Chapter = 08

THERMAL PROPERTIES OF MATTER

TEMPERATURE

Definition:- The degree of hotness or coldness of a body is known as temperature. OR
The average kinetic energy of molecules of a body is known as temperature.

Symbol:- It is denoted by "**T**".

Unit:- Its **SI** unit is **Kelvin**(K).

Other Units:- Its other units are

(i) Centigrade

(ii) Fahrenheit.

Quantity:- It is a **scalar** quantity.

Nature: - It is a **base** quantity.

Measurement:- It is measured with the help of **thermometer**.

Note:- Basically temperature is measure how hot or cold a body .

HEAT

Definition:- Something which enter from hotter body towards cold body is called heat OR .
It is a form of thermal energy which always flows from hotter body towards cold body up to thermal equilibrium. OR
According to kinetic molecular theory it is defined as **" The total kinetic energy of molecules of a body is known as called heat ".**

Symbol:- It is denoted by **"Q".**

Unit:- Its SI unit is Joule which is represented by **"J".**

Quantity:- It is a **scalar** quantity.

Nature:- It is a **derived** physical quantity.

Measurement:- It is measured with the help of **Calorimeter**.

EXPLANATION:-If we take some water in a kettle and place it on fire .After some time water become hot and start boiling. Because something enter from fire into water this thing is heat .Which make it hotter and then boiled.

DIFFERENCE BETWEEN TEMPERATURE AND HEAT

TEMPERATURE	HEAT
It is the average K.E of molecules of a body	It is the total K.E of molecules of a body
It is denoted by "T".	It is denoted by "Q".
Its SI unit is Kelvin.	Its SI unit is Joule.
It is measured with the help of thermometer.	It is measured with the help of **Calorimeter.**
It is a base quantity.	It is a derived quantity.
Its other units are (i) Centigrade (ii) Fahrenheit.	Its other unit is Calories.
Rises when heated and falls when cooled.	It flows from hot body to cold body.

INTERNAL ENERGY

Definition: -

The sum of all forms of molecular energies is known as internal energy. OR

The total energy present in a system is called internal energy. OR

It is the sum of kinetic and potential energies related with random motion of a substance.

Other Names:- It is also called Thermal Energy.

Symbol: - It is represented as by "**U**".

Quantity:-It is a **scalar** quantity.

Unit: - Its SI unit is **Joule**.

Other units:- Its other unit is **Calories**.

Factors of Internal Energy:- The internal energy of a body depends upon various factors which are given below.

(i) Mass of the body.

(ii) Kinetic energies of the molecules.

(iii) Potential energies of the molecules.

INTERNAL ENERGY AND TEMPERATURE

Internal energy is directly related with temperature i.e greater the temperature of a system greater will be its internal energy i.e the internal energy of a hotter body is greater than the internal energy of a colder body.

TEMPERATURE	INTERNAL ENERGY
It is the average K.E of molecules of a body.	It is the sum of all forms of molecular energies.
It is denoted by "**T**".	It is denoted by **"U".**
Its SI unit is **Kelvin**.	Its SI unit is **Joule**.
It is a **base** quantity.	It is a **derived** quantity.

MEASUREMENT OF TEMPERATURE

THERMOMETRY

Definition:-The branch of physics which deal with the measurement of temperature is known as thermometry.

Thermometer:-The device with the help of which the temperature is measured is called thermometer.

Explanation:- We can also measure temperature in a simple way by touching to feel its hotness or coldness. But this mechanism did not measure temperature correctly.

THERMOMETRIC PROPERTY:-

Definition:-Those properties of a substance that increase or decrease uniformly with temperature and can be used for the measurement of temperature is called thermometric property.

Examples:-

(i) Change in volume of a liquid .
(ii) Change in length of solid.
(iii) Change in gas pressure.
(iv) Change in electric resistance.
(v) Change in colour of a substance etc.

Commonly used thermometric property is the thermal expansion of materials.

THERMAL EXPANSION OF MATERIALS

All material expand on heating and contract on cooling. Thus the degree of expansion or contraction of matter can be calibrated on suitable scale to record temperature. The most common of these devices in the liquid in glass thermometer. Due to change in temperature volume of the liquid changes means that increase in temperature liquid expand.

TEMPERATURE SCALES

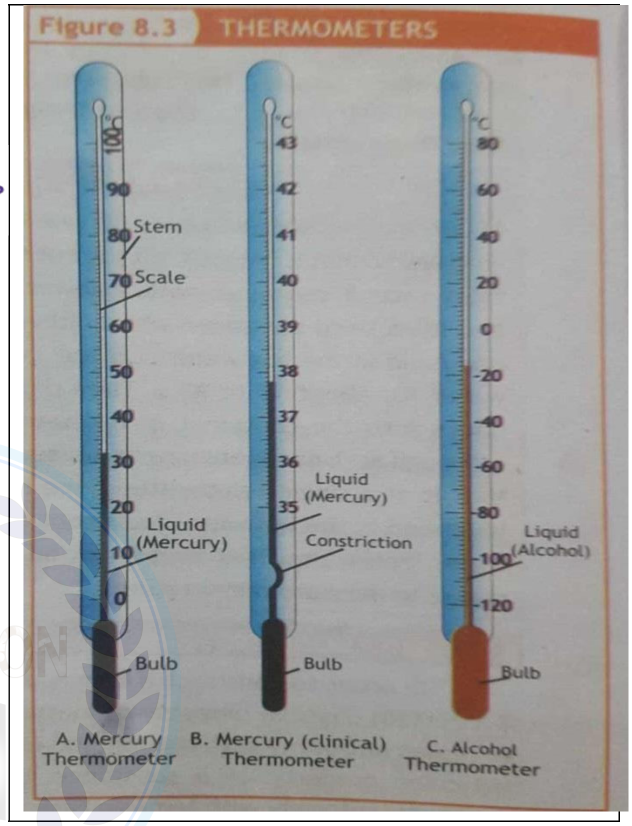
Definition:-The scale which is made for the measurement of temperature is called temperature scale.

Other Name:- These scales are also called thermometric scale.

Explanation:-These scales comprises of two reference points called fixed points. These points are given arbitrarily assigned numerical values. They must be reproducible. The interval between these two fixed points are divided arbitrarily in equal divisions.

Types of temperature scales:- There are three scales of temperature which are given below.

(1) Centigrade Scale .
(2) Fahrenheit Scale.
(3) Kelvin Scale.



(1) CENTRIGRADE SCALE

History:-This scale was introduced by a **Swedish** astronomer **Anders Celsius in 1742**.

Other Name:- This scale is also called **centigrade scale** Because of the 100 degree intervals between the defined points.

Explanation:- On this scale

(i) The ice point or freezing point is marked as 0 ^{0}C .

(ii) The steam point or boiling point is marked as 100 ^{0}C.

(iii) The interval between freezing and boiling point is divided into **"100"** equal parts.

(iv) Each division is called one degree centigrade or Celsius and denoted by ^{0}C.

Use: - Centigrade scale is used in laboratory for scientific purposes.

(2) FAHRENHEIT SCALE

History:-This scale was introduced by **German physician** Daniel Gabriel Fahrenheit **1714**.

Explanation: - On this scale

(i) The ice point or freezing point on this scale is **32 ^{0}F** .

(ii) The steam point or boiling point is marked as **212 ^{0} F**.

(iii) The interval between the ice point and steam point is divided into **180** equal parts.

(iv) Each division is called one degree Fahrenheit and denoted by **^{0}F**.

Use:- Fahrenheit scale is used for clinical purposes to measure the temperature of patient.

(3) KELVIN SCALE

History:-This scale was introduced by **William Thomson 1848** .

Other Name:-This scale is also called **ABSOLUTE SCALE**.

Explanation:- On this scale

(i) The ice point is marked as **273K** .

(ii) The boiling point of water is marked as **373K**.

(iii) The interval between the ice point and boiling point is divided into **100** equal parts.

(iv) Each division is called one Kelvin and denoted by **1 K.**

KELVIN ZERO:-

Definition:- The lowest temperature at which the molecular movements of matter ceases is known as kelvin zero.

Other name:- It is also called absolute zero.

Its value on the Celsius scale is -273 ^{0}C . Kelvin scale is adopted in the International system (SI) of units.

RELATION BETWEEN DIFFERENT SCALE OF TEMPERATURE

With the help of the following relationship we can convert one scale of temperature into other scale. For conversion of one scale into other the following important things should must be remember.

(1) Ice point of water on different scales.

(2) Boiling point of water on different scales.

(3) Number of division between the ice point and boiling point .

(A) INTER-CONVERSION BETWEEN CENTIGRADE AND FAHRENHEIT SCALE:-To inter convert centigrade into Fahrenheit and Fahrenheit into centigrade we must remember the ice point of water on both scales .Similarly number of divisions between ice and boiling point on both scales.

$$\frac{Temperature\ on\ centigrade\ scale - ice\ point}{Number\ of\ division\ on\ centigrade\ scale} = \frac{Temperature\ on\ Fahrenheit\ scale - ice\ point}{Number\ of\ division\ on\ Fahrenheit\ scale}$$

$$\frac{T_C^0 - 0}{100} = \frac{T°F - 32}{180}$$

For T_c^0 :- As we know that

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

$$100 \times \frac{T°C}{100} = \frac{T°F - 32}{180} \times 100$$ multiply 100 on both sides.

$$\cancel{100} \times \frac{T°C}{\cancel{100}} = \frac{T°F - 32}{180} \times 100$$

$T_c^0 = \frac{T°F}{180} \times 100$ OR $T_c^0 = \frac{100}{180}(T°F - 32) = \frac{5}{9}((T°F - 32)$

$$T°C = \frac{5}{9}(T°F - 32)$$

For T°F :- As we know that

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

$$180 \times \frac{T°C}{100} = \frac{T°F - 32}{180} \times 180$$ multiply 180 on both sides

$$180 \times \frac{T°C}{100} = \frac{T°F - 32}{180} \times 180$$

$$\frac{9}{5}T°C = T°F - 32$$

$$\frac{9}{5}T°C + 32 = T°F \quad \text{OR} \quad T°F = \frac{9}{5}T°C + 32$$

$$T°F = \frac{9}{5}T°C + 32$$

CONVERSION BETWEEN CENTIGRADE AND KELVIN SCALE:-

$$\frac{T°C - 0}{100} = \frac{TK - 273}{100}$$

For T°C :- As we know that

$$\frac{T°C - 0}{100} = \frac{TK - 273}{100}$$

$$100 \times \frac{T°C - 0}{100} = \frac{TK - 273}{100} \times 100$$ Multiply 100 on both sides

$$100 \times \frac{T°C - 0}{100} = \frac{TK - 273}{100} \times 100$$

$$T°C - 0 = T_K - 273 \quad \text{OR} \quad T°C = T_K - 273$$

$$T°C = T_K - 273$$

For T_K :- As we know that

$$\frac{T°C-0}{100} = \frac{T_K-273}{100}$$

$$100 \times \frac{T°C-0}{100} = \frac{TK-273}{100} \times 100$$ Multiply 100 on both sides

$$\cancel{100} \times \frac{T°C-0}{\cancel{100}} = \frac{TK-273}{\cancel{100}} \times \cancel{100}$$

$T°C - 0 = T_K - 273$ OR $T°C = T_K - 273$ OR $T°C - 273 = T_K$

$$T_K = T°C - 273$$

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THERMAL EXPANSION

Definition:- The increase in size of a substance due heat is known as thermal expansion.

Cause:- Due the increase of amplitude of vibrations.

Explanation:- As we know that most substances expand when heated and contract on cooling.

Factor: -

(i) Change in temperature.

(ii) Original size of substance.

(iii) Nature of substance.

Note:- Thermal expansion is different for different states i-e Solid, liquid or gas of the same substance. From experimental results Gases more expand than Liquids and Liquids

THERMAL EXPANSION OF SOLIDS

LINEAR THERMAL EXPANSION IN SOLIDS:-

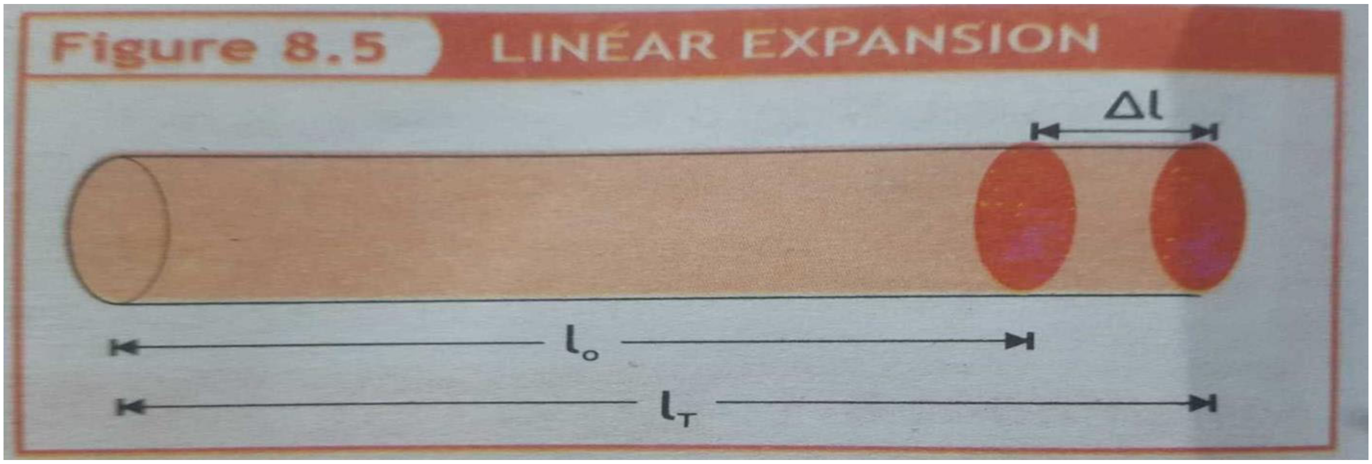
Definition:-"The length of solid changes with the change in temperature, it is called linear thermal expansion". OR

The increase in length of a solid substance due to heat is known as linear thermal expansion.

Explanation:- Consider a metal rod having original length "L_0" at temperature "T_0". Let us heat this metal rod to temperature **"T ^{0}C"** . Rod will expand and its new length will be **"L_T"** as shown the figure.

Increase in length of the rod = ΔL = $L_T - L_0$

Increase in temperature = ΔT = T – T_0.



Dependence of Linear Thermal Expansion:- From experiments

$$\Delta L \propto L_0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\Delta L \propto \Delta T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

By combining Equation of (1) and (2) we get

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

By changing proportionality into equality.

$$\Delta L = Constant\ (L_0 \, \Delta T)$$

$$\Delta L = \alpha(L_0 \, \Delta T) \ldots\ldots\ldots\ldots (3)$$

Constant = α (Alpha)

In equation (3) α is the constant of proportionality and is known as co-efficient of linear thermal expansion of the material.

For final length: -

$$L_T - L_o = \alpha \, L_0 \, \Delta T$$

$$L_T = L_o + \alpha \, L_0 \, \Delta T$$

$$L_T = L_o(1 + \alpha \, \Delta T) \ldots\ldots\ldots\ldots (4)$$

Take L_o common

Co-efficient of linear Thermal expansion:-

Definition:- The increase in length per unit length of the solid per kelvin rise in temperature.

Symbol: - It is denoted by "α " .

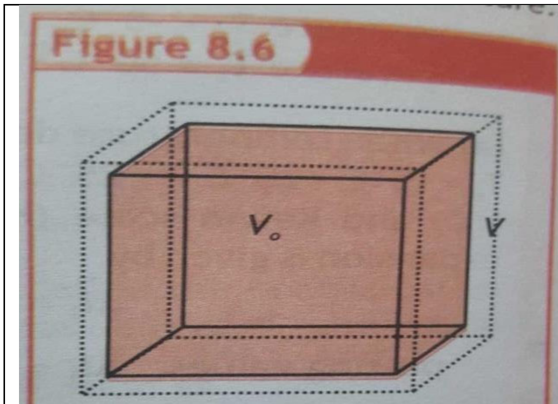
Mathematical Form:- From equation (4)

$$\alpha = \frac{\Delta L}{L_o \, \Delta T} \ldots\ldots\ldots\ldots (5)$$

Unit: - Its SI unit is **K^{-1}**.

Factor:- The value of α depends upon the nature of the material.

VOLUME THERMAL EXPANSION



Volume thermal expansion for cubical object

Definition:- The increase in volume of solids due to heat is called volume thermal expansion.

Other Name:- It is also called cubical thermal expansion of solids.

Explanation:- Consider a metallic block having an initial volume" V_o" at temperature "T_0". Let us heat this block to temperature **"T ^{0}C".** The block will expand and its new volume will be comes **"V_T"** as shown in figure.

Change in volume of block = ΔV = V_T - V_o

Change in temperature = ΔT= T - T_0

Dependence of volume thermal expansion:- From experiments

$\Delta V \propto V_O$................................ (1)

$\Delta V \propto \Delta T$ ... ... (2)

Changing proportionality into equality

$\Delta V \propto V_o \Delta T$

$\Delta V = Constant\ (V_o \Delta T\ )$

$\Delta V = \gamma V_o \Delta T$ ... ... (3)

Constant = γ (Gamma)

In equation (3) **"γ"** is the constant of proportionality and is known as coefficient of volumetric thermal expansion.

For final volume:-

V_T - V_o $= \gamma V_o \Delta T$ OR V_T $= V_o + \gamma V_o \Delta T$

V_T $= V_o\ (\ 1 + \gamma \Delta T\ )$ .... (4) Take V_o common

Co-efficient of linear thermal expansion: -

Definition:- The change in volume per unit volume per kelvin change in temperature.

Symbol:- It is denoted by "γ".

Mathematical Form:- $\gamma = \frac{\Delta V}{V_0 \Delta T}$

Unit:- Its SI unit is $°C^{-1}$ OR K^{-1}.

Factor: -Its value depends upon nature of the substance.

NOTE:- This is a general rule for solids that they expand to the same extent in all directions. It can be proved that the co-efficient of volume thermal expansion of solids "γ" is about three times the co-efficient of linear thermal expansion "α" of solids i-e $= 3\alpha$.

SHOW THAT $\gamma = 3\alpha$

Proof: - As we know that V= L^3 .... (1)

Differentiate both sides of equation (1)

$$\Delta(V) = \Delta(L)^3$$

$$\Delta V = 3L^2 \Delta L \quad \text{............ (2)}$$

As we know that $\Delta L = \alpha L \Delta T$ .... (3)

By putting equation (3) in equation (2) we get.

$$\Delta V = 3L^2 \alpha L \Delta T \quad \text{............ (3)}$$

As $L^2 \times L = L^3$ then equation (3) becomes

$L^2 \times L = L^3$

$$\Delta V = 3\alpha L^3 \Delta T \quad \text{................ (4)}$$

As $L^3 = V$ Then equation (4) becomes

$$\Delta V = 3\alpha V \Delta T \text{ ... . (5)}$$

We also know that $$\Delta V = \gamma V \Delta T \text{ .... (6)}$$

By comparing (5) and (6) we get.

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

$$\gamma \cancel{V} \cancel{\Delta T} = 3\alpha \cancel{V} \cancel{\Delta T}$$

$$\boxed{\gamma = 3\alpha} \text{ .... (7)}$$

So equation (7) is the required proof.

The values of co-efficient of volume thermal expansion "γ" for different substances are given in the table which is approximately three times the co-efficient of linear thermal expansion "α".

THERMAL EXPANSION OF CO-EFFICIENTS AT 20^0C		
Materials	Co-efficient of linear thermal expansion K^{-1} ($^0C^{-1}$ OR K^{-1})	Co-efficient of volume thermal expansion K^{-1} ($^0C^{-1}$ OR K^{-1})
SOLIDS		
Aluminum	25×10^6	75×10^6
Brass	19×10^6	57×10^6
Copper	17×10^6	51×10^6
Iron or Steel	12×10^6	35×10^6
Lead	29×10^6	87×10^6
Concrete , Break	12×10^6	36×10^6

FLUIDS		
Ethyl alcohol		1100×10^{6}
Petrol		950×10^{6}
Mercury		180×10^{6}
Water		210×10^{6}
Air and most other gases at atmospheric pressure		3400×10^{6}

THERMAL EXPANSION OF LIQUIDS

Definition:- The increase in the volume of a liquid due to thermal effect of heating is known as thermal expansion of liquids.

Explanation:-Like solids, liquids also expand on heating and contract on cooling. A liquid has no definite length and surface area, therefore, We cannot consider the linear expansion or superficial expansion of liquid. But liquids always takes up the shape of the container (vessels).Therefore in case of liquids we are concerned only with the volume changes when they are heated.

Types of thermal expansion of liquids:- In case of liquids there are two types of expansion which are given below.

(1) Apparent expansion.

(2) Real expansion

(1)Real expansion of liquid:-

Definition:- A real expansion in the volume of liquid including the expansion of the container due to heat is called real expansion of liquid.

Symbol:- It is represented by V_R.

APPARENT EXPANSION OF LIQUID:-

Definition:- The apparent expansion in the volume of liquid due to heat is called apparent expansion.

Symbol:- It is represented by V_A.

Explanation:- When a liquid is taken in a container and heated, both the liquid and the container expand at the same time. First of all container expands due to which the level of the water falls. When the liquid gets heated, it expands more and beyond its original level. On heating the expansion of liquid appear to be from A to C. This is called apparent expansion of liquid. But actually the liquid on heating has expanded from B to C.This is called real expansion of liquid .The fall in the level of the liquid from A to B is actually equal to increase in the volume of the container.

For real expansion:-

Real expansion =Apparent expansion + expansion of the container

$$V_R = V_A + V_C \quad \text{.....................} \ (1)$$

For apparent expansion:-

From equation(1) we can also find equation for apparent expantion

$$V_A = V_R - V_C \quad \text{.................} \ (2)$$

Similarly we can say that

BC=AC+AB

Real expansion =Apparent expansion+ expansion of container

COEFFICIENT OF REAL EXPANSION: -

Definition: - It is defined as the real increase in volume of liquid per unit original volume per unit degree rise in temperature.

$$V_R = \frac{real\ increase\ in\ volume}{Original\ volume \times Rise\ in\ temperature}$$

Unit:- Its unit is$°C^{-1}$, K^{-1}

COEFFICIENT OF APPARENT EXPANSION: -

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

$$V_A = \frac{APPARENT\ INCREASE\ IN\ VOLUME}{ORIGINAL\ VOLUME \times RISE\ IN\ TEMPERATURE}$$

Unit:-Its unit is$°C^{-1}$, K^{-1}.

ANAMOLOUS EXPANSION OF WATER

Definition:- The increase in the volume of water as its temperature is lowered **4 ^{0}C to 0 ^{0}C** is known as anomalous expansion of water.

Other Name:- It is also called:

(i) Unusual expansion of water.

(ii) Irregular expansion of water.

Cause: - Due to the formation of more number of **hydrogen bonds**.

Explanation:- As we know that liquids expands on heating except water between **0 ^{0}C and 4 ^{0}C .** Water is unusual in its expansion characteristics. When water at **0 ^{0}C** is heated its volume decreases up to **4 ^{0}C** and from **4 ^{0}C** its volume increases with the increase of temperature. This peculiar behavior of water is called anomalous expansion of water.

TEMPERATURE	FREEZING POINT	MELTING POINT	BOILING POINT
Values	0^0C	4^0C	100^0C
Volume	Greater	Less	Greater
Density	Less	Greater	Less

Question:- Why ice floats on water?

Ans:- **Statement**:- Ice floats on water surface.

Reason: - Because of anomalous expansion of water.

Explanation:- As we know that water after contracting up to 4^0C beings to expand so the density of water before and after 4^0C decreases. Thus at 4^0C water has maximum density and least volume .This unusual property of water irregular or anomalous expansion of water. This is why ice floats on water, we can see this when put water ice cubes in water to cool it or icebergs floating in ocean.

Conclusion: - So as a result we can conclude that the Ice floats on water surface.

APPLICATION AND CONSEQUENCESOF THERMAL EXPANSION

(1)RAILWAY LINES:-A small gap leaves between two railway tracks due to thermal expansion in summer. When there is no gap leaves due to thermal expansion in summer cause them to bend. Due to which a major accidents and loss of lives occurs. So that's why a small gap leaves behind to joined to railway tracks.

(**2) OPENING A TIGHT JAR LID:-** When the lid of the jar is too tight to open , holding the lid under hot water for a short time. Due to hot water lid of glass jar expands and easily opens.

HEAT CAPACITY AND SPECIFIC HEAT CAPACITY

HEAT CAPACITY:-

Definition:- The quantity of heat required to rise the temperature of a substance of mass by 1c° or 1 K.

Other Name: - It is also called **Thermal capacity**.

Symbol:- It is denoted by c_m.

Mathematical Form:- $$C_m = \frac{Change\ in\ heat}{Change\ in\ temperature}$$

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

Factors:- The value of C_m depends upon

- The nature of the material of the substance.
- The mass of the material of the substance.
- The rise in the temperature.

Unit:- Its SI unit is Joule per kelvin (J/k or Jk^{-1}).

Note:-Means that no two substance have same heat capacity. Similarly the heat capacity of different masses objects are different.

By using equation (1) we can also find the unit of heat capacity.

$$C_m = \frac{J}{K}$$

Unit: - Its SI unit is JK^{-1} or $J°C^{-1}$.

SPECIFIC HEAT CAPICITY

Definition:-The amount of heat required to rise the temperature of 1 kg object by1℃ or 1K is known as specific heat capacity.

Nature:- It is a scalar quantity.

Representation:- It is represented by ”C”.

Explanation:- Different substances have different specific heat capacity .For example if we take equal amount of copper and iron and heat them for equal interval of time in a same flame .So that all substance absorb equal amount of heat .But the rise in temperature is not same for all substance. It is maximum for copper minimum for water and intermediate for iron. Means that specific heat capacity for different substances is different .

MATHAMETICAL FORM:-

Form experiments:-

$$\Delta Q \propto \Delta T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\Delta Q \propto m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

By combining (1) and (2) we get

$$\Delta Q \propto m\,\Delta T$$

$$\Delta Q = Constant\,(m\,\Delta T)$$

$$\Delta Q = C\,m\,\Delta T \quad \ldots\ldots\ldots\ldots (3) \qquad \text{constant} = C$$

$$C = \frac{\Delta Q}{m\Delta T} \quad \ldots\ldots\ldots\ldots\ldots \quad (4)$$

we also know that

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

So equation (i) becomes

$$C = \frac{Cm}{m} \ldots\ldots\ldots\ldots\ldots (5)$$

From equation (5) we can also define heat capacity as

The ratio between heat capacity and mass is equal to specific heat capacity.

Unit :- The SI unit for specific heat capacity is $C = \frac{J}{kg.K}$ OR J $K^{-1}kg^{-1}$.

The specific heat capacity of water is 4190J.While "**AL**" has 910J.Means that the specific heat capacity of water "5" times more than aluminum.

LATEN HEAT AND PHASE CHANGE

We know that when heat is supplied to an object its temperature increases .But sometimes heat energy does not change the temperature of a body. In this case state of matter change due to which temperature does not increases while heat is continuously given to the system .Some of the phase change or state of matter change are given below

Solid to liquid, Liquid to gas similarly gas to liquid, and liquid to solid.

LATENT HEAT OF FUSION

Definition :-The amount of heat required to convert a given mass of substance from the solid state to the liquid state without any rise in temperature is called latent heat of fusion of solid

SPECIFIC LATENT HEAT OF FUSION:-

Definition:- The amount of heat required to convert one kilogram of the solid at its melting point to liquid without any rise in temperature is known as specific latent heat of fusion of the solid.

Explanation:- If "ΔQ" is the amount of heat needed to melt mass "m" . Then it is clear that greater the mass greater will be the heat required to melt it means that

$$\Delta Q \propto m$$

$$\Delta Q = constant\ (m) \quad \text{.................. (1)}$$

As constant = L_f then equation (1) becomes

$$\Delta Q = mL_f \text{.............. (2)}$$

In equation (2) $\Delta \boldsymbol{Q}$ is the heat required **"m"** is the mass of the solid substance where **"L_f"** constant of proportionality and is known as latent heat of fusion of solid.

From equation (2) we can also find latent heat of fusion of solid state.

$$L_f = \frac{\Delta Q}{m} \text{..........(B)}$$

Unit Its unit is $\frac{J}{kg}$ OR JKg^{-1}.

Note:-Different substance have different specific latent heat of fusion.

LATENT HEAT OF VAPORIZATION

Definition:-The amount of heat energy required to convert a given mass of liquid into gaseous state without any rise in temperature is known as latent heat of vaporization.

Note:-Similarly gaseous state is converted into liquid by releasing the absorb amount of heat.

SPECIFIC LATENT HEAT OF VAPORIZATION :-

Definition:-The amount of heat energy required to convert one kilogram of liquid into gas without increasing the temperature known as specific latent heat of vaporization.

Mathematical Form:- Let ΔQ is the amount of heat required to vaporize "m" mass of a liquid to gas. Then from experiments:-

$$\Delta Q \propto m$$

$$\Delta Q = constant(\,m)$$.................. (1)

As constant= L_V then equation (1) becomes

$$\Delta Q = m\,L_v$$ .... (2)

In equation (2) $\Delta \boldsymbol{Q}$ is the amount of heat required **"m"** is the given mass where **"L_V"** constant of proportionality and known as latent heat of fusion of solid.

From equation (i) we can also find L_v

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

Unit:- Its unit is $\frac{J}{kg}$ OR J kg^{-1}.

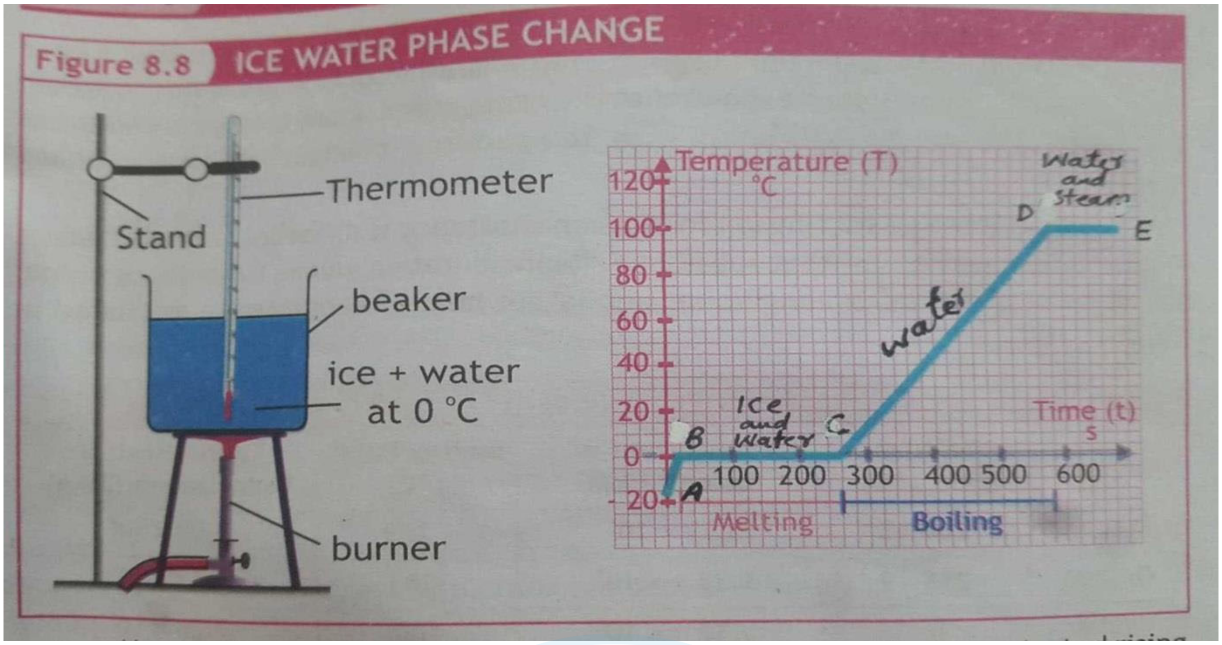
Note:-Different substance have different specific latent heat of vaporization.

EXAMPLE:- Water boils at 100°C it temperature remain at 100°C until it is changed completely into steam latent heat of vaporization is 2.26 $10^6 Jkg^{-1}$.
It means one kilogram of water requires 2.26× 10^6J heat to change it completely in gaseous state its boiling point.

EXPERIMENT FOR ICE-WATER PHASE CHANGE AND TEMPERATURE –TIME GRAPH ON HEATING ICE

When thermal energy is added or remove from substance it change from one state of matter into other.

EXAMPLE: - Take a beaker and place it over a stand. Put small pieces of ice in the beaker and suspend a thermometer in the beaker to measure the temperature. Place a burner under the beaker. The ice will start melting. The temperature of the mixture containing ice and water will not increase above **0**°C until all the ice melts. Note the time which the ice takes to melt completely into water **at 0**°C . Continue heating the water **at 0**°C in the beaker. Its temperature will start to increase above 0°C . Note the time which the water in the beaker takes to reach its boiling point at **100**°C as shown in the temperature – time graph.



(i)PART AB :-On this portion of the graph temperature of ice increases from **-20**°C **to 0**°C.

PART BC:- When the temperature of ice reach 0°C .The mixture (Ice and water) remain at this temperature until all ice melts.

(iii) PART CD : - Now the temperature gradually increases from **0**°C **to 100**°C . The supplied heat increases the temperature of water.

(iv)PART DE :-At 100°C *water begin to boil and changes into gas*. The temperature remains 100°C the same until all the water changes into steam.

EVAPORATION OF LIQUIDS

Definition:- The process by which a liquid slowly changes into its vapors at any temperature without the aid of any external source of heat is known as evaporation. OR
The changing of liquid into gaseous state from the surface of the liquid without heating is known as evaporation.

Example:-A spread wet cloth on being exposed to the air becomes dry in short time due evaporation of water. Water left in an open dish also disappears due to evaporation.

Factors of evaporation:- Evaporation of liquids depends upon the following factors.

(1) Nature of the liquid:- We known that different liquids having different boiling points. Liquids with low boiling points evaporate rapidly than those with higher boiling points.

$$\text{Rate of evaporation} \propto \frac{1}{\textit{Boiling points liquids}}$$

Example:- The rate of evaporation of alcohol higher than that of water due to low boiling point.

(2) Temperature of Liquid:- Due to higher temperature, molecules of liquids at the surface will have more kinetic energy and chances of escaping will increase and evaporation will be fast.

Rate of evaporation ∝ Temperature of liquids .

Example:- Under a hot iron wet clothes dry out quickly as the water evaporates quickly.

(3) Temperature of surrounding:- The higher the temperature of surrounding ,the higher is the rate of evaporation and vice versa.

Rate of evaporation ∝ Temperature of surrounding

Example:- Wet clothes dry rapidly in the summer than in winter.

(4) Presence of water vapor in air:- The more the amount of water vapours present in air, the less is the rate of evaporation and vice versa.

$$\text{Rate of evaporation} \propto \frac{1}{\textbf{Presence of water vapours in the air}}$$

Example:- Wet clothes dry slowly in the rainy season as a lot of water vapour are present in the air.

(5) Area of the exposed surface of the liquid:- Larger is the surface area of a liquid greater the number of molecules escape out from its surface. Thus evaporation is faster when surface area is larger.

(6) Movement of air:- The more rapid the flow of air, the higher is the rate of evaporation .

Rate of evaporation ∝ Moment of air

Example: - Wet clothes dry more rapid on a windy day as compared on a clam day because of higher rate of evaporation.

(7) Dryness of air:-Drier the air, the more rapid is the evaporation. It means that more the dryness of the air greater will be rate evaporation.

Rate of evaporation ∝ Dryness of air

Example:- Wet clothes dry quickly on a dry day and slowly on a humid day because of higher rate of evaporation.

(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 and vice versa.

$$\text{Rate of evaporation} \propto \frac{1}{\text{Air pressure on the surface of the liquid}}$$

EVAPORATION CAUSES COOLING

During evaporation fast moving molecules escape out from the surface of liquid. Molecules that have lower kinetic energies are left behind. This lowers the average kinetic energy of liquid molecules and the temperature of the liquid. Since the temperature of substance depends on the average kinetic energy of its molecules. Thus evaporation causes cooling.

Evaporation VS boiling point

Evaporation	Boiling point
The changing of liquid into gaseous state from the surface of the liquid without heating is known as evaporation	The temperature at which a liquid boils and turns to vapours is known as boiling point.
It is a slow process.	It is a rapid process
It is a continuous process	It is a random process.
It occurs at any temperature.	It occurs at particular temperature.
It cause cooling effect.	It donot cause cooling effect
It take place from the surface of liquid.	It take place throughout the liquid.

Applications of Cooling by Evaporation:-

(1) **Cooling by Fans**:- we use fane in the hot season because the moving air increases the rate of evaporation or perspiration from our bodies. Hence we get a cooling sensation.

(2) **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 heat remains within the safe limits and the patient does not suffer any brain damage.

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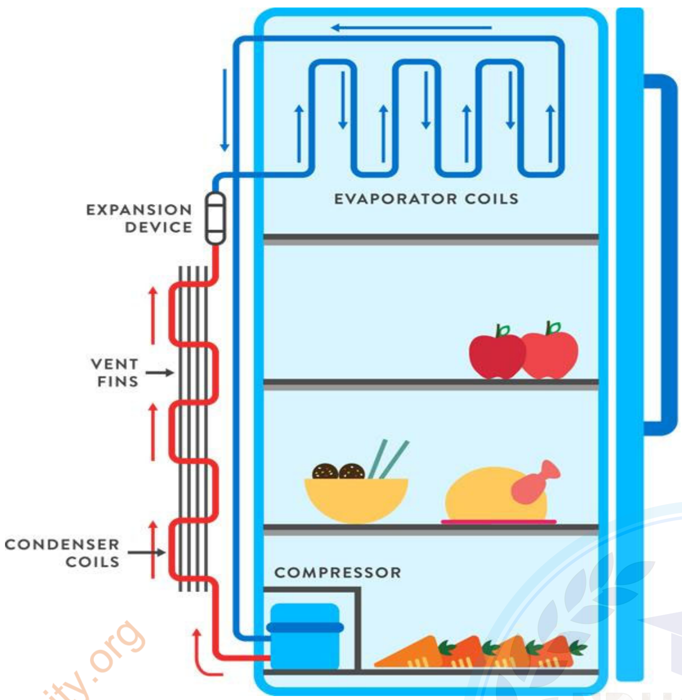
(3) **Refrigerator**:- Definition:- It is a device which is used for keeping food or other items cool.



Principle:- Its basic principle is evaporation and compression.

Parts of Refrigerator:- There are six parts of Refrigerator which are given below.

(1) 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.

.(2) Refrigerant:- This the substance which evaporates in the fridge causing freezing temperature.

(3)Expansion Value:- The expansion value which is made up of a thin copper coil reduces the pressure on the liquid refrigerant.

(4) Compressor :- A compressor is a metal object which compresses the refrigerant thus raising the pressure and in turn the temperature of the gas.

(5) Condenser :- A condenser condenses that is it converts the refrigerant into liquid form reducing its temperature.

(6) Evaporator :- A 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 cool as it flowed through it. Outside the refrigerator, we have a pump (compressor) to compress the gas and release the its heat. As the gas flow around the loop , expanding when it is inside the refrigerator and compressing when it is outside , it constantly pick up heat from the inside and carry it to the outside.

Refrigerant and Environmental Concern:- the cooling effect in many old Refrigerators is produced by the evaporation of refrigerant called Freon a chlorofluorocarbon CFC chemical. According to modern research this CFC is dangerous for ozone layer. So many old refrigerators is disposal due to increasing important environmental concern. In modern refrigerators mostly HFC is used as refrigerant. which has zero effects on ozone layer. But according to modern research this HFC damage earth atmosphere. Scientist are now looking to develop a new refrigerant which have low global warming and zero ozone depletion.

CONCEPTUAL QUESTIONS

Question #1: Ordinary electric fan increases the kinetic energy of the air molecules caused by the fan blades pushing them means the air temperature increases slightly rather than cool the air? Why use it.

Ans:- **Statement**:- Ordinary electric fan increases the kinetic energy of the air molecules caused by the fan blades pushing them means the air temperature increases slightly rather than cool the air.

Reason:- It is due to increase of the rate of evaporation.

Explanation:- As we know that we use electric fan for cooling effect. It does not cool the air inside the room. It increases the kinetic energy of the air molecules due to which the temperature of the molecules increases. When these speed up touches our body and increase the rate of evaporation of water from the body.

Question #2: Why are small gaps left behind the girders mounted in walls?

Ans:- Statement:- Small gaps are left behind the girders mounted in wall.

Reason:- It is because they allow thermal expansion.

Explanation:- As we know that the solid expands on heating and contract on cooling. In summer season the girder expand due to heating. If there is no gap lift, the expansion will cause the girder to buckle (bend at middle).

Conclusion:- As a result we conclude that Small gaps are left behind the girders mounted in wall.

Question #3: Why you should not put a closed glass jar into a campfire. What could happen if you tossed an empty glass jar, with the led on tight, into a fire?

Ans:- **Statement**:- When we put an empty closed glass jar into a campfire it explodes.

Reason:-It is because of the thermal expansion.

Explanation:- As we that know that the inside jar is not empty. It is filled with air. When we put a sealed jar into a campfire it will explodes. As the temperature and the kinetic energy of the gas molecules its volume increases. So the gas inside the jar expands. Thus high pressure inside the gas jar makes it to burst.

Conclusion:- As a result we conclude that When we put an empty closed glass jar into a campfire it explodes.

Question #4: Explain why it is advisable to add water to an overheated automobile engine only slowly, and only with the engine running.

Ans:- **Statement**:- It is advisable to add water to an overheated automobile engine only slowly, and only with the engine running.

Reason:- It is because substances expands on heating and contracts on cooling.

Explanation:- We know that 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, while other part will not. Some of the water will quickly turn to steam and will rapidly expand which can result a cracked engine block or radiator, due to the thermal stress or the emission of high-temperature steam from the radiator. So Water should be added slowly with the running engine. The water will mix with the hotter water already present in the system and then will circulate through the engine, so by this gradually cooling all parts will down at the same rate.

Conclusion:- As a result It is advisable to add water to an overheated automobile engine only slowly, and only with the engine running.

Question #5: Explain why burns caused by steam at 100^{o}C on the skin are often more severe than burns caused by water at 100^{o}C.

Ans:- **Statement**:- Burns caused by steam at 100^{o}C on the skin are often more severe than burns caused by water at 100^{o}C .

Reason:- It is because steam possesses latent heat of vaporization.

Explanation:- As we know that steam at 100^{o}C contains more thermal energy than water. The difference is due to the latent heat of vaporization, which for water is quite high. As the steam touches the skin and condenses, a large amount of energy is released, causing more severe burns.

Conclusion:- As a result we conclude that Burns caused by steam at 100^{o}C on the skin are often more severe than burns caused by water at 100^{o}C .

Question #6: Explain why cities like Karachi situated by the ocean tend to have less extreme temperature than inland cities at the same latitude.

Ans:- **Statement**:- Cities like Karachi situated by the ocean tend to have less extreme temperature than inland cities at the same latitude.

Reason:- It is because Water has a higher heat capacity than soil and rock.
Explanation:- As we know that Water has a higher heat capacity than soil and rock, so the ocean takes much longer to heat and to cool than the land.
• Coastal areas will generally have more moderate temperature than inland areas because of the heat capacity of the ocean. So during the day the land heats much faster than the sea, and during night the land cools faster. When the land heats up, the air above it heats up as well. On the other hand, the ocean heats up and cools down relatively slowly. Therefore, areas near the ocean generally stay cooler during the day and have a more moderate temperature range than inland areas.
Conclusion:- As a we conclude that Cities like Karachi situated by the ocean tend to have less extreme temperature than inland cities at the same latitude.
Question #7: An iron rim which is fixed around a wooden wheel is heated before its fixture. Explain it?
Ans:- Statement:- An iron rim which is fixed around a wooden wheel is heated before its fixture.
Reason:- Because to increase its diameter OR Thermal expansion.
Explanation:- As we know that an iron rim which is fixed around a wooden wheel is made a little smaller in diameter than the wooden wheel. The rim (ring) expands on heating and can be placed around the wooden wheel. When the rim (ring) comes to room temperature it contracts and produce a tight fit.
Conclusion:- As a result An iron rim which is fixed around a wooden wheel is heated before its fixture.
Question #8: Why is ice at $0\,^{o}C$ a better coolant of soft drink than water at $0^{o}C$?
Ans:- Statement:- The ice at $0\,^{o}C$ a better coolant of soft drink than water at $0^{o}C$.
Reason:- It is because of Latent heat of fusion.
Explanation:- As the ice is more effective in cooling than water at the same temperature. It absorbs more heat from the soft drinks quickly to change into water at $0\,^{o}C$. Thus it has greater cooling effect than water at $0\,^{o}C$.
Conclusion:- As a result we can conclude that the ice at $0\,^{o}C$ a better coolant of soft drink than water at $0^{o}C$
Question #9: Why we feel cool after perspiration?
Ans:- **Statement**:- We feel cool after perspiration.
Reason:- It is because of evaporation.
Explanation:- As we know that the evaporation of sweat from the skin surface has cooling effect due to the latent heat of evaporation of water. It absorbs in excess heat from our body. Due to which our body temperature decreases and evaporates. Thus we feel cool.
Conclusion:- As a result we feel cool after perspiration.

NUMERICAL QUESTIONS

Problem # 1:-Perform the temperature conversion
(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 kelvins and in Fahrenheit degrees.
(b) Blood storage. Blood stored at 4.0 °C lasts safely for about three weeks, whereas blood stored at -160 °C lasts for 5 years. Express both temperatures on the Fahrenheit and Kelvin scales.

Ans:- Solution:-

Given Data:-

(a) The surface temperature of the body = T_S = 7 °C.

Inter temperature of body= T_{int} = 37 °C .

Temperature difference = ΔT= T_{int} - T_S = 37 – 7 = 30 °C.

Required Data:-

(i) Temperature in kelvin = ΔT_K= ?

(ii) Temperature in Fahrenheit = $\Delta T_{°F}$ = ?

(i)For Temperature in kelvin = ΔT_K:-

Formula:- As we know that $\Delta T_K = \Delta T_{1\,K} + \Delta T_{2\,K}$ .... (1)

First we find $\Delta T_{1\,K}$ and $\Delta T_{2\,K}$:-

For $\Delta T_{1\,K}$: - $\Delta T_{1\,K} = T_{int}$ + 273 = 37 + 273 = 310 K.

For $\Delta T_{2\,K}$: - $\Delta T_{2\,K} = T_S$ + 273 = 30 + 273 = 303 K

Calculation:- By putting the values $\Delta T_{1\,K}$ and $\Delta T_{2\,K}$ in equation (1) we get

$\Delta T_K = \Delta T_{1\,K} + \Delta T_{2\,K}$ = 310 – 303 = 7K

(ii) Temperature in Fahrenheit = $\Delta T_{°F}$:- $\Delta T_{°F} = \Delta T_{1\,°F} + \Delta T_{2\,°F}$ .... (2)

First we find $\Delta T_{1\,°F}$ and $\Delta T_{2\,°F}$:-

$\Delta T_{1\,°F} = \frac{9}{5}\ T_{int} + 32 = \frac{9}{5}$ x 37 + 32 = 66.6 F^0

$\Delta T_{2\,°F} = \frac{9}{5}$ + 32 = 39.2 °F .

(c) (i) **Given data** :- T_c = -160 °C .

Required data= T_k = ?

We know that $T_k = T_c$ + 273 = -160 + 273 = 113 K

(ii)For T_F:- As we know that

$T_F = \frac{9}{5} T_c + 32 = \frac{9}{5}$ x -160 + 32 = -288 + 32 = - 256 ^{0}F .

Problem # 2: Consider a meter-stick composed of platinum (the coefficient of linear expansion for platinum is α = 8.8×10^{-6} K^{-1}). By what amount does the length of this meter-stick change if the temperature increases by 1.0K .

Ans:- <u>Solution</u>:-

<u>Given Data</u>:-

Length of meter-stick = L_0 = 1m

Change in temperature = Δ T = 1.0 K

Co-efficient of linear expansion of Platinum = α = 12 x $10^{-6} K^{-1}$

<u>Required Data</u>:-

Change in length = Δ L = ?

<u>Formula</u>:- As we know that

$\Delta L = \alpha L_0 \Delta T$ .... (i)

<u>Calculation</u>:- By putting values in equation (i) we get.

$\Delta L = 12 \times 10^{-6} \times 1 \times 1.0 = 12 \times 1 \times 1.0 \times 10^{-6} = 12 \times 10^{-6}$ m

<u>Result</u>:- So as a result the change in length of meter – stick is = Δ L = 12 x 10^{-6} m.

Problem # 3

A railway line made of iron is 1200km 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 a =12×10^{-6} K^{-1}).

Ans:- <u>Solution</u>:-

<u>Given Data</u>:-

Length of railway line = L_1 = 1200km = 1200 x 10^3 m = 1.2 x 10^{3+3} = 1.2 x 10^6m

<u>In case of Contraction</u>:-

Initial Temperature = T_i = 25 °C = 25 + 273 = 298 K

Final Temperature = T_f = 15 °C = 15 + 273 = 288 K

Change in temperature = ΔT = T_i - T_f = 298 – 288 = 10 K

Coefficient of linear expansion of iron = α =12×10^{-6} K^{-1}

<u>Required Data</u>:-

Change in length = ΔL =?

<u>Formula</u>:- As we know that

$\Delta L = \alpha L_1 \Delta T$ .... (i)

<u>Calculation</u>:- By putting values in equation (i) we get

ΔL = 12×10^{-6} x 1.2 x 10^{6}m x 10 = 12 x 1.2 x 10 x 10^{-6+6}

ΔL_1 = 144 x 10^{0} = 144 x 1 = 144 m

In case of summer (expansion):-

Given Data:-

Length of railway line = L_1 = 1.2 x 10^{6}m

Initial Temperature = T_i = 25 °C = 25 + 273 = 298 K

Final Temperature = T_f = 40 °C = 40 + 273 = 313 K

Change in temperature = ΔT = T_f - T_i = 313 – 298 = 15 K

Coefficient of linear expansion of iron = α =12×10^{-6} K^{-1}

Required Data:-

Change in length = ΔL_2 = ?

Formula:- As we know that

$\Delta L_2 = \alpha\, L_1\, \Delta T$ ……………………. (ii)

Calculation:- By putting values in equation (ii) we get

ΔL_2 = 12×10^{-6} x 1.2 x 10^{6}m x 15 = 12 x 1.2 x 15 x 10^{-6+6}

ΔL_2 = 216 x 10^{0} = 216 x 1 = 216 K

Problem # 4: The volume of a brass ball is 800 cm^3 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 57×10^{-6} K^{-1}.

Ans:- Solution:-

Given Data:-

Initial Volume of a brass ball = V_i = 800 cm^3

Initial temperature = T_i = 20°C

Final temperature = T_f = 52°C

Change in temperature = ΔT = T_f - T_i = 52 – 20 = 32 °C

Co-efficient of volumetric expansion of brass = γ = 57 x $10^{-6}\ K^{-1}$

Required Data:-

Final volume of a brass ball = V_f = ?

Formula:- As we know that

$V_f = V_i\ (1 + \gamma\, \Delta T)$ ……………. (i)

Calculation:- By putting values in equation (i) we get

V_f = 800 (1 + 57 x 10^{-6} x 32) = 800 (1 + 57 x 32 x 10^{-6})

V_f = 800 (1 + 1824 x 10^{-6}) = 800 (1 + $\frac{1824}{10^6}$)

V_f = 800 (1 + $\frac{1824}{1000000}$) = 800 (1 + 0.001824)

V_f = 800 x 1.001824 = 801.45 Cm^{-3}.

Result: - So as a result the final volume of a brass ball is = V_f = 801.45 Cm^{-3}.

Problem # 5:-What is the specific heat of metal substance if 135kJ of heat is needed to raise 4.1 kg of the metal from 18.0°C to 37.2°C?

Ans:- Solution:-

Given Data:-

Heat supplied = ΔQ = 135 KJ = 135 x 10^3 J = 135000 J

Mass of metal = m = 4.1 kg

Initial temperature = T_i = 18.0 ^{0}C

Final temperature = T_f = 37.2 ^{0}C

Change in temperature = ΔT= T_f - T_i = 37.2 -18.0 = 19.2 ^{0}C

Required data:-

Specific Heat = C = ?

Formula:- As we know that

C = $\frac{\Delta Q}{m\Delta T}$ ………………………. (i)

Calculation:- By putting values in equation (i) we get

C = $\frac{135000}{4.1 \, x \, 19.2}$ = $\frac{135000}{78.72}$ = 1714.93 J / kg K

Result:- So as a result the specific heat of metal substance is 1714.93 J / kg K.

Problem # 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=230Jkg^{-1}K^{-1} Latent heat of fusion for silver is L_f = 8.8×10^4).

Ans:- Solution:-

Given Data:-

Mass of silver = m = 23.50 kg

Initial temperature = T_i = 25°C = 25 + 273 =298 K

Final temperature of silver = Melting point of silver = T_f = 961.8 + 273 = 1234.8K

Change in temperature = ΔT = 1234.8 – 298 = 936.8 K
Specific heat of silver is = C =230$Jkg^{-1}K^{-1}$
Latent heat of fusion of silver is = L_f = 8.8×10^4

Required Data:-

Heat = ΔQ = ?

Formula:- In this case $\Delta Q = \Delta Q_L + \Delta Q_c$ .... (1)

First we find out the values of ΔQ_L and ΔQ_c .

(i)For ΔQ_L :- ΔQ_L= m C ΔT = 230 x 23.50 x 936.8 = 5,063,404 K = 5.06 x10^6 J ……. (2)

(ii)For ΔL_f :- ΔQ_L = m L_f = 23.50 x 8.8×10^4 = 206.8 x 10^4 J

ΔQ_L = 2.068 x 10^{2+5} =2.068 x 10^6J ………… (3)

Calculation:- By putting values in equation (1) we get

$\Delta Q = \Delta Q_L + \Delta Q_c$ = 2.068 x 10^6J + 5.06 x10^6 J = 7.128 x 10^6J.

Result: - **So as a result the required heat is ΔQ = 7.128 x 10^6J.**