UNIT 8

Thermal Properties of Matter

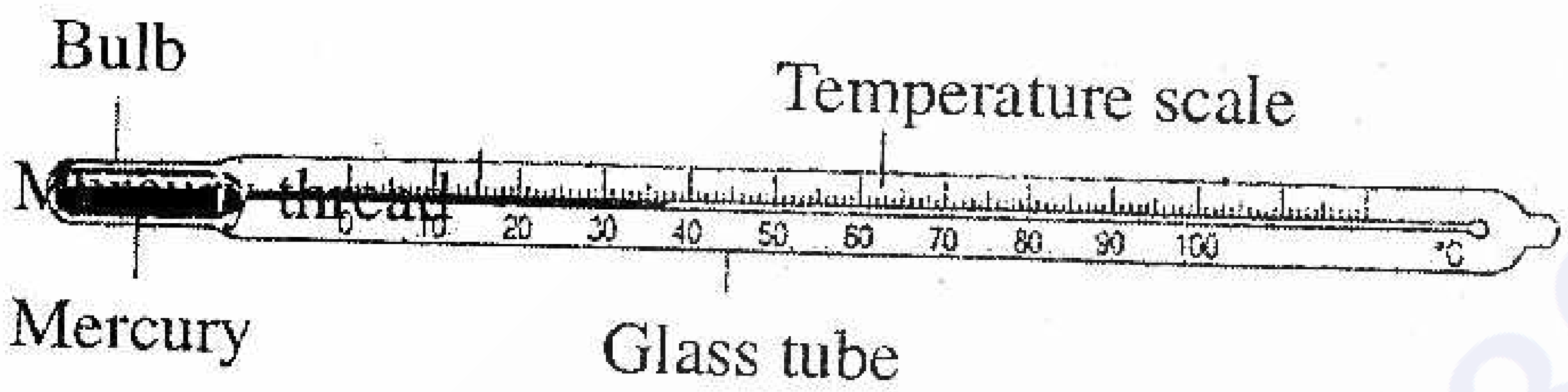
1 **What is thermometre? Write note on liquid-in-glass thermometer.**

Ans. **Thermometre**

The device that is used to measure the temperature of a body in called thermometer.

Liquid in Glass Thermometer

A liquid-in-glass thermometer has a bulb with a long capitulary tube of uniform and fine bore such as shown in figure.



A mercury-in-glass thermometer

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 made it easy to see the liquid level in the glass tube.

Mercury-in-glass thermometers are widely used in laboratories, clinics and houses to measure temperature in the range from –10 °C to 150 °C.

Lower and Upper Fixed Points

A thermometer has a scale on its stem. This 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 point is marked to show the position of liquid in the thermometer when it is placed in steam at standard pressure above boiling water.

2 **Describe different scales of temperature. Also give the relation between them.**

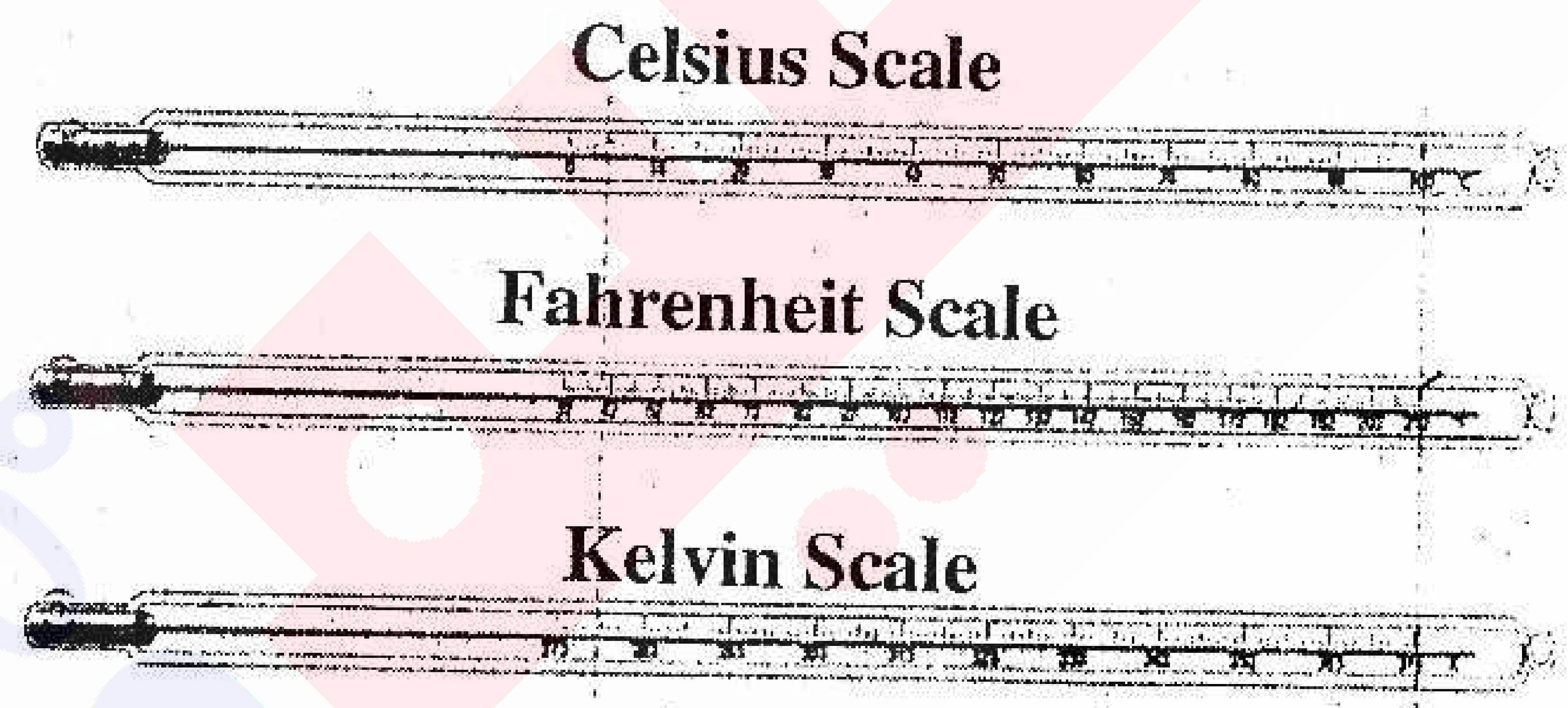
Ans. **Scales of Temperature**

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 use. There are:

(i) Celsius scale or centigrade scale

(ii) Fahrenheit scale

(iii) Kelvin scale



(i) Celsius Scale

On Celsius scale, the interval between lower and upper fixed points is divided into 100 equal parts as shown in figure. The lower fixed point is marked as 0°C and the upper fixed point is marked as 100°C.

(ii) Fahrenheit Scale

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

(iii) 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 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 the scale is called the absolute zero and is equal to –273 °C.

Conversion of Temperature from one Scale into other Temperature Scale:

(i) 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

$$T(K) = 273 + C$$

(ii) From Celsius to Fahrenheit Scale

$$F = 1.8\,C + 32$$

(iii) From Fahrenheit to Celsius Scales

$$1.8C = F - 32$$

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 oxygen	– 180 °C

3 What are thermometric materials? Write down the properties of a thermometric liquid.

Ans. Thermometric Materials

Substance that show a change with temperature are called thermometric materials.

Properties of a Thermometric Liquid

A thermometric liquid should have the following properties:

(i) It should be visible.

(ii) It should have uniform thermal expansion.

(iii) It should have a low freezing point.

(iv) It should have a high boiling point.

(v) It should not wet glass.

(vi) It should be a good conductor of heat.

(vii) It should have a small specific heat capacity.

4 Define specific heat capacity. Write its SI unit and derive its relation.

Ans. Definition

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

Relation

Generally, when a body is heated. Its temperature increases. Increases in the temperature of a body is found to be proportional to the amount of heat absorbed by it. 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 $$\Delta Q = cm\,\Delta T$$

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.

Mathematically,

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

SI Unit

In SI units, mass m is measured in kilogram (kg), heat ΔQ is measured in joule (J) and temperature increase ΔT is taken in kelvin (K). Hence, SI unit of specific heat is $Jkg^{-1}\,K^{-1}$. Specific heat of some common substances are given in table.

Specific heat of some common substances

Substance	Specific heat $Jkg^{-1}\,K^{-1}$
Alcohol	2500.0
Aluminium	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	138.0
Sand	835.0
Silver	235.0
Soil (dry)	810.0
Steam	2016.0
Tungsten	134.0
Turpentine	1760.0
Water	4200.0
Zinc	385.0

5 **Define heat capacity and prove that the heat capacity of a body is equal to the product of the mass of the body and its specific heat capacity.**

Ans. **Heat capacity**

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

Thus, 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

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

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

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

6 **What is the importance of large specific heat capacity of water?**

Ans. **Importance of Large Specific heat Capacity of Water:**

(i) Specific heat of water is 4200 $Jkg^{-1}\,K^{-1}$ and that 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. 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.

(ii) 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 maintains its temperature. Water absorbs unwanted thermal energy of the engine and dissipated heat through its radiator.

(iii) 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.

7 **Describe the energy changes with the help of graph when ice at $-30^{\circ}C$ is changed into steam.**

Ans. **Part AB**

On this portion of the curve, the temperature of ice increases from $-30\ ^{\circ}C$ to $0\ ^{\circ}C$.

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 Define the latent heat of fusion; find the latent heat of fusion of ice with the help of graph.

Ans. Latent Heat of Fusion

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

It is denoted by H_f.

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

or $\Delta Q_f = m H_f$

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

Let the mass of ice is = m

Finding the time from the graph:

Time taken by ice to melt completely at 0 °C

$$= t_1 = t_2 - t_1 = 3.6\ min.$$

Heat from 0 °C to 100 °C

$$= t_o = t_3 - t_2 = 4.6\text{ min.}$$

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

Increase in the temperature of water

$$= \Delta T = 100\ °C = 100\ K$$

Heat required by water from 0 °C to 100 °C

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

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

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

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

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

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

∴ Heat absorbed in time $t_f = \Delta Q_f$

$$= \frac{\Delta Q \times t_f}{t_o}$$

$$= \Delta Q \times \frac{t_f}{t_o}$$

since $\Delta Q_f = m \times H_f$

Putting the values, we get

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

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

The values of t_f and t_o 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 $3.36 \times 10^5\ Jkg^{-1}$.

9 What is meant by latent heat of *vaporization, calculate the heat of* vaporization of water with the help of graph.

Ans. Latent Heat of Vaporization

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.

It is denoted by H_v.

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

or $\Delta Q_v = m H_v$

When water is heated, it boils at 100°C under standard pressure. Its temperature remains 100°C until it is changed completely into steam. Its latent heat of vaporization is 2.26×10^6 Jkg^{-1}.

Let Mass of ice = m

Time to taken to heat water from 0°C to 100°C (melt) $= t_o = t_3 - t_2 = 4.6$ min

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

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

Increase in the temperature of water

$= \Delta T = 100$ °C = 100 K

Heat required to heat water from 0 °C to 100 °C

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

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

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

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

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

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

$\therefore$ Heat absorbed in time $t_v = \Delta Q_v$

$$= \frac{\Delta Q \times t_v}{t_o}$$

$$= \Delta Q \times \frac{t_v}{t_o}$$

since $\Delta Q_v = m \times H_v$

Putting the values, we get

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

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

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

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

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

The latent heat of vaporization of water found by the above experiment is 2.23×10^6 Jkg^{-1} while its actual value is 2.26×10^6 Jkg^{-1}.

10 What is meant by evaporation describe the factors which affect the rate of evaporation.

Ans. Evaporation

The changing of a liquid into vapors from the surface of the liquid with out heating is called evaporation.

Factors which affect the rate of evaporation

The rate of evaporation is effected by various factors.

(i) 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 than at low temperature.

(ii) Surface Area

Water evaporates faster when spread over large area. Larger is the surface area of a liquid, greater number of molecules has the change to escape from its surface.

(iii) Wind

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

(iv) Nature of the Liquid:

Different liquids have different rate of evaporations. Non polar solvents have greater rate of evaporation as compare to polar. E.g. petrol (non-polar) has greater rate of evaporation as compare to water (polar).

11 What is meant by linear thermal expansion? Prove that $L = L_o(1 + \propto \Delta T)$.

Ans. Linear Thermal Expansion Definition

Thermal expansion results an increase in length of a solid is called linear thermal expansion.

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

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

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

From equation, we get

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

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

Coefficient of linear thermal expansion (α) of some common solids.

Substance	α (K^{-1})
Aluminium	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}
Tangsten	0.4×10^{-5}
Glass (pyrex)	0.4×10^{-5}
Glass (ordinary)	0.9×10^{-5}
Concrete	1.2×10^{-5}

12 What are the consequences of thermal expansion.

Ans. (i) Consequence of Thermal Expansion

Why gaps are left in railway tracks? The expansion of solids may damage the bridges, railway tracks and roads as they are constantly subjected to temperature changes. So provision is made during construction for expansion and contraction with temperature. For example, railway tracks buckled on a hot summer day due to expansion if gaps are not left between sections.

(ii) 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 girders rests on rollers in the gap left for expansion. Overhead transmission lines are also given a certain amount of sag so that they can contract in winter without snapping.

13 What are the applications of thermal expansion in our daily life.

Ans. Application of Thermal Expansion:

(i) Thermal expansion is used in our daily life. In thermometers, thermal expansion is used in temperature measurement.

(ii) 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 nor be easy to turn it to open.

(iii) 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 bring the plates tightly gripped.

(iv) 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.

14 What are Bimetal strips? What is their use in daily life?

Ans. Bimetal Strip

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

Uses:

Bimetal strips are used for various purposes.

(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 is used to control the temperature of heater coil in an electric iron.

15 Describe the thermal expansion of liquids with the help a simple experiment.

OR

Prove with the help of a simple experiment the real expansion of liquid is greater than apparent expansion.

Ans. Thermal Expansion of Liquid:

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

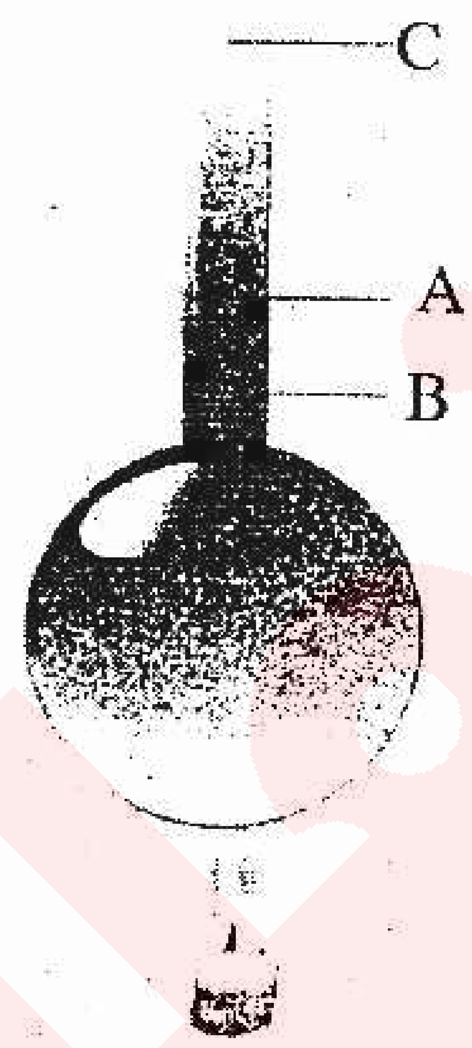
Apparent volume expansion

Real volume expansion

Experiment:

Take a long-necked flask. Fill it with some coloured liquid upto 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 th volume of the liquid. Actual expansion of the liqui is greater than that due to the expansion because c the expansion of the glass flask. Thus real expansio of the liquid is equal to the volume differenc between A and C in addition to the volume expansio of the flask.



Real and apparent expansion of liquid

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

or $BC = AC + AB$

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 container β_g. Thus

$$\beta_r = \beta_a + \beta_g$$

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

16 Describe the volume thermal expansion of solids and prove that

$$v = v_o (1 + \beta \Delta T)$$

Ans. Volume Thermal Expansion

The volume of a solid also changes with the change in temperature and is called volume thermal expansion or cubical thermal expansion. Consider a solid of initial volume V_o at certain temperature To.

On heating the solid to a temperature T. let its volume becomes V, then

Change in the 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

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

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

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

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

where β is the temperature coefficient of volume expansion. Using equation, we get

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

Thus, we can define the temperature coefficient of volume expansion β as the fractional change in its coefficients of linear expansion and volume expansion are related by the equation:

$$\beta = 3\alpha$$

Coefficient of volume expansion of various substances.

Substance	β (K^{-1})
Aluminium	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}

EXERCISE

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 °C (d) 98.6 °C

(iii) **Mercury is used as thermometric material because it has**

(a) uniform thermal expansion

(b) low freezing point

(c) *small heat capacity*

(d) all 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 materials 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 a value of 2×10^{-5} K^{-1}?**

(a) 2×10^{-5} K^{-1} (b) 6×10^{-15} K^{-1}

(c) 8×10^{-5} K^{-1} (d) 8×10^{-5} K^{-1}

vii) **A large water reservoir keeps the temperature of near by 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

Answers

(i)	(b)	**(ii)**	(b)	**(iii)**	(d)	**(iv)**	(c)
(v)	(c)	**(vi)**	(b)	**(vii)**	(d)	**(viii)**	(d)

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

Ans. The heat flows from hot body to the cold body due the difference of temperature between them.

8.3. Define the terms heat and temperature.

Ans. Temperature

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

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 between them.

8.4. What is meant by internal energy of a body.

Ans. Once heat enters a body it becomes its internal energy.

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

Ans. When a gas is heated the kinetic energy of the molecules also increases because the K.E of the molecule is directly proportional to the temperature. So their motion increases.

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

Ans. Thermometer

A device that is used to measure the temperature of a body is called thermometer.

8.7. Explain the volumetric thermal expansion.

Ans. See Long Question No.16.

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

Ans. Specific Heat

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

To find the Specific heat of a solid

The specific heat of a solid is found by using the law of heat exchange. For this purpose colorimeter is used.

Procedure

First of all the mass of calorimeter is found. The some amount of water is pour in the calorimeter. Then again the mass of calorimeter with water is found. By the differ of these two weights the mass of water is found. The temperature of the water is also noted. The the mass of the solid whose specific heat is to be found is found and heated it hypsometre upto a particular temperature. After this solid is put in the calorimeter. The mixture is stirrer untill the temperature becomes constant. A gain temperature is noted. The using the law of heat exchange the specific heat of the solid is calculated.

Let consider the mass of calorimeter = m_1 kg

Mass of calorimeter + Water = m_2 kg

Mass of water = $m_2 - m_1 = m_3$ kg

Temperature of the water = T_1 k

The mass of the solid = m_4 kg

The temperature of the solid = T_2

The temperature of the mixture = T_3

Specific heat of water = C_1 = 4200 $Jkg^{-1}\ K^{-1}$

Specific heat of calorimeter = C_2 =

Specific heat of solid = C_3 = ?

Heat lost by the solid = $m_4 \times (T_2 - T_3) \times C_3$

Heat gain by water = $m_3 \times (T_3 - T_1) \times 4200$

Heat gain by calorimeter = $m1 \times (T_3 - T_1) \times C_2$

So, according to law of heat exchange

Total heat lost = Total heat gain

$$m_4 \times (T_2 - T_3) \times C_3 = m_3 \times (T_3 - T_1) \times 4200 + m_1 \times (T_3 - T_1) \times C_2$$

$$C_3 = \frac{m_3 \times (T_3 - T_1) \times 4200 + m_1 \times (T_3 - T_1) \times C_2}{m_4 \times (T_2 - T_3)}$$

8.9. Define and explain latent heat of fusion.

Ans. Latent heat of Fusion

Heat energy required to change unit mass of a substance from solid to liquid state at its melting point with out change in its temperature is called its latent heat of fusion.

Mathematically

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

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 joule heat is required to melt 1 kg of ice into water at 0 °C.

8.10. Define latent heat of vaporization.

Ans. The quantity of heat that changes unit mass of a liquid completely into gas at its boiling point with out any change in its temperature is called its latent heat of vaporization.

Mathematically

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

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

Ans. Evaporation

The change of a liquid into vapours from the surface of the liquid with out heat is called evaporation.

Factors that affect the rate of evaporation:

The rate of evaporation is affected by the following factors.

(i) Temperature

The rate of evaporation is directly proportional to the temperature. The evaporation is faster at high temperature than at low temperature.

(ii) Surface Area:

Larger the surface area of a liquid, greater number of molecules has the chance to escape from its surface.

(iii) Wind:

Wind blowing over the surface of a liquid increases the chance for more liquid molecules to escape out.

(iii) Nature of Liquid

Different liquids have different rate of evaporation. So, the rate of evaporation also depends on the nature of liquid.

PROBLEMS

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

Sol. $C = 50\ °C$

$F = ?$

$F = 1.8c + 32$

$= 1.5 \times 50 + 32$

$= 90.0 + 32 = 122\ °F$

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

Sol. $F = 98.6\ °F$

$C = ?$

$D = ?$

$$C = \frac{F - 32}{1.8}$$

$$C = \frac{98.6 - 32}{1.8}$$

$$C = \frac{66.6}{1.8} = 37\ °C$$

$d = C + 273 = 310\ k$

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

Sol. $L_o = 2m$

$T_1 = 0°C = 0 + 273 = 273\ k$

$T_2 = 20\ °C = 20 + 273 = 293\ k$

$\propto = 2.5 \times 10^{-5}\ k^{-1}$

$\Delta L = ?$

$\Delta T = 293 - 273 = 20\ k$

$\Delta L = \propto \times L_o \times \Delta T$

$= 2.5 \times 10^{-5} \times 2 \times 20$

$\Delta L = 100 \times 10^{-5}$ m

$= 0.1$ cm

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

Sol. $V_o = 1.2\ m^3$

$T_1 = 15\ °C = 15 + 273 = 288$ k

$T_2 = 40\ °C = 40 + 273 = 313$ k

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

$v = ?$

$\Delta T = 313 - 288 = 25$ k

$v = v_o (1 + \beta \times \Delta T)$

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

$v = 1.2 (1 + 91.15 \times 10^{-3})$

$v = 1.2 + 110.1 \times 10^{-3}$

$v = 1.2 + 0.110 = 1.31\ m^3$

8.5. How much heat is required to increase the temperature of 0.5 kg of water from 10°C to 65°C?

Sol. $M = 0.5$ kg

$C = 4200\ Jkg^{-1}\ k^{-1}$

$T_1 = 10°C = 10 + 273 = 282$ k

$T_2 = 65°C = 65 = 273 = 338$ k

$\Delta T = 338 - 283 = 55$ k

$\Delta T = 55$ k

$Q = ?$

$Q = mc\Delta T$

$Q = 0.5 \times 4200 \times 55$

$Q = 115500$ J

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

Sol. $M = 200$ g $= 0.2$ kg

$T_1 = 20°C \Rightarrow 20 + 273 = 293$ k

$T_2 = 90°C \Rightarrow 90 + 273 = 363$ k

$\Delta T = 363 - 293$

$= 70$ k

$c = 4200\ Jkg^{-1}\ k^{-1}$

$Q = mc\Delta T$

$= 0.2 \times 4200 \times 70$

$= 58800$ J

Time required $= \frac{58800}{1000} = 58.8$ sec.

9.7. How much ice will melt by 50000 J of heat? Latent heat of fusion of ice = 336000 Jkg^{-1}.

Sol. $Q = 50000$ J

$H_f = 336000\ Jkg^{-1}$

$M = ?$

$Q_f = mH_f$

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

$m = \frac{50}{336} = 0.1488$ kg.

$m = 148$ g

8.8. Find the quantity of heat needed to melt 100g of ice at –10°C into water at 10°C.

Note: Specific heat of ice is 2100 $Jkg^{-1}\ k^{-1}$, specific heat of water is 4200 $Jkg^{-1}\ K^{-1}$. Latent heat f fusion of ice is 3366000 Jkg^{-1}.

Sol. $t = -10°C$

$Q = ?$

$m = 100\ g = 0.1$ kg

Heat required to convert the ice in to

$-10°C \rightarrow \underset{ice}{0_oC} \rightarrow \underset{water}{0_oC} \rightarrow \underset{water}{10_oC}$

$0°C$ ice $= Q_1 = mc\ \Delta T$

$= 0.1 \times 2100 \times 10$

$= 2100$ J

(ii) Heat required to convert 0°C ice to 0°C water.

$Q_f = m \times H_f$

$= 0.1 \times 3.36 \times 10^5$

$= 3.36 \times 10^4$ J

(iii) Heat required to convert 0°C water in to 10°C water.

$Q_2 = m \times C \times \Delta T$

$= 0.1 \times 4200 \times 10 = 4200$ J

$$Q = Q_1 + Q_f + Q_2$$

$$= 2100 + 3.36 \times 10^4 + 4200$$

$$= 2100 + 33600 + 4200$$

$$Q = 39900 \text{ J}$$

8.9. How much heat if required to change 100g of water at 100°C into steam? (Latent heat of vaporization of water is 2.26×10^6 Jkg^{-1}).

Sol. m = 100 g = 0.1 g , H_v = ?

$$H_v = Q_v \times m$$

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

$$H_v = 2.26 \times 10^5 \text{ J}$$

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

Note: Specific heat of water is 4200 Jkg^{-1} K^{-1}. Latent heat of vaporization of water is 2.26×10^6 Jkg^{-1}. Let the final temperature is T^2.

Sol. Mass of steam = 5g ⇒ 0.005 kg

Heat lest by steam to convert in to 100°C water.

$$Q_v = m \times H_v$$

$$= .005 \times 2.26 \times 10^6 = 11300 \text{ J}$$

Heat lost by 100°C water to attain the temperature T_2

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

$$= .005 \times 4200 \times (100 - T_2)$$

$$= 21\ (100 - T_2) = 2100 - 21\ T_2$$

Heat gain by water to attain the temperature T_2

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

$$= 0.5 \times 4200\ (T_2 - 10)$$

$$= 2100\ (T_2 - 10)$$

$$Q = 2100T - 21000$$

Heat lost = Heat gain

$$11300 + 2100 - 21T = 2100\ T_2 - 21000$$

$$34400 = 2121\ T_2$$

$$T_2 = \frac{34400}{2121} \Rightarrow 16.2°C$$