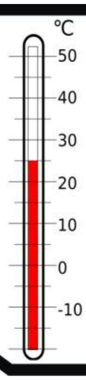


UNIT 8

THERMAL PROPERTIES OF MATTER

8.1 TEMPERATURE AND HEAT
8.2 THERMOMETER

LONG QUESTIONS

Q.1 What is thermometer? Explain its different types. *(K.B+U.B+A.B)*

Ans:

THERMOMETER

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

Thermometric Material:

"The material that is used in thermometer for measuring temperature is called thermometric material."

Some substances have property that changes with temperature. Substance that show change with temperature can be used as thermometric material. For example some substances expand on heating, some change their colours, some change their electric resistance etc. Nearly all the substances expand on heating liquids also expand on heating and are suitable as thermometric materials.

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 heat
- 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 as shown in the figure:

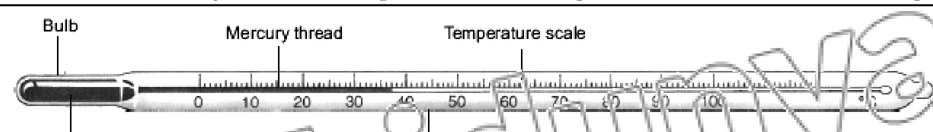


Figure: A Mercury – in – Glass Thermometer

Mercury the Best Thermometric Material:

Mercury freezes at -39 ^{o}C and boils at 357 ^{o}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 ^{o}C to 150 ^{o}C.

Reference Points: **(GRW 2017)**

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 **steam** 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 thermometer. The temperature of the body in contact with the thermometer can be read on that scale.

Types of Temperature Scale: **(LHR 2017)**
There are three types of temperature scale, which are as follows:

- Celsius scale or centigrade scale
- Fahrenheit scale
- 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. Various scales of temperature are shown below:

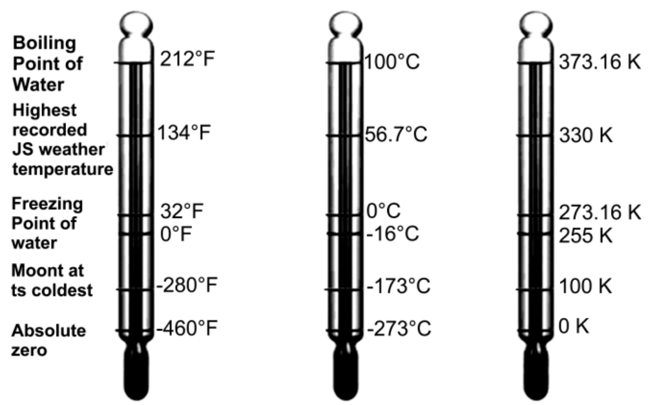


Figure: Various Scales of Temperature

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 ^{o}C** and the upper fixed point is marked **as 100 ^{o}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 ^{o}F** and the upper fixed point is marked as **212 ^{o}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 the lower and upper fixed points is divided into **100** equal divisions. Thus a change in **1^{o}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 ^{o}C**.

Scale Conversion Formula:

Following are scale conversion formulae

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

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

From Kelvin to Celsius Scale:

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

$$C = T\ (K) - 273$$

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.

$$F = 1.8\ C + 32$$

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

Q.2 Define and explain internal energy of a body. *(K.B)*

Ans: **INTERNAL ENERGY**

Introduction:

Heat is called as the **energy** in transit. Once heat enters a body, it becomes its internal energy and no longer exists as heat energy.

Definition:

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

Dependence:

Internal energy of a body depends on many factors such as the mass of the body, kinetic and potential energies of molecules etc. Kinetic energy of an atom or molecule is due to its motion which depends upon the temperature. Potential energy of atoms or molecules is the stored energy due to intermolecular forces.

Q.3 Interesting information:

Ans: Nearly all liquids expand slightly when heated. This property is used in liquid-in-glass thermometers, which are normally filled with alcohol or mercury.

Sensitivity:

Some thermometers are more sensitive to temperature change than others. The 'thread' of liquid moves further. The diagrams on the right show how tube width affects the sensitivity. The narrower the tube, the higher the sensitivity of the thermometer.

Mercury expands less than alcohol (for the same volume and same temperature rise). So a mercury thermometer must have a narrower tube than an alcohol thermometer to give the same sensitivity.

Range:

Mercury freeze at -39 ^{o}C; alcohol freeze at a much lower temperature, -115 ^{o}C. However, some mercury thermometers have an upper limit of 500 ^{o}C, which is much higher than that of any alcohol thermometer:

Responsiveness:

Some thermometers respond more quickly to a change in temperature than others. A thermometers with a larger bulb, or thicker glass round the bulb, is less responsive because it takes longer for the alcohol or mercury to reach the temperature of the surroundings.

Linearity:

Although mercury and alcohol thermometers must agree at the fixed points, they do not exactly agree at other temperatures. That is because the expansion of one liquid is not quite linear compared with the other.

However; within the 0- 100 ^{o}C range, the disagreement is very small.

8.1, 8.2 SHORT QUESTIONS

Q.1 Define temperature and write its unit. *(K.B)* **(LHR 2014, GRW 2015)**

Ans: **TEMPERATURE**

Definition:

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

Quantity:

Temperature is a base and scalar quantity.

Unit:

SI unit of temperature is kelvin (K)

Q.2 Define heat. Write its unit. *(K.B)* **(LHR 2014)**

Ans: **HEAT**

Definition:

"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**"**

Quantity:

Heat is a derived and scalar quantity.

Unit:

SI unit of heat is Joule (J)

Q.3 Define thermal contact *(K.B)*

Ans: **THERMAL CONTACT**

"Such a contact of bodies in which exchange of heat takes place is called thermal contact.**"**

Example:

To store ice in summer, people wrap it with cloth or keep it in wooden box or in thermos flask. In this way, they avoid the thermal contact of ice with its hot surroundings otherwise ice will soon melt away.

Q.4 Define thermal equilibrium. *(K.B)*

Ans: **THERMAL EQUILIBRIUM**

"The state of thermal contact at which two bodies attain same temperature and no exchange of heat takes place is called thermal equilibrium.**"**

Example:

When you place a cup of hot tea or water in a room, it cools down gradually. It stops cooling as it reaches the room temperature. Thus, temperature determines the direction of flow of heat. Heat flows from a hot body to a cold body until thermal equilibrium is reached.

Q.5 What happens when we touch a hot body? *(K.B)*

Ans:

<u>TOUCH OF A HOT BODY</u>

When we touch a hot body the thermal energy flows from hot body to our body and this flow of heat continue until both the bodies become at same temperature i.e. Thermal equilibrium.

Q.6 Define thermometer. *(K.B)* **(LHR 2013)**

Ans:

<u>THERMOMETER</u>

“The instrument which is used to measure the temperature is called a thermometer**”**

<u>Thermometric Material</u>:

“The material that is used in thermometer for measuring temperature is called thermometric material.**”**

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.

Q.7 Define absolute zero. *(K.B)*

Ans:

<u>ABSOLUTE ZERO</u>

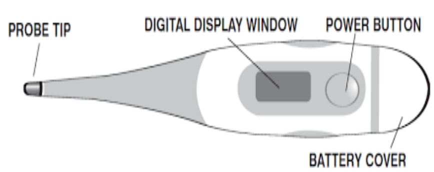
Absolute zero is the point at which the fundamental particles of nature have minimal vibrational motion, retaining only quantum mechanical, zero-point energy-induced particle motion.

By international agreement, absolute zero is defined as precisely; 0 K on the Kelvin scale, which is a thermodynamic (absolute) temperature scale; and –273.15 degrees Celsius on the Celsius scale.

Q.8 What is difference between Thermistor and Thermocouple thermometer. (*C.B*)

Ans:

<u>Difference</u>

Thermistor Thermometer	**Thermocouple Thermometer**
The thermistor is a device which becomes a much better electrical conductor when its temperature rises. This means that a higher current flows from the battery, causing a higher reading on the meter. 	A thermocouple is robust, quick to respond to temperature change, has a wide range (-200 ^{o}C to 1100 ^{o}C), and can be linked to other electrical circuits or a computer. Two different metals are joined to form two junctions. A temperature difference between the junctions causes a tiny voltage which makes a current flow. The greater the temperature difference, the greater the current.

Q.9 What is clinical thermometer? *(K.B)* **(Do you know Pg # 173)**

Ans:

<u>CLINICAL THERMOMETER</u>

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

Q.10 Write down the conversions of thermometer scales. *(K.B+U.B)* **(LHR 2013, GRW 2014, 2015)**

Ans:

<u>CONVERSIONS OF SCALES</u>

Following are scale conversion formulae.

<u>Conversion of Celsius (centigrade) to Fahrenheit scale</u>:

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

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.11 Every thermometer makes use of some property of a material that varies with temperature. Name the property used in: **(Mini exercise Pg. # 170)**

(a) Strip thermometers

(b) Mercury thermometers

Ans. **PROPERTIES OF MATERIALS**

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

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

EXAMPLE 8.1 *(A.B+U.B)*

What will be the temperature on Kelvin scale of temperature, when it is 20 ^oC on Celsius scale?

Solution:

Given Data:

Temperature on Celsius scale = C = 20 ^0C

To Find:

Temperature on Kelvin scale = T (K) = 20 ^0C

Calculations:

We know

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

Putting values

$$T (K) = 273 + 20 = 293 K$$

Result:

20 ^oC on Celsius scale is equal to 293 K.

EXAMPLE 8.2 *(A.B+U.B)*

Change 300K on Kelvin scale into Celsius scale of temperature.

Solution:

Given Data:

Temperature on Kelvin scale = T (K) = 300K

To Find:

Temperature on Celsius scale = C =?

Calculations:

We know

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

And $C = T (K) - 273$

Putting values

$$C = 300 - 273 = 27\ ^oC$$

Result:

300 K is equal to 27 ^oC.

EXAMPLE 8.3 *(A.B+U.B)*

Convert 50°C on Celsius scale into Fahrenheit temperature scale.

Solution:

Given Data:

Temperature on Celsius scale = C = 50 °C

To Find:

Temperature on Fahrenheit scale = F =?

Calculations:

We know

$$F = (1.8 \times C + 32)$$

Putting values

$$F = (1.8 \times 50 + 32)$$

$$F = 122\ ^{o}F$$

Result:

50 °C on Celsius scale is equal to 122 °F.

EXAMPLE 8.4 *(A.B+U.B)*

Convert 100 °F into the temperature of Celsius scale. **(GRW 2017)**

Solution:

Given Data:

Temperature on Fahrenheit scale = F =100°F

To Find:

Temperature on Celsius scale = C =?

Calculations:

We know

$$1.8C = F - 32$$

Putting values

$$1.8C = 100 - 32$$

$$1.8\ C = 68$$

$$C = \frac{68}{1.8} = 37.8°C$$

Results:

100 °F is equal to 37.8 °C

8.1, 8.2 MULTIPLE CHOICE QUESTIONS

1. **Temperature is the: *(K.B)***
(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

2. **The SI unit of temperature is: *(K.B)***
(A) °C (B) °F
(C) K (D) °K

3. **Temperature of 30 ^oC in Fahrenheit is:** ***(K.B)***
(A) 86 ^oF (B) 80 ^oF
(C) 30 ^oF (D) 90 ^oF

4. **Human normal body temperature of 37 ^oC in Fahrenheit is:** ***(K.B)***
(A) 98. 6 ^oF (B) 98 ^oF
(C) 100 ^oF (D) None of above

5. **Boiling point of water in Fahrenheit is:** ***(K.B)***
(A) 100 ^oF (B) 273 ^oF
(C) 212 ^oF (D) 373 ^oF

6. **Celsius equivalent of 0K is:** ***(K.B)***
(A) -273 ^oC (B) -459.4 ^oC
(C) 0 ^oC (D) 100 ^oC

7. **Fahrenheit equivalent of 0K is:** ***(K.B)***
(A) -273 ^oF (B) -459.4 ^oF
(C) 0 ^oF (D) 100 ^oF

8. **Heat is a type of:** ***(K.B)***
(A) Kinetic energy (B) Potential energy
(C) Mechanical energy (D) None of above

9. **Which of the following substances have greater average kinetic energy of its molecules at 10^{o}C?** ***(K.B)***
(A) Steel (B) copper
(C) Water (D) Mercury

10. **Which flower is a natural thermometer?** ***(K.B)***
(A) Jasmine (B) Rose
(C) Daisy (D) Crocus

11. **Crocus flower opens at:** ***(K.B)***
(A) -273 ^oC (B) -459.4 ^oC
(C) 0 ^oC (D) 23 ^oC

12. **The temperature in the Sun's core is:** ***(K.B)***
(A) 6000 ^oC (B) 15000000 ^oC
(C) 2500 ^oC (D) 1580 ^oC

13. **The temperature in the Sun's surface is:** ***(K.B)***
(A) 6000 ^oC (B) 15000000 ^oC
(C) 2500 ^oC (D) 1580 ^oC

14. **The temperature of the electric lamp is:** ***(K.B)***
(A) 6000 ^oC (B) 15000000 ^oC
(C) 2500 ^oC (D) 1580 ^oC

15. **The temperature of the gas lamp is:** ***(K.B)***
(A) 6000 ^oC (B) 15000000 ^oC
(C) 2500 ^oC (D) 1580 ^oC

16. **The temperature of the boiling water is:** ***(K.B)***
(A) 100 ^oC (B) 37 ^oC
(C) 0 ^oC (D) -18 ^oC

17. **The temperature of normal human body is:** ***(K.B)***
(A) 100 ^oC (B) 37 ^oC
(C) 0 ^oC (D) -18 ^oC

18. **The temperature of the freezing water is:** ***(K.B)***
(A) 100 ^oC (B) 37 ^oC
(C) 0 ^oC (D) -18 ^oC

19. The temperature of ice in freezer is: ***(K.B)***

(A) 100 ^oC (B) 37 ^oC

(C) 0 ^oC (D) -18 ^oC

20. The temperature of liquid oxygen is: ***(K.B)***

(A) 100 ^oC (B) 37 ^oC

(C) 0 ^oC (D) -180 ^oC

8.3 SPECIFIC HEAT CAPACITY

LONG QUESTIONS

Q.1 What is specific heat? Explain with examples and derive its mathematical formula. ***(K.B+U.B+A.B)***

Ans. **SPECIFIC HEAT CAPACITY**

Definition:

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

Formula:

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

Unit:

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

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.

It has also been observed that the quantity of heat Δ**Q** required to raise the temperature Δ**T** 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 Δ**Q** 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 $$c = \frac{\Delta Q}{m\Delta T}$$

Examples:

Specific heat capacity of water is 4200 $Jkg^{-1}K^{-1}$ and specific heat capacity of dry soil is 810 $Jkg^{-1}K^{-1}$

IMPORTANCE OF LARGE SPECIFIC HEAT OF WATER

Introduction:

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.

Importance:

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.

Some roles of water due to its large specific heat are given below

Keeping a Moderate Temperature:

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.

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

Cooling System of Automobiles:

The cooling system of the 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 the temperature. Water absorbs unwanted thermal energy of the engine and dissipates heat through its radiator as shown in the figure:

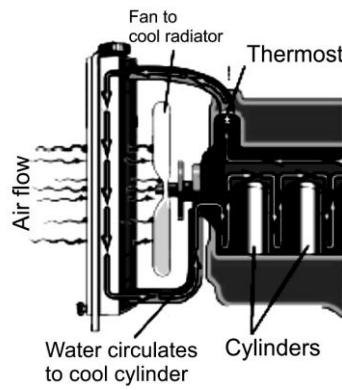


Figure: A Cooling System in Automobile

Water in Central Heating System:

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 as shown in the figure:

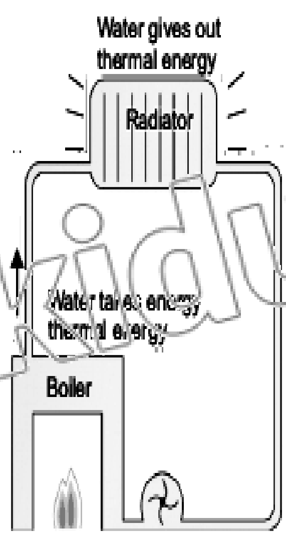


Figure: Central Heating System

Q.2 Define heat capacity and derive its mathematical formula. ***(K.B+U.B+A.B)***

Ans: **HEAT CAPACITY**

Definition:

"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 Δ**T** on adding Δ**Q** amount of heat, then its heat capacity will be $\Delta Q/\Delta T$. putting the value of Δ**Q,** 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.

Unit:

SI unit of heat capacity is JK^{-1}

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.

8.3 SHORT QUESTIONS

Q.1 Define specific heat capacity. Write its formula and unit. ***(K.B+U.B+A.B)***
(GRW 2013, 2014, 2016 LHR 2015, 2017)

Ans: Given on Page #296

Q.2 Define heat capacity. Write its formula and unit. ***(K.B+U.B+A.B)*** **(GRW 2015)**

Ans: Given on Page # 298

Q.3 How specific heat differs from heat capacity? **(Mini exercise Pg. # 182)**

Ans: Given on Page # 296

EXAMPLE 8.5

A container has 2.5 litres of water at 20°C. How much heat is required to boil the water? ***(U.B+A.B)*** **(LHR 2017)**

Solution:

Given Data:

Volume of water = V =2.5 litres
As 1 litre = 1 kg so
Mass of water = m = 2.5 kg
Specific heat of water = c = 4200 $Jkg^{-1}K^{-1}$
Initial temperature = T_1 = 20 ^oC
Finall temperature (As water is boiling) = T_2 = 100 ^oC

To Find:

Heat required to boil the water = $\Delta Q = ?$

Calculations:

We know
Change in temperature $\Delta T = T_2 - T_1$
Putting values
Change in temperature $\Delta T = 100°C - 20°C$

$= 80°C$ or $80K$

Now we find Heat required to boil the water

$$\Delta Q = cm\Delta T$$

Putting values

$$\Delta Q = (42000)(2.5)(80)$$

$$\Delta Q = 840000J$$

Result.

Hence, the heat required to boil the water will be 84000 J or 840 kJ.

8.3 MULTIPLE CHOICE QUESTIONS

1. **Ice is a (an):** ***(K.B)***
(A) Good conductor (B) Bad conductor
(C) Perfect Conductor (D) None

2. **The quantity of heat that causes 1K change in temperature in a substance of mass 1 Kg is called:** ***(K.B)***
(A) Specific heat (B) Latent heat
(C) Heat of exchange (D) None of above

3. **Unit of specific heat is:** ***(K.B)***
(A) $Jkg^{-1}K$ (B) $JkgK^{-1}$
(C) $Jkg^{-1}K^{-1}$ (D) J

4. **Which of the following has highest specific heat?** ***(K.B)***
(A) Water (B) Ice
(C) Mercury (D) Alcohol

5. **Specific heat of water is:** ***(K.B)*** **(GRW 2013, 2014)**
(A) 2100 $Jkg^{-1}K^{-1}$ (B) 2500 $Jkg^{-1}K^{-1}$
(C) 3200 $Jkg^{-1}K^{-1}$ (D) 4200 $Jkg^{-1}K^{-1}$

6. **Climate of regions near sea shore remains moderate due to:** ***(K.B)***
(A) Greater specific heat of water (B) Less specific heat of water
(C) Low freezing point of water (D) High boiling point of water

7. **Cause of land and sea breeze is:** ***(K.B)***
(A) Greater specific heat of water (B) Less specific heat of water
(C) Low freezing point of water (D) High boiling point of water

8. **The device used to measure of the specific heat of an object is:** ***(K.B+A.B)***
(A) Thermometer (B) Burner
(C) Calorimeter (D) Thermostat

9. **Quantity of heat that changes one kilogram of a of solid into liquid is called:** ***(K.B)***
(A) Specific heat (B) Latent heat of fusion
(C) Latent heat of vaporization (D) All of above

10. **The specific heat of alcohol is:** ***(K.B)***
(A) 2500 $Jkg^{-1}K^{-1}$ (B) 903$Jkg^{-1}K^{-1}$
(C) 900 $Jkg^{-1}K^{-1}$ (D) 121$Jkg^{-1}K^{-1}$

11. **The specific heat of Aluminum is:** ***(K.B)***
(A) 2500 $Jkg^{-1}K^{-1}$ (B) 903$Jkg^{-1}K^{-1}$
(C) 900 $Jkg^{-1}K^{-1}$ (D) 121$Jkg^{-1}K^{-1}$

12. **The specific heat of Bricks is:** ***(K.B)***
(A) 2500 $Jkg^{-1}K^{-1}$ (B) 903$Jkg^{-1}K^{-1}$
(C) 900 $Jkg^{-1}K^{-1}$ (D) 121$Jkg^{-1}K^{-1}$

13. The specific heat of Carbon is: *(K.B)*
(A) 2500 $Jkg^{-1}K^{-1}$ (B) 903$Jkg^{-1}K^{-1}$
(C) 900 $Jkg^{-1}K^{-1}$ (D) 121$Jkg^{-1}K^{-1}$

14. The specific heat of Clay is: *(K.B)*
(A) 920 $Jkg^{-1}K^{-1}$ (B) 387$Jkg^{-1}K^{-1}$
(C) 2010 $Jkg^{-1}K^{-1}$ (D) 840$Jkg^{-1}K^{-1}$

15. The specific heat of Copper is: *(K.B)*
(A) 920 $Jkg^{-1}K^{-1}$ (B) 387$Jkg^{-1}K^{-1}$
(C) 2010 $Jkg^{-1}K^{-1}$ (D) 840$Jkg^{-1}K^{-1}$

16. The specific heat of Ether is: *(K.B)*
(A) 920 $Jkg^{-1}K^{-1}$ (B) 387$Jkg^{-1}K^{-1}$
(C) 2010 $Jkg^{-1}K^{-1}$ (D) 840$Jkg^{-1}K^{-1}$

17. The specific heat of Glass is: *(K.B)*
(A) 920 $Jkg^{-1}K^{-1}$ (B) 387$Jkg^{-1}K^{-1}$
(C) 2010 $Jkg^{-1}K^{-1}$ (D) 840$Jkg^{-1}K^{-1}$

18. The specific heat of Gold is: *(K.B)*
(A) 128 $Jkg^{-1}K^{-1}$ (B) 790$Jkg^{-1}K^{-1}$
(C) 2100$Jkg^{-1}K^{-1}$ (D) 470$Jkg^{-1}K^{-1}$

19. The specific heat of Granite is: *(K.B)*
(A) 128 $Jkg^{-1}K^{-1}$ (B) 790$Jkg^{-1}K^{-1}$
(C) 2100$Jkg^{-1}K^{-1}$ (D) 470$Jkg^{-1}K^{-1}$

20. The specific heat of Ice is: *(K.B)*
(A) 128 $Jkg^{-1}K^{-1}$ (B) 790$Jkg^{-1}K^{-1}$
(C) 2100$Jkg^{-1}K^{-1}$ (D) 470$Jkg^{-1}K^{-1}$

21. The specific heat of Iron is: *(K.B)*
(A) 128 $Jkg^{-1}K^{-1}$ (B) 790$Jkg^{-1}K^{-1}$
(C) 2100$Jkg^{-1}K^{-1}$ (D) 470$Jkg^{-1}K^{-1}$

22. The specific heat of Lead is: *(K.B)*
(A) 128 $Jkg^{-1}K^{-1}$ (B) 138.6$Jkg^{-1}K^{-1}$
(C) 835$Jkg^{-1}K^{-1}$ (D) 235$Jkg^{-1}K^{-1}$

23. The specific heat of Mercury is: *(K.B)*
(A) 128 $Jkg^{-1}K^{-1}$ (B) 138.6$Jkg^{-1}K^{-1}$
(C) 835$Jkg^{-1}K^{-1}$ (D) 235$Jkg^{-1}K^{-1}$

24. The specific heat of Sand is: *(K.B)*
(A) 128 $Jkg^{-1}K^{-1}$ (B) 138.6$Jkg^{-1}K^{-1}$
(C) 835$Jkg^{-1}K^{-1}$ (D) 235$Jkg^{-1}K^{-1}$

25. The specific heat of Silver is: *(K.B)*
(A) 128 $Jkg^{-1}K^{-1}$ (B) 138.6$Jkg^{-1}K^{-1}$
(C) 835$Jkg^{-1}K^{-1}$ (D) 235$Jkg^{-1}K^{-1}$

26. The specific heat of Soil (dry) is: *(K.B)*
(A) 810 $Jkg^{-1}K^{-1}$ (B) 2016 $Jkg^{-1}K^{-1}$
(C) 134.8 $Jkg^{-1}K^{-1}$ (D) 1760$Jkg^{-1}K^{-1}$

27. The specific heat of Steam is: *(K.B)*
(A) 810 $Jkg^{-1}K^{-1}$ (B) 2016 $Jkg^{-1}K^{-1}$
(C) 134.8 $Jkg^{-1}K^{-1}$ (D) 1760$Jkg^{-1}K^{-1}$

28. The specific heat of Tungsten is: *(K.B)*

(A) 810 $Jkg^{-1}K^{-1}$ (B) 2016 $Jkg^{-1}K^{-1}$
(C) 134.8 $Jkg^{-1}K^{-1}$ (D) 1760$Jkg^{-1}K^{-1}$

29. The specific heat of Turpentine is: *(K.B)*

(A) 810 $Jkg^{-1}K^{-1}$ (B) 2016 $Jkg^{-1}K^{-1}$
(C) 134.8 $Jkg^{-1}K^{-1}$ (D) 1760$Jkg^{-1}K^{-1}$

30. 4200 $Jkg^{-1}K^{-1}$ is the specific heat capacity of: *(K.B)*

(A) Soil (B) Water
(C) Zinc (D) Ice

31. 385.0 $Jkg^{-1}K^{-1}$ is the specific heat capacity of: *(K.B)*

(A) Soil (B) Water
(C) Zinc (D) Ice

8.4 CHANGE OF STATE
8.5 LATENT HEAT OF FUSION
8.6 LATENT HEAT OF VAPORIZATION

LONG QUESTIONS

Q.1 Explain with an activity the change of states of matter. *(K.B+U.B+A.B)*

Ans:

STATES OF MATTER

Matter exists in three states:

- Solid
- Liquid
- Gas

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 as shown in the figure:

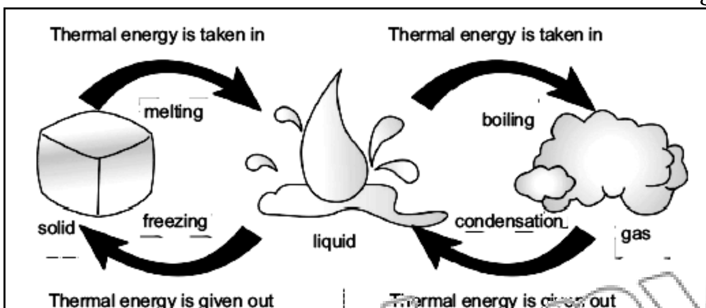


Figure: ***Heat Energy Brings About Change of State in Matter***

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 ^{o}C until all the ice melts and we get water at 0^{o} C If this water at 0^{o} C is further heated, its temperature will begin to increase above 0^{o} C as shown in figure.

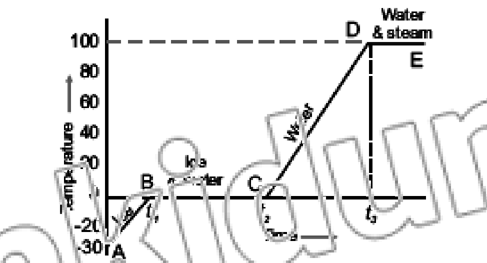


Figure. A Graph of Temperature and Time Showing Change of State of Ice into water and steam.

Explanation of the Graph:

Different parts of the graph can be explained as:

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

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

Reason For Not Changing Temperature:

At this stage temperature does not increase for a while because whole thermal energy is being utilized in breaking intermolecular forces and converting solid state into liquid state.

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

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

Reason For Not Changing Temperature:

At this stage again temperature does not increase for a while because whole thermal energy is being utilized in breaking intermolecular forces and converting liquid state into gaseous state.

Q.2 Define latent heat of fusion. Write down its mathematical formula and unit also find Latent Heat of Fusion of ice by an experiment. ***(K.B+U.B+A.B)***

Ans: **LATENT HEAT OF FUSION**

Introduction:

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 starts melting is called its **fusion point** or **melting point.** When the process is reversed i.e. when a liquid is cooled, it changes into solid state. The temperature at which a substance changes from liquid to solid state is called its **freezing point**. Different substances have different melting points. However, the freezing point of a substance is the same as its melting point.

Definition:

"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

$$\Delta Q_f = m\,H_f$$

Unit:
SI unit of Latent Heat of Fusion is Jkg^{-1}

Latent Heat of Fusion of Ice:
Ice changes at 0^o 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^o C.

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 as shown in the figure:

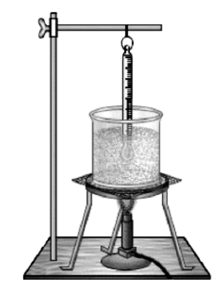


Figure: **Heating Ice**

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

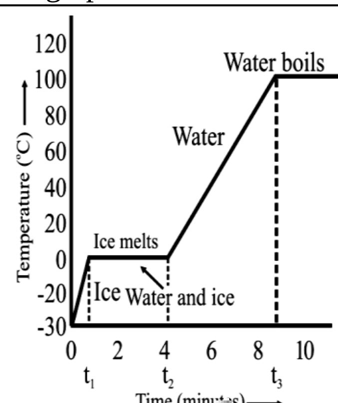


Figure: **Temperature-time Graph as Ice Changes into Water That Boils as heating Continues.**

Calculations:
Calculate the latent heat of fusion of ice from the data as follows:
Let the mass of ice = m
Finding the time from the graph
Time taken by ice to melt completely at 0^o C = $t_f = t_2 - t_1$ = 3.6 minutes
Time taken by water to heat from 0^oC to 100^o 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 $\Delta T = 100^o\ C = 100K$
Heat required by water from 0^o C to 100^o C = ΔQ = ?

As we know that

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

$= m \times 4200 \times 100$

$= m \times 42000$

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

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

Heat ΔQ is supplies to water in time t_o to raise the temperature of the water from 0^o C to 100^o C, Hence, the rate of absorbing heat by water in beaker can be given by

Rate of absorbing heat

$= \Delta Q/t_o$

Since heat absorption in time $t_f = \Delta Q_f = \dfrac{\Delta Q \times t_f}{t_o}$

$$= \Delta Q \times \frac{t_f}{t_0}$$

As we know that

$\Delta Q_f = m \times H_f$

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

$$H_f = 4.2 \times 10^5 \times \frac{t_f}{t_0}$$

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

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

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

Conclusion:

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}.

Q.3 Define latent heat of vaporization. Write its mathematical formula. *(K.B+U.B+A.B)*

Ans:

LATENT HEAT OF VAPORIZATION

Introduction:

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.

Definition:

"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".

Mathematical Form:

It is denoted by H_v

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

OR

$\Delta Q_v = m H_v$

Unit:

SI unit of Latent Heat of vaporization is Jkg^{-1}

Latent Heat of Vaporization of Water:

When water is heated, it boils at 100 ^oC under standard pressure. Its temperature remains 100^oC until it is changed into steam. Its latent heat of vaporization is 2.26×10^6 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:

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 as shown in the figure:

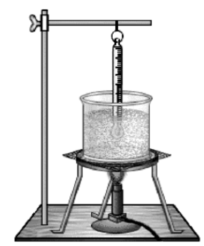


Figure: Heating Ice

The ice will start melting and will convert into 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.

Extend the temperature time graph such as shown in the figure:

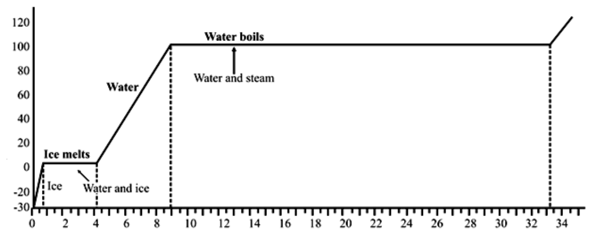


Figure: Temperature – time Graph As Ice Changes Into Water and Water into Steam on Heating

Calculations:

Calculate the latent heat of vaporization of boiled water with the data as given:

Let

The mass of ice = m

Measuring the time from the graph

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

Time taken by water 100^o C 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 $\Delta T = 100^o$ C

Heat required to heat water from 0^o C to 100^o C $= \Delta Q = m\, c\, \Delta T$

$$= m \times 4200 \times 100$$
$$= m \times 4.2 \times 10^3 \times 10^2$$
$$= 4.2 \times 10^5 \times m\ JKg^{-1}$$

To raise the temperature of the water from 0^o C to 100^o 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 tv $= Q_v = \dfrac{\Delta Q \times t_v}{t_o}$

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

As we know that $\Delta Q_v = m \text{ x } H_v$

$$m \times H_v = 4.2 \times 10^5 \times m \times \left(\frac{t_v}{t_0}\right)$$

$$H_v = 4.2 \times 10^5 \times \left(\frac{t_v}{t_o}\right)$$

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

$$H_v = 4.2 \times 10^5 \times \left(\frac{24.4}{4.6}\right) \text{Jkg}^{-1}$$

$$H_v = 2.23 \text{ x } 10^6 \text{ Jkg}^{-1}$$

<u>Results</u>:

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

8.4, 8.5, 8.6 SHORT QUESTIONS

Q.1 Define latent heat of fusion. Write its formula and unit. ***(K.B+U.B+A.B)***

(GRW 2013, 2015, LHR 2017)

Ans: Given on Page # 302

Q.2 Define latent heat of vaporization. Write its formula and unit? ***(K.B+U.B+A.B)***

(GRW 2014)

Ans: Given on Page # 304

Q.3 Define fusion point or melting point. ***(K.B)***

Ans:

<u>FUSION POINT</u>

"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 starts melting is called its **fusion point** or **melting point."**

<u>Examples</u>:

- Melting point of ice is 0 ^{o}C
- Melting point of Mercury is -39 ^{o}C

Q.4 Define boiling point or melting point. ***(K.B)*** **(LHR 2017)**

Ans:

<u>BOILING POINT</u>

"When a substance is changed from liquid to gaseous state by adding heat, the process is called boiling. The temperature at which a liquid starts to convert into gas is called its boiling point.

<u>Examples</u>:

- Boiling point of water is 100°C
- Boiling point of Mercury is 357°C

Q.5 Define freezing point. ***(K.B)*** **(LHR 2017)**

Ans:

FREEZING POINT

"When a liquid is cooled, it changes into solid state. The temperature at which a substance changes from liquid to solid state is called its **freezing point**. Different substances have different melting points. However, the freezing point of a substance is the same as its melting point."

Examples:

- Freezing point of water is 0^oC
- Freezing point of Mercury is -39^oC

Q.6 What is the difference between specific heat and latent heat of a material? ***(K.B)***

Ans:

DIFFERENTIATION

Specific heat and latent heat of a material can be differentiated as:

Specific Heat	Latent Heat
Definition	
• Specific heat is the amount of heat required to raise the temperature of unit mass of a substance through one Kelvin.	• 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.
Unit	
• Its unit is $Jkg^{-1}K^{-1}$.	• It unit is Jkg^{-1}.
Example	
• Specific Heat of water is 4200 $Jkg^{-1}K^{-1}$.	• Latent heat of vaporization of water is 2.26×10^6 Jkg^{-1}.

Q.7 Why temperature of a substance does not change while it is changing its state from solid to liquid? ***(K.B)***

Ans:

TEMPERATURE AT CHANGING STATE

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.

Q.8 Tabulate melting point, boiling point, latent heat of fusion and latent heat of Vaporization of some common substances. ***(Table for MCQS)***

Ans:

TABULATION

Table for above mentioned quantities of common substances is given below:

Sr #	Substance	Melting Point (oC)	Boiling Point (oC)	Heat of Fusion KJkg -1	Heat of Vaporization KJkg -1
1	Aluminium	660	2450	397	10500
2	Copper	1083	2595	205.0	4810
3	Gold	1063	2660	64.0	1580
4	Helium	-270	-269	5.2	21
5	Lead	327	1750	23.0	858
6	Murcury	-39	357	11.7	270
7	Nitrogen	-21-	-196	25.5	200
8	Oxygen	-219	-183	13.8	210
9	Water	0	100	336.0	2260

8.4, 8.5, 8.6 MULTIPLE CHOICE QUESTIONS

1. **Quantity of heat that changes one kilogram of a of liquid into gas is called: *(K.B)***
(A) Specific heat | (B) Latent heat of fusion
(C) Latent heat of vaporization | (D) All of above

2. **Unit of latent heat is: *(K.B)***
(A) $Jkg^{-1}K$ | (B) Jkg
(C) J | (D) Jkg^{-1}

3. **Latent heat of fusion of ice is: *(K.B)***
(A) 2,260,000 Jkg^{-1} | (B) 336,000 Jkg^{-1}
(C) 3,260,000 Jkg^{-1} | (D) None of above

4. **Latent heat of vaporization of water is: *(K.B)***
(A) 2,260,000 Jkg^{-1} | (B) 336,000 Jkg^{-1}
(C) 3,260,000 Jkg^{-1} | (D) None of above

8.7 EVAPORATION

LONG QUESTIONS

Q.1 Define evaporation. On what factor speed of evaporation depend? Explain. *(K.B)*
(LHR 2016, GRW 2017)

Ans: **EVAPORATION**

Definition:

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

Introduction:

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 this process is called evaporation as shown in the figure:

Figure: Evaporation is Escaping Out of Fast Moving Molecules From The Surface Of The Liquid Without Heating

Comparison of Boiling and Evaporation:

Unlike boiling, evaporation takes place at all temperatures but only from the surface of a liquid. The process of boiling takes place at a certain fixed temperature which is the boiling point of that 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.

Evaporation Cause Cooling:

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.

In refrigerator evaporation of liquefied gas produces cooling.

Factors:

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

- **Temperature:**
  Wet clothes dry up more quickly in summer than in winter because 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:**
  Large is the surface area of a liquid, greater number of molecules has the chance to escape from its surface that is why we spread wet clothes to increase their surface area and to increase rate of evaporation.
- **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. The molecules having weaker intermolecular forces evaporate more quickly as compared to others, 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.

Q.2 Define the cooling effect of evaporation?

Evaporation has a cooling effect. For example, if example, if you wet your hands, the water on them starts to evaporate. As it evaporate. As it evaporates, it takes thermal energy away from your skin. So your hands feel cold.

The kinetic theory explains the cooling effect like this. If faster particles escape from the liquid, slower once are left behind, so the temperature of the liquid is less than before.

Refrigerators use the cooling effect of evaporation. In the refrigerator on the right, the process works like this:

1. In the Pipes in the freezer compartment, a liquid called a **refrigerant** evaporates and takes thermal energy form the food and air
2. The vapour is drawn away by the pump, which compresses it and turns it into a liquid. This releases thermal energy, so the liquid heats up.
3. The hot liquid is cooled as it passes through the pipes at the back, and the thermal energy is carried away by the air:

Overall, thermal energy is transferred from the things inside the fridge to the air outside.

Sweating also uses the cooling effect of evaporation. You start to sweat if your body temperature rises more than about 0.5 ^{o}C above normal. The sweat, which is mainly water; comes out of the tiny pores in your skin. As it evaporates, it takes thermal energy from your body and cools you down.

On a humid ('close') day, sweat cannot evaporate so easily, so it is more difficult to stay cool and comfortable.

8.7 SHORT QUESTIONS

Q.1 Differentiate evaporation and boiling *(K.B)*

Ans:

DIFFERENTIATION

Evaporation and Boiling can be differentiated as:

Evaporation	Boiling
Definition	
• Evaporation is the changing of a **liquid** into **vapors** (gaseous state) from the surface of the liquid without heating it.	• When a substance is **changed** from **liquid** to **gaseous state** by adding heat, the process is called boiling.
Temperature	
• Evaporation takes place at all temperatures.	• Boiling takes place at specific temperature called boiling point.
Bubbles	
• There is no bubble formation during evaporation.	• Bubbles form during process of boiling.
Area of Occurrence	
• Evaporation takes place on the surface of the liquid only.	• Boiling takes place throughout the liquid.
Effect	
• Evaporation cause cooling.	• Boiling cause burning.
Example	
• 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 this process is called evaporation.	• The process in which liquid converts into gas at its boiling point is called vaporization or boiling. Boiling point of water is $100^{o}C$

Q.2 How evaporation differs from vaporization? *(K.B)* **(Mini exercise Pg. # 182)**

Ans:

DIFFERENTIATION

Evaporation and vaporization can be differentiated as:

Evaporation	Vaporization
Definition	
• Evaporation is the changing of a liquid into vapors (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.
Temperature	
• Evaporation takes place at all temperatures.	• Vaporization takes place at specific temperature called boiling point.
Bubbles	
• There is no bubble formation during evaporation.	• Bubbles form during process of vaporization.
Example	

• 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 this process is called evaporation.	• Vaporization of water takes at 100^oC

Q.3 How is cooling effect produced by evaporation? ***(K.B)***

Ans:

COOLING EFFECT OF EVEPORATION

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.

Q.4 Why wet clothes dry up more quickly in summer than in winter? ***(K.B+U.B)***

Ans:

WET CLOTH

Wet clothes dry up more quickly in summer than in winter because 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.

Q.5 Why water evaporates faster when spread over large area? ***(K.B)***

Ans:

LARGE AREA

Large is the surface area of a liquid, greater number of molecules has the chance to escape from its surface that is why we spread wet clothes to increase their surface area and to increase rate of evaporation.

Q.6 Does spirit and water evaporates at the same rate? ***(K.B)***

Ans:

RATE OF EVAPORATION

No, spirit and water does not evaporate at the same rate because evaporation depends on the nature of the liquid. The molecules having weaker intermolecular forces evaporate more quickly as compared to others, spirit has weaker intermolecular forces than water so spirit evaporates more quickly than water.

Q.7 Spread a few drops of ether or spirit on your palm. You feel cold, why? ***(K.B)***

Ans:

COOLING EFFECT

If we take ether or spirit on our palm. Ether or spirit having weaker intermolecular evaporates more quickly so we feel cooling effect due to evaporation of spirit or ether.

Q.8 Give two uses of cooling effect by evaporation. ***(A.B)*** **(Mini exercise Pg. # 182)**

Ans.

USES OF COOLING EFFECT

Following are uses of cooling effect produced by evaporation

- Evaporation of perspiration helps to cool our body.
- In refrigerator evaporation of liquefied gas produces cooling.

8.7 MULTIPLE CHOICE QUESTIONS

1. Cooling is produced in refrigerator by: ***(K.B)***

(A) Boiling (B) Evaporation of liquefied gas
(C) Electric current (D) Objects present in it

2. Initially following were used in refrigerator: ***(A.B)***

(A) Freon and Ammonia (B) Freon and CFC
(C) Ammonia and CFC (D) Mercury and CFC

3. In refrigerator Freon has been replaced by *(K.B)*

(A) Ammonia (B) CFC

(C) Ammonia and CFC (D) Mercury and CFC

4. Boiling is same as *(K.B)*

(A) Evaporation (B) Melting

(C) Vaporization (D) Freezing

5. Which will evaporate more quickly? *(K.B)*

(A) Water (B) Mercury

(C) Ether (D) Milk

8.3 THERMAL EXPANSION

LONG QUESTIONS

Q.1 What is thermal expansion? Explain on the basis of kinetic molecular theory. *(K.B)* (LHR 2014)

Ans: **THERMAL EXPANSION**

Definition:

"Increase in the **length** or **volume** of a substance due to **heat** is called thermal expansion.**"**

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 as shown in the figure:

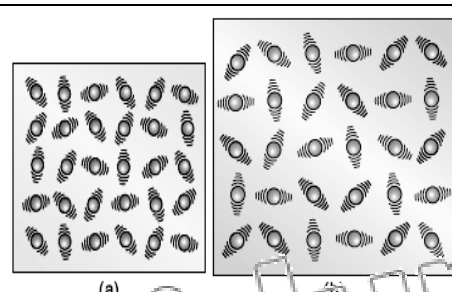


Figure: **(a) Smaller Amplitude of Molecules at Low Temperature**
(b) Larger Amplitude of Molecules at High Temperature

Thermal expansion results an increase in length, breadth and thickness of a substance.

Q.2 **What is linear Expansion? On what factor it depends? Derive its mathematical formula. *(K.B+U.B+A.B)***

Ans: **LINEAR THERMAL EXPANSION**

Definition:

"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:

- **Length** of thin rod.
- **Change** in **temperature**.
- **Nature of material** of the rod.

Explanation:

Solids expand on heating and their expansion is nearly uniform over a wide range of temperature. Consider a metal rod of length $\mathbf{L_o}$ at certain temperature $\mathbf{T}_o$. Let its length on heating to a temperature **T** becomes **L** as shown in the figure:

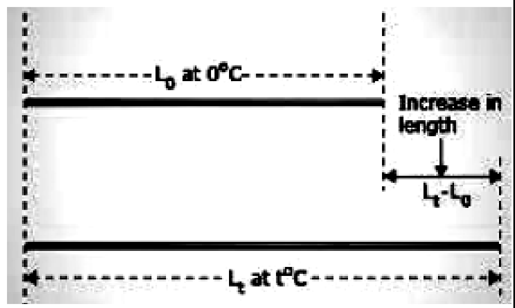


Figure: Linear Thermal Expansion

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 $\mathbf{\Delta L}$ of a solid is directly proportional to its original length $\mathbf{L_o}$ and the change in temperature $\Delta\mathbf{T}$. 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:

We know

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

Where α is the proportionality constant and it is called **co-efficient of linear expansion of the substance** it can be defined as:

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

Thus we can define coefficient of linear expansion **α** of a substance as **"**The fractional increase in its **length per Kelvin rise in temperature."**

Unit:

Its unit is Per Kelvin (K^{-1})

Value:

Its value depends on the nature of the material of the rod and

Relationship Between β and α:

Relationship Between β and α is given below:

$\beta = 3\alpha$

<u>Examples</u>:

Some values for α and β are given:

Sr. #	Substance	$\alpha\ (K^{-1})$	$\beta\ (K^{-1})$
1	Aluminum	2.4×10^{-5}	7.2×510^{-5}
2	Brass	1.9×10^{-5}	6.0×10^{-5}
3	Copper	1.7×10^{-5}	5.1×10^{-5}

Q.3 What is volume expansion? On what factors it depends? Derive its mathematical formula. *(K.B+U.B+A.B)*

Ans:

<u>VOLUME THERMAL EXPANSION</u>

<u>Definition</u>:

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

<u>Dependence</u>:

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

- Original volume of block.
- Change in temperature.
- Nature of material of the block.

<u>Explanation</u>:

Consider a solid of initial volume $\mathbf{V_o}$ at certain temperature $\mathbf{T_o}$. On heating the solid to a temperature **T**, let its volume becomes **V** as shown in the figure:

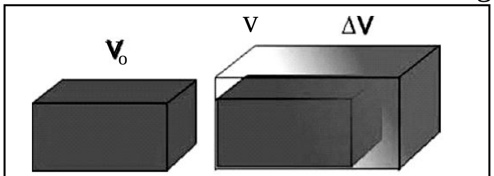


Figure: <u>Volume Thermal Expansion</u>

Then

Change 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 $\mathbf{\Delta V}$ is found to be proportional to its original volume $\mathbf{V_o}$ and change in temperature $\mathbf{\Delta T}$. Thus

$$\Delta V \ \alpha \ V_o$$

And

$$\Delta V \ \alpha \ \Delta T$$

$$\Delta V \ \alpha \ V_o \Delta T$$

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

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

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

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

<u>Coefficient of Volume Expansion</u>:

We know

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

Where **β** is the proportionality constant and is called the **co-efficient of volume expansion.** And it can be defined as

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

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

Unit:

Its unit is Per Kelvin (K^{-1})

Value:

Its value depends on the nature of the material of the rod and

Relationship Between β and α

The coefficients of linear and volume expansion are related by the following equation $\beta = 3\alpha$

Examples:

Some values for α and β are given:

Sr.#	Substance	α (K^{-1})	β (K^{-1})
1	Aluminum	2.4×10^{-5}	7.2×10^{-5}
2	Brass	1.9×10^{-5}	6.0×10^{-5}
3	Copper	1.7×10^{-5}	5.1×10^{-5}

Q.4 Write down the consequences of thermal expansion. ***(A.B)***

Ans:

CONSEQUENCES OF THERMAL EXPANSION

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.
- 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 as shown in the figure:

Figure: **Gaps are Left in Railway Tracks to Compensate Thermal Expansion During Hot Season**.

- 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 as shown in the figure:

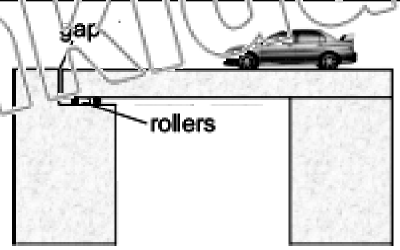


Figure: **Gaps are Left in Railway Tracks to Compensate Thermal Expansion During Hot Season**.

Q.5 Write down the applications of thermal expansion. ***(A.B)***

Ans: **APPLICATIONS OF THERMAL EXPANSION**

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 as shown in the figure:

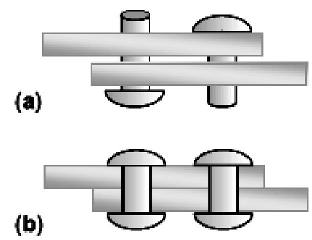


Figure: **(a) Hot rivets inserted (b) after hammering, rivets are cold down.**

- Wires on electric poles are given some sag to prevent breaking in winter.
- Thermal expansion concept is applied in Bimetal strip.

Q.6 What is Bimetal strip? Write its construction and working. ***(K.B+A.B)***

Ans: **BIMETAL STRIP**

A bimetal strip consists of two thin strips of different metals such as brass and iron joined together as shown in figure.

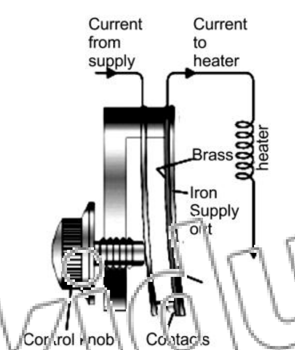


Figure: **Bimetal Thermostat Breaks the Electrical Circuit at Preset Temperature**

On heating the strip brass expands more than iron. This unequal expansion causes bending of the strip as shown in figure:

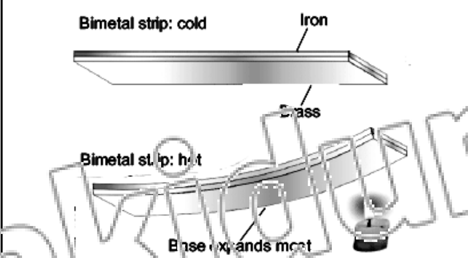


Figure: (a) A bimetal strip of brass and iron
(b) Bending of brass iron bimetal strip on heating due to the difference in their thermal expansion

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.

Q.7 Explain the thermal expansion of liquid. ***(K.B+U.B)***

Ans:

THERMAL EXPANSION IN LIQUIDS

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.

Types of Thermal Expansion For Liquids:

There are two types of thermal expansion for liquids:

- Real volume expansion
- Apparent volume expansion

Activity:

Take a long-necked flask. Fill it with some colored liquid up to mark **A** on its neck as shown in figure.

Figure: Real and apparent expansion of liquid

Now start heating the flask from bottom. The liquid level first falls to **B** and then rises to **C.**

Relation between expansions:

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

- Real volume expansion
- Apparent volume expansion

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 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 $\boldsymbol{\beta_r}$ of a liquid is defined as the actual change in unit volume of a liquid for 1K (or 1 ^{o}C) rise in its temperature. The real rate of volume expansion $\boldsymbol{\beta_r}$ is always greater than the rate of volume expansion $\boldsymbol{\beta_a}$ by an amount equal to the rate of volume expansion of the container $\boldsymbol{\beta_g}$.

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 co-efficient of expansion are also measured in two ways:

- Coefficient of apparent expansion
- Coefficient of real expansion

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

8.8 SHORT QUESTIONS

Q.1 Define linear thermal expansion. On which factors does it depend? *(K.B+U.B+A.B)*

Ans: Given on Page #312

Q.2 Define coefficient of linear thermal expansion. Write its formula and unit. *(K.B+U.B+A.B)*

Ans: Given on Page #313

Q.3 Define Volume thermal expansion. On which factors does it depend? *(K.B+U.B+A.B)* (GRW 2013)

Ans: Given on Page # 314

Q.4 Define coefficient of linear thermal expansion. Write its formula and unit. *(K.B+U.B+A.B)*

Ans: Given on Page # 313

Q.5 Tabulate coefficient of linear and volume expansion of some common substances.

Q.6 (Table for MCQS)

Ans: **VALUES OF COEFFICIENT OF THERMAL EXPANSION**

Following vales have been tabulated by applying relation

Sr. #	Substance	α (K^{-1})	β (K^{-1})
1	Aluminum	2.4×10^{-5}	7.2×10^{-5}
2	Brass	1.9×10^{-5}	6.0×10^{-5}
3	Copper	1.7×10^{-5}	5.1×10^{-5}
4	Steel	1.2×10^{-5}	3.6×10^{-5}
5	Silver	1.93×10^{-5}	5.79×10^{-5}
6	Gold	1.3×10^{-5}	3.9×10^{-5}
7	Platinum	8.6×10^{-5}	27.0×10^{-5}
8	Tungsten	0.4×10^{-5}	4.2×10^{-5}
9	Glass (Pyrex)	0.4×10^{-5}	1.2×10^{-5}
10	Glass (Ordinary)	0.9×10^{-5}	2.7×10^{-5}
11	Concrete	1.2×10^{-5}	3.6×10^{-5}
12	Glycerine	17.7×10^{-5}	53×10^{-5}
13	Mercury	6×10^{-5}	18×10^{-5}
14	Water	7×10^{-5}	21×10^{-5}
15	Air	1.22×10^{-3}	3.67×10^{-3}
16	Carbon dioxide	1.24×10^{-3}	3.72×10^{-3}
17	Hydrogen	1.22×10^{-3}	3.66×10^{-3}

Q.7 Why steel rods are used in construction? *(K.B +A.B)*

Ans: The steel rods are used to reinforce concrete because both materials expand equally. If the expansions were different, the steel might crack the concrete on a hot day.

Q.8 Why gaps are left in railway tracks? *(K.B)* **(LHR 2017)**

Ans: **GAPS IN RAILWAY TRACKS**

Gaps are left in railway tracks to compensate thermal expansion during hot season. Railway tracks buckled on a hot summer day due to expansion if gaps are not left between sections

Q.9 What is anomalous expansion of water? *(K.B)*

Ans: **ANOMALOUS EXPANSION**

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

Q.10 Explain the expansion of water and ice? *(K.B)*

Ans: When hot water cools, it contracts. However, when water freezes it expands as it turns into ice. The force of the expansion can burst water pipes and split rock with rainwater trapped in them.

Water expands on freezing for the following reason. In liquid water, the particles (water molecules) are close together. But the ice, the molecules link up in a very open structure that actually takes up more space than in the liquid.

Ice has a lower density than liquid water – in other words, each kilogram has a greater volume. Because of its lower density, ice floats on water: when liquid water is cooled the molecules start forming into an open structure at 4 ^{o}C to 0 ^{o}C. It takes up least space, and therefore has its maximum density, at 4 ^{o}C.

Q.11 What is Thermostats? ***(K.B)***

Ans: A thermostats is device which used to detect temperature changes for the purpose of maintaining the temperature of an enclosed area essentially constant. In a system including relays, valves, switches, etc, the thermostat generates signals, usually electrical, when the temperature exceeds or falls below the desired value.

Q.12 Why we use pyrex in oven in place of glass dish? ***(K.B)***

Ans: The Heat resistant quality to bear up to 425 degrees F makes the pyrex products ideal for the use in the kitchen especially for cooking or baking purposes in oven. If an ordinary glass dish is put straight into a hot oven, the outside of the glass expands before the inside and the strain cracks the glass. Pyrex expands much less than ordinary glass, so should not crack.

EXAMPLE 8.6 *(U.B+A.B)*

A brass rod is 1 m long at 0°C. Find its length at 30°C. (Coefficient of linear expansion of brass =$1.9\times10^{-5}K^{-1}$) **(LHR 2017)**

Solution:

Given Data:

Initial length of the brass rod = L_o = 1m

Initial temperature of the brass rod = $T_o = 0^oC = 0+273 = 273$ K

Final temperature of the brass rod = $T = 30^oC = 30 + 273 = 303$ K

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

Change in temperature $\Delta T = 303 - 273 = 30K$

Coefficient of linear expansion of brass = $\alpha = 1.9\times10^{-5}K^{-1}$

To Find:

Final length of the brass rod = L =?

Calculations:

We know

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

Putting values

$$L = 1(1+1.9\times10^{-5}\times30)$$

$$L = 1.00057 \text{ m}$$

Result:

Hence, the length of the brass bar at 30°C will be 1.00057 m.

EXAMPLE 8.7 *(U.B+A.B)*

Find the volume of a brass cube at 100°C whose side is 10 cm at 0°C. (Coefficient of linear thermal expansion of brass = $1.9\times10^{-5}K^{-1}$).

Solution:

Given Data:

Initial length of the a side of brass = L_o = 0.1m

Initial volume of the brass cube = $V_o = (L_o)^3 = (0.1m)^3 = 0.001m^3 = 10^{-3}m^3$

Initial temperature of the brass cube= $T_o = 0\,^oC = 0+273 = 273$ K

Final temperature of the brass cube = $T = 100\,^oC = 100 + 273 = 373$ K

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

Change in temperature $\Delta T = 373 - 273 = 100K$

Coefficient of linear expansion of brass = $\alpha = 1.9\times10^{-5}\text{K}^{-1}$

To Find:

Final volume of the brass cube = L =?

Calculations:

We know

Coefficient of linear expansion of brass = $\alpha = 1.9\times10^{-5}\text{K}^{-1}$

We can find β as

$$\beta = 3\alpha$$

Putting values

$$\beta = 3\left(1.9\times10^{-5}\right)$$

$$\beta = 5.7\times10^{-5}\text{K}^{-1}$$

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

Putting values

$$V = 10^{-3}\left(1+5.7\times10^{-5}\times100\right)$$

$$L = 1.0057 \times 10^{-5}\ \text{m}^3$$

Result:

Hence, the volume of brass cube at 100^oC will be $1.0057\times10^{-3}\text{m}^3$.

8.8 MULTIPLE CHOICE QUESTIONS

1. **The kinetic energy of molecules of an object depends on *(K.B)***
   (A) Position (B) Temperature
   (C) Area (D) All of the above
2. **Linear expansion of a rod occur along dimension (s): *(K.B)***
   (A) One dimension (B) Two dimension
   (C) Three dimension (D) All
3. **The characteristic of unequal expansion of different metals is employed in a device known as: *(K.B)***
   (A) Thermometer (B) Burner
   (C) Calorimeter (D) Thermostat
4. **Linear expansion depends on: *(K.B)***
   (A) Length of rod (B) Change in temperature
   (C) Nature of material of rod (D) All of above
5. **Thermostat works on the principle of: *(K.B)***
   (A) Unequal expansion of solids (B) Pascal's law
   (C) Anomalous expansion of water (D) Vaporization
6. **Thermostat is used in: *(K.B)***
   (A) Electric iron (B) Refrigerator
   (C) Fire alarm (D) All of above
7. **SI unit of Coefficient of linear & volume expansion is: *(K.B)***
   (A) m (B) K
   (C) K^{-1} (D) ^oC
8. **Volume expansion depends on: *(K.B)***
   (A) Volume of block (B) Change in temperature
   (C) Nature of material of block (D) All of above

9. **β = *(K.B+U.B)***

(A) α (B) 2α
(C) 3α (D) 5α

10. **Liquid expansion is if: *(K.B)***

(A) One type (B) Two type
(C) Three type (D) Four type

11. **The liquid (s) used in thermometers is (are): *(K.B)***

(A) Mercury (B) Alcohol
(C) Water (D) Both A & B

MCQ'S ANSWER KEY (TOPIC WISE)

8.1 TEMPERATURE AND HEAT

8.2 THEROMETER

1	2	3	4	5	6	7	8	9	10	11	12
C	C	A	A	C	A	B	C	D	D	D	B
13	**14**	**15**	**16**	**17**	**18**	**19**	**20**				
A	C	D	A	B	C	D	D				

8.3 SPECIFIC HEAT CAPACITY

1	2	3	4	5	6	7	8	9	10	11	12
B	A	C	A	D	A	A	C	B	A	B	C
13	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
D	A	B	C	D	A	B	C	D	A	B	C
25	**26**	**27**	**28**	**29**	**30**						
D	A	B	C	D	B						

8.4 CHANGE OF STATE

8.5 LATENT HEAT OF FUSION

8.6 LATENT HEAT OF VAPORIZATION

1	2	3	4
C	D	B	A

8.7 THE EVAPORATION

1	2	3	4	5
B	B	A	C	C

8.8 THERMAL EXPANSION

1	2	3	4	5	6	7	8	9	10	11
D	A	C	D	A	A	C	D	C	B	D

TEXT BOOK EXERCISE

MULTIPLE CHOICE QUESTIONS

8.1 Encircle the correct answer from the given choices.

i. Water freezes at: *(K.B)* **(LHR 2013, 2016)**

(a) 0^oF (b) 32^oF
(c) -273 K (d) 0 K

ii. Normal human body temperature is: *(K.B)* **(LHR 2016)**

(a) 15^oC (b) 37^oC
(c) 37^oF (d) 98.6^oF

iii. Mercury is used as thermometric material because it has: *(K.B)*

(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? *(K.B)* **(GRW 2013)**

(a) Copper (b) Ice
(c) Water (d) Mercury

v. Which of the following material has large value of temperature coefficient of linear expansion? *(K.B)*

(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 $2 \times 10^{-5}\ K^{-1}$? *(U.B+A.B)*

(a) $2\times10^{-5}\ K^{-1}$ (b) $6\times10^{-5}\ K^{-1}$
(c) $8\times10^{-15}\ K^{-1}$ (d) $8\times10^{-5}\ K^{-1}$

vii. A large water reservoir keeps temperature of nearby land moderate due to: *(K.B)*

(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? *(K.B)*

(a) Temperature (b) Surface area of the liquid
(c) Wind (d) All of the above

ANSWER KEY

i	ii	iii	iv	v	vi	vii	viii
b	b	d	c	a	b	d	d

8.2 Why does heat flow from hot body to cold body? *(K.B)*

Ans:

FLOW OF HEAT

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. In other word we can say heat flows from hot body to cold body due to temperature difference between them.

8.3 Define the term heat and temperature. *(K.B)* **(LHR 2013)**

Ans: Given on Page # 291

8.4 What is meant by internal energy of a body? *(K.B)*

Ans: Given on Page # 290

8.5 How does heating affect the motion of molecules of a gas? *(K.B)*

Ans:

EFFECT OF HEAT ON GAS

The kinetic energy of gas molecules goes on increasing if a gas is heated continuously. This causes the gas molecules move faster and faster. The collisions between atoms and molecules of the gas become so strong that they tear off the atoms. Atoms lose their electrons and become positive ions. This ionic state of matter is called plasma.

In short on heating the gas, the motion of the molecules becomes faster. As a result average K.E and temperature of gas increases.

8.6 What is thermometer? Why mercury is preferred as thermometric substance? *(K.B)*

Ans: Given on Page #

8.7 Explain the volumetric thermal expansion. *(K.B+A.B+U.B)*

Ans: See Q. 3 Long Question TOPIC 8.8 Given on Page # 314

8.8 Define specific heat. How would you find the specific heat of a solid? *(K.B+A.B+U.B)*

Ans: See Q. 1 'Long Question TOPIC 8.3 Given on Page # 296

8.9 Define and explain latent heat of fusion. *(K.B+A.B+U.B)*

Ans: See Q. 2 Long Question TOPIC 8.5 Given on Page # 302

8.10 Define latent heat of vaporization. *(K.B+A.B+U.B)*

Ans: See Q. 3 Long Question TOPIC 8.6 Given on Page # 304

8.11 What is meant by evaporation? On what factors the evaporation of a liquid depends? Explain how cooling is produced by evaporation? *(K.B+A.B+U.B)*

Ans: See Q. 1 Long Question TOPIC 8.7 Given on Page # 308

NUMERICAL PROBLEMS *(U.B+A.B)*

8.1 Temperature of the water in beaker is 50^0C. What is its value in Fahrenheit scale?

Solution:

Given Data:

Temperature in Celsius = $T_c = 50^0C$

To Find:

Temperature in Fahrenheit = T_f = ?

Calculations:sss

As we know that

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

By putting the values, we have

$$F = \frac{9}{5} \times 50 + 32$$

F = 90 + 32

F = 122 ^oF

Result:

Hence, the temperature in Fahrenheit will be 122°F.

8.2 Normal human body temperature is 98.6^0 F. Convert it into Celsius and Kelvin scale.
(GRW 2013, LHR 2013, 2015, 2017)

Solution:

Given Data:

Normal human Temperature in Fahrenheit = $T_f = 98.6^0$ F

To Find:

Temperature in Celsius = T_c =?

Temperature in Kelvin = T_k =?

Calculations:

As we know that

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

By putting the values, we have

$$C = \frac{5}{9}(98.6 - 32)$$

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

$$T_K = C + 273$$

By putting the values, we have

$T_K = 37 + 273 = 310$ K

Result:

Hence, the Temperature of normal human body in Celsius will be 37 ^{o}C and the temperature of normal human body in Kelvin will be 310 K.

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

Solution:

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}

To Find:

Increase in length = $L - L_o$ =?

Calculations:

As we know that

$$L - L_o = \alpha L_o (T_2 - T_1)$$

By putting the values, we have

$$L - L_o = 2.5 \times 10^{-5} \times 2 \times (293 - 273)$$

$$L - L_o = 5 \times 10^{-5} (20)$$

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

$$L - L_o = 1 \times 10^{-3} \text{ m} = 0.1 \text{ cm} = 1 \text{ mm}$$

Result:

Hence, the increase in length of Aluminum bar will be 1×10^{-3} m = 0.1 cm = 1 mm.

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

Solution:

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}

To Find:

Final volume of gas = V_2 = ?

Calculations:

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:

Hence, the final volume of gas will be 1.3 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. **(LHR 2014 GRW 2015)**

Solution:

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:

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

To Find:

Heat required = Q =?

Calculations:

As we know that

$\Delta Q = mc\Delta T$

By putting the values, we have

$\Delta Q = 0.5 \times 4200 \times 55$
$\Delta Q = 115500$ J

Result:

Hence, the heat required will be 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 200 g of water from 20°C to 90°C?

Solution:

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 $kg^{-1}k^{-1}$
Initial temperature = $T_1 = 20^0$ C
Final temperature = $T_2 = 90^0$ C
Change in temperature = $\Delta T = 90 - 20 = 70^o$ C = 70K

To Find:

Heat required = Q =?
Time = t =?

Calculations:

As we know that

$Q = cm\ \Delta T$

$Q = 0.2 \times 4200 \times 70$
$Q = 58800$ J

As we also know that

$P \times t = Q$
$t = Q/P$
$t = 588000/1000$
$t = 58.8$ s

Result:

Hence, the heat required will be 58800 J and the time taken will be 58.8 s.

8.7 How much ice will melt by 50000 J of heat? Latent heat of fusion of ice 336000 Jkg^{-1}.
(GRW 2013, 14)

Solution:

Given Data:

Heat supplied to ice = ΔQ_f = 50000 J
Latent heat of fusion of ice = H_f = 336000 Jkg^{-1}

To Find:

Mass of ice = m = ?

Calculations:

As we know that

$\Delta Q = m \times H_f$

So $m = \dfrac{\Delta Q}{H_f}$

By putting the values, we have

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

$m = 0.15$ kg = 150 g

Result:

Hence, the mass of ice will be 150 g.

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

Solution:

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}
Initial temperature of ice = T_1 = -10^0 C
Final temperature = T_2 = 10^0 C

To Find:

Heat required to raise the temperature of ice from –10°C to 10°C = Q = ?

Calculations:

Step-I:

Heat required to raise the temperature of ice from –10°C to 0°C = ΔQ_1 = ?
T_1 = –10°C

$T_2 = 0°C$
$\Delta T = 0°C–(–10)°C = 10°C = 10\ K$
$\Delta Q = cm\Delta T$
$\Delta Q_1 = 2100 \times 0.1 \times 10$
$\Delta Q_1 = 2100\ J$

Step-II:

Heat required to convert ice at 0°C into water at 0°C = ΔQ_2 =?
We know that
$\Delta Q_2 = mL_f$
$\Delta Q_2 = 0.1 \times 336000$
$\Delta Q_2 = 33600\ J$

Step-III:

Heat required to raise temperature water from 0°C to 10°C = ΔQ_3 =?
T1 = 0°C
T2 = 10°C
$\Delta T = 10°C – 0°C = 10°C = 10K$
We know that
$\Delta Q = cm\Delta T$
$\Delta Q_3 = 4200 \times 0.1 \times 10$
$\Delta Q_3 = 4200\ J$
Total heat required = $Q = \Delta Q_1 + \Delta Q_2 + \Delta Q_3$
$Q = 2100+33600+4200$
$Q = 39900\ J$

Result:

Hence, the total heat required will be 39900 J.

8.9 How much heat is required to change 100 g of water at 100^0 C into steam?
(LHR 2013, 2015)

Solution:

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 = $H_v = 2.26 \times 10^6\ Jkg^{-1}$

To Find:

Heat required to change water into steam = 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:

Hence, the heat required to change water into steam will be 2.26×10^5 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°C.

Solution:

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 = 2.26×106 Jkg^{-1}

To Find:

Final temperature of water = T =?

Calculations:

According to law of heat exchange

Heat lost by steam = Heat gain by water

$$mH_v + cm\Delta T = cm\Delta T$$

$$(0.005)(2.26\times10^6) + (4200)(0.005)(100-T) = (4200)(0.5)(T-10)$$

$$11300+21(100-T) = 2100(T-10)$$

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

$$11300+2100+21000 = 2100T+21T$$

$$344400 = 2121T$$

$$T = \frac{34400}{2121}$$

$$T = 16.2°C$$

Result:

Hence, the final temperature of water will be 16.2^oC.

SELF TEST

Time: 40 min. **Marks: 25**

Q.1 Four possible answers (A), (B), (C) & (D) to each question are given, mark the correct answer. **(6×1=6)**

1. What will be the value of β for a solid for which α has a value of $2\times10^{-5}\ K^{-1}$?

(A) $2\times10^{-5}\ K^{-1}$ (B) $6\times10^{-5}\ K^{-1}$
(C) $8\times10^{-5}\ K^{-1}$ (D) $12\times10^{-5}\ K^{-1}$

2. The unit of heat is:

(A) kelvin (B) joule (J)
(C) $Jkg^{-1}K^{-1}$ (D) kg

3. Density of water in kgm^{-3} is:

(A) 1000 (B) 4200
(C) 4300 (D) 4500

4. The relation between co-efficient of linear expansion and volume expansion is

(A) $\alpha = 3\beta$ (B) $\beta = 3\alpha$
(C) $\alpha = \frac{3}{\beta}$ (D) $\beta = \frac{3}{\alpha}$

5. The value of absolute zero on Kelvin scale is equal to:

(A) $273^{o}C$ (B) 273K
(C) 273F (D) $-273^{o}C$

6. Heat capacity of 5 kg of water, is:

(A) $4200\ JK^{-1}$ (B) $21000\ JK^{-1}$
(C) $2100\ JK^{-1}$ (D) $2900\ JK^{-1}$

Q.2 Give short answers to following questions. **(5×2=10)**

i. What is thermostate? Write its uses.
ii. How much ice will melt by 50,000 J of heat? Latent heat of fusion of ice is $336000\ Jkg^{-1}$.
iii. Why does ether evaporate quickly than water?
iv. Why the temperature of ice does not change at 0°C for some time?
v. What happens when we touch a hot body?

Q.3 Answer the following questions in detail. **(4+5=9)**

a) Explain volume thermal expansion in solids. Also derive the formula for volume expansion.
b) 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?

<u>**Note:**</u>

Parents or guardians can conduct this test in their supervision in order to check the skill of students.