

# PHYSICS

**Class 9th (KPK)**

NAME: \_\_\_\_\_

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CLASS: \_\_\_\_\_ SECTION: \_\_\_\_\_

ROLL #: \_\_\_\_\_ SUBJECT: \_\_\_\_\_

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## Chapter # 8

# **Thermal Properties of matter** **Comprehensive Questions**

**Q1: Explain the term internal energy and temperature. Use kinetic theory to distinguish between heat, internal energy and temperature.**

**Ans: Internal Energy:**

Internal energy is the sum of the kinetic and potential energies associated with the motion of the atoms of the substance.

**Explanation:**

When we touch a hot body, internal energy flows in the form of heat into our body, so it appears to be hot. On the other hand, when we touch a cold object internal energy flows as heat from our body into the cold object, so it appears to be cold.

**Temperature:**

The measure of the degree of hotness or coldness of a body with respect to some standard is called temperature.

Or

The temperature can also be defined as: “The average kinetic energy of molecules of a body.”

**Explanation:**

Temperature is a measure of the average kinetic energy of particles. The kinetic energy may be in the form of translational, vibrational and rotational kinetic energy. As atoms or molecules of the material are in constant motion, at high temperature the kinetic energy of molecules is more and at lower temperatures, it is less. Temperature also affects the physical states (shape, size) of material. For example, water at low temperature is ice (a solid), at a high temperature it is water (a liquid) and still at higher temperature it is steam (a gas).

**Distinguishing Temperature, Heat & Internal Energy:**

Using the kinetic theory, we make a clear distinction between temperature, heat and internal energy. Temperature is a measure of the average kinetic energy of individual molecules. Internal energy refers to the total energy of all the molecules within the object. Thus two equal mass hot ingots of iron may have the same temperature, but two of them have twice as much internal energy as one does. Heat, finally, refers to a transfer of energy from one object to another because of a difference in temperature.

**Q2: How do we measure temperature? Explain liquid in glass thermometer.**

**Ans: Measurement of temperature:**

Temperature could be measured in a simple way by using our hand to sense the hotness or coldness of an object. However, the range of temperatures that our hand can bear is very small and our hand is not precise enough to measure temperature correctly. The branch of physics which deals with the measurements of temperature is called thermometry. For scientific work, we need



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some reliable device or instrument to measure temperature accurately. Such an instrument is called thermometer.

### **Liquid in glass thermometer:**

The liquid in glass thermometer utilizes the variation in volume of a liquid in temperature.

### **Construction or working:**

The fluid is contained in a sealed glass bulb, and its expansion is measured using a scale etched in the stem of the thermometer. The thermometer utilizes the variation of length of liquid with temperature. In this type the liquid in a glass bulb expands up a capillary tube when the bulb is heated. The liquid must be easily seen and must expand (or contract) rapidly and by a large amount over a wide range of temperature. The tube has a constriction just beyond the bulb. When the thermometer is removed, the liquid in the bulb cools and contracts breaking the liquid (mercury) thread at the constriction. The liquid beyond the constriction stays in the tube and shows the temperature. It must not stick to the inside of the tube. Liquids commonly used include mercury and alcohol.

**Q3: What are various temperature scales. Derive mathematical expressions to convert between various scales of temperature.**

### **Ans: Temperature Scales:**

The scale which is made for the measurement of temperature is called temperature scale or thermometric scale. The scale comprises of two reference points, called fixed points. There are freezing point (ice point) and boiling point (steam point). The interval between these point is divided arbitrarily into equal divisions. There are three scales of temperature which are the following.

1. Centigrade or Celsius scale.
2. Fahrenheit scale.
3. Kelvin or absolute scale.

#### **1. Centigrade or Celsius scale:**

- i. This scale was introduced by a Swedish astronomer Anders Celsius.
- ii. It is denoted by  $^{\circ}\text{C}$ .
- iii. Its ice point is marked as  $0^{\circ}\text{C}$ .
- iv. Its steam point is marked as  $100^{\circ}\text{C}$ .
- v. The interval between ice point and steam point is divided into 100 equal parts (divisions).
- vi. Each part is called degree centigrade.

#### **2. Fahrenheit Scale:**

- i. This scale was introduced by German physicist Daniel Gabriel Fahrenheit.
- ii. It is denoted by  $^{\circ}\text{F}$ .
- iii. Its ice point is marked as  $32^{\circ}\text{F}$ .
- iv. Its steam point is marked as  $212^{\circ}\text{F}$ .
- v. The interval between ice point and steam point is divided into 180 equal parts (divisions).
- vi. Each part (division) is called degree Fahrenheit.



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#### 3. Kelvin or absolute scale:

- i. This scale was introduced by William Thomson, (Lord Kelvin). He named this scale as absolute scale.
- ii. It is denoted by K.
- iii. Its ice point is marked as 273 K.
- iv. Its steam point is marked as 373 K.
- v. The interval between ice point and steam point is divided into 100 equal parts.
- vi. The lowest temperature at which the molecular movement of matter ceases is called Kelvin zero or absolute zero. Its magnitude on the Celsius scale is -273 °C or (0K).
- vii. Kelvin is the S.I unit of temperature.

#### Relationship Between Different Scales of temperature

A Temperature measured on one scale sometimes, needs conversion to another scale. A general relation for the conversion of temperature from one scale to the other is

$$\frac{\text{Temp on one scale} - \text{ice point}}{\text{No. of division b/w fixed points}} = \frac{\text{Temp on other scale} - \text{ice point}}{\text{No. of divisions b/w fixed point}}$$

#### A. Conversion between centigrade and Fahrenheit scale:

Using the general relation, we have

$$\frac{T_{\text{°C}} - 0}{100} = \frac{T_{\text{°F}} - 32}{180}$$

$$\frac{T_{\text{°C}}}{100} = \frac{T_{\text{°F}} - 32}{180}$$

$$T_{\text{°C}} = 100 \times \left[ \frac{T_{\text{°F}} - 32}{180} \right]$$

$$T_{\text{°C}} = \frac{100}{180} (T_{\text{°F}} - 32)$$

$$T_{\text{°C}} = \frac{10}{18} (T_{\text{°F}} - 32)$$

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

Or

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

$$\frac{9}{5} T_{\text{°C}} = T_{\text{°F}} - 32$$

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

$$\text{Or } T_{\text{°F}} = \frac{9}{5} T_{\text{°C}} + 32$$

#### B. Conversion between centigrade and Kelvin scale:

Using the general relation, we have

$$\frac{T_{\text{°C}} - 0}{100} = \frac{T_{\text{K}} - 273}{100}$$

$$\frac{T_{\text{°C}}}{100} = \frac{T_{\text{K}} - 273}{100}$$

$$T_{\text{°C}} = T_{\text{K}} - 273$$



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Or

$$T_{°C} = T_K - 273$$

$$T_{°C} + 273 = T_K$$

$$T_K = T_{°C} + 273$$

**Q4: What is meant by linear thermal expansion and volume thermal expansion of solids?**

**Ans: Linear Thermal Expansion of Solids:**

**Definition:**

The increase in length of a substance due to rise in temperature is called linear thermal expansion.

**Mathematical Derivation:**

Consider a metal rod having an original length “ $l_0$ ” at temperature “ $T_0$ ”. After heating metal rod to temperature “ $T$ ”, the rod expands to its new length “ $l_T$ ”. This means for the change in temperature  $\Delta T$  (where  $\Delta T = T - T_0$ ) there is corresponding change in length  $\Delta l$  (where  $\Delta l = l_T - l_0$ ).



The change in length  $\Delta l$  of almost all solids is directly proportional to the change in temperature  $\Delta T$  as long as is not too large. This means by changing temperature the length also changes, more the change in temperature more is the change in length and vice versa.

$$\Delta l \propto \Delta T \dots\dots(i)$$

The change in length  $\Delta l$  is also directly proportional to original length  $l_0$  of the object.

i.e. 
$$\Delta l \propto l_0 \dots\dots(ii)$$

Combining eq (i) and eq (ii), we get

$$\Delta l \propto l_0 \Delta T$$

Changing proportionality into equality.

$$\Delta l = \alpha l_0 \Delta T \dots\dots(iii)$$

Where “ $\alpha$ ” the proportionality constant is called the coefficient of linear thermal expansion for the particular material.

Since  $\Delta l = l_T - l_0$ , we can write eq(iii) as

$$l_T - l_0 = \alpha l_0 \Delta T$$

$$l_T = l_0 + \alpha l_0 \Delta T$$

Taking  $l_0$  common

$$l_T = l_0 (1 + \alpha \Delta T)$$

If the temperature change  $\Delta T = T - T_0$  is negative, then  $\Delta l = l_T - l_0$  is also negative; the length shortens as the temperature decreases.

**Coefficient of linear thermal expansion:**

From eq(iii), we can define coefficient of linear thermal expansion “ $\alpha$ ” of a substance as the increase in length per unit length of the solid per Kelvin “K” rise in temperature

$$\alpha = \frac{\Delta l}{l_0 \Delta T}$$

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In simple words,  $\alpha$  is numerically the increase in 1m long wire for 1 degree rise of temperature. The value of  $\alpha$  depends upon the nature of material and is different for different materials.

### **Unit:**

The coefficient of linear thermal expansion has units of  $^{\circ}\text{C}^{-1}$  and in SI as  $\text{K}^{-1}$ .

### **Volume (cubical) Thermal Expansion of Solids:**

#### **Definition:**

The increase in volume of a substance due to rise in temperature is called volume thermal expansion.

#### **Explanation:**

Consider a metal block having an original volume " $V_0$ " at temperature " $T_0$ ". After heating metal block to temperature " $T$ ", the block expands to its new volume " $V_T$ ". This means for the change in temperature  $\Delta T$  (where  $\Delta T = T - T_0$ ), there is corresponding change in volume  $\Delta V$  (where  $\Delta V = V_T - V_0$ ).

The increase in volume of a metal block on heating is directly proportional to original volume of the metal block and rise in temperature. Mathematically,

$$\Delta V \propto \Delta T \dots\dots(i)$$

and  $\Delta V \propto V_0 \dots\dots(ii)$

combining eq(i) & eq(ii), we get

$$\Delta V \propto V_0 \Delta T$$

Changing proportionality in equality

$$\Delta V = \gamma V_0 \Delta T \dots\dots(iii)$$

Where " $\gamma$ " is the proportionally constant is called the coefficient of volume thermal expansion for the particular material.

Since  $\Delta V = V_T - V_0$  we can write eq(iii) as

$$V_T - V_0 = \gamma V_0 \Delta T$$

$$V_T = V_0 + \gamma V_0 \Delta T$$

Taking  $V_0$  common

$$V_T = V_0 (1 + \gamma \Delta T) \dots\dots(iv)$$

Eq (iv) represents the final volume of the object after expansion.

### **Coefficient of volume thermal expansion:**

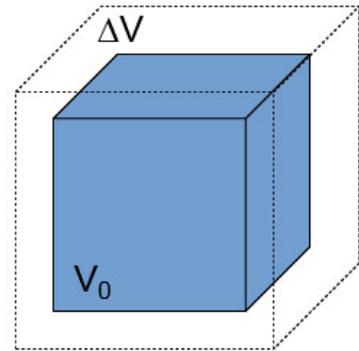
From eq(iii), we can define coefficient of volume thermal expansion ( $\gamma$ ) of a substance as the change in volume per unit volume per Kelvin change in temperature.

$$\gamma = \frac{\Delta V}{V_0 \Delta T}$$

The volume of  $\gamma$  depends upon the nature of material and is different for different materials.

### **Unit:**

The coefficient of volume thermal expansion has unit of  $^{\circ}\text{C}^{-1}$  and in SI as  $\text{K}^{-1}$ .





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This is general rule for solids that they expand to the same extent in three directions. It can be proved that all the coefficient of volume thermal expansion of solids  $\gamma$  is about three times the coefficient of linear thermal expansion ' $\alpha$ ' of solids i.e.

$$\gamma = 3 \alpha$$

so, eq 3 becomes

$$\Delta V = 3 \alpha V_0 \Delta T$$

**Q5: What is thermal expansion of liquid? Why we have real and apparent thermal expansion in liquids. Illustrate with the help of an experiment.**

**Ans: Thermal Expansion of Liquids:**

The increase in the volume of a liquid due to the thermal effect of heating is called thermal expansion of liquids. Since heat affects both the liquid and the container the real expansion of a liquid cannot be detected directly. In case of liquids, we have two kinds of thermal expansion.

1. Real expansion
2. Apparent expansion

**1. Real expansion of liquid:**

A real increase in the volume of a liquid that take place due to increase of temperature is called real expansion ( $V_R$ ) of liquid. This expansion is independent of the expansion of the container.

**2. Apparent expansion of liquid:**

An apparent increase in the column of a liquid that takes place due to increase of temperature is called apparent expansion ( $V_A$ ) of liquid. When a liquid is taken in a container and heated, both the liquid and the container expand at same time. The difference of these expansions is called apparent expansion. If  $V_R$  is the expansion in the volume of the liquid (called real expansion) and  $V_C$  is the expansion in the volume of container on heating, then the apparent expansion  $V_A$  is given by as;

$$V_A = V_R - V_C$$

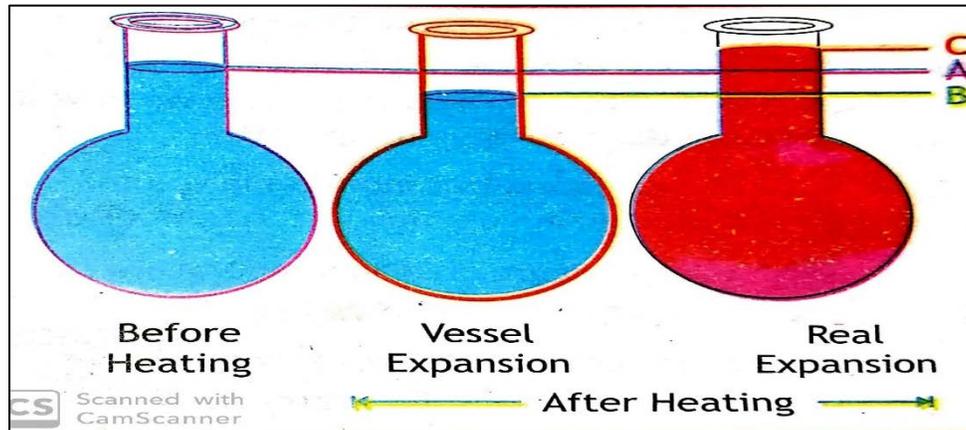
**Experiment:**

Let a vessel has water up to level A. If heat is applied, the vessel will first expand which will produce an illusion that the water has fallen. This is due to the expansion of the vessel and is given by the levels i.e. AB. On further heating the heat energy will start reaching the liquid. The liquid will then start expanding rapidly, according to its nature exceeding its previous level to reach up to level C. So the measurement of BC gives the true (real) expansion of the liquid only. An observer presents at the start and at the end will see the whole process as just the expansion of the liquid from A to C. So AC measures the apparent expansion of the liquid. Mathematically,

$$BC = AC + AB$$

**Real expansion of liquid = Apparent expansion of liquid + Vessel Expansion.**

Since there are two different types of expansion of liquids their coefficients of expansion should also be defined differently.



### Coefficient of real expansion “ $\gamma_R$ ”:

It is defined as the apparent increase in volume of liquid per unit original volume per unit degree rise in temperature.

$$\gamma_R = \frac{\text{real increase in volume}}{\text{original volume} \times \text{rise in temperature}}$$

Its unit is per degree rise in temperature i.e.  $^{\circ}\text{C}^{-1}$  or  $\text{K}^{-1}$

### Coefficient of apparent expansion “ $\gamma_A$ ”:

It is defined as the apparent increase in volume of liquid per unit original volume per unit degree rise in temperature.

$$\gamma_A = \frac{\text{apparent increase in volume}}{\text{original volume} \times \text{rise in temperature}}$$

Its unit is per degree rise in temperature i.e.  $^{\circ}\text{C}^{-1}$  or  $\text{K}^{-1}$ .

**Q6: Define heat capacity and specific heat capacity of a substance. Explain the importance of high specific heat capacity of water.**

**Ans: Heat Capacity (Thermal Capacity):**

The quantity of heat required to raise the temperature of a substance of mass (m) by  $1^{\circ}\text{C}$  or  $1\text{ K}$  is called the heat capacity ( $c_m$ ) of that substance.

**Mathematically:**

If  $\Delta Q$  is the change in heat and  $\Delta T$  is the change in temperature, then

$$c_m = \frac{\Delta Q}{\Delta T}$$

The value of “ $c_m$ ” depends upon.

1. The nature of the material of the substance.
2. The mass of the material of the substance.
3. The rise in temperature.

**Unit:**

The S.I unit of heat capacity is joule per Kelvin which is expressed as  $\text{JK}^{-1}$ .



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### **Specific heat capacity (specific heat):**

The quantity of heat required to raise the temperature of unit mass (1.0 kg) of the substance by 1°C or 1K is called specific heat capacity of that substance.

### **Mathematically:**

$$C = \frac{c_m}{m} \quad \therefore c_m = \frac{\Delta Q}{\Delta T}$$

Putting value of  $c_m$

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

### **Unit:**

The S.I unit of specific heat capacity or specific heat is joule per kilogram per Kelvin which is expressed as  $\text{JKg}^{-1} \text{K}^{-1}$ .

### **Importance of the high specific heat capacity of water:**

The specific heat capacity of water is equal to  $4190 \text{JKg}^{-1} \text{K}^{-1}$ . It has some important implications.

#### **1. Moderate climate of sea shore:**

The specific heat of sand is about  $800 \text{JKg}^{-1} \text{K}^{-1}$ . A certain mass of water needs five times more heat than the same mass of solid for its temperature to rise by 1°C or 1 K. Hence, the land gets heated much more easily than water. Also it cools down much easily hence a large difference in temperature is formed that gives rise to land breeze and sea breeze. It keeps the climate of the coastal areas moderate moon soon in Pakistan is also due to the difference in temperature between the land and the surrounding sea.

#### **2. As a coolant:**

Water is used as an effective coolant. By allowing water to flow in radiator pipes of the vehicles, heat energy from such part is removed. Thus, water extracts much heat without much rise in temperature.

### **Q7: What is meant by the latent heat of fusion and latent heat of vaporization of a substance?**

#### **Ans: Latent Heat of Fusion:**

The amount of heat energy is required to convert a given mass of a substance from the solid state to the liquid state (melt) without any rise in temperature is called its latent heat of fusion. Liquids release the same amount of heat when they solidify (freeze).

#### **Specific latent heat of fusion:**

The amount of heat energy required to convert unit mass (1 kg) of solid at its melting point of liquid (or liquid into solid) without any change in temperature is called its specific latent heat of fusion of the solid.

#### **Explanation:**

If “ $\Delta Q$ ” is the amount of heat energy needed to melt mass “ $m$ ” of a solid to liquid (or freeze liquid to solid), then mathematically.

$$\Delta Q = mL_f$$

Where  $L_f$  is the latent heat of fusion of substance and is given as



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$$L_f = \frac{\Delta Q}{m}$$

### Unit:

The S.I unit of specific latent heat of fusion is joule per kilogram which is expressed as  $\text{JKg}^{-1}$ . Different substances have different specific latent heat of fusion.

### Latent heat of vaporization:

The amount of heat energy required to convert a given mass of a substance from liquid state to the gaseous state (boil) without any rise in temperature is called its latent heat of vaporization. Gases release the same amount of heat when they liquify (condense).

### Specific latent heat of vaporization:

The amount of heat energy required to convert unit mass (1 Kg) of the liquid at its boiling point to gas, (or gas into liquid) without any change in temperature is called its specific latent heat of vaporization of the solid.

### Explanation:

If “ $\Delta Q$ ” is the amount of heat energy needed to vaporize mass “ $m$ ” of a liquid to gas (or condense gas to liquid), then mathematically,

$$\Delta Q = m L_v$$

Where  $L_v$  is the latent heat of vaporization such that

$$L_v = \frac{\Delta Q}{m}$$

### Unit:

The S.I unit of specific heat of vaporization is joule per kilogram which is expressed as  $\text{JKg}^{-1}$ . Different substances have different specific latent heat of vaporization.

**Q8: What is meant by evaporation? On what factors the evaporation of liquid depends. Explain how cooling is produced by evaporation. Differentiate between boiling and evaporation.**

**Ans: Evaporation of liquid:**

The process by which a liquid slowly changes into its vapors at any temperature (below its boiling point) without the aid of any external source of heat is called evaporation of liquids.

### Explanation:

Liquid starts to boil if they are heated to their boiling temperatures. The liquid starts to transform into vapors’ but the change of liquids into vapors goes on even when the temperature is below the boiling point. For example, a spread wet cloth on being exposed to the air becomes dry in a short time due to evaporation of water. Water left in open dish also disappears due to evaporation. We know that the molecules of a liquid move with wide of range of instantaneous velocities and they have different kinetic energies ranging from minimum to a very high value. Some of the molecules having sufficient kinetic energy to overcome the forces of attraction leave the surface of the liquid and escape out in the form of vapors. We call this escaping of high energy molecules as evaporation.



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### **Factors on which evaporation of liquid depends:**

Evaporation of liquids depends on the following factors.

**1. Nature of liquid:**

Liquid with low boiling points evaporates more rapidly than those with higher boiling points. For example, the rate of evaporation of alcohol is higher than that of water.

**2. Temperature of liquid:**

Due to higher temperature, molecules of liquid at the surface will have more kinetic energy and chances of escaping will increase and evaporation will be fast. This can be seen while ironing clothes. Under a hot iron wet clothes dry out quickly as the water evaporates quickly.

**3. Temperature of surrounding:**

The higher the temperature of the surrounding, the higher is the rate of evaporation. It is for this reason that wet clothes dry rapidly in summer than in winter.

**4. Presence of water vapor in Air:**

The more the amount of water vapor present in air, the less is the rate of evaporation. It is for this reason that wet clothes dry slowly in rainy season as a lot of water vapor are present in the air.

**5. Area of the exposed surface of liquid:**

Increased surface area gives the molecules a greater chance of escaping. Wet roads dry out quickly because the rain water is spread over large area.

**6. Movement of Air:**

The more rapid the flow of air the higher is the rate of evaporation. It is for this reason that wet clothes dry more rapid on a windy day compared on a calm day.

**7. Dryness of Air:**

Drier the air, the more rapid is the evaporation. Presence of water vapor reduces the rate of evaporation. Desert room coolers are more effective in cooling by evaporation in the dry month of June than it is in the humid month of August.

**8. Air Pressure on the surface of the liquid:**

The lower the pressure on the surface of the liquid, higher is the rate of evaporation.

### **Evaporation causes cooling:**

A liquid needs latent heat for its evaporation. If the liquid is not being heated by an external source, the heat required for evaporation of liquid must come from the liquid itself. Since the molecule is taking heat with it as its leaving, this has a cooling effect on the surface left behind. For example, spirit spilled on your palm quickly evaporates. As a result, your palm feels cold. You can feel the chilling effect of the evaporation of water if you sit under a fan and wearing wet clothes. Perspiration in a human body helps to cool the body and to maintain a stable body temperature. The kinetic theory explains the cooling caused by evaporation. During evaporation, more energetic molecules escape from the liquid surface. Molecules that remain in the liquid have lower kinetic energy. A liquid with molecules of less kinetic energy has a lower temperature. Thus evaporation produces cooling.



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### **Evaporation Vs Boiling:**

Vaporization of an element or compound is a phase transition from the liquid phase to vapor. There are two types of vaporization: evaporation and boiling.

#### **Evaporation:**

Evaporation is a phase change from the liquid phase to vapor that occurs at temperatures below the boiling temperature at a given pressure. Evaporation usually occurs on the surface.

#### **Boiling:**

Boiling is a phase transition from the liquid phase to gas phase that occurs at or above the boiling temperature as opposed to evaporation, occurs below the surface.

### **Some Important Questions**

**Q9: Define and explain heat?**

**Ans: Heat:**

Heat is a form of energy transferred from a hotter body to a colder body.

OR

The form of energy which is transferred from one body to another body due to the difference in temperature is called heat.

**Explanation:**

When two objects with different temperature are placed in thermal contact, the temperature of the warmer object decreases with the temperature of the cooler object increases. With time they reach a common equilibrium temperature somewhere in between their initial temperatures. During this process we say that energy is transferred from the warmer object to the cooler one. For example, water in a kettle can be heated by placing it on flame. The water gradually becomes warmer and eventually starts boiling. Something must have transferred from the hot flame to the cold water. This something which flows from hotter body to the colder body till the temperature of two bodies becomes equal is called heat. In general temperature of any object can be raised by placing it in thermal contact with another hotter object.

**Q10: Define and explain thermometric property?**

**Ans: Thermometric Property:**

The particular property of a substance that increases and decreases uniformly with temperature and can be used for the measurement of temperature is called thermometric property.

**Explanation:**

In order to construct a thermometer, we make use of a certain physical property of matter that increases or decreases uniformly with rise and fall in temperature. This particular property of substance is called thermometric property. The commonly used thermometric property is the thermal expansion of materials. This property makes use of the fact that matter (solid, liquid or gas) expands on heating and contracts on cooling. Thus, the degree of expansion or contraction of matter can be calibrated on suitable scale to record temperature. For example, mercury and alcohol are the substances which contain this property and therefore used in thermometer for the measurement of temperature.



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### Q11: Define and explain thermal expansion?

**Ans: Thermal Expansion:**

The increase in size of a substance on heating is called thermal expansion.

**Explanation:**

Most substances expand when heated and contract when cooled. However, the amount of expansions or contraction varies depending on the material, the change in temperature and the original size of the substance. Thermal expansion is different for different states e.g. solid, liquid or gas of the same substance. It is experienced that gases expand more than liquids and liquids expand more than solids.

**Thermal expansion of solids:**

A solid substance can undergo three types of expansion:

1. Expansion in length is known as linear thermal expansion. When a metal rod is heated it will expand in length, so it will be linear thermal expansion.
2. Expansion in area is known as superficial thermal expansion. When a metal sheet is heated, it will expand in length and breadth, so it will be superficial thermal expansion.
3. Expansion in volume is called volume or cubical thermal expansion. When a metal block is heated, it will expand its length, Breadth and height. So, it will be volume or cubical thermal expansion.

### Q12: Discuss practical applications of thermal expansion?

**Ans:** Following are a few applications of thermal expansion of solids.

**i. Railway lines:**

When railway tracks are laid, the engineers leave a small gap between two rails. If two railway tracks are laid together without any gap between them they will push against each other when they expand with the rise of temperature. This may cause them to bend or tracks may also break free from one another. Such a situation result in the derailment of the trains causing major accidents and loss of lives. So, the railway engineers always leave a small gap between two rails to compensate for the expansion of the rails during the not summer and contraction during cold winter.

**ii. Opening a tight jar lid:**

When the lid of a glass jar is too tight to open, holding the lid under hot water for a short time will often make it easier to open. The top expand before the heat reaches the bottle but even if not, metals generally expand more than glass for the same temperature change.

**iii. Transmission lines:**

Transmission lines in the summer sag more as compared to winter.

**iv. Shrink-fitting of axles into gear wheels:**

The axles have been shrunk by cooling in liquid nitrogen at  $-196^{\circ}\text{C}$  until the gear wheels can be slipped on to them. On regaining normal temperature, the axles expand to give a very tight fit.



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### v. **Expand fitting iron ring to a cart wheel:**

An iron ring can be tightly fixed into the wooden wheel of a Tonga. At room temperature, the diameter of the iron ring is slightly less than the diameter of the wooden wheel. The ring expands on heating and can be placed around the wooden wheel. When the ring comes to room temperature, it contracts and produces a tight fit.

### vi. **Expansion joints:**

Most large bridges include expansion joints, which look rather like two metal combs facing one another, their teeth interlocking. When heat causes the bridge to expand during the sunlight hours of a hot day, the two sides of the expansion joint move toward one another; then as the bridge cool down after dark they being gradually to retract. Thus, the bridge has a built-in safety zone; otherwise, it would have no room for expansion or contraction in response to temperature changes.

### vii. **Bimetallic strip:**

A Bimetallic strip is used to convert a temperature change into mechanical displacement. The strip consists of two strips of different rates as they are heated. When their temperature increases, the unequal amounts of expansion cause the bimetallic strip to bend. For example, if equal length of two different metals such as copper and iron are riveted together so that they cannot move separately, they form a bimetallic strip. When heated, copper expands more than iron and to allow the strip bends with copper on the outside. Bimetal strips have many uses, like fire alarm and thermostat.

### **Q13: Explain the anomalous expansion of water?**

#### **Ans: Anomalous expansion of water:**

Liquids expand on heating except water between 0°C and 4°C. Water is unusual in its expansion characteristics. When water at 0°C is heated, its volume decreases up to 4°C and from 4°C, its volume increases with the increase of temperature. This peculiar behavior of water is called anomalous expansion of water. Due to the formation of more number of hydrogen bonds, water has anomalous expansion. As the temperature increases from 0°C to 4°C, the density increases and as the temperature further increases, the density decreases. Hence water has maximum density at 4°C. This is why ice floats on water we can see this when we put ice cubes in water to cool it or icebergs floating in ocean.

### **Q14: Explain latent heat and phase change?**

#### **Ans: Latent Heat:**

The heat required to change the physical state of a substance (solid into a liquid or vapour, or a liquid into a vapour) but does not change its temperature is called latent heat of that substance.

#### **Explanation:**

A substance usually undergoes a change in temperature with transfer of energy (heat). In some cases, however the transfer of energy doesn't result in a change in temperature. This can occur when the physical characteristics of the substance change from one from to another, commonly referred to as a phase change. Some common phase changes are solid to (melting),

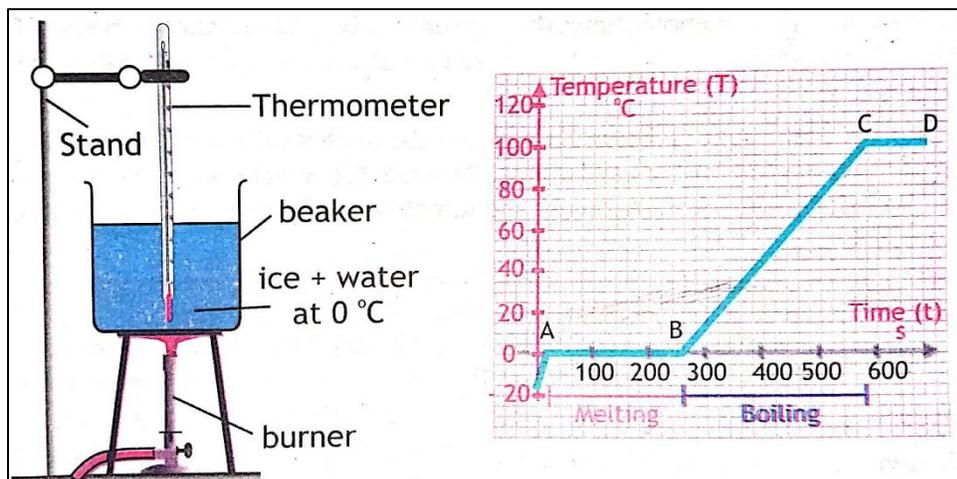
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liquid to gas (boiling), liquid to solid (freezing) and gas to liquid (condensation). Energy used to cause a phase change does not cause a temperature change. When ice melts at  $0^{\circ}\text{C}$  it becomes water at  $0^{\circ}\text{C}$ , when water boils at  $100^{\circ}\text{C}$ , it becomes steam at  $100^{\circ}\text{C}$ . The same is true in reverse, when water at  $0^{\circ}\text{C}$  freezes it becomes ice at  $0^{\circ}\text{C}$ , when steam at  $100^{\circ}\text{C}$  condenses it becomes water at  $100^{\circ}\text{C}$ .

**Q15: Explain experiment for ice-water phase change and temperature-time graph on heating ice?**

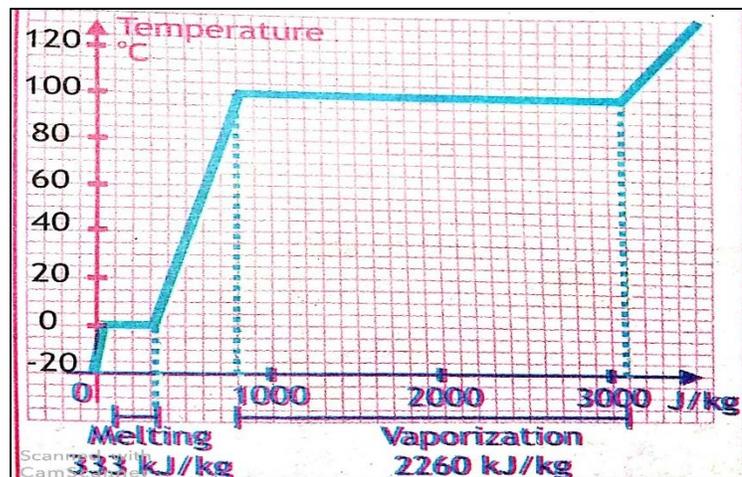
**Ans: Experiment for ice-water phase change:**

Take a beaker and place it over a stand. Put small pieces of ice in the beaker and suspend a thermometer in the beaker to measure the temperature. Place a burner under the beaker. The ice will start melting. The temperature of the mixture containing ice and water will not increase above  $0^{\circ}\text{C}$  until all the ice melts. Note the time which the ice takes to melt completely in to water at  $0^{\circ}\text{C}$ . Continue heating the water at  $0^{\circ}\text{C}$  in the beaker. Its temperature will start to increase. Note the time which the water in the beaker takes to reach its boiling point at  $100^{\circ}\text{C}$ .



**Explanation of temperature-time graph on heating ice:**

From the graph we can see that at curve "AB" even we were providing heat to the ice water mixture but the temperature remained constant at  $0^{\circ}\text{C}$ . At point B, all the ice has melted to form water. Now, on heating beyond point "B", the temperature of water started rising as shown by the slope line "BC" in the graph. Since the heat absorbed during the change of state of a substance does not raise its temperature, it is called latent heat or hidden heat. The graph also shows when water is boiling and changing into



steam.



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steam, the temperature remains constant at 100°C through heat is being given continuously to water. This heat which is going into water but not increasing its temperature is the energy required to convert the water from the liquid state to the vapour state. Since this heat does not show its presence by producing a rise in temperature, it is called latent heat of vaporization of water.

### **Q16: Discuss the applications of cooling by evaporation:**

**Ans: Applications of cooling by evaporation:**

**i. Cooling by Fans:**

We use fans in the hot season because the moving air increases the rate of evaporation or perspiration from our bodies. Hence we get a cooling sensation. As discussed earlier, perspiration helps in cooling the body and regulating its temperature.

**ii. Fever Control:**

Wet towel is applied on the forehead of a person running high fever. It is because, as the water evaporates, it takes heat from the head. Thus the temperature of the head remains within the safe limits and the patient does not suffer any brain damage.

**iii. Refrigerator:**

The cooling effect in many refrigerators is produced by the evaporation of a volatile liquid called Freon. The liquid Freon evaporates in the pipes of freezer compartment. As the Freon evaporates, it draws the necessary latent heat from the food inside the refrigerators.

### **Q17: What is refrigerator? Discuss its principle, construction and working?**

**Ans: Refrigerator:**

It is a device which produces cooling effect and thus the food items kept inside it remain in safe conditions.

**Working principle:**

The working principle of refrigerator is evaporation and compression.

**Construction:**

There are six parts of a refrigerator.

**a. Heat exchanging pipes:**

These coils are present on the inside and the outside of the fridge, they carry the refrigerant from one part of the fridge to another.

**b. Refrigerant:**

This is the substance which evaporates in the fridge causing freezing temperatures.

**c. Expansion Valve:**

The expansion valve which is made up of a thin copper coil reduces the pressure on the liquid refrigerant.

**d. Compressor:**

A compressor is a metal object which compresses the refrigerant thus raising the pressure and in turn the temperature of the gas.

**e. Condenser:**

A condenser condenses, that is, it converts the refrigerant into liquid form, reducing its temperature.



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### f. **Evaporator:**

An evaporator absorbs the heat in the refrigerator with assistance of the evaporating liquid refrigerant.

### **Working:**

Refrigerator has a pipe that is partly inside a refrigerator and partly outside it, and sealed so it is a continuous loop. The pipe is filled with a refrigerant. Inside the refrigerator, we make the pipe gradually get wider, so the refrigerant expands and cools as it flowed through it. Outside the refrigerator, we have a pump (compressor) to compress the gas and release its heat. As the gas flow round and round the loop, expanding when it is inside the refrigerator and compressing when it is outside, it constantly picks up heat from the inside and carry it to the outside.

## **CONCEPTUAL QUESTIONS**

**Q1: Ordinary electric fan increases the kinetic energy of the air molecules caused by the fan blades pushing them means the air temperature increase slightly rather than cool the air?**

**Why use it.**

**Ans.** For cooling, we usually use electric fans. But the electric fan does not actually cool the air inside the room. It increases the kinetic energy of air molecules due to which the temperature of molecules increases. Such high speed molecules touch our body and evaporate water molecules from our body. The evaporated water molecules absorb heat of vaporization from our body and as a result we feel cool.

**Q2: Why are small gap left behind the girders mounted in walls?**

**Ans:** Small gaps are left behind the girders mounted in walls because to allow for the expansion of the girders during summer usually one end of the iron structure is fixed and the other end is allowed to expand in summer into the left out gap. If there is no gap left, then the expansion will cause the girders to buckle.

**Q3: Why you should not put a closed glass jar into a campfire. What could happen if you tossed an empty glass jar, with the lid on tight, into a fire?**

**Ans:** When we put a closed glass jar into a campfire, the inside of the glass jar is not empty. It is filled with air. As the fire heats the air inside, its temperature rises and as a result the pressure inside the jar increases. Due to high internal pressure the jar may explode and turn into pieces. Also if we tossed an empty glass jar into a fire, then due to high internal pressure in jar may cause it crack. So we should not throw a close glass jar into a campfire.

**Q4: Explain why it is advisable to add water to an overheated automobile engine only slowly, and only with the engine running.**

**Ans:** It is advisable to add water to an overheated automobile engine slowly and only with the engine running it is because if we add water quickly to an overheated engine, water will come into contact with the hot metal part of the engine. Some area of metal part will cool down very rapidly,



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while other part will not. Some part of the water will quickly turn to steam and will rapidly expand which can result a cracked engine block or radiator.

**Q5: Explain why burns caused by steam at 100 °C on the skin are often more severe than burns caused by water at 100 °C.**

**Ans:** When the temperature of water rises at 100°C, water is converted to steam. At this point the temperature remains constant. Although heat is being given to water. Heat equal to latent heat of vaporization i.e.  $2.26 \times 10^6 \text{ J Kg}^{-1} \text{ K}^{-1}$  is added to steam. The steam while leaving the container carries this extra amount of heat which produces more severe burns as compared to water at 100°C.

**Q6: Explain why cities like Karachi situated by the ocean tend to have less extreme temperatures than inland cities at the same latitude.**

**Ans:** Coastal areas like Karachi have moderate temperature than inland areas because of the high specific heat capacity of water of the sea. During the day, the sun shines equally on land and sea. The land heats up more quickly than the sea because of high specific heat of water. The hot air over the land rises and the cold air from the sea blows to replace it. Thus there is a sea breeze during the day. At night the reverse occurs, the land cools more quickly than the sea because the sea water has absorbed a huge quantity of heat throughout the day. So the hot air over the sea rises and cool air from the land blows to replace it. Thus, there is a land breeze during the night. So the temperature of coastal area like Karachi remains at moderate level i.e. not too hot in summer and not too cold in winter than inland cities at the same latitude.

**Q7: An iron rim which is fixed around a wooden wheel is heated before its fixture. Explain why?**

**Ans:** An iron rim which is fixed around a wooden wheel is heated before its fixture because at room temperature the diameter of the iron rim is made slightly less than the diameter of wooden wheel. The rim expands on heating and can be placed around wooden wheel. When the rim comes to room temperature, it contracts and produces tight fit.

**Q8: Why is ice at 0°C a better coolant of soft drink than water at 0 °C?**

**Ans:** The ice when absorb heat, it melts. During melting the temperature of ice remains constant at 0°C. When the ice is put in the soft drink, it absorbs heat from the drink. So, its temperature falls and become cool. But in case of water at 0°C when it absorbs heat its temperature rises. Therefore, ice is the better coolant than water at 0°C.

**Q9: Why we feel cool after perspiration?**

**Ans:** We feel cool after perspiration because for evaporation there is need of heat energy. When the sweat drops evaporate from our body it absorbs heat from our body and as a result we feel cool due to decrease in temperature of our body.



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**ASSIGNMENTS**

**8.1: Temperature of an object is 250 K, Find its temperature in centigrade.**

**Data:**

$$T_k = 250 \text{ K}$$

**Find:**

$$T^{\circ}\text{C} = ?$$

**Solution:**

**As we know that**

$$T^{\circ}\text{C} = T_K - 273$$

**Putting values**

$$T_C = 250 - 273$$

$$T_C = -23^{\circ}\text{C}$$

**8.2: The length of a bar of certain metal is 60 cm. When the bar is heated from 8°C to 100 °C, its length becomes 60.127 cm. Calculate the coefficient of linear thermal expansion of the metal.**

**Data:**

Initial length of bar =  $l_o = 60\text{cm}$

$$= \frac{60}{100}\text{m}$$

$$= 0.6 \text{ m}$$

Final length of bar =  $l_T = 60.127 \text{ cm}$

$$= \frac{60.127 \text{ m}}{100}$$

$$= 0.60127 \text{ m}$$

Change in length =  $\Delta l = l_L - l_o$

$$= (0.60127 - 0.60) \text{ m}$$

$$= 0.00127 \text{ m}$$

Initial temperature =  $T_o = 8^{\circ}\text{C}$

Final temperature =  $T = 100^{\circ}\text{C}$

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

$$= 100^{\circ}\text{C} - 8^{\circ}\text{C}$$

$$= 92^{\circ}\text{C}$$

**Find:**

Co-efficient of linear thermal expansion =  $\alpha = ?$

**Solution:**

We know that

$$\alpha = \frac{\Delta l}{l_o \Delta T}$$

Putting values

$$\alpha = \frac{0.00127}{0.6 \times 92}$$

$$= \frac{0.00127}{55.2}$$



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$$\alpha = 0.000023$$

$$\alpha = 2.3 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$$

**Or**

**Data:**

Initial length of bar =  $l_0 = 60 \text{ cm}$

Final length of bar =  $l_T = 60.127 \text{ cm}$

Change in length =  $\Delta l = l_T - l_0$   
=  $(60.127 - 60) \text{ cm}$   
=  $0.127 \text{ cm}$

Initial temperature =  $T_0 = 8 \text{ }^\circ\text{C}$

Final Temperature =  $T = 100 \text{ }^\circ\text{C}$

Change in temperature =  $\Delta T = T - T_0$   
=  $100 \text{ }^\circ\text{C} - 8 \text{ }^\circ\text{C}$   
=  $92 \text{ }^\circ\text{C}$

**Find:**

Co-efficient of linear thermal expansion =  $\alpha = ?$

**Solution:**

We know that

$$\alpha = \frac{\Delta l}{l_0 \Delta T}$$

Putting value

$$\alpha = \frac{0.127}{60 \times 92}$$

$$\alpha = \frac{0.127}{5520}$$

$$\alpha = 0.000023$$

$$\alpha = 2.3 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$$

**8.3: A  $200 \text{ cm}^3$  piece of lead ( $\gamma = 87 \times 10^{-6} \text{ K}^{-1}$ ) is at  $10 \text{ }^\circ\text{C}$ . If it is heated to a temperature of  $40 \text{ }^\circ\text{C}$ , find the change in volume of the lead.**

**Data:**

Initial volume =  $V_0 = 200 \text{ cm}^3$

Initial temperature =  $T_0 = 10 \text{ }^\circ\text{C}$

Final temperature =  $T = 40 \text{ }^\circ\text{C}$

Change in temperature =  $\Delta T = T - T_0$   
=  $40 \text{ }^\circ\text{C} - 10 \text{ }^\circ\text{C}$   
=  $30 \text{ }^\circ\text{C}$   
=  $30 \text{ K}$

Coefficient of volume thermal expansion =  $\gamma = 87 \times 10^{-6} \text{ K}^{-1}$

**Find:**

Change in volume =  $\Delta V = ?$

**Solution:**

We know that

$$\Delta V = \gamma V_0 \Delta T$$



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Putting value

$$\begin{aligned} \Delta V &= 87 \times 10^{-6} \times 200 \times 30 \\ \Delta V &= 522000 \times 10^{-6} \\ &= 0.522 \times 10^6 \times 10^{-6} \\ &= 0.522 \times 10^{6-6} \\ &= 0.522 \times 10^0 \\ \Delta V &= \mathbf{0.522 \text{ cm}^3} \end{aligned}$$

**8.4: If petrol at 0°C occupies 250 liters. What is its volume at 50°C? For petrol take  $\gamma = 9.6 \times 10^{-4} \text{ K}^{-1}$ .**

**Data:**

- Initial volume =  $V_o = 250$  liters
- Initial temperature =  $T_o = 0$  °C
- Final Temperature =  $T = 50$  °C
- Change in temperature =  $\Delta T = T - T_o$   
 $= 50$  °C -  $0$ °C  
 $= 50$  °C  
 $= 50$  K

Coefficient of volume thermal expansion =  $\gamma = 9.6 \times 10^{-4} \text{ K}^{-1}$

**Find:**

Final volume =  $V_T = ?$

**Solution:**

As we know that

$$V_T = V_o (1 + \gamma \Delta T)$$

Putting values

$$\begin{aligned} V_T &= 250 (1 + 9.6 \times 10^{-4} \times 50) \\ &= 250 (1 + 480 \times 10^{-4}) \\ &= 250 (1 + 0.0480) \text{ liters} \\ &= 250 (1.0480) \text{ liters} \\ V_T &= \mathbf{262 \text{ liters}} \end{aligned}$$

**8.5: If 117.60 J of heat is required to raise the temperature of 10g of silver through 50 °C. Calculate the specific heat of silver.**

**Data:**

- Heat required =  $\Delta Q = 117.60$  J
- Mass =  $m = 10$ g  
 $= \frac{10}{1000}$ kg (1 Kg = 1000g)  
 $= 0.01$  Kg
- Rise in temperature =  $\Delta T = 50$ °C

**Find:**

Specific heat of silver =  $c = ?$



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**Solution:**

We know that

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

Putting values

$$c = \frac{117.6}{0.01 \times 50} \text{ JKg}^{-1} \text{ K}^{-1}$$

$$= \frac{117.60}{0.5} \text{ JKg}^{-1} \text{ K}^{-1}$$

$$c = 235.2 \text{ J Kg}^{-1} \text{ K}^{-1}$$

**8.6 Find the amount of heat for evaporating 2.8 kg of water at 45°C? (Latent heat of vaporization of water  $L_v = 2.3 \times 10^6 \text{ J/Kg}$  and specific heat of water  $c = 4190 \text{ J Kg}^{-1} \text{ K}^{-1}$ .)**

**Data:**

Mass of water =  $m = 2.8 \text{ Kg}$

Latent heat of vaporization for water =  $L_v = 2.3 \times 10^6 \text{ J Kg}^{-1}$

Specific heat of water =  $C = 4190 \text{ J Kg}^{-1} \text{ K}^{-1}$

Initial temperature =  $T_o = 45 \text{ }^\circ\text{C}$

Final temperature =  $T = 100 \text{ }^\circ\text{C}$

Change in temperature =  $\Delta T = T - T_o$   
=  $100 - 45 = 55 \text{ }^\circ\text{C}$

**Find:**

Heat required =  $\Delta Q = ?$

**Solution:**

Heat required by water at 45 °C to attain the temperature of 100 °C

$$\Delta Q_1 = c m \Delta T$$

Putting the value

$$\Delta Q_1 = 4190 \times 2.8 \times 55$$

$$= 645260 \text{ J}$$

$$\Delta Q_1 = 0.65 \times 10^6 \text{ J}$$

Now we will find heat required for vaporization of water at 100 °C

$$\Delta Q_2 = mL_v$$

Putting values

$$= 2.8 \times 2.3 \times 10^6$$

$$\Delta Q_2 = 6.44 \times 10^6 \text{ J}$$

Amount of heat required for evaporation of water at 45 °C

$$\Delta Q = \Delta Q_1 + \Delta Q_2$$

$$= 0.65 \times 10^6 \text{ J} + 6.44 \times 10^6 \text{ J}$$

$$= (0.65 + 6.44) \times 10^6 \text{ J}$$

$$\Delta Q = 7.09 \times 10^6 \text{ J}$$

$$\Delta Q = 7.1 \times 10^6 \text{ J}$$



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**NUMERICAL QUESTIONS**

1. Perform the temperature conversions

a). Temperature difference in the body. The surface temperature of the body is normally about 7 °C lower than the internal temperature. Express this temperature difference in kelvins and in Fahrenheit degrees.

b). Blood storage. Blood stored at 4.0°C lasts safely for about 3 weeks, whereas blood stored at -160 °C lasts for 5 years. Express both temperatures on the Fahrenheit and Kelvin scales.

a). **Data:**

Temperature in °C =  $T_{1^{\circ}\text{C}} = 37\text{ }^{\circ}\text{C}$

Temperature in °C =  $T_{2^{\circ}\text{C}} = 37 - 7$   
 $= 30\text{ }^{\circ}\text{C}$

**Find:**

Temperature difference in kelvin =  $(\Delta T)_K = ?$

Temperature difference in Fahrenheit =  $(\Delta T)_F = ?$

**Solution:**

To find  $(\Delta T)_K$ , we first convert  $T_{1^{\circ}\text{C}}$  and  $T_{2^{\circ}\text{C}}$  in Kelvin.

So,

$T_{1K} = 37\text{ }^{\circ}\text{C}$

We know that

$T_{1K} = T_{1^{\circ}\text{C}} + 273$

Putting values

$T_{1K} = 37 + 273$

**$T_{1K} = 310\text{ K.}$**

And

$T_{2^{\circ}\text{C}} = 30\text{ }^{\circ}\text{C}$

We know that

$T_{2K} = T_{2^{\circ}\text{C}} + 273$

Putting value

$= 30 + 273$

**$T_{2K} = 303\text{ K}$**

Now

$(\Delta T)_K = T_{1K} - T_{2K}$

Putting value

$= (310 - 303)\text{ K}$

**$(\Delta T)_K = 7\text{ K}$**

To find  $(\Delta T)_F$  we first convert  $t_{1C}$  and  $T_{2C}$  in Fahrenheit.

So,

$T_{1C} = 37\text{ }^{\circ}\text{C}$

We know that

$T_{1F} = \frac{9}{5} T_{1C} + 32$

Putting value

$= \frac{9}{5} (37) + 32$

$= \frac{333}{5} + 32$

$= 66.6 + 32$

**$T_{1F} = 98.6\text{ }^{\circ}\text{F}$**



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And

$$T_{2C} = 30 \text{ }^\circ\text{C}$$

We know that

$$T_{2F} = \frac{9}{5} T_{2c} + 32$$

Putting value

$$\begin{aligned} T_{2F} &= \frac{9}{5} (30) + 32 \\ &= 9 \times 6 + 32 \\ &= 54 + 32 \end{aligned}$$

$$T_{2F} = 86 \text{ }^\circ\text{F}$$

Now

$$\begin{aligned} (\Delta T)_F &= T_{1F} - T_{2F} \\ &= 98.6 \text{ }^\circ\text{F} - 86 \text{ }^\circ\text{F} \end{aligned}$$

$$(\Delta T)_F = 12.6 \text{ }^\circ\text{F}$$

$$(\Delta T)_F = 13 \text{ }^\circ\text{F}$$

b). **Data:**

(i) Temperature in  $^\circ\text{C} = T_{1C} = 4 \text{ }^\circ\text{C}$

(ii) Temperature in  $^\circ\text{C} = T_{2C} = -160 \text{ }^\circ\text{C}$

**Required:**

(i)  $T_{1k} = ?$

$$T_{1F} = ?$$

(ii)  $T_{2k} = ?$

$$T_{2F} = ?$$

**Solution:**

(i) Temperature in  $^\circ\text{C} = T_{1c} = 4 \text{ }^\circ\text{C}$

Now to convert  $T_{1C}$  in  $T_{1k}$  and  $T_{1F}$

For  $T_{1C} = 4 \text{ }^\circ\text{C}$

We know that  $T_{1k} = T_{1c} + 273$

Putting value  $= 4 + 273$

$$T_{1k} = 277 \text{ K}$$

For  $T_{1C} = 4 \text{ }^\circ\text{C}$  We have

We know that

$$T_{1F} = \frac{9}{5} T_{1C} + 32$$

Putting value of  $T_{1C}$

$$T_{1F} = \frac{9}{5} (4 + 32)$$

$$= \frac{36}{5} + 32$$

$$T_{1F} = 7.2 + 32$$

$$T_{1F} = 39.2 \text{ }^\circ\text{F}$$

(ii) Temperature in  $^\circ\text{C} = T_{2C} = -160 \text{ }^\circ\text{C}$

We have to convert  $T_{2C}$  in  $T_{2k}$  and  $T_{2F}$

$$T_{2C} = -160 \text{ }^\circ\text{C}$$



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We know that  $T_{2k} = T_{2C} + 273$

Putting value

$$= -160 + 273$$

$$T_{2k} = 113 \text{ K}$$

For  $T_{2C} = -160 \text{ }^\circ\text{C}$

We know that  $T_{2F} = \frac{9}{5} T_{2c} + 32$

$$= \frac{9}{5} (-160) + 32$$

$$= 9 (-32) + 32$$

$$T_{2F} = -288 + 32$$

$$T_{2F} = -256 \text{ }^\circ\text{F}$$

**2. Consider a meter – stick composed of platinum (the coefficient of linear expansion for platinum is  $\alpha = 8.8 \times 10^{-6} \text{ K}^{-1}$ ). By what amount does the length of this meter – stick change if the temperature increases by 1.0 K?**

**Data:**

Length of meter - stick  $= L_o = 1\text{m}$

Coefficient of linear thermal expansion  $= \alpha = 8.8 \times 10^{-6} \text{ K}^{-1}$

Change in temperature  $= \Delta T = 1.0 \text{ K}$

**Find:**

Change in length  $= \Delta L = ?$

**Solution:**

We know that

$$\Delta L = \alpha l_o \Delta T$$

Putting values

$$\Delta L = 8.8 \times 10^{-6} \times 1 \times 1.0$$

$$\Delta L = 8.8 \times 10^{-6} \text{ m}$$

**3. A railway line made of iron is 1200 km long and is laid at 25 °C. By how much will it contract in winter when the temperature falls to 15 °C? By how much will it expand when the temperature rises to 40 °C in summer? (the coefficient of linear expansion for iron is  $\alpha = 12 \times 10^{-6} \text{ K}^{-1}$ ).**

**Data:**

Length of railway line  $= L_o = 1200 \text{ km}$

$$= 1200 \times 1000 \text{ m} \quad (1\text{km} = 1000 \text{ m})$$

$$= 1200000 \text{ m}$$

Initial temperature  $= T = 25 \text{ }^\circ\text{C}$

Temperature in winter  $= T_w = 15 \text{ }^\circ\text{C}$

Temperature difference  $= \Delta T = 25^\circ - 15^\circ$

$$= 10 \text{ }^\circ\text{C}$$

Temperature in summer  $= T_s = 40 \text{ }^\circ\text{C}$

Temperature difference  $= \Delta T = 40 - 25$



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= 15 °C

Coefficient of linear thermal expansion =  $\alpha = 12 \times 10^{-6} \text{ K}^{-1}$

**Find:**

Length in winter =  $L_w = ?$

Length in summer =  $L_s = ?$

**Solution:**

In winter

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

Putting values

$$L_w = 1200000 (1 + 12 \times 10^{-6} \times 10)$$

$$= 1200000 (1 + 120 \times 10^{-6})$$

$$L_w = 1200000 (1 + 0.000120)$$

$$= 1200000 (1.00012) \text{ m}$$

$$L_w = \mathbf{1200144 \text{ m}}$$

So,

$$\Delta L = L_w - L_o$$

$$= 1200144 - 1200000$$

$$\Delta L = \mathbf{144 \text{ m}}$$

**In summer:**

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

Putting values

$$L_s = 1200000 (1 + 12 \times 10^{-6} \times 15)$$

$$= 1200000 (1 + 180 \times 10^{-6})$$

$$= 1200000 (1.000180)$$

$$L_s = 1200000 (1.00018) \text{ m}$$

$$L_s = \mathbf{1200216 \text{ m}}$$

So,

$$\Delta L = L_s - L_o$$

$$= 1200216 - 1200000$$

$$\Delta L = \mathbf{216 \text{ m}}$$

**4. The volume of a brass ball is 800 cm<sup>3</sup> at 20 °C. Find out the new volume of the ball if the temperature is raised to 52 °C. The coefficient of volumetric expansion of brass is 57 x 10<sup>-6</sup> K<sup>-1</sup>.**

**Data:**

Initial Volume of brass =  $V_o = 800 \text{ cm}^3$

Initial temperature =  $T_o = 20 \text{ °C}$

Final temperature =  $T = 52 \text{ °C}$

Coefficient of volumetric expansion of brass =  $r = 57 \times 10^{-6} \text{ K}^{-1}$

Temperature difference =  $\Delta T = T - T_o$

$$= 52 \text{ °C} - 20 \text{ °C}$$

$$= 32 \text{ °C}$$

**Find:**

Final volume of brass =  $V_T = ?$



**Solution:**

Using formula

$$V_T = V_o (1 + \gamma \Delta T)$$

Putting value

$$\begin{aligned} V &= 800 (1 + 57 \times 10^{-6} \times 32) \\ &= 800 (1 + 1824 \times 10^{-6}) \\ &= 800 (1 + 0.001824) \\ &= 800 (1.001824) \text{ cm}^3 \\ V &= 801.459 \text{ cm}^3 \end{aligned}$$

Or

$$V = 801.5 \text{ cm}^3$$

**5. What is the specific heat of a metal substance of 135 KJ of heat is needed to raise 4.1 Kg of the metal from 18.0 °C to 37.2 °C?**

**Data:**

$$\begin{aligned} \text{Heat supplied} &= \Delta Q = 135 \text{ KJ} \\ &= 135 \times 10^3 \text{ J} \end{aligned}$$

$$= 135000 \text{ J}$$

$$\text{Initial temperature} = T_o = 18 \text{ }^\circ\text{C}$$

$$\text{Final temperature} = T = 37.2 \text{ }^\circ\text{C}$$

$$\begin{aligned} \text{Change in temperature} &= \Delta T = T - T_o \\ &= 37.2 \text{ }^\circ\text{C} - 18 \text{ }^\circ\text{C} \end{aligned}$$

$$\Delta T = 19.2 \text{ }^\circ\text{C}$$

Or

$$\Delta T = 19.2 \text{ K}$$

$$\text{Mass of metal} = m = 4.1 \text{ Kg}$$

**Find:**

$$\text{Specific heat of metal} = c = ?$$

**Solution:**

We know that

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

Putting values

$$\begin{aligned} c &= \frac{135000}{4.1 \times 19.2} \\ &= \frac{135000}{78.72} \\ c &= 1714.93 \text{ J Kg}^{-1} \text{ K}^{-1} \end{aligned}$$

Or

$$c = 1715 \text{ J Kg}^{-1} \text{ K}^{-1}$$



### Chapter # 8

6. How much heat is needed to melt 23.50 Kg of silver that is initially at 25 °C? (Specific heat of silver is  $C = 230 \text{ J Kg}^{-1} \text{ K}^{-1}$ . Latent heat of fusion for silver is  $L_F = 8.82 \text{ K } 10^4$ )

**Data:**

Mass of silver =  $m = 23.50 \text{ Kg}$

Specific heat of silver =  $c = 230 \text{ J Kg}^{-1} \text{ K}^{-1}$

Latent heat of fusion for silver =  $L_F = 8.82 \times 10^4 \text{ J Kg}^{-1}$

Initial temperature =  $T_o = 25 \text{ }^\circ\text{C}$

Final temperature or melting point of silver =  $T = 961 \text{ }^\circ\text{C}$

Change in temperature =  $\Delta T = T - T_o$   
 $= 961 \text{ }^\circ\text{C} - 25 \text{ }^\circ\text{C}$

$$\Delta T = 936 \text{ }^\circ\text{C}$$

Or

$$\Delta T = 936 \text{ K}$$

**Find:**

Heat required =  $\Delta Q = ?$

**Solution:**

Heat required to raise the temperature of silver from 25 °C to 961 °C

$$\Delta Q_1 = mc\Delta T$$

Putting values

$$\Delta Q_1 = 23.50 \times 230 \times 936 \text{ J}$$
$$= 5059080 \text{ J}$$

$$\Delta Q_1 = 5.059080 \times 10^6 \text{ J}$$

Heat required to melt silver

$$\Delta Q_2 = mL_F$$

Putting values

$$\Delta Q_2 = 23.50 \times 8.82 \times 10^4 \text{ J}$$
$$\Delta Q_2 = 207.27 \times 10^4 \text{ J}$$

$$= 2.0727 \times 10^2 \times 10^4 \text{ J}$$

$$= 2.0727 \times 10^{2+4} \text{ J}$$

$$\Delta Q_2 = 2.0727 \times 10^6 \text{ J}$$

Heat required to melt silver at 25 °C

$$\Delta Q = \Delta Q_1 + \Delta Q_2$$

$$= 5.059080 \times 10^6 + 2.0727 \times 10^6$$

$$= (5.059080 + 2.0727) \times 10^6 \text{ J}$$

$$\Delta Q = 7.13178 \times 10^6 \text{ J}$$

$$\Delta Q = 7.1 \times 10^6 \text{ J}$$