# 7 CHAPTER

# THERMAL PROPERTIES OF MATTER



## 7.1 KINETIC MOLECULAR MODEL OF MATTER

### LONG QUESTIONS

**Q.2 Explain different states of matter on the basis of kinetic molecular theory.** **(LHR 2013)**
***(K.B+U.B+A.B)***

**Ans:** Kinetic molecular model is used to explain the four states of matter – solid, liquid, gas and plasma.

**(i) Solid:**

Solids have **fixed shapes** and **volume**. Their molecules are held close together by **strong forces of attraction**. However, they vibrate about their mean positions but do not move from place to place.

**Examples:**

Examples of solids are stone, metal spoon, pencil etc.

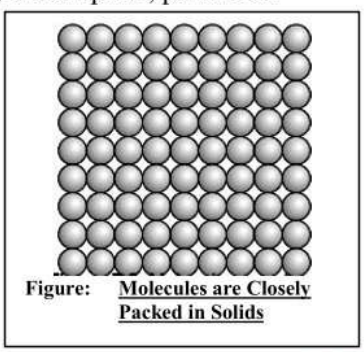


**Figure: Molecules are Closely Packed in Solids**

**(ii) Liquids:**

The distances between the molecules of a liquid are more than in solids. Thus, **attractive forces** between them are **weaker**. Like solids, molecules of a liquid also vibrate about their mean position but are not rigidly held with each other. Due to the weaker attractive forces, they can slide over one another. Thus, the liquids can flow. The volume of a certain amount of liquid remains the same but because it can flow hence; it attains the shape of a container to which it is put.

**Examples:**

Examples of liquids are milk, and liquid water etc.

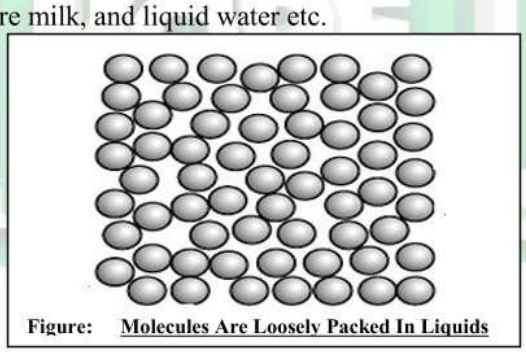


**Figure: Molecules Are Loosely Packed In Liquids**

**(iii) Gases:**

Gases such as air have **no fixed shape** or volume. They can be filled in any container of any shape. Their molecules have random motion and move with very high velocities. In gases, molecules are much farther apart than solids or liquids. Thus, gases are much lighter than solids and liquids. They can be **squeezed** into smaller volumes.

**Examples:**

Oxygen, Nitrogen and Carbon dioxide are examples of gases.

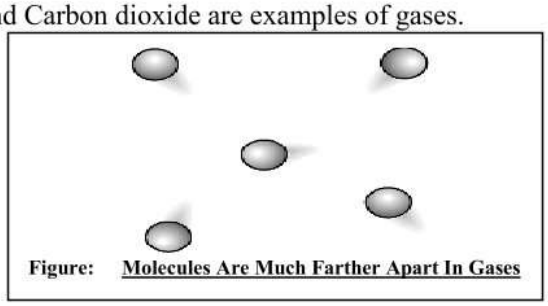


**Figure: Molecules Are Much Farther Apart In Gases**

**Pressure of Gases:**

The molecules of a gas are constantly striking the walls of a container. Thus, a gas exerts pressure on the walls of the container.

**(iv) Plasma:** **(LHR 2017)**

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.

**Plasma in Discharge Tubes:**

Plasma is also formed in gas discharge tubes when electric current passes through these tubes.

**Plasma – The Fourth State of Matter:**

Plasma is also called the **fourth state** of **matter** in which **gas** occurs in its **ionic state**. Positive ions and electrons get separated in the presence of electric and magnetic field. Plasma also exists in neon and fluorescent tubes when they glow.

**Universe Formation:**

Most of the matter that fills the universe is in plasma state. In stars such as our sun, gases exist in their ionic state.

**Plasma Good Conductor:**

Plasma is highly conducting state of mater. It allows electric current to pass through it.

**Q.4 What are the particles? *(K.B)***

**Ans:** Everything is made from about 100 simple substances called elements. An atom is the smallest possible amount of an element. In some materials, the 'moving particles' of the kinetic theory are atoms. However, in most materials, they are group of atoms called molecules.

**Q.5 Why does a gas exert pressure? *(K.B)***

**Ans:**

**GASEOUS PRESSURE**

Gaseous molecules have random motion and move with very high velocities. They collide with one another and with the walls of container hence they exert pressure.

**Q.6 What is Kinetic molecular theory? Write down its postulates. *(K.B)***

**Ans:**

Most of the properties of solids, liquids, and gases can be explained on the basis of the intermolecular forces that has been explained by Kinetic molecular model. Kinetic molecular model has some important features.

- Matter is made up of particles called molecules.
- The molecules remain in continuous motion. The motion of molecules could be linear, vibrational, or rotational.
- The molecules attract each other.

## 7.2 TEMPERATURE AND HEAT
## 7.3 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 Material:**

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:

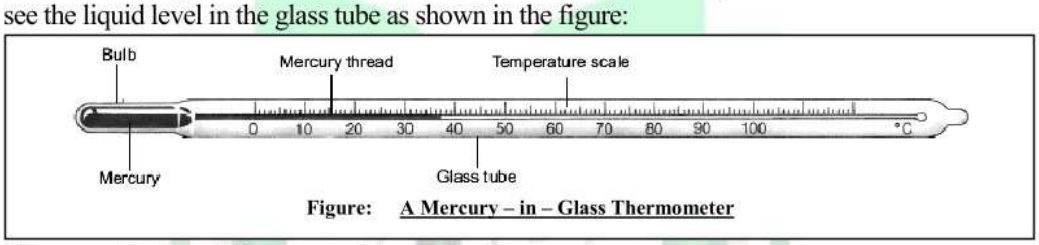



**Figure: A Mercury – in – Glass Thermometer**

**Mercury the Best Thermometric Material:**

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

**Reference Points:** **(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:

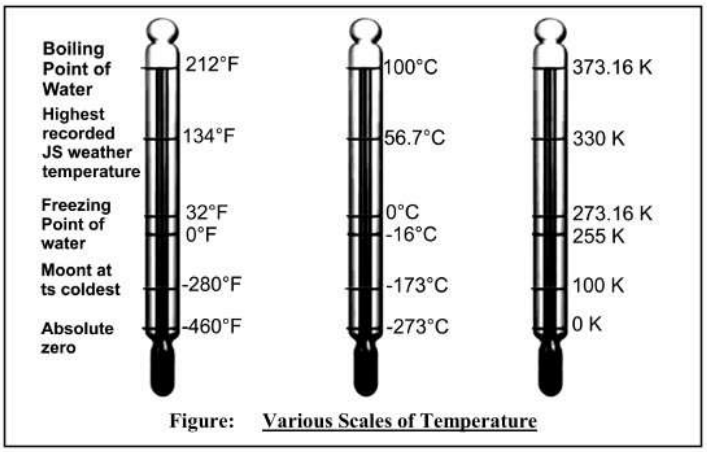



**Figure: Various Scales of Temperature**

**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 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.

## 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:**

**TOUCH OF A HOT BODY**

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:**

**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. Common thermometers are generally made using some suitable liquid as thermometric material.

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

**Ans:**

**ABSOLUTE ZERO**

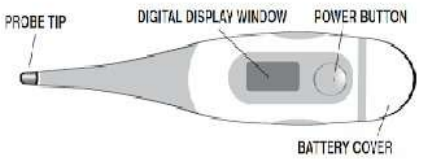
Absolute zero is the point at which the fundamental particles of nature have minimal vibrational motion, retaining only quantum mechanical, zero-point energy-induced particle motion. By international agreement, absolute zero is defined as precisely; 0 K on the Kelvin scale, which is a thermodynamic (absolute) temperature scale; and –273.15 degrees Celsius on the Celsius scale.

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

**Ans:**

**Difference**

| 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.<br>  <br> | A thermocouple is robust, quick to respond to temperature change, has a wide range (-200 °C to 1100 °C ), and can be linked to other electrical circuits or a computer.<br>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:** **CLINICAL THERMOMETER**

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

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

**Ans:** **CONVERSIONS OF SCALES**

Following are scale conversion formulae.

**Conversion of Celsius (centigrade) to Fahrenheit scale:**

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

**Conversion of Fahrenheit to Celsius scale:**

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

**Relationship between Kelvin and Celsius scales:**

$$T_k = T_c + 273$$

**Q.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.

## MULTIPLE CHOICE QUESTIONS

**25. 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

**26. The SI unit of temperature is: *(K.B)***

(A) °C (B) °F

(C) K (D) °K

**27. Temperature of 30 °C in Fahrenheit is: *(K.B)***

(A) 86 °F (B) 80 °F

(C) 30 °F (D) 90 °F

**28. Human normal body temperature of 37 °C in Fahrenheit is: *(K.B)***

(A) 98. 6 °F (B) 98 °F
(C) 100 °F (D) None of above

**29. Boiling point of water in Fahrenheit is: *(K.B)***

(A) 100 °F (B) 273 °F
(C) 212 °F (D) 373 °F

**30. Celsius equivalent of 0K is: *(K.B)***

(A) -273 °C (B) -459.4 °C
(C) 0 °C (D) 100 °C

**31. Fahrenheit equivalent of 0K is: *(K.B)***

(A) -273 °F (B) -459.4 °F
(C) 0 °F (D) 100 °F

**32. Heat is a type of: *(K.B)***

(A) Kinetic energy (B) Potential energy
(C) Mechanical energy (D) None of above

**33. Which of the following substances have greater average kinetic energy of its molecules at 10°C? *(K.B)***

(A) Steel (B) copper
(C) Water (D) Mercury

**34. Which flower is a natural thermometer? *(K.B)***

(A) Jasmine (B) Rose
(C) Daisy (D) Crocus

**35. Crocus flower opens at: *(K.B)***

(A) -273 °C (B) -459.4 °C
(C) 0 °C (D) 23 °C

**36. The temperature in the Sun's core is: *(K.B)***

(A) 6000 °C (B) 15000000 °C
(C) 2500 °C (D) 1580 °C

**37. The temperature in the Sun's surface is: *(K.B)***

(A) 6000 °C (B) 15000000 °C
(C) 2500 °C (D) 1580 °C

**38. The temperature of the boiling water is: *(K.B)***

(A) 100 °C (B) 37 °C
(C) 0 °C (D) -18 °C

**39. The temperature of normal human body is: *(K.B)***

(A) 100 °C (B) 37 °C
(C) 0 °C (D) -18 °C

**40. The temperature of the freezing water is: *(K.B)***

(A) 100 °C (B) 37 °C
(C) 0 °C (D) -18 °C

## 7.4 SENSITIVITY, RANGE AND LINEARITY OF THERMOMETERS

### LONG QUESTIONS

**Q.1 Discuss sensitivity, range and linearity of thermometers:**

**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.

## 7.5 STRUCTURE OF A LIQUID IN-GLASS THERMOMETER

### LONG QUESTIONS

**Q.1 Discuss the structure of liquid in glass thermometer.**

**Ans:**

**Structure:**

A liquid-in-glass thermometer has a narrow and uniform capillary tube having as mall bulb filled with mercury or alcohol at its lower end. The thin wall of the glass bulb allows quick conduction through glass to the liquid from a hot object whose temperature is to be measured.

**Working:**

Mercury being metal is a good conductor and hence responds quickly to the change in temperature. The small amount of liquid also responds more quickly to a change in temperature. The quick response makes the device sensitive. Use of mercury is quite sensitive for normal measurements.

**For Greater Accuracy:**

For greater accuracy, alcohol can be used as its expansively is six times more than mercury but it has range limitation to higher temperature measurements due to its low boiling point (78°C).

**Explanation:**

The uniformity of the narrow tube or bore ensures even expansion of the liquid required to make the linear measuring scale. The choice of mercury allows to use it over a long-range temperature due to its low freezing point and high boiling point. It provides a fairly long range of measurement of temperature.

### TEXT BOOK EXERCISE

### MULTIPLE CHOICE QUESTIONS

***7.1*** **How do the molecules in a solid behave?**

(a) Move randomly
(b) Vibrate about their mean positions
(c) Rotate and vibrate randomly at their own positions
(d) Move in a straight line from hot to cold ends.

***7.2*** **What type of motion is of the molecules in a gas?**

(a) Linear motion (b) Random motion
(c) Vibratory motion (d) Rotatory motion

***7.3*** **Temperature of a substance is:**

(a) The total amount of heat contained in it (b) The total number of molecules in it
(c) Degree of hotness or coldness (d) Dependent upon the intermolecular distance

*7.4* **Heat is the:**
(a) Total kinetic energy of the molecules (b) The internal energy
(c) Work done by the molecules (d) The energy in transit

*7.5* **In Kelvin scale, the temperature corresponding to melting point of ice is:**
(a) zero (b)32
(c)-273 (d) +273

*7.6* **The temperature which has the same value on Celsius and Fahrenheit scale is:**
(a) -40 (b) +40
(c) +45 (d)-45

*7.7* **Which one is a better choice for a liquid-in-glass thermometer?**
(a) Is colourless (b) Is a bad conductor
(c) Expand linearly (d) Wets glass

*7.8* **One disadvantage of using alcohol in a liquid-in-glass thermometer:**
(a) it has large expansivity (b) it has low freezing point (-112°C)
(c) it wets the glass tube (d) its expansion is linear

*7.9* **Water is not used as a thermometric liquid mainly due to:**
(a) colour less (b) a bad conductor of heat
(c) non-linear expansion (d) a low boiling point (100°C)

*7.10* **A thermometer has a narrow capillary tube so that it:**
(a) quickly responds to temperature changes
(b) can read the maximum temperature
(c) gives a large change for a given temperature rise
(d) can measure a large range of temperature

*7.11* **Which thermometer is most suitable for recording rapidly varying temperature?**
(a) Thermocouple thermometer
(b) Mercury-in-glass laboratory thermometer
(c) Alcohol-in-glass thermometer
(d) Mercury-in-glass clinical thermometer

## SHORT ANSWER QUESTIONS

**7.1 Why solids have a fixed volume and shape according to particle theory of matter?**

**Ans:** In case of solids, the intermolecular forces are so strong that they keep the molecules bound. So, the molecules are held at fixed positions but still they show vibrational motion about their fixed points. This is why, the solids have a definite shape and a definite volume.

**7.2 What are the reasons that gases have neither a fixed volume nor a fixed shape?**

**Ans:** Gas molecules are relatively far away from one and another. Due to which, gas neither posses a definite volume nor a definite shape.

**7.3 Compare the spacing of molecules in the solid, liquid and gaseous state.**

**Ans:** **Solids:**

In case of solids, the intermolecular forces are so strong that they keep the molecules bound. So, the molecules are held at fixed positions but still they show vibrational motion about their fixed points. This is why, the solids have a definite shape and a definite volume.

**Liquids:**

In case of liquids, intermolecular force is so weak that it cannot hold the molecules at fixed positions and the molecules can slide over each other in random directions. A liquid, therefore, possesses a

definite volume but has no definite shape. Due to flow of the molecules, it acquires the shape of the containing vessel.

**Gases:**

Gas molecules are relatively far away from one and another. Due to which, gas neither posses a definite volume nor a definite shape.

**7.4 What is the effect of raising the temperature of a liquid?**

**Ans:** When we heat a substance, its molecular motion becomes more vigorous which means an increase in its internal energy. As a result, temperature of the substance rises. The heat energy transferred to a body increases the internal energy of its molecules due to which its temperature rises.

**7.5 What is meant by temperature of a body?**

**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)

**7.6 Define heat as 'energy in transit'**

**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 therefore heat is also known as energy in transit.

**7.7 What is meant by thermometric property of a substance? Describe some thermometric properties.**

**Ans:** 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

**Properties of Thermometric Material:**

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

**7.8 Describe the main scales used for the measurement of temperature. How are they related with each other?**

**Ans:** **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

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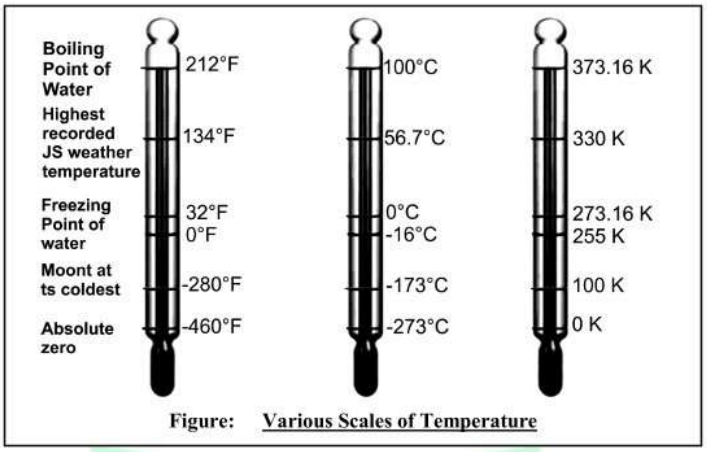


**Figure: Various Scales of Temperature**

**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

**7.9 What is meant by sensitivity of a thermometer?**

**Ans:** **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.

**7.10 What do you mean by the linearity of a thermometer?**

**Ans:** **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.

**7.11 What makes the scale reading of a thermometer accurate?**

**Ans:** **For Greater Accuracy:**

For greater accuracy, alcohol can be used as its expansivity is six times more than mercury but it has range limitation to higher temperature measurements due to its low boiling point (78°C).

**7.12 What does determines the direction of heat flow?**

**Ans:** The direction of heat flow is determined by the temperature difference between two objects or systems. Heat always flows from a region of higher temperature to a region of lower temperature. This principle is governed by the second law of thermodynamics, which states that heat naturally flows in such a way that it tends to equalize the temperature difference between systems.

**7.13 Distinguish between the heat and internal energy.**

**Ans:** **Difference**

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

**7.14 When you touch a cold surface, does cold travel from the surface to your hand or does energy travel from your hand to cold surface?**

**Ans:** When you touch a cold surface, energy flows from your hand to the surface. Your hand feels cold because it is losing heat to the cooler surface. There is no transfer of "cold" itself; instead, the energy (heat) moves from the warmer object (your hand) to the cooler one (the surface).

**7.15 Can you feel your fever by touching your own forehead? Explain.**

**Ans:** You can feel if you have a fever by touching your own forehead, but this is not a precise measurement of your body temperature.

## CONSTRUCTED RESPONSE QUESTIONS

**7.1 Is kinetic molecular theory of matter applicable to the plasma state of matter? Describe briefly.**

**Ans:** While plasma involves additional complexities due to the presence of charged particles and electromagnetic interactions, the Kinetic Molecular Theory still applies because the behavior of particles in plasma is fundamentally based on motion and energy transfer. However, the theory needs to be extended to account for the presence of charged particles and their interactions in the plasma state.

**7.2 Why is mercury usually preferred to alcohol as a thermometric liquid?**

**Ans:** Mercury is generally preferred over alcohol in thermometers because of its consistent thermal expansion, wide temperature range, and accuracy. However, due to its toxicity, mercury thermometers are being phased out in many applications, and alcohol thermometers are often used as safer alternatives in low-temperature applications or when non-toxicity is a priority.

**7.3 Why is water not suitable for use in thermometers? Without calculations, guess what is equivalent temperature of 373K on Celsius and Fahrenheit scales?**

**Ans:** Water is unsuitable for use in thermometers because it freezes at 0°C, boils at 100°C, has non-uniform thermal expansion, and suffers from issues related to evaporation, meniscus formation, and viscosity.

**373K=100C=212F**

**7.4 Mention two ways in which the design of a liquid-in-glass thermometer may be altered to increase its sensitivity.**

**Ans:** To increase the sensitivity of a liquid-in-glass thermometer, we can use a narrower tube and/or a liquid with a higher coefficient of thermal expansion. Both adjustments lead to a greater visible change in the liquid column for small changes in temperature, improving the precision of the thermometer.

**7.5 One litre of water is heated by a stove and its temperature rises by 2°C. If two litres of water is heated on the same stove for the same time, what will be then rise in temperature?**

**Ans:** When two litres of water are heated on the same stove for the same amount of time, the rise in temperature will be 1°C, half of the rise in temperature observed for 1 litre of water.

**7.6 Why are there no negative numbers on the Kelvin scale?**

**Ans:** The absence of negative numbers on the Kelvin scale is because absolute zero (0 K) represents the lowest possible temperature, where all particle motion theoretically stops, and temperatures cannot go below that point. Hence, the Kelvin scale starts at 0 and only has positive values.

**7.7 Comment on the statement, "A thermometer measures its own temperature".**

**Ans:** This statement is somehow true. Because, when we touch the bulb of thermometer heat starts travelling from us to the thermometer and after sometime its bulb attain thermal equilibrium and hence, thermometer measures the temperature of its own.

**7.8 There are various objects made of cotton, wood, plastic, metals etc. in a winter night. Compare their temperatures with the air temperature by touching them with your hand.**

Ans: On a winter night, touching these objects would lead you to feel:

- Cotton, wood, and plastic: cooler than your body temperature but not as cold as metals.
- Metals: much colder than the air temperature because they conduct heat away from your hand more quickly.

This difference in how materials feel is due to their varying thermal conductivity and how efficiently they transfer heat.

**7.9 Which is greater :an increase in temperature 1°C or one 1°F?**

**Ans:** Thus, an increase of 1°C corresponds to a larger temperature change than an increase of 1°F. Specifically, a 1°C increase represents a 1.8°F increase. So, 1°C is greater than 1°F.

**7.10 Why would not you expect all the molecules in a gas to have the same speed?**

**Ans:** The molecules in a gas have different speeds because of their random motion, the distribution of kinetic energy, and the collisions they experience with each other and with the walls of the container. These factors cause the gas molecules to have a variety of speeds, following the Maxwell-Boltzmann distribution rather than all having the same speed.

**7.11 Does it make sense to talk about the temperature of a vacuum?**

**Ans:** Vacuum itself does not have a temperature because it lacks particles to have kinetic energy. However, we can discuss the temperature of objects within a vacuum or the radiation present in a vacuum. Thus, when people refer to the "temperature of a vacuum," they are usually talking about the temperature of objects in that vacuum or the background radiation, not the vacuum itself.

**7.12 Comment on the statement: "A hot body does not contain heat".**

**Ans:** The statement "A hot body does not contain heat" is correct in the sense that heat refers to the energy in transit, not something a body inherently contains. A hot body has thermal energy, and heat is the energy that flows from it to another body with lower temperature. This distinction is crucial for understanding the concepts of heat transfer and thermal energy.

**7.13 Discuss whether the Sun is matter.**

**Ans:** While the Sun is not matter in the solid, liquid, or gas states that we are familiar with on Earth, it is made of matter—specifically, a highly energized and ionized form of matter known as plasma. Therefore, the Sun is composed of matter, just in a different state than most objects we encounter in our everyday lives.

## COMPREHENSIVE QUESTIONS

**7.1 Describe the main points of particle theory of matter which differentiate solids, liquids and gases.**

**Ans:** Kinetic molecular model is used to explain the four states of matter – solid, liquid, gas and plasma.

**(i) Solid:**

Solids have **fixed shapes** and **volume**. Their molecules are held close together by **strong forces of attraction**. However, they vibrate about their mean positions but do not move from place to place.

**Examples:**

Examples of solids are stone, metal spoon, pencil etc.

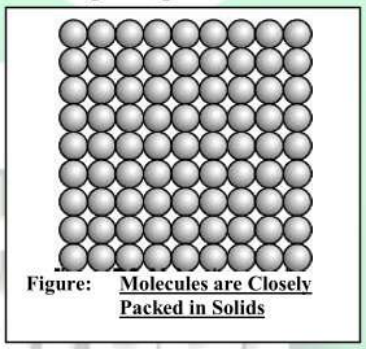

**Figure: Molecules are Closely Packed in Solids**

**(ii) Liquids:**

The distances between the molecules of a liquid are more than in solids. Thus, **attractive forces** between them are **weaker**. Like solids, molecules of a liquid also vibrate about their mean position but are not rigidly held with each other. Due to the weaker attractive forces, they can slide over one another. Thus, the liquids can flow. The volume of a certain amount of liquid remains the same but because it can flow hence; it attains the shape of a container to which it is put.

**Examples:**

Examples of liquids are milk, and liquid water etc.

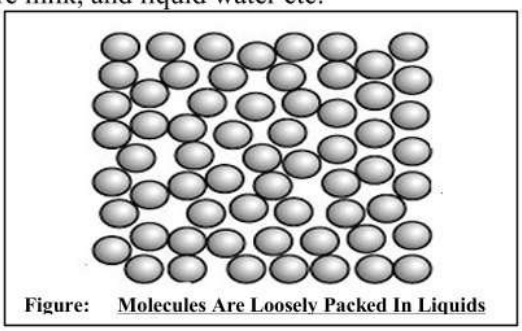

**Figure: Molecules Are Loosely Packed In Liquids**

**(iii) Gases:**

Gases such as air have **no fixed shape** or volume. They can be filled in any container of any shape. Their molecules have random motion and move with very high velocities. In gases, molecules are much farther apart than solids or liquids. Thus, gases are much lighter than solids and liquids. They can be

**squeezed** into smaller volumes.

**Examples:**

Oxygen, Nitrogen and Carbon dioxide are examples of gases.

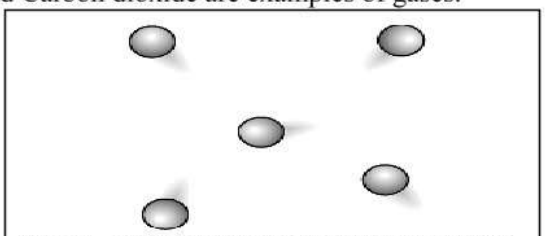

**Figure: Molecules Are Much Farther Apart In Gases**

**Pressure of Gases:**

The molecules of a gas are constantly striking the walls of a container. Thus, a gas exerts pressure on the walls of the container.

**(iv) Plasma:** **(LHR 2017)**

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.

**Plasma in Discharge Tubes:**

Plasma is also formed in gas discharge tubes when electric current passes through these tubes.

**Plasma – The Fourth State of Matter:**

Plasma is also called the **fourth state** of **matter** in which **gas** occurs in its **ionic state**. Positive ions and electrons get separated in the presence of electric and magnetic field. Plasma also exists in neon and fluorescent tubes when they glow.

**Universe Formation:**

Most of the matter that fills the universe is in plasma state. In stars such as our sun, gases exist in their ionic state.

**Plasma Good Conductor:**

Plasma is highly conducting state of mater. It allows electric current to pass through it.

**7.2 What is temperature? How is it measured? Describe briefly the construction of a mercury-in-glass thermometer.**

**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:

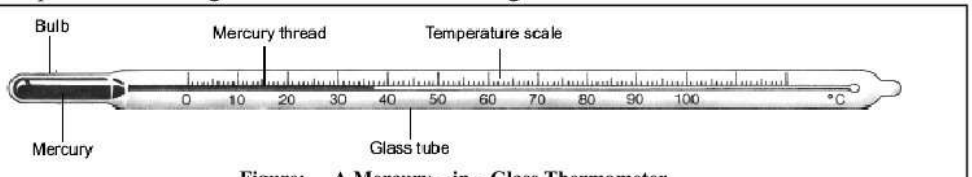


**Figure: A Mercury – in – Glass Thermometer**

**Mercury the Best Thermometric Material:**

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

**Reference Points:** **(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.

**7.3 Compare the three scales used for measuring temperature.**

**Ans: 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:

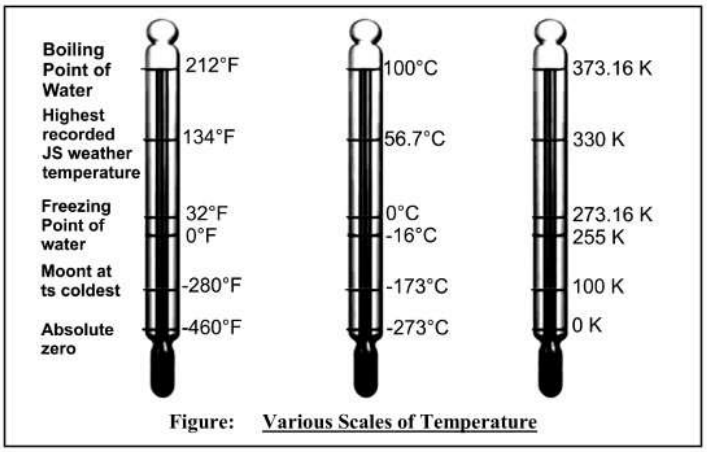


**Figure: Various Scales of Temperature**

**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**.

**7.4 What is meant by sensitive, range and linearity of thermometers? Explain with examples.**

**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.

**7.5 Explain, how the parameters mentioned in question 7.4 are improved in the structure of glass-in-thermometer.**

**Ans:** The uniformity of the narrow tube or bore ensures even expansion of the liquid required to make the linear measuring scale. The choice of mercury allows to use it over a long-range temperature due to its low freezing point and high boiling point. It provides a fairly long range of measurement of temperature.

## NUMERICAL PROBLEMS

**7.1 The temperature of normal human body on Fahrenheit scale is 98.6°F. Convert it into Celsius scale and Kelvin scale.**

**(37 $^{o}$C 310 K)**

**Given Data:**

Temperature in fahsinhit = F = 98.6$^{o}$F

**To Find:**

Temperature in Celsius = C = ?

Temperature in Kelvin = T (k) = ?

**Solution:**

**Formula:**

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

$$T_{(k)} = 273 + C$$

By applying values

$$C = \frac{98.6 - 32}{1.8} \Rightarrow \frac{66.6}{1.8} \Rightarrow \boxed{37^{o}C}$$

$$T_{(k)} = 273 + 37 \Rightarrow \boxed{310k}$$

**Results:**

Temperature of normal human body fahrinhert and in kelvin scale is 37$^{o}$C and 310k respectively.

**7.2 At what temperature Celsius and Fahrenheit thermometer reading would be the same?**

**(- 40$^{o}$)**

**Given Data:**

Temperature where Celsius and fahranheit values are same = T = ?

As we know

**To Find:**

$$T_{F} = \frac{9}{5}Tc + 32$$

For this we will consider TF = Tc = I

So,

$$T = \frac{9}{5}T + 32$$

$$T - \frac{9}{5}T = 32$$

$$T\left(1 - \frac{9}{5}\right) = 32$$

$$T\left(\frac{5-9}{5}\right) = 32$$

$$T\left(-\frac{4}{5}\right) = 32$$

$$T = \frac{32 \times 5}{-4}$$

$$T = \frac{-160}{4} \Rightarrow \boxed{-40^{o}C}$$

**Result:**

At – 40° the celsius and fahrenhit scales show the same temperature

**7.3 Convert 5°F to Celsius and Kelvin scale.** **(- 15 °C, 258K)**

**Given Data:**

Fahrenhit temperature = F = 5°F

**To Find:**

Celsius scale temperature = °C= ?

Kelvin scale temperature (k) = ?

**Solution:**

**Formula:**

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

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

By applying values

$$C = \frac{5 - 32}{1.8} \Rightarrow \frac{-27}{1.8} \Rightarrow \boxed{-15^{o}C}$$

$$T(k) = -15 + 273 \Rightarrow \boxed{258k}$$

**Results:**

SF in Celsius and kelvin -15°C and 258k respectively.

**7.4 What is equivalent temperature of 25 °C on Fahrenheit and Kelvin scales? (77 °F, 298K)**

**Given Data:**

Temperature in celsius = C = 25°C

**To Find:**

Fahrenheit temperature = F = ?

Temperature in Kelvin = T(k) = ?

**Solution**

**Formula:**

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

$$F = 1.8C + 32$$

By applying values

$$T(k) = 25 + 273 \Rightarrow \boxed{298k}$$

$$F = 1.8(25) + 32 \Rightarrow 45 + 32 \Rightarrow \boxed{77^{\circ} F}$$

**Result:**

25°C temperature in kelvin is 298k and in Fahrenheit it is 77°F.

**7.5 The ice and steam points on an ungraduated thermometer are found to be 192 mm apart. What temperature will be on Celsius scale if the length of mercury thread is at 67.2 mm above the ice point mark? (35 °C)**

**Given Data:**

Difference of ice point and steam point = 192 mm

Length of mercury third above ice point = 67.2 mm

**To Find:**

Temperature in Celsius scale = C = ?

**Solution**

**Formula:**

$$\text{Change in each } mm = \frac{100}{192} \Rightarrow 0.52083$$

$\therefore$ Temperature of steam = 100°C

$$\text{Temperature in C} = 67.2 \times 0.52083 \Rightarrow \boxed{35^{\circ} C}$$

**Result:**

Temperature in Celsius is 35°C.

**7.6 The length between the fixed point of liquid-in-glass thermometer is 20 cm. if the mercury level is 4.5 cm above the lower mark, what is the temperature on the Fahrenheit scale? (72.5°F)**

**Given Data:**

Length between fired point = 20cm

Mercury level abve lower mark = 4.5 am

**To Find:**

Temperature in Fahrenheit = F°= ?

**Solution:**

**Formula:**

$$\text{Change in each } m = \frac{100}{20} = 5$$

Temperature in °C = 5 × 4.5 ⇒ 22.5°C

$$F^{\circ} = 1.8^{\circ}\text{C} + 32 \Rightarrow 1.8(22.5) + 32$$

$$F^{\circ} = 40.5 + 32 \Rightarrow \boxed{72.5^{\circ} F}$$

**Result:**

Temperature in Fahrenheit will be $\boxed{72.5^{\circ} F}$

## STUDENT LEARNING OBJECTIVE

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| C | C | A | A | C | A | B | C | C | D |
| **11** | **12** | **13** | **14** | **15** | **16** | | | | |
| D | B | A | A | B | C | | | | |

## TEXT BOOK EXERCISE

## MULTIPLE CHOICE QUESTIONS

## ANSWER KEY

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