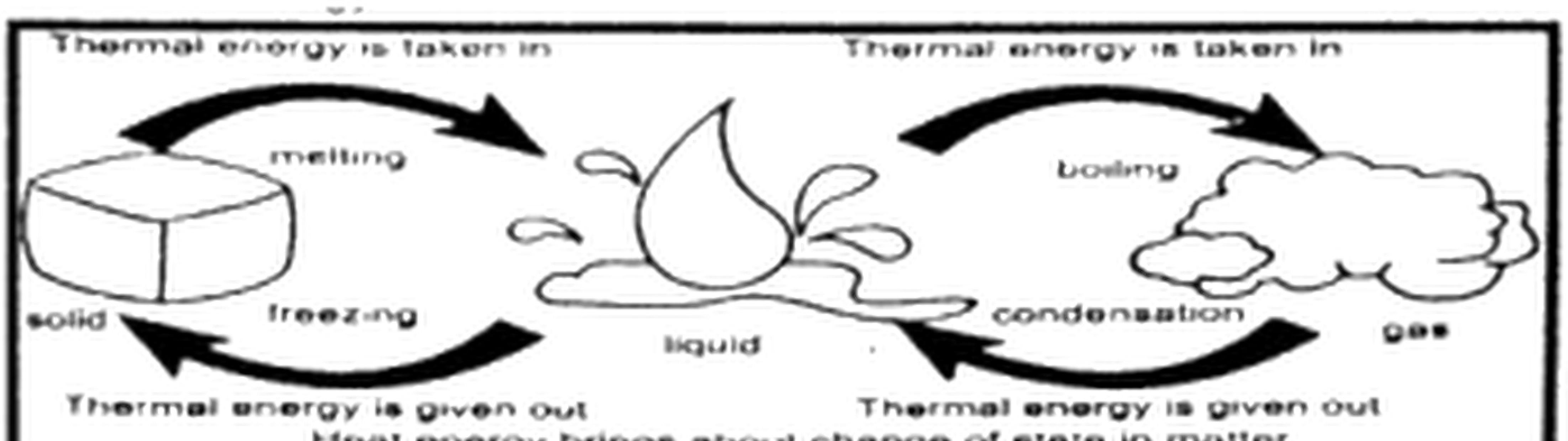
Equation (i) shows that heat capacity of a body is equal to the product of its mass of the body and its specific heat capacity.

For example, heat capacity of 5kg of water is (5 kg × 4200 $Jkg^{-1}K^{-1}$) 21000 JK^{-1}. That is; 5kg 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.

Q13. Describe activity to determine the change of state of ice into water and steam by sketching graph.

Ans: Change of state:

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



Heat energy brings about change of state in matter

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. If this water at 0°C is further heated, its temperature will begin to increase above 0°C as shown by the graph in figure. 8.9.

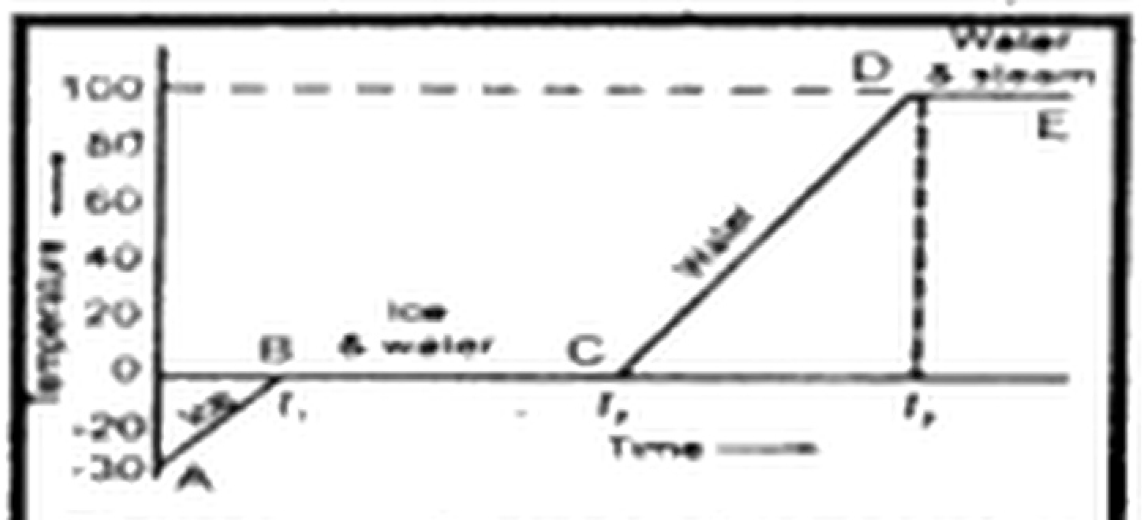


Figure: A graph of temperature and time showing change of state of ice into water and steam.

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.

Q14. Define fusion point and freezing point?

Ans: Fusion point or melting point:

When a substance is changed from solid to liquid state by adding heat, the process is called melting or fusion.

The temperature at which a solid start melting is called its fusion point or melting point.

Freezing point:

The temperature at which a substance is changed from liquid to solid state is called freezing point. However, the freezing point of a substance is the same as its melting point.

Q15. Define and explain latent heat of fusion.

Ans: See Q # 8.9 from Exercise.

Q16. Find the latent heat of fusion of ice with the help of experiment.

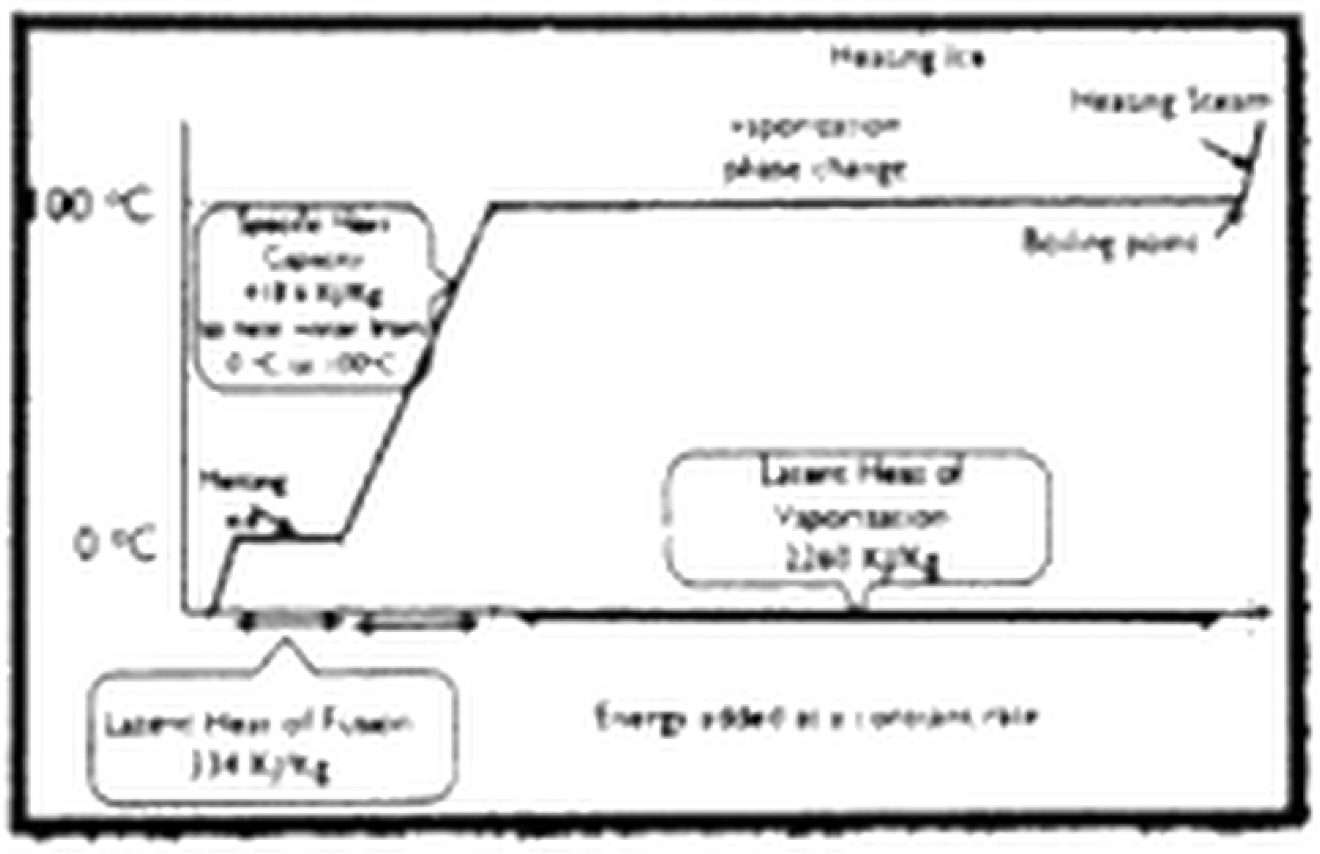
OR

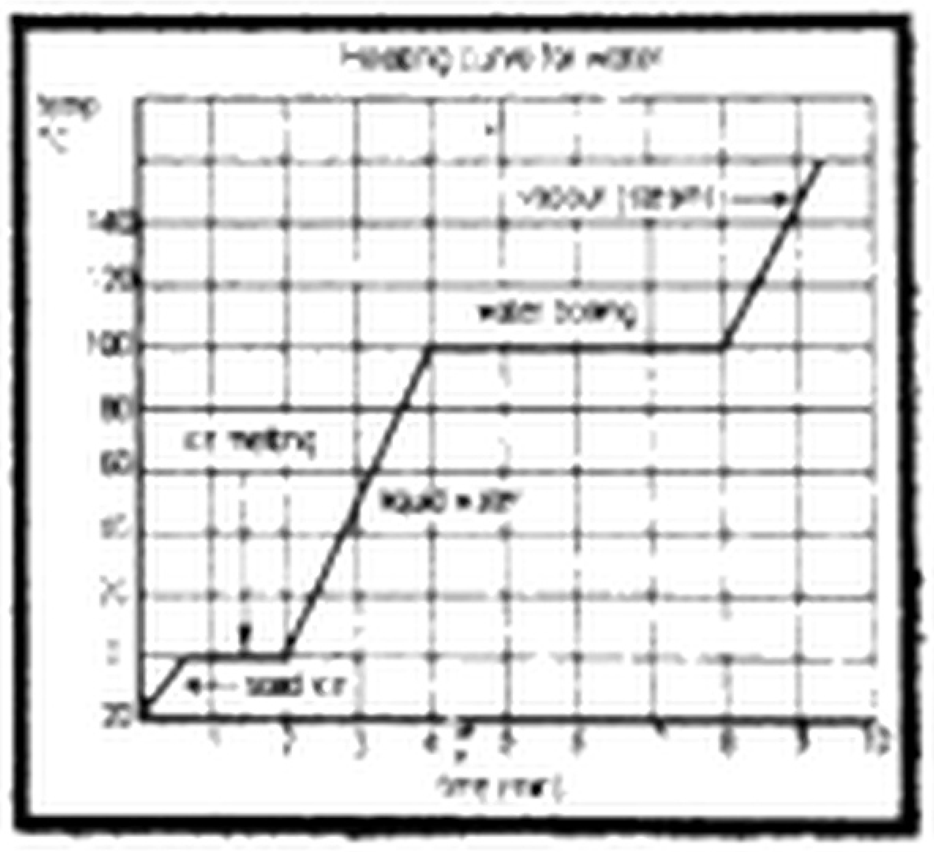
Describe experiments to determine heat of fusion and latent heat of fusion of ice by sketching temperature-time graph on heating ice.

Ans: Experiment:

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. 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. Note the time which the ice takes to melt completely into water at 0°C

Continue heating the water at 0°C in the beaker. Its temperature will begin to increase. Note the time which the water in the beaker takes to reach its boiling point at 100°C from 0°C.





Draw a temperature-time graph such as shown in figure 8.11.

Calculate the latent heat of fusion of ice from the data as follows:

Let mass of ice = m

Finding the time from the graph:

Time taken by ice to melt completely at 0°C = $t_f = t_{2-} t_1 =$ 3.6 min.

Time taken by water to heat from 0°C to 100°C = $t_0 = t_{3-} t_2 =$ 4.6 min.

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

Increase in the temperature of water = Δ T = 100°C =100 K

Heat required by water from 0°C to 100°C = Δ Q = mc Δ T

$$= m \times 4200\ Jkg^{-1}K^{-1} \times 100K$$

$$= m \times 420\,000\ Jkg^{-1}$$

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

Heat Δ Q is supplied to water in time t_0 to raise its temperature from 0°C to 100°C. Hence, the rate of absorbing heat by the water in the beaker is given by

Rate of absorbing heat = $\frac{\Delta Q}{t_0}$

$\therefore$ Heat absorbed in time $t_f = \Delta Q = \frac{\Delta Q \times t_f}{t_0} = \Delta Q \times \frac{t_f}{t_0}$

Since $\Delta Q_f = m \times H_f$ (from eq. 8.7)

Putting the values, we get

$$m \times H_f = m \times 4.2 \times 10^5 \ Jkg^{-1} \times \frac{t_f}{t_0}$$

or $$H_f = 4.2 \times 10^5 \ Jkg^{-1} \times \frac{t_f}{t_0}$$

The values of t_f and t_0 can be found from the graph. Put the values in the above equation to get

$$H_f = 4.2 \times 10^5 \ Jkg^{-1} \times \frac{3.6\text{min}}{4.6\text{min}}$$

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

The latent heat of fusion of ice found by the above experiment is 3.29 $\times 10^5 \ Jkg^{-1}$ while its actual value is 3.36 $\times 10^5 \ Jkg^{-1}$.

Q17. Define latent heat of vaporization.

Ans: See Q # 8.10 from Exercise.

Q18. List the value of melting point, boiling point, latent heat of fusion and vaporization of some of the substances?

Ans: Melting point, boiling point, latent heat of fusion and latent heat of vaporization of some common substances.

Substance	Melting point	Boiling point	Heat of fusion	Heat of vaporization

	(°C)	(°C)	$(kJkg^{-1})$	$(kJkg^{-1})$
Aluminum	660	2450	39.7	10500
copper	1083	2595	205.0	4810
Gold	1063	2660	64.0	1580
Helium	-270	-269	5.2	21
Lead	327	1750	23.0	858
Mercury	-39	357	11.7	270
Nitrogen	-210	-196	25.5	200
Oxygen	-219	-183	13.8	210
Water	0	100	336.0	2260

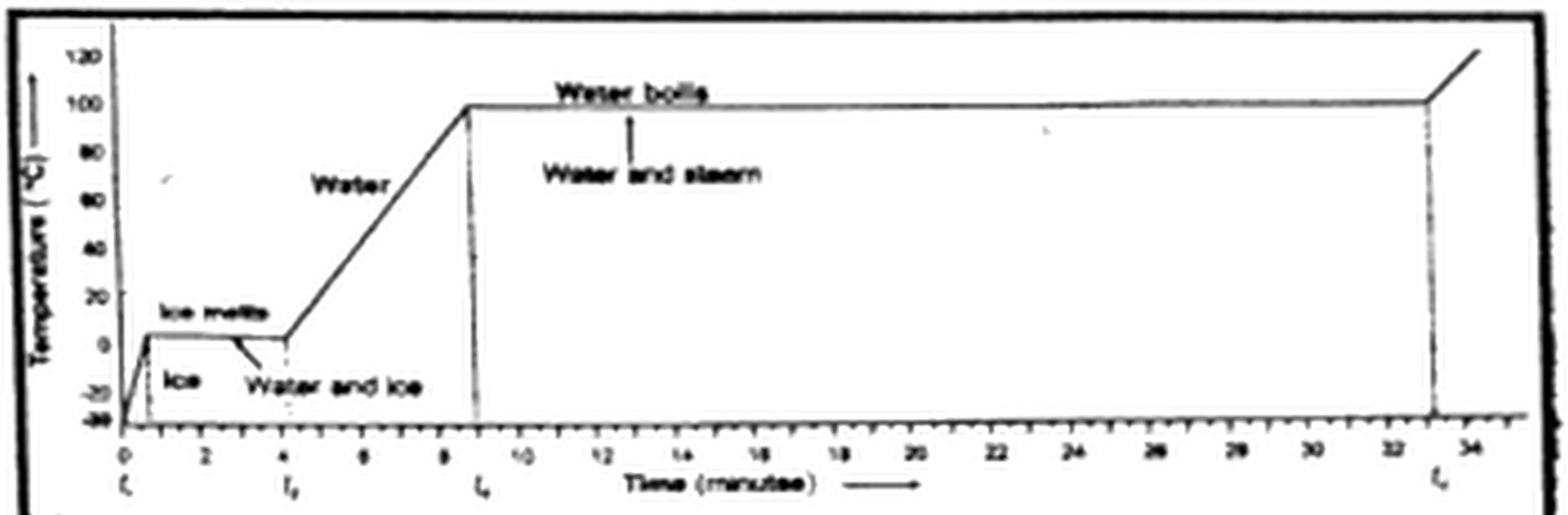
Q19. Define the latent heat of vaporization of water with the help of experiment.

OR

Describe experiment to determine heat of vaporization and heat of vaporization of water by sketching temperature-time graph.

Ans: Experiment:

At the end of experiment 8.1 the beaker contains boiling water. Continue heating water till all the water changes into steam. Note the time which the water in the beaker takes to change completely into steam at its boiling point 100°C



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

Extend the temperature-time graph as shown in figure.

Calculate the latent heat of fusion of ice from the data as follows:

Let Mass of ice = m

Time t_0 taken to heat water from 0°C to 100°C (melt) = $t_0 = t_{3-} t_2 =$ 4.6 min.

Time taken by water at 100°C to change it into steam = $t_4 = t_{4-} t_3 =$ 24.4 min.

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

Increase in the temperature of water = Δ T = 100°C =100 K

Heat required by water from 0°C to 100°C = Δ Q = mc Δ T

=m × 4200 $Jkg^{-1}K^{-1}$ × 100K

= m × 420 000 Jkg^{-1}

= m × 4.2 × 10^5 Jkg^{-1}

As burner supplies heat Δ Q to water in time t_0 to raise its temperature from 0°C to 100°C. Hence, the rate at which heat is absorbed by the beaker is given by

Rate of absorbing heat = $\frac{\Delta Q}{t_0}$

∴ Heat absorbed in time t_v = ΔQ_v = $\frac{\Delta Q \times t_v}{t_0}$

= Δ Q × $\frac{t_v}{t_0}$

Since ΔQ_v = m × H_v (from eq. 8.8)

Putting the values, we get

$$m \times H_v = m \times 4.2 \times 10^5 \ Jkg^{-1} \times \frac{t_v}{t_0}$$

or $$H_v = 4.2 \times 10^5 \ Jkg^{-1} \times \frac{t_v}{t_0}$$

Putting the values of t_v and t_0 from the graph, we get

$$H_v = 4.2 \times 10^5 \ Jkg^{-1} \times \frac{24.4\text{min}}{4.6\text{min}}$$

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

The latent heat of vaporization of water found by the above experiment is $2.23 \times 10^6 \ Jkg^{-1}$ while its actual value is $2.23 \times 10^6 \ Jkg^{-1}$.

Q20. What is meant by evaporation? On what factors the evaporation of liquid depends? Explain how cooling is produced by evaporation.

Ans: See Q # 8.11 from Exercise.

Mini Exercise

1. 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 if 1kg mass of that substance through 1K.	Heat capacity of a body is the quantity of thermal energy absorbed y it for one Kelvin (1K) increase in its temperature.
Specific heat can be found out by the relation. $c = \frac{\Delta Q}{m \Delta T}$	Heat capacity can be found out by the relation Heat capacity = mc

SI unit of specific heat is $Jkg^{-1}K^{-1}$	Unit of heat capacity is JK^{-1}

2. Give two uses of cooling effect by evaporation.

Ans: Uses of cooling effect by evaporation:

i. During hot summers, the water is usually kept in the earthen pot to keep it cool. Water is cooled in the pot since the surface of the pot contains large pores and water seeps via there pores to outside of pot. This water evaporates and takes the latent heat for vaporization hence retaining the water inside pot to be cooled.

ii. Especially in villages, people often sprinkle water on the round in front of their homes during hot summers.

iii. Water vaporization from leaves of trees also cools the surroundings.

iv. A desert cooler cools better on a hot and dry day.

v. It is a common observation that we are able to sip hot tea (or milk) faster from a saucer than from a cup.

vi. Wearing cotton clothes in summer days to keep the body cool and comfortable.

vii. Put a little of spirit on your hand and wave around, the spirit evaporates rapidly and our hands feels cooler.

3. How evaporation differs from vaporization?

Ans: Difference between vaporization and evaporation:

Vaporization:

Vaporization is a transitional phase of an element or compound from a solid phase or liquid phase to a gas phase. It changes matter from one state or phase into another without changing its chemical composition.

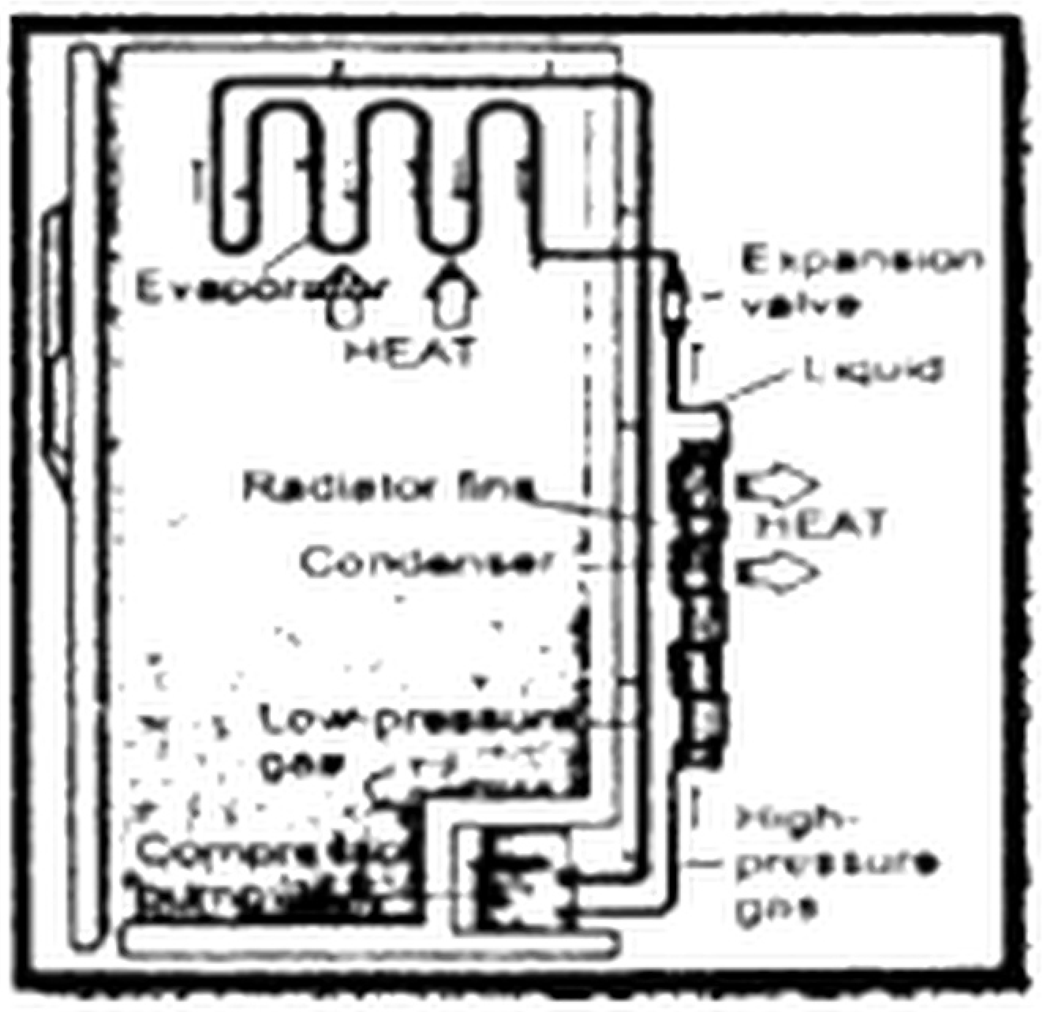
Vaporization has three types:

i. Boiling ii. Evaporation iii. Sublimation

Evaporation:

Evaporation, wherein the transition from liquid phase to gas phase takes place below the boiling temperature at a given pressure, and it occurs on the surface.

COOLING IN REFRIGERATORS



Cooling is produced in refrigerators evaporation of a liquefied gas. This produces cooling effect. Freon, a CFC, was used as a refrigerator gas. But its use has been forbidden when it was known that CFC is the cause of ozone depletion in the upper atmosphere which results increase in amount of UV rays from the Sun. The rays are harmful to all living matter. Freon gas is now replaced by Ammonia and other substances which are not harmful to the environment.

Q21: Define thermal expansion.

Ans: Thermal expansion:

Thermal expansion is the tendency of matter to change in volume in response to a change in temperature.

On heating, the amplitude of vibration of the atoms and 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.

Q22. Derive the relation for linear thermal expansion in solids.

OR

Show that $L = L_0 (1 + a \Delta T)$?

Ans: Linear thermal expansion in solids:

Consider a metal rod of length L_0 at certain temperature T_0. Let its length on heating to a temperature T becomes L Thus

Increase in length of the rod = $\Delta L = L - L_0$

Increase in temperature = $\Delta T = T - T_0$

It is found that change in length ΔL of a solid is directly proportional to its original length L_0, and the change in temperature ΔT. That is;

$$\Delta L \propto L_0 \Delta T$$

or $$\Delta L = \alpha L_0 \Delta T \text{ .... (i)}$$

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

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

or $$L = L_0 (1 + a \Delta T) \text{ .... (ii)}$$

where α is called the coefficient of linear thermal expansion of the substance.

From equation (i), we get

$$\alpha = \frac{\Delta L}{L_0 \Delta T} \quad \text{(iii)}$$

Coefficient of linear expansion α:

We can define the coefficient of linear expansion α of a substance as the fractional increase in its length per kelvin rise in temperature.

Q23. Give coefficient of linear thermal expansion of some common solids.

Ans: Table gives coefficient of linear expansion of some common solids.

Coefficient of linear expansion (α) of some common solids.	
Substance	$\alpha(K^{-1})$
Aluminum	2.4×10^{-5}
Brass	1.9×10^{-5}
Copper	1.7×10^{-5}
Steel	1.2×10^{-5}
Silver	1.93×10^{-5}
Gold	1.3×10^{-5}
Platinum	8.6×10^{-5}
Tungsten	0.4×10^{-5}
Glass (pyrex)	0.4×10^{-5}
Glass (ordinary)	0.9×10^{-5}
Concrete	1.2×10^{-5}

Q24. Explain the volumetric thermal expansion.

OR

Derive the relation for volume thermal expansion in solids.

OR

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

Ans: See Q # 8.7 from Exercise.

Q25. Give the values of β for different substances?

Ans: Values of β for different substances are given in Table

Coefficient of volume expansion of various substances.	
Substance	$\beta(K^{-1})$
Aluminum	7.2×10^{-5}
Brass	6.0×10^{-5}
Copper	5.1×10^{-5}
Steel	3.6×10^{-5}
Platinum	27.0×10^{-5}
Glass (ordinary)	2.7×10^{-5}
Glass (pyrex)	1.2×10^{-5}
Glycerine	53×10^{-5}
Mercury	18×10^{-5}
Water	21×10^{-5}

Air	3.67×10^{-3}
Carbon dioxide	3.72×10^{-3}
Hydrogen	3.66×10^{-3}

Q26. Why gaps are left in railway tracks?

Ans: Gapes are left in railway tracks to compensate thermal expansion during hot season. Railway tracks buckled on a hot summer day due to expansion if aps is not left between sections.

Q27. Why gaps are left in bridge with rollers?

Ans: Bridges made of steel girders also expand 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 end of the girder rests on rollers in the gap left for expansion.

Q28. Why overhead transmission lines (wires on electric poles) are also given a certain amount of sag?

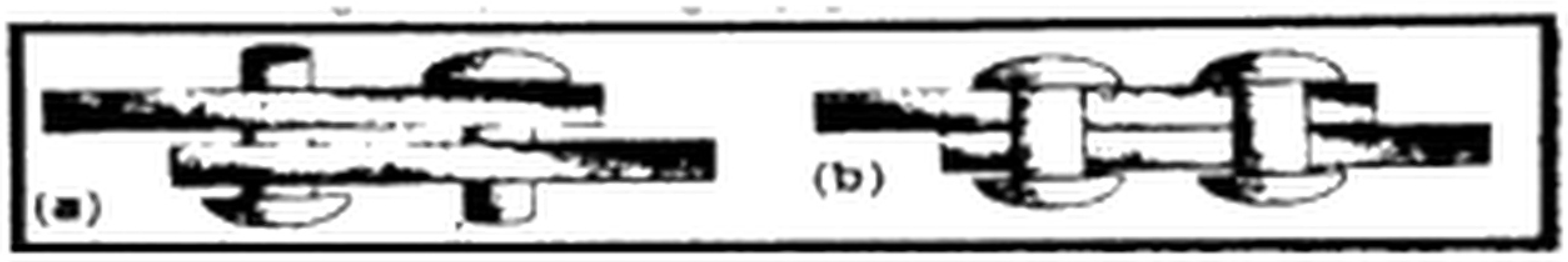
Ans: Overhead transmission lines are also given a certain amount of sag so that they can contract in winter without snapping.

Q29. List the application of thermal expansion?

Ans: Application of thermal expansion:

1. In thermometers, thermal expansion is used in temperature measurements.

2. 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.
3. To join steel plates tightly together, red hot rivets are forced through holes in the plates. The end of hot rivet is then hammered. On cooling, the rivets contract and brings the plates tightly gripped.

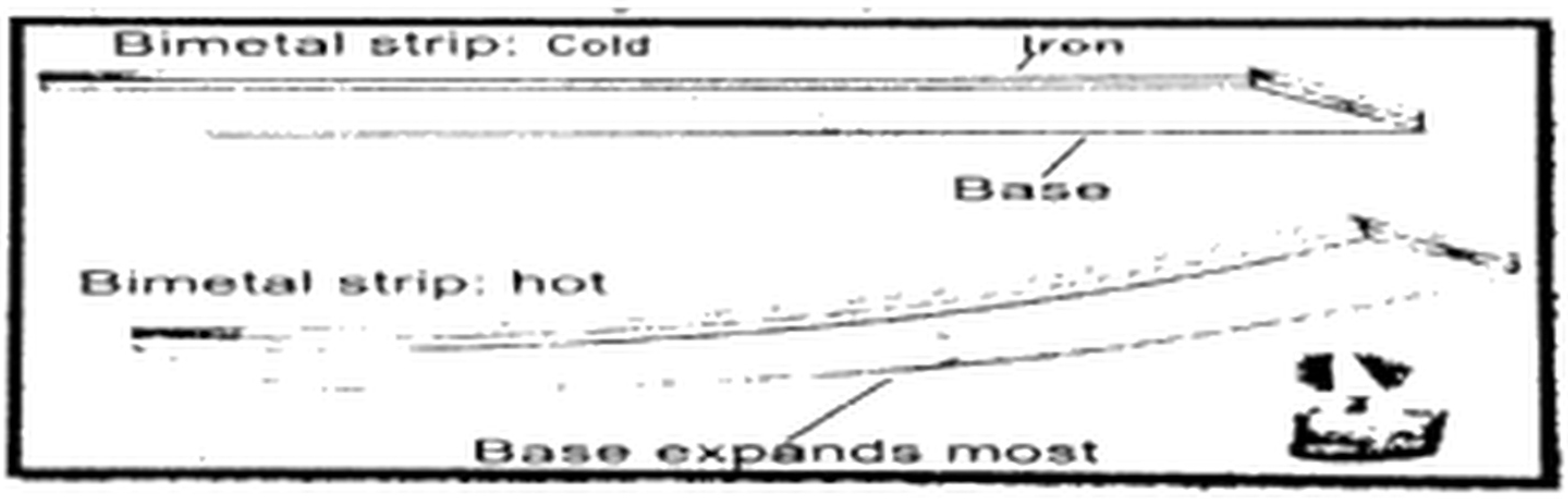


4. Iron rims are fixed on wooden wheels of carts. Iron rims are heated. Thermal expansion allows them to slip over the wooden wheel. Water is poured on it to cool. The rim contracts and becomes tight over the wheel.

Q30. Explain that the bimetallic strip used in thermostat is based on different rate of expansion of different metals on heating.

Ans: Bimetal strips:

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



(a) A bimetal strip of brass and iron

(b) Bending of brass-iron bimetal strip on heating due to the difference in their thermal expansion.

Uses of bimetal strips:

- **(i)** Bimetal thermometers are used to measure temperatures especially in furnaces and ovens.
- **(ii)** Bimetal strips are also used in thermostats.
- **(iii)** Bimetal thermostat switch such is used to control the temperature of heater coil in an electric iron.

DO YOU KNOW

Anomalous expansion of water:

Water on cooling below 4°C begins to expand until it reaches 0°C. On further cooling its volume increases suddenly as it changes into ice at 0°C. When ice is cooled below 0°C, it contracts i.e. its volume decreases like solids. This unusual expansion of water is called the anomalous expansion of water.

Q31. Why the coefficient of volume expansion of liquids is greater than solids?

Ans: The molecules of liquids are free to move in all directions within the liquid. On heating, 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.

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.

Q32. Explain thermal expansion of liquids

OR

Differentiate between real and apparent expansion of liquid?

Ans: Thermal expansion of liquids:

Thus, there are two types of thermal volume expansion for liquid

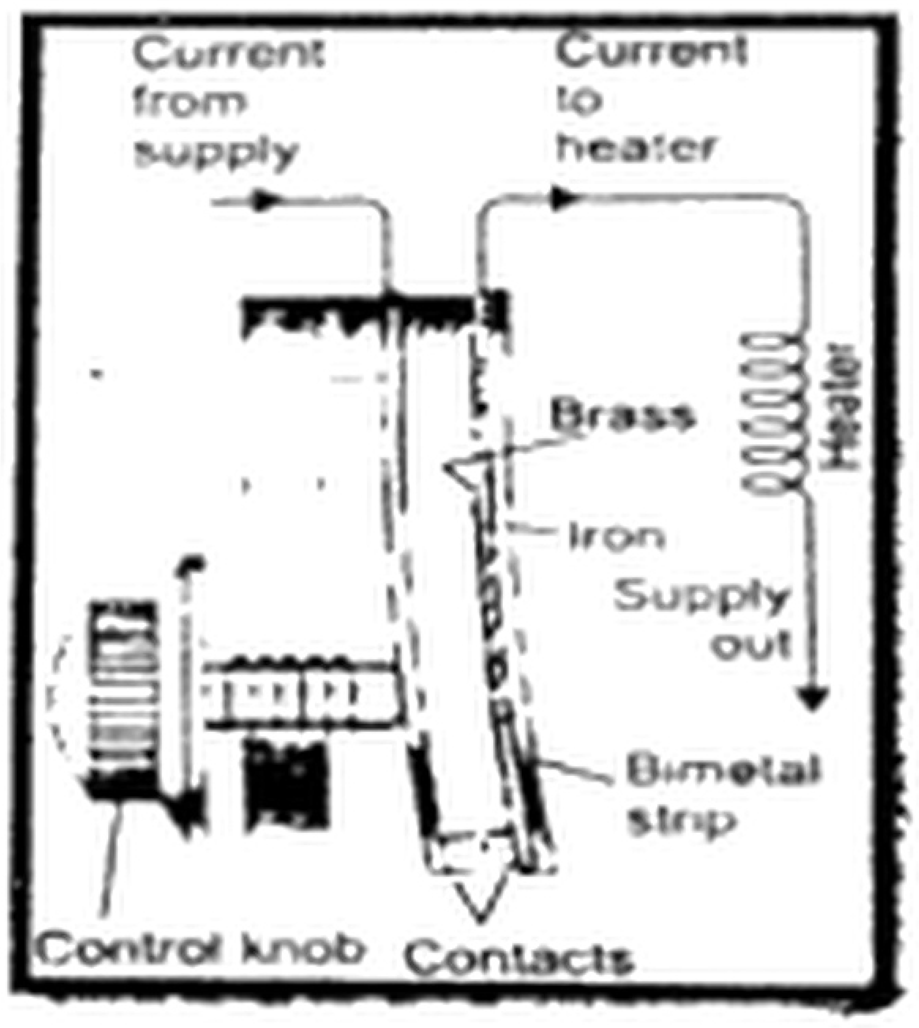
- Apparent volume expansion
- Real volume expansion

Activity:

Take a long-necked flask. Fill it with some colored liquid up to the 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.

The heat first reaches the flask which expands and its volume increases. As a result, liquid descends in the flask and its level falls to B. After sometime, the liquid begins to rise above B on getting hot. At certain temperature it reaches at C. the rise in level from A to C is due to the apparent expansion in the volume of the liquid. Actual expansion of the liquid is greater than that due to the expansion because of the expansion of the glass flask. Thus, real expansion of the liquid is equal to the volume difference between A and C in addition to the volume expansion of the flask. Hence

Real expansion		Apparent expansion		Expansion of the
of the liquid	=	of the flask	=	liquid
or BC	=	AC + AB	(i)	



The expansion of the volume of a liquid taking into consideration the expansion of the container also, is called the real volume expansion of the liquid. The real rate of volume expansion β_r of a liquid is defined as the actual change in the unit volume of a liquid for 1K (or 1°C) rise in its temperature. The real rate of volume expansion β_r is always greater than the apparent rate of volume expansion β_a by an amount equal to the rate of volume expansion of the containerβ_g. Thus

$$\beta_r = \beta_a + \beta_g \quad \text{..................} \quad \text{(ii)}$$

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

SUMMARY

1. **Temperature:** The temperature of a body is the degree of hotness or coldness of the body.
2. **Thermometers:** Thermometers are made to measure the temperature of a body of places
3. **Position of mercury:** The lower of fixed point is the mark that gives the position of mercury in the thermometer when it is placed in ice.

4. **Point of mercury:** The upper fixed point is the mark that shows the point of mercury in the thermometer when it is placed in steam from boiling water at standard pressure
5. **Inter- conversion between scales:**
6. **From Celsius to Kelvin Scale**: T(K) = 273 + C
7. **From Kelvin to Celsius Scale:** C = T(K) – 273

   From Celsius to Fahrenheit Scale: F = 1.8C + 32
8. **Heat:** Heat is a form of energy and this energy is called heat as long as it is in the process of transfer from one body to another body. When a body is heated, the kinetic energy of its molecules increases, the average distances between the molecules increase.
9. **Specific heat:** The specific heat of a substance is defined as the amount of heat required to raise the temperature of a unit mass of that substance through one degree centigrade (1°C) or one kelvin (1K).
10. **Latent heat of fusion:** The heat required by unit mass of a substance at its melting point to change it from solid state to liquid state is called the latent heat of fusion.
11. **Latent heat of vaporization:** The quantity of heat required by the unit mass of a liquid at a certain constant temperature to change its state completely from liquid into gas is called the latent heat of vaporization.
12. It has been observed that solids expand on heating and their expansion is nearly uniform over a wide range of temperature. Mathematically,

$$L = L_0 \ (1 + \alpha \ \Delta T)$$

13. **Thermal coefficient of linear expansion α:** the thermal coefficient of linear expansion α of a substance is defined as the fractional increase in its length per kelvin rise in temperature.
14. **Volume or cubical expansion:** the volume of a solid changes with the change in temperature and is called as volume or cubical expansion.

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

15. **Thermal coefficient of volume expansion β:** The Thermal coefficient of volume expansion β is defined as the fractional change in its volume per kelvin change in temperature.

16. **Types of thermal volume expansion for liquid:** there are two types of thermal volume expansion for liquids as well as for gases. Apparent volume expansion and real volume expansion.