Thermal Expansion & Calorimetry

Thermal Expansion & Calorimetry

Temperature:

- Temperature (T) is defined as the degree of hotness or coldness of a body.
- It is scalar quantity.
- SI unit is Kelvin.
- Normally temperature of human body is 310.15 K = 37°C = 98.6°F,
- The measurement of temperature of a matter is known as thermometry. In old thermometry, freezing point (0°C) and steam point (100°C) are taken to define the temperature scale. If the thermometric effect at temperature 0°C, 100°C and t°C are x_0, x_{100} and x respectively then

$$\frac{t-0}{100-0} = \frac{x-x_0}{x_{100}-x_0}$$

Concept Reminder

Temperature is one of seven fundamental physical quantities with dimension [K] or [θ]

Scale of temperature:

Scale	Symbol	LFP	UFP	No. of divisions on the scale
Celsius	°C	0°C	100°C	100
Fahrenheit	°F	32°F	212°F	180
Kelvin	K	273.15	373.15 K	100

LFP = Lower fixed point; UFP = Upper fixed point.

Relation between different scale:

$$\frac{\text{Reading on any scale} - \text{LFP}}{\text{UFP} - \text{LFP}} = \text{constant for all scales}$$

$$\frac{C-0}{100} = \frac{F-32}{212-32} = \frac{K-273.15}{373.15-273.15}$$

$$\frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5}$$

Concept Reminder

- Temperature
- Thermometer

- The Celsius and Kelvin scale have different zero points but the same sized degrees. Any temperature difference (ΔT) is equal on the Celsius and kelvin scales.

$$(T_2' - T_1')°C = (T_2 - T_1)K$$

Thermal Expansion & Calorimetry

Ex. The temperature on Celsius scale is 20°C. What is the corresponding temperature on the Fahrenheit scale?

Sol. $\frac{C}{5} = \frac{F-32}{9}$ $\Rightarrow \frac{20}{5} = \frac{F-32}{9}$

$F - 32 = 9 \times 4$ $\Rightarrow F = 36 + 32 = 68°F$

Ex. The temperature of a body on kelvin scale is found to be x K. When it is measured by Fahrenheit thermometer, it is found to be x°F, then the value of x is.

Sol. $\frac{F-32}{9} = \frac{K-273}{5}$

$\Rightarrow \frac{x-32}{9} = \frac{x-273}{5}$

$\Rightarrow 5x - 160 = 9x - 2457$

$\Rightarrow x = \frac{2297}{4} = 574.25$

Ex. At what temperature the centigrade (Celsius) and Fahrenheit, readings are the same?

Sol. $\frac{C}{5} = \frac{F-32}{9}$ $\Rightarrow \frac{t}{5} = \frac{t-32}{9}$

$9t = 5t - 160$ $\Rightarrow t = \frac{-160}{4} = -40°C$

Ex. On centigrade scale the temperature of a body increases by 30 degrees. The increase in temperature on Fahrenheit scale is.

Sol. Difference of 100°C = difference of 180°C

difference of 1°C = $\frac{180}{100}$

difference of 30°C = $\frac{180}{100} \times 30 = 54°$

Rack your Brain

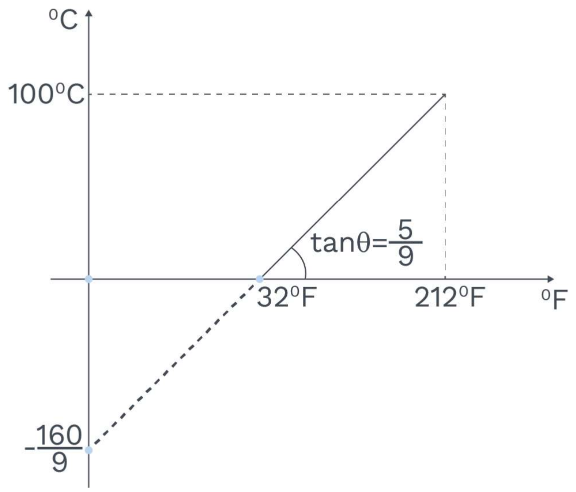
A centigrade and a Fahrenheit thermometer are dipped in boiling water. The water temperature is lowered until the Fahrenheit thermometer registers 140°F. What is the fall in temperature as registered by the centigrade thermometer.

Ex. Draw the graph between the temperature of a body in degree Celsius vs degree Fahrenheit and mention its slope.

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

$C = \frac{5F}{9} - \frac{160}{9}$ $\Rightarrow y = mx + C$

$m = \frac{5}{9}$ $\Rightarrow C = -\frac{160}{9}$



Expansion:

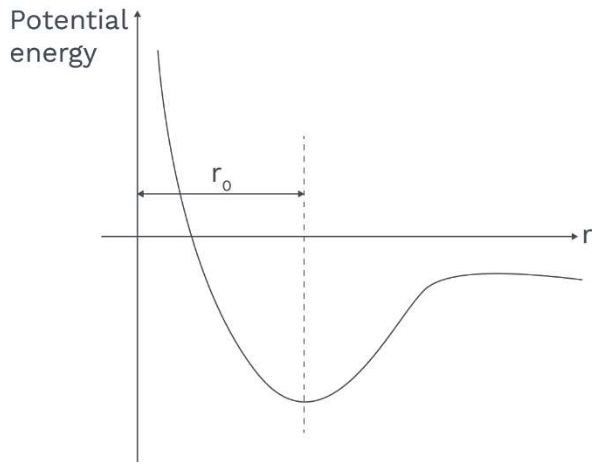
- When substance is heated without any change in its state, it usually expands, with rise in temperature the amplitude of vibration and hence energy of atoms increases, hence the average distance between the atoms increases so the matter expands.
- Almost all solids and liquids expand as their temperature increases, gases also expand if allowed.
- Intermolecular force is maximum in case of solids but minimum in gases so thermal expansion is minimum in case of solid but maximum in case of gases.

Definitions

A thermometer is an instrument used to measure temperature of a body.

Concept Reminder

- If potential energy curve had been symmetrical then thermal expansion would not have taken place in spite of heating.



Thermal expansion arises because the well is not symmetrical about the equilibrium position r_0.

- Solids can change in length, area or volume, while liquids change in their volumes.
- Solids can expand in one dimensional (linear expansion), two dimensional (superficial/aerial expansion) and three dimension (volume expansion) while liquids and gases usually suffers change in volume only.

Linear Expansion:

- Change in length is called linear expansion.
- If change in temperature by 1°C or 1 K of unit length then change in length represent the linear expansion coefficient α.

Before heating After heating

$$\boxed{\alpha = \frac{\Delta L}{L\Delta T}}, \ L = \text{initial length}$$

α = coefficient of linear expansion.

$$\boxed{\Delta L = \alpha L\, \Delta T}$$

$$L_f = L_i + \Delta L$$

$$L_f = L + \alpha L \Delta T$$

Rack your Brain

A copper rod of 88 cm and an aluminium rod of unknown length have their increase in length independent of increase in temperature. Find the length of aluminium rod.

$$\alpha_{cu} = 1.7 \times 10^{-5} k^{-1}$$

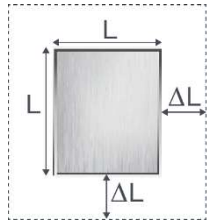
$$\alpha_{Al} = 2.2 \times 10^{-5} k^{-1}$$

$$\boxed{L_f = L(1+\alpha\Delta T)}$$

Unit of α is $°C^{-1}$ or K^{-1}. Dimension is $[\theta^{-1}]$

Superficial/aerial expansion:

- The expansion in area is called superficial expansion.
- If change in temperature by 1°C or 1 K of unit area then change in area represent the superficial expansion coefficient β.



$$\boxed{\beta = \frac{\Delta A}{A\Delta T}} \qquad [A = \text{initial area}]$$

β = coefficient of aerial expansion.

$$\boxed{\Delta A = \beta A \Delta T}$$

$$A_f = A_i + \Delta A$$

$$A_f = A + \beta A \Delta T$$

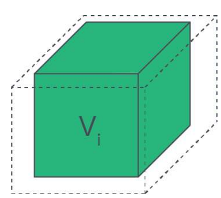
$$\boxed{A_f = A(1+\beta\Delta T)}$$

KEY POINTS

- Thermal expansion
- Linear expansion
- Superficial expansion
- Volume expansion

Volume expansion:

- The expansion in volume is called volume expansion.
- If change in temperature by 1°C or 1 K of unit volume then change in volume represent the volume expansion coefficient γ.



$$\gamma = \frac{\Delta V}{V\Delta T} \qquad [V = \text{initial volume}]$$

γ = coefficient of volume expansion.

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

$$V_f = V_i + \Delta V$$

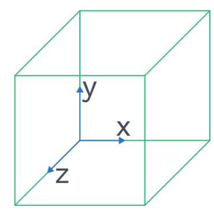
$$V_f = V + \gamma V \Delta T$$

$$\boxed{V_f = V(1+\gamma\Delta T)}$$

- Unit of α, β and γ is $\frac{1}{°C}$ or $\frac{1}{K}$.
- Value of α, β and γ is very small.
- Value of α is positive for metals except carbon.

- The value of α is negative for plastic and rubber because in these, when temperature increase length decrease.
- Linear and aerial expansion are shown in solids but volume expansion shown in all states- solid, liquid and gas.

Relation between α, β, and γ:



$$\alpha_x = \alpha_y = \alpha_z = \alpha$$

$$\beta = \alpha_x + \alpha_y = \alpha_y + \alpha_z = \alpha_x + \alpha_z$$

$$\boxed{\beta = 2\alpha}$$

$$\gamma = \alpha_x + \alpha_y + \alpha_z$$

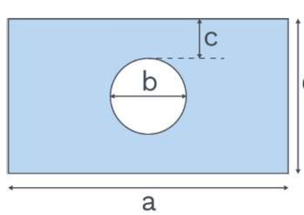
$$\boxed{\gamma = 3\alpha}$$

$$\boxed{\alpha : \beta : \gamma = 1 : 2 : 3}$$

Ex. A 100 m metal rod at 0°C is heated to 100°C. Its length is increases by 25 cm. Coefficient of linear expansion of the road is.

Sol. $\alpha = \dfrac{\Delta L}{L(\Delta\theta)} = \dfrac{0.25}{100(100-0)} = 2.5 \times 10^{-5}\ /\ ^\circ C$

Ex. A rectangular plate has a circular cavity as shown in the figure. If we increase its temperature then which dimension will increase in following figure.

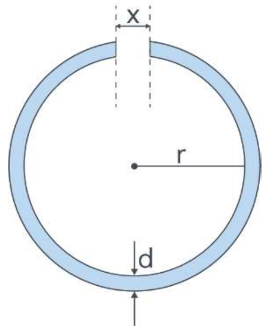


Sol. Distance between any two points on an object increases with increase in temperature. So all dimension a, b, c and d will increase.

Concept Reminder

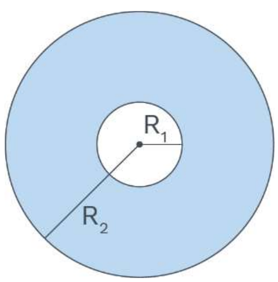
Thermal expansion of an isotropic object may be imagined as a photographic enlargement.

Ex. A cylindrical metal rod of length L_0 is shaped into a ring with a small gap as shown on heating the system dimension are:



Sol. x, r and d all increases.

Ex. In the given figure, when temperature is increased then which of the following increases.



(1) R_1 (2) R_2
(3) $R_2 - R_1$ (4) All of these

Sol. (4)
All dimensions increases.

Effect of temperature on the time period of a simple pendulum:-

- A pendulum keeps keeps proper time at temperature θ. If temperature is increases to θ' ($>\theta$) then due to linear expansion length of pendulum and hence its time period will increase.

$$T = 2\pi\sqrt{\frac{l}{g}}$$

If temperature is increased by $\Delta\theta$

Concept Reminder

The gain or lose in time is independent of time period T and depends upon change in temperature $\Delta\theta$.

$$T' = 2\pi\sqrt{\frac{l(1+\alpha\Delta\theta)}{g}}$$

By using binomial theorem

$$T' = T\left(1+\frac{\alpha}{2}\Delta\theta\right)$$

Fractional change in timeperiod $\frac{\Delta T}{T}$

$$\boxed{\frac{\Delta T}{T} = \frac{1}{2}\alpha\Delta\theta}$$

Clock will lose time hence will become slow is summer and will gain time i.e. will become fast in winter.

Ex. A uniform metal rod (bar pendulum), which is coefficient of linear expansion is 2×10^{-6}/°C, the period of the pendulum will have percentage increase, if room temperature rise by 10°C.

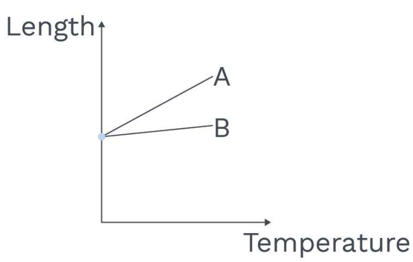
Sol. Change in time period

$$\frac{\Delta T}{T} = \frac{1}{2}\alpha\Delta\theta$$

$$= \frac{1}{2} \times 2 \times 10^{-6} \times 10 = 10^{-5}$$

percentage change = $\frac{\Delta T}{T} \times 100 = 10^{-5} \times 100 = 10^{-3}\%$

Ex. Length v/s temperature graph of A and B is given below. Find the relation between α_A and α_B.



Sol. $\alpha = \frac{\Delta l}{\Delta\theta} = \text{slope}$

Slope (α)

$\alpha_A > \alpha_B$

Ex. Percentage change in length of a cylinder is 2% then find out the percentage change in area.

Sol. $\beta = 2\alpha$

Percentage change in area = $2 \times 2 = 4\%$

Ex. Length of two metallic rod is l_1 and l_2 and linear expansion coefficient is α_1 and α_2 if same temperature change then change in length is same.Then find out the l_1/l_2 and $\frac{l_1 + l_2}{l_1 - l_2}$.

Sol. $\Delta l_1 = \Delta l_2$ $\quad (\Delta l = \alpha L \Delta T)$

$$\alpha_1 l_1 \Delta T = \alpha_2 l_2 \Delta T$$

$$\frac{l_1}{l_2} = \frac{\alpha_2}{\alpha_1}$$

$$\frac{l_1 + l_2}{l_1 - l_2} = \frac{\alpha_2 + \alpha_1}{\alpha_2 - \alpha_1}$$

Ex. A metallic rod length is 10 cm at 20°C, then find out the change in length at 19°C temperature, where $\alpha = 10^{-4}$/°C.

Sol. $\Delta l = \alpha l \Delta T$

$\Delta l = 10^{-4} \times 10 \times \Delta T$

$\Delta l = 10^{-4} \times 10 \times (19 - 20)$

$\Delta l = -10^{-3}$ cm (l decreases)

Temperature increases expansion
Temperature decreases $\rightarrow$ contraction.

Ex. For a simple pendulum change in length is 1/200% when its temperature is increase by 10°C. Then find out the linear expansion coefficient of pendulum string.

Sol. $\Delta l = \alpha l \Delta T$

$$\frac{\Delta l}{l} \times 100 = \alpha \Delta T$$

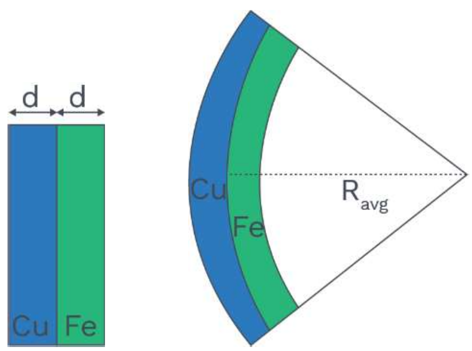
Change in length $= \frac{1}{200} = \alpha \Delta T(100)$

$$\Rightarrow \quad \alpha = \frac{1}{2 \times 10^5}$$

$$\alpha = \frac{1}{2} \times 10^{-5}\ °C$$

Bimetallic strip:

- If two rod of different material and same length (different coefficient of linear expansion) are join together then this system is called bimetallic strip.
- If temperature increases of bimetallic strip then more α of material represent the outer surface of arc and if temperature is decrease then more α of material is represent the inner surface of arc.



$$\boxed{R_{avg} = \frac{d}{(\alpha_{Cu} - \alpha_{Fe})\Delta T}}$$

Variation of density:

$$T\uparrow,\ V\uparrow,\ \rho\downarrow,\ \rho = \frac{M}{V}$$

$$\rho_i = \frac{M}{V_i}$$

If $T\uparrow$,

$$\rho_f = \frac{M}{V_f} = \frac{M}{V_i(1+\gamma\Delta T)}$$

$$\rho_f = \rho_i(1+\gamma\Delta T)^{-1}$$

$$\boxed{\rho_f = \rho_i(1-\gamma\Delta T)}$$

Apparent expansion of liquid:

- If liquid is filled in a vessel and heated then expansion of liquid w.r.t. vessel is called apparent expansion of liquid.

Concept Reminder

A bimetallic strip has characteristic property of bending on heating due to unequal linear expansion of two metals.

Rack your Brain

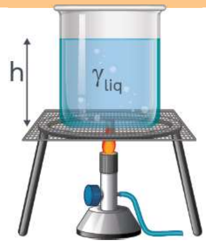
The density of water at 20°C is 998 kg/m^3 and at 40°C is 992 kg/m^3. Find the coefficient of volume expansion of water.

$$\gamma_{app} = \gamma_{liquid/vessel} = \gamma_{liquid} - \gamma_{vessel}$$

If $\gamma_{liquid} > \gamma_{vessel} \Rightarrow$ liquid level rises

If $\gamma_{liquid} < \gamma_{vessel} \Rightarrow$ liquid level falls

If $\gamma_{liquid} = \gamma_{vessel} \Rightarrow$ liquid level remains same



Ex. A liquid expansion coefficient is γ filled in a vessel of linear expansion coefficient $\gamma/3$ if liquid is heated then find out the height of liquid.

Sol. $\gamma_{app} = \gamma_{liquid} - \gamma_{vessel}$

$$\gamma_{app} = \gamma - 3 \cdot \frac{\gamma}{3} \qquad \left(\alpha = \frac{\gamma}{3}\right)$$

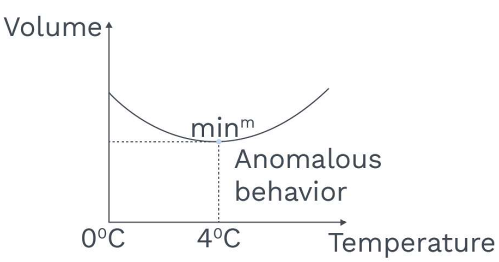
$$\gamma_{app} = 0$$

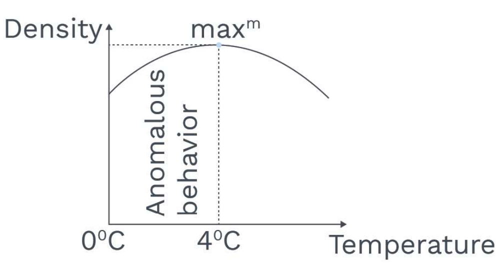
$\therefore$ h remains constant.

Anomalous expansion of water:

Aquatic life is able to keep on the cold winter as the lake bottom remains unfrozen at a temperature of about 4°C.

- At 4°C, specific volume is minimum while its density of water is maximum.





Concept Reminder

The lake freezes first at the surface and water in contact with ice has 0°C temperature while at the bottom of lake 4°C temperature. Thus fish and other aquatic animals remain alive in this water.

CALORIMETRY

HEAT:

- When energy will flow from higher temperature body to lower temperature body then this energy is known as heat.
- Heat is a form of energy.
- For heat transfer, there must be temperature difference between bodies in contact.
- SI unit: Joule, CGS unit: erg (1 joule = 10^7 erg)
- Calorie is the amount of heat transferred to raise the temperature of 1 gram of water by 1°C or 1 K.

Mechanical Equivalent of Heat:

- According to joule, work may be converted into heat and vice-versa.
- The ratio of work-done to the heat produced is always constant.

$$\frac{W}{Q} = \text{constant (J)} \Rightarrow W = JQ$$

W must be in joule and Q must be in calorie.
J = 4.186 Joule/cal
Generally we take, J = 4.2 Joule/cal.

Specific heat capacity/specific heat:

- It is the specific amount of heat given to any substance to increase its temperature by 1°C or 1 K having mass 1 gram at normal pressure (1 atm).

$$\boxed{Q = ms\Delta T}$$

Q = heat, s = specific heat capacity, m = mass of substance and ΔT = change in temperature.

$$\therefore \quad s = \frac{Q}{m \cdot \Delta T}$$

SI unit

$$\Rightarrow \frac{J}{kg\,K}, \frac{J}{kg\,°C}, \frac{cal}{gK}, \frac{cal}{g\,°C}$$

Dimension is $[L^2T^{-2}\theta^{-1}]$
specific heat capacity of water

Definitions

The heat is energy in transit which is transferred from one body to the other due to temperature difference between them.

KEY POINTS

- Heat
- Specific heat capacity
- Calorie
- Heat capacity

$$= \frac{1\,cal}{1\,gm\,°C} = 4200\,J/kg\,K$$

specific heat capacity of ice/steam

$$= \frac{1}{2}\frac{cal}{gm\,°C} = 2100\frac{J}{kg\,K}$$

specific heat of solid and liquid are considered to be constant.

specific heat of gases are variable.

$\boxed{s_{vapour} > s_{liquid} > s_{solid}}$ not for water.

specific heat is maximum in gases.

Mechanical energy of heat:

$$\frac{1}{2}\frac{mv^2}{J} = ms\Delta T$$

$$\frac{mgh}{J} = ms\Delta T$$

$$\frac{1}{2}\frac{I\omega^2}{J} = ms\Delta T$$

Ex. Find amount of heat required to increase the temperature of 5 g of water by 40°C.

Sol. $Q = ms\Delta T$

$Q = 5 \times 1 \times 40 = 200$ cal

$= 200 \times 4.2 = 840$ J

Ex. A wooden block of mass '10' kg is dropped from a height of 400 m. Find the temperature rise in the block. If 25% of energy is lost in the surroundings. ($s_{block} = 200$ J/kg^{-1} °C)

Sol. $$\frac{75}{100}\cdot mgh = ms\Delta T$$

$$\frac{3}{4} \times 10 \times 400 = 200 \times \Delta T$$

$$\Delta T = \frac{3}{4}\left(\frac{10 \times 400}{200}\right) = 15°C$$

Rack your Brain

Two identical bodies are made of a material for which the heat capacity increases with temperature one of these is at 100°C, while the other is at 0°C. If the two bodies are brought into contact, then assuming no heat loss, the final common temperature is

(1) 50°C

(2) more than 50°C

(3) less than 50°C

(4) 0°C

Heat capacity (thermal capacity) :

- It is the amount of heat required to increase the temperature of whole body by 1°C.
- Heat capacity, $ms = \frac{Q}{\Delta T}$
- SI unit = $\frac{J}{K}$ or JK^{-1} or $J\ °C^{-1}$
- Dimension = $[ML^2T^{-2}\theta^{-1}]$
- Thermal capacity depends on mass of the body and property of material.

$$\boxed{(H_c)_{vapour} > (H_c)_{liquid} > (H_c)_{solid}}$$

Molar specific heat:

It is amount of heat required to raise the temperature of one mole of substance by 1°C.

Molar specific heat = $M_w \times s$

$$= M_w \times \frac{Q}{m\Delta T} = \frac{1}{n}\left(\frac{Q}{\Delta T}\right)$$

$$n = \frac{m}{M_w}$$

Unit = $J\ mol^{-1}\ K^{-1}$ or $J\ mol^{-1}\ °C^{-1}$ or $cal\ mol^{-1}\ K^{-1}$.

Water equivalent:

Water equivalent of an object is the amount of water (in gram) that absorbs or gives out the same amount of heat as is done by the body when heated or cooled through 1°C.

Phase conversion:

Solid $\xrightarrow{\text{melting}}$ Liquid

Liquid $\xrightarrow{\text{vapourization}}$ Gas

Solid $\xrightarrow{\text{sublimation}}$ Gas

Liquid $\xrightarrow{\text{freezing}}$ Solid

Gas $\xrightarrow{\text{condensation}}$ Liquid

Rack your Brain

If 1 gm of steam is mixed with 1 gm of ice, then what is temperature of the mixture.

Gas $\xrightarrow{\text{deposition}}$ Solid

In phase conversion temperature and pressure remains constant, if pressure is not given then consider 1 atm pressure.

Latent Heat/Hidden Heat (L):

- The amount of heat require to convert the phase of unit substance is called latent heat.
  For unit mass $\rightarrow$ L
  For m – mass $\rightarrow$ mL

$$\boxed{Q = mL}$$

Types of latent heat:

1. Latent heat of fusion:

- The amount of heat require to convert 1 gm substance from solid to liquid.

$$\underset{\text{(ice)}}{\text{Solid}} \xrightarrow{L_f} \underset{\text{(water)}}{\text{liquid}}$$

$$Q_f = mL_f$$

$$L_{f \text{ or ice}} = 80 \text{ cal / gm}$$

2. Latent heat of vapourization:

- The amount of heat require to convert 1 gm substance from liquid to gas.

$$\text{Liquid} \rightarrow \text{Gas}$$

$$\boxed{Q_v = mL_v}$$

$$L_{v \text{ or steam}} \simeq 540 \text{ cal / gm}$$

Note:
In phase conversion $\rightarrow$ latent heat
In temperature change $\rightarrow$ specific heat.

Concept Reminder

Melting of ice under pressure & solidification when pressure is released is called regelation.

Ex. For m mass heat is given with constant rate P watt then its phase is change in time 't' then find out latent heat of substance.

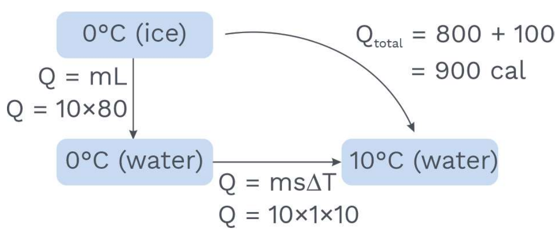
Sol. $P_{watt} = PJ / sec$

$Q = mL, \quad Pt = mL$

$L = \frac{Pt}{m}$

Ex. 10 gm ice is at 0°C then find out the how much heat required to convert into 10°C water.

Sol. Specific heat of H_2O = 1 cal/gm°C
specific heat of ice = 0.5 cal/gm°C
specific heat of steam = 0.47 cal/gm°C



Ex. 10 gm ice is at –10°C then find out the how much heat is required to convert into 102°C steam.

Sol.

10gm (–10°C) (ice)

↓ $Q = ms\Delta T = 10 \times (0.5)10 = 50$

10gm 0°C (ice)

↓ $Q = mL = 10 \times 80 = 800$

0°C (water)

↓ $Q = ms\Delta T = 10 \times 1 \times 100 = 1000$

100°C (water)

↓ $Q = mL = 10 \times (540) = 5400$

100°C (steam)

↓ $\Delta Q = ms\Delta T = 10 \times (0.47)2 = 9.4$

102°C (steam)

KEY POINTS

- Latent heat of fusion
- Latent heat of vaporization
- Phase conversion

Rack your Brain

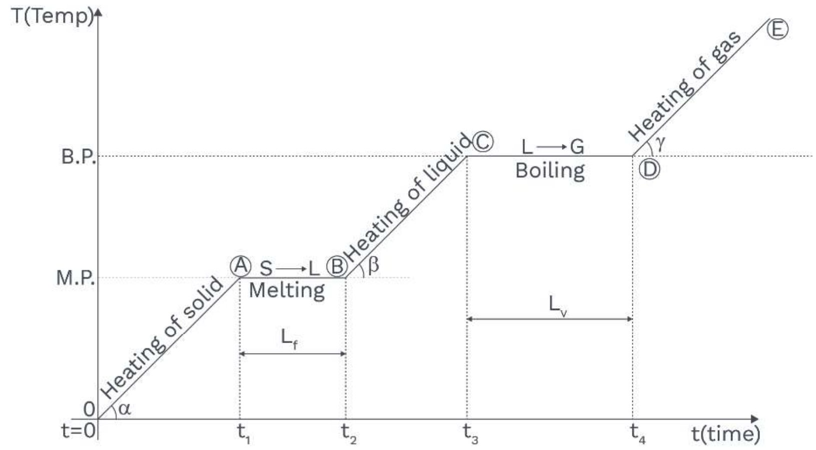
The temperature of 100 g of water is to be raised from 24°C to 90°C by adding steam to it. Calculate the mass of the steam required for this purpose.

Total heat required

$\Delta Q = 50 + 800 + 1000 + 5400 + 9.4 = 7259.4$ cal

Heating Curve:

- For a solid 'm' mass heat is supply with constant rate P_{watt} then curve plot between temperature v/s time is called heating curve.



In region OA, BC and DE (temperature change)

$\Delta Q = ms\Delta T$

$P_{watt} = \dfrac{Q}{\Delta t}$

$P\Delta t = ms\Delta T$

slope $(m) = \dfrac{\Delta T}{\Delta t} = \dfrac{P}{ms} \Rightarrow m \propto \dfrac{1}{s}$

$\boxed{\text{Slope of curve} \propto \dfrac{1}{\text{specific heat}}}$

Then $s_{ice} \simeq s_{steam} < s_{liquid}$

$\boxed{\alpha \simeq \gamma > \beta}$

In region AB and CD (temperature constant)

$Q = mL$

$P = \dfrac{Q}{t} \Rightarrow Q = Pt$

$Pt = mL \Rightarrow L \propto t,\quad \boxed{L \propto t}$

$\boxed{\text{Latent heat} \propto \text{time} \propto \text{length of curve}}$

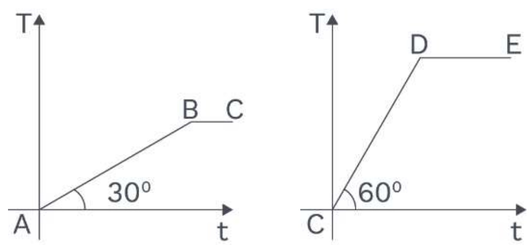
(latent heat)$_v$> (latent heat)$_f$

then

(length of curve)$_v$> (length of curve)$_f$

- In phase conversion specific heat is infinite because slope of curve in phase conversion is zero.

Ex. In given curve compare the specific heat and latent heat.



Sol. Slope of curve $\propto \dfrac{1}{\text{specific heat}}$

$m = \tan\theta \Rightarrow m_{CD} > m_{AB}$

$s_{AB} > s_{CD}$

Latent heat $\propto$ time $\propto$ length of curve

$L_{DE} > L_{BC}$

Ex. If water is falling from 84 m height then find out the increasing in temperature when it strike on ground. (total energy convert into heat)

Sol. W = Q

mgh = (msΔT)

$$\Delta T = \frac{gh}{s}$$

$$\Delta T = \frac{10 \times 84}{4200} \quad (s = 1 \text{ cal/gm°C} \Rightarrow 4200 \text{ J/kg°C})$$

$\Delta T = 0.2°C$

Concept Reminder

- Specific heat (or thermal capacity) is inversely proportional to the slope of temperature/time curve.
- Latent heat is proportional to length of line of zero slope.

Ex. An ice piece is drop from 84 m height then find out the fraction of melting ice when it reach on ground.

Sol. Total mass of ice = M

melting mass of ice = M'

melting fraction = $\frac{M'}{M}$ = ?

Q = M'L

L = 80 cal/gm = 80 × 4200 J/kg

W = Q

Mgh = M'L

$$\frac{M'}{M} = \frac{gh}{L}$$

$$\frac{M'}{M} = \frac{10 \times 84}{80000 \times 4.2} = \frac{1}{400}$$

Ex. A bullet moving with 300 m/s it penetrate a wooden block then it 50% energy convert into heat then find out temperature increasing of bullet when specific heat of bullet is 150 J/kg°C.

Sol. At here J is not consider because specific heat is given in J/kg.

W = Q

$$\Rightarrow \quad \left[\frac{1}{2}mv^2\right]\frac{1}{2} = ms\Delta T \qquad \Rightarrow \frac{1}{4}v^2 = s\Delta T$$

$$\Rightarrow \quad \Delta T = \frac{1}{4s}v^2 = \frac{(300)^2}{4 \times 150} = 150°C$$

Ex. Assuming radius of earth is 'R', specific heat is 's' and angular velocity is 'ω' if earth rotation is suddenly stop then find out the increasing the temperature of earth surface.

Sol. W = JQ, $I = \frac{2}{5}MR^2$

$$\frac{1}{2}I\omega^2 = Ms\Delta T$$

$$\frac{1}{2}\frac{2}{5}MR^2\omega^2 = JMs\Delta T$$

$$\frac{\omega^2R^2}{5} = Js\Delta T$$

$$\Delta T = \frac{\omega^2R^2}{5Js}$$

Ex. Mass of a person is 32 kg it carry a 10 kg box upto 10 m height energy of a piece of cake is 250 cal and its efficiency is 40% then find out the how much piece of cake is required for given work?

Sol. $mgh = 250 \text{ cal} \Rightarrow 250 \times 4.2\,J$

$$mgh = \left[250 \times 4.2\,J \times \frac{40}{100}\right] n$$

$$42 \times 10 \times 10 \Rightarrow 16.8 \times 25 \times n$$

$$\Rightarrow \quad \frac{42 \times 100}{16.8 \times 25} = n$$

$n = 10$

Law of Mixture (Principle of Calorimetry):

- According to this law two different temperature substance are mix together then heat given by substance at high temperature must be equal to heat absorbed by substance at low temperature.

  heat loss = heat gain

  $$m_1 s_1 \Delta T = m_2 s_2 \Delta T$$

  $$m_1 s_1 (T_H - T_{mix}) = m_2 s_2 (T_{mix} - T_L)$$

  $$\boxed{T_L \le T_{mix} \le T_H}$$

- This law follow the conversion of energy.

Ex. 20 gm water is at 10°C and 30 gm water is at 40°C if these are mix together then find out the T_{mix}.

Sol. Heat loss = heat gain

$\Delta Q = ms\Delta T$

$20(1)\,(T_{mix} - 10) = 30(1)(40 - T_{mix})$

$2\,T_{mix} - 20 = 120 - 3\,T_{mix}$

$5\,T_{mix} = 140$

$$T_{mix} = \frac{140}{5} = 28°C$$

Concept Reminder

- If two bodies are at same temperature, no transfer of heat between them can take place.

Rack your Brain

A piece of ice falls from a height h so that it melts completely only one-quarter of the heat produced is absorbed by the ice and all energy of ice gets converted into heat during its fall. Find the value of h.
[Latent heat of ice is 3.4×10^5 J/kg]

Ex. Heat capacity of a metal is 4200 J/K then find out the water equivalent.

Sol. $W = (MS)_{substance} = (MS)_{water}$

4200 J/K = 4200 J/kg

M = 1 kg

Ex. 25 gm water is filled in a vessel of water equivalent 5 gm at 70°C then find out the T_{mix} when 20 gm of water at 0°C is mixed.

Sol. [25 gm + 5 gm] H_2O at 70°C = 20 gm H_2O at 0°C

$30(1)(70 - T_{mix}) = 20(1)(T_{mix} - 0)$

$210 - 3\,T_{mix} = 2\,T_{mix}$

$210 = 5\,T_{mix}$

$$T_{mix} = \frac{210}{5} = 42°C$$

Ex. For two substance ratio of mass is 1 : 2 and ratio of specific heat is 2 : 3 and its temperature is 10°C and 40°C respectively then find out the temperature of mixture.

Sol. $1 \times 2(T_{mix} - 10) = 2 \times 3(40 - T_{mix})$

$T_{mix} - 10 = 120 - 3\,T_{mix}$

$$T_{mix} = \frac{130}{4} = 32.5°C$$

Ex. Three different substance A, B and C have mass equal and temperature is 10°C, 25°C and 40°C, if temperature of mixture of A and B is 15°C and temperature of mix of B and C is 30°C then find out the temperature of mixture of A and C.

Sol. For AB

$ms_A(15 - 10) = ms_B(25 - 15)$

$5s_A = 10\,s_B$

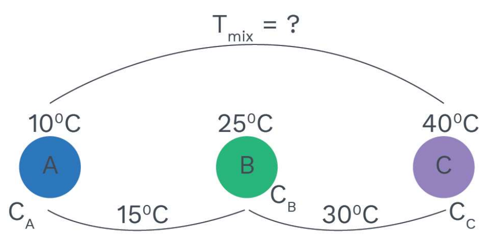
$s_A = 2\,s_B$

For BC

$ms_B(30 - 25°) = ms_C(40 - 30)$

$5\,s_B = 10\,s_C$

$s_B = 2\,s_C$



$$\frac{s_A}{2} = s_B$$

$s_B = 2\,s_C$

$$\Rightarrow \quad \frac{s_A}{2} = 2\,s_C$$

$s_A = 4\,s_C$

For AC

$ms_A(T_{mix} - 10) = ms_C(40 - T_{mix})$

$4s_C(T_{mix} - 10) = s_C(40 - T_{mix})$

$4\,T_{mix} - 40 = 40 - T_{mix}$

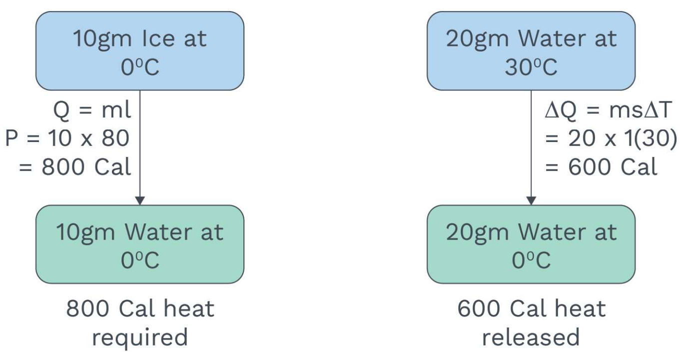
$$T_{mix} = \frac{80}{5}$$

$T_{mix} = 16°C$

> **Concept Reminder**
>
> Temperature of mixture (T) is always $\geq$ lower temperature (T_L) and $\leq$ higher temperature (T_H).

Ex. 10 gm ice is at 0°C is mixed with 20 gm water is at 30°C then find out the final temperature of mix and find out the final combination?

Sol.



$T_{mix} = 0°C$

$\text{Ice} \xrightarrow{600\,\text{cal}} \text{water}$

$Q = mL$

$600 = m(80)$

$m = 7.5$ gm

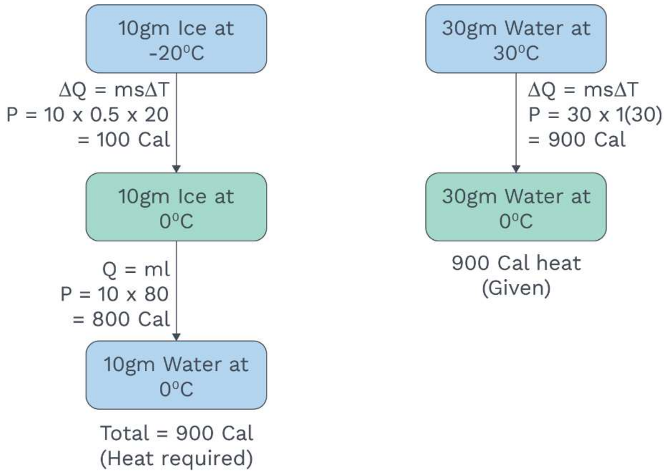
Final amount of water = 20 + 7.5 = 27.5 gm

Final amount of ice = 10 − 7.5 = 2.5 gm

> **Rack your Brain**
>
> When vapour condenser into liquid:
>
> (1) It absorbs heat
>
> (2) It liberates heat
>
> (3) Its temperature increases
>
> (4) Its temperature decreases.

Ex. 10 gm ice is at –20°C and mixed with 30 gm water at 30°C. Then find out the final combination in mixture:

Sol.



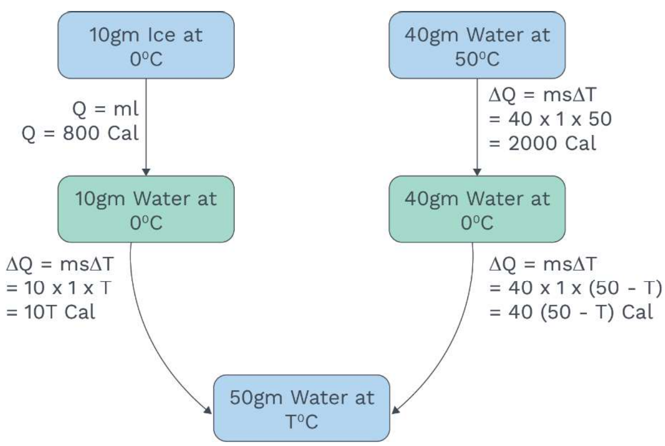
complete ice melt in water.

final amount of water = 30 + 10 = 40 gm

final amount of ice = 0 gm

Ex. 10 gm ice is at 0°C is mixed with 40 gm water is at 50°C then find out the final temperature of mixture.

Sol.



$$\Delta Q = ms\Delta T$$

$$1200 = 50 \times 1(T_{mix} - 0)$$

$$T_{mix} = \frac{1200}{50}$$

$$T_{mix} = 24°C$$

Ex. 2 gm steam is at 100°C is mixed with 20 gm water is at 60°C then find out the final temperature of mix and find out the how much steam can convert into water.

Sol.

20gm water 60°C → 20gm water 100°C

$\Delta Q = ms\Delta T$
$= 20 \times 1 \times 40 = 800$

2gm steam 100°C → 2gm water 100°C

$Q = mL$
$= 2 \times 540 = 1080$ cal

$T_{mix} = 100°C$

$\text{Steam} \xrightarrow{800\,\text{cal}} \text{water}$

$Q = mL_v$

$280 = m(540)$

$\Rightarrow \quad m_{steam} = \frac{280}{540} = 0.51\,\text{gm}$

Steam convert into water is

$2 - 0.51 = 1.48$ gm

$T_{mix} = 100°C$

Total amount of steam remaining in mixture

$= 0.51$ gm

Total amount of water in mixture

$= 20 + 1.48 = 21.48$ gm

Phase diagram:

- A phase diagram is a graph in which pressure (P) is represented along the y-axis and temperature (T) is represented along the x-axis.
- **Characteristics of phase diagram:**

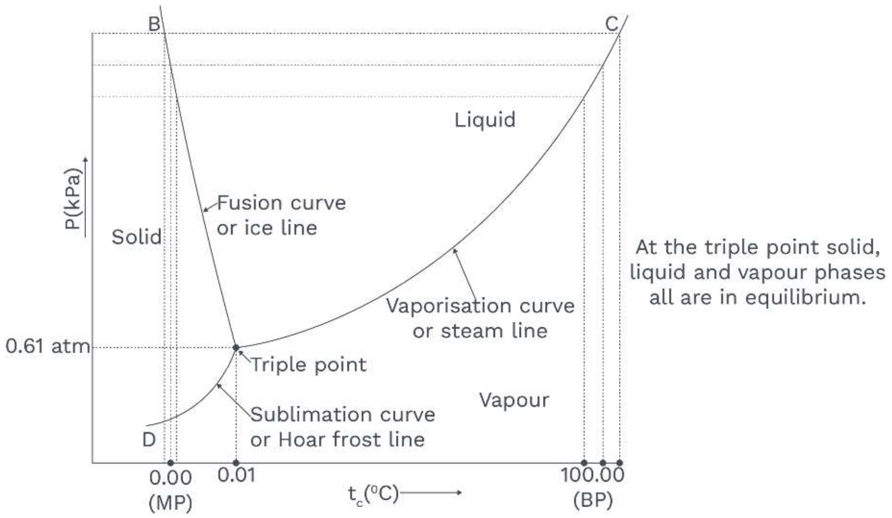
(a) Different phases of a matter can be shown on a phase diagram.

(b) A region on the phase diagram represents a single phase of the substance, a curve represents equilibrium between two phases and a common point represents equilibrium between three phases.

(c) A phase diagram helps to calculate the condition under which the different phases are in equilibrium condition.

(d) A phase diagram is helpful for finding a convenient way in which a desired change of phase can be produced.

Phase diagram for water:
The phase diagram for water consists of three curves, AB, AC and AD meeting each other at the point A, these curves divide the phase diagram into three regions.



Phase diagram for Water

Region to the left of the curve AB and above the curve AD represents the solid phase of water (ice). The region to the right of the curve AB and above the curve AC represents the liquid phase of water. The region below the curves AC and AD represents the gaseous phase of water (i.e. water vapour). A curve on the phase diagram show the boundary between two phases of the substance.

Concept Reminder

The boiling point of water increases with increased pressure up-to critical point. Whereas melting point decreases as pressure increases.

Along any curve the two phases can coexist in equilibrium:

- Along curve AB, ice and water can remain in equilibrium. This curve is called fusion curve or ice line. This curve shows that the melting point of ice decreases with increase in pressure.
- Along the curve AC, water and water vapour can remain in equilibrium. The curve is called vaporisation curve or steam line. The curve shows that the boiling point of water increases

with increase in pressure.

- Along the curve AD, ice and water vapour can remain in equilibrium. This curve is called sublimation curve or hoar frost line.

Triple point of water :

The three curves in the phase diagram of water meet at a single point A, which is called the triple point of water. The triple point of water show the co-existence of all the three phases of water ice water and water vapour in equilibrium. The pressure corresponding to triple point of water is 6.03×10^{-3} atmosphere or 4.58 mm of Hg and temperature corresponding to it is 273.16 K.

- **Significance of triple point of water:**
Triple point of water represents a unique condition and it is used to define the absolute temperature. While making Kelvin's absolute scale, upper fixed point is 273.16 K and lower fixed point is 0 K. One kelvin of temperature is $\frac{1}{273.16}$ part of the temperature of triple point of water.

Effect of change in pressure on M.P. and B.P. for water:

- If $P\uparrow \xrightarrow{\text{then result}}$ M.P. $\downarrow$ and B.P. $\uparrow$
- If $P\downarrow \xrightarrow{\text{then result}}$ M.P. $\uparrow$ and B.P. $\downarrow$

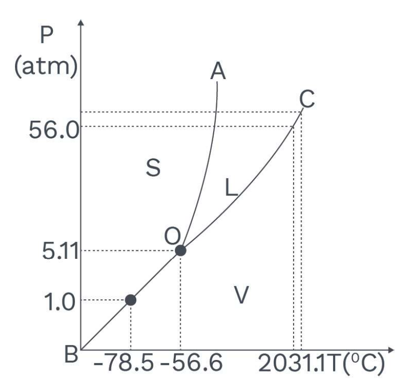
Phase diagram for CO_2:

Effect of change in pressure on M.P. and B.P. for CO_2

- If $P\uparrow \xrightarrow{\text{then result}}$ M.P. $\uparrow$ and B.P. $\uparrow$
- If $P\downarrow \xrightarrow{\text{then result}}$ M.P. $\downarrow$ and B.P. $\downarrow$

Definitions

The triple point is the temperature and pressure at which solid liquid and vapour phases of a particular substance coexist in equilibrium.
Triple point of water is
T = 273.16 K and P = 4.6 mm of Hg.



Example:

(1) A bottle is filled with water at 30°C on opening at moon then water will boil and vapourised.

(2) At higher altitudes of mountain, food can not be cooked properly.

Special points:

- At triple point of water
  Temperature = $0.01^{\circ}C \simeq 273.16\,K$
  Pressure = 4.6 mm of Hg
- Effect of pressure variation on melting point temperature and boiling point temperature can be analysed by phase indicator diagram.
- Slope = $\frac{dP}{dT} = \frac{JL}{T(V_2 - V_1)}$ [by Clausius]

EXAMPLES

Q1 **A pitcher contains 20 kg of water. 0.5 gm of water comes out on the surface of the pitcher every second through the pores and gets evaporated taking energy from the remaining water. Calculate the approximate time in which temperature of the water decreases by 5°C .Neglect backward heat transfer from the atmosphere to the water.**
Specific heat capacity of water = 4200J/Kg°C
Latent heat of vaporization of water 2.27×10^6 J/Kg

Sol: $20 \times 4200 \times 5 = 5 \times 10^{-4} \times 2.27 \times 10^{6} \times t$

$$t = \frac{20 \times 4200}{227 \times 60} = 6.16\,\text{min}$$

Q2 **A thermally insulated, closed copper vessel contains water at '15°C'. When the vessel is shaken vigorously for '15' minutes, the temperature rises to '17°C'. The mass of the vessel is 100 g and that of the water is '200 g'. The specific heat capacities of copper and water are '4200' J/kg-K and '420' J/kg-Kre-spectively. Not consider any thermal expansion. (a) Find out how much heat is transferred to the vessel-liquid system? (b) How much work has been work-done on this system? (c) How much is the rise in internal energy of the sys-tem?**

Sol:
(a) Zero, because there is no heat transfer from outside.
(b) $W = 100 \times 10^{-3} \times 420 \times 2 + 200 \times 10^{-3} \times 4200 \times 2 = 1764\,J$
(c) $\Delta U = 1764\,J$

Q3 **A one liter flask contains some mercury. It is show that at different temperatures the volume of air inside the flask remains the equal. Find out the volume of mercury in the flask? Linear expansion coefficient of glass = 9×10^{-6} /°C. Coefficient of volume expansion of mercury = 1.8×10^{-4} /°C.**

Sol:

$$V_C - V_{Hg} = V_C' - V_{Hg}' = \text{volume of air}$$

$$\Rightarrow \quad V_C' - V_C(1 + 3\alpha_s \Delta\theta)$$

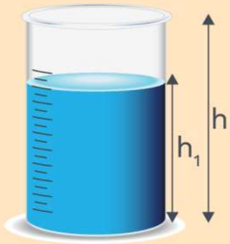
$$V_{Hg}' = V_{Hg}(1 + \gamma_L \Delta\theta)$$

So, $$V_C \times 3\alpha_s = V_{Hg} \times \gamma_L$$

$$V_{Hg} = \frac{1 \times 3 \times 9 \times 10^{-6}}{1.8 \times 10^{-4}}$$

$$V_{Hg} = 0.15\,L$$

Q4 **Consider a cylindrical container of cross section area 'A', length 'h' having coefficient of linear expansion α_c . The container is filled by liquid of expansion coefficient γ_L up to height h_1. When temperature of the system is raised by $\Delta\theta$ then**



(a) Calculate new volume, height and area of cylindrical container and new volume of liquid.
(b) Find the height of liquid level when expansion of container is neglected.
(c) Find the relation between γ_L and α_c for which volume of container above the liquid level.
(i) increases (ii) decreases (iii) remains constant.
(d) If $\gamma_l > 3\alpha_c$ and h = h_1 then calculate, the overflow of liquid volume.

(e) If the surface of a container (cylindrical) is marked with numbers for the measurement level of liquid of liquid filled inside it. Assuming correct reading at initial temperature if we increase the temperature of the system by '$\Delta\theta$' then

(i) Calculate height of liquid level as shown by the scale on the vessel. Neglect expansion of liquid

(ii) Calculate height of liquid level as shown by the scale on the vessel. Neglect expansion of container.

(iii) Find relation between γ_L and α_C so that height of liquid level with respect to ground

(1) increases (2) decreases (3) remains constant.

(a) $h_f = h\{1+\alpha_c\Delta\theta\}$

Sol:

$A_f = A\{1+2\alpha_c\Delta\theta\}$

$V_f = Ah\{1+3\alpha_c\Delta\theta\}$

volume of liquid $V_w = Ah_1(1+\gamma_L\Delta\theta)$

(b) $h_f = h_1\{1+\gamma_L\Delta\theta\}$

(c) (i) $3h\alpha_c > h_1\gamma_l$

(ii) $3h\alpha_c < h_1\gamma_l$

(iii) $3h\alpha_c = h_1\gamma_l$

(d) $\Delta V = Ah(\gamma_L - 3\alpha_c)\Delta\theta$

(e) (i) $h_f = h_1(1-3\alpha_c\Delta\theta)$

(ii) $h_f = h_1(1+\gamma_L\Delta\theta)$

(iii) (1) $\gamma_L > 2\alpha_c$ (2) $\gamma_L < 2\alpha_c$ (3) $\gamma = 2\alpha_c$

Q5 **A metal piece weighing '15g' is heated to '100°C' and then immersed in a mixture of ice and water at the thermal equilibrium. The volume of the mixture is that reduced by 0.15 cm³ with the temperature of mixture remaining constant. Find the specific heat of the metal. Given specific gravity of ice = '0.92', latent heat of fusion of ice = '80' cal/gm.**

Sol:

$$\frac{m}{\rho_{ice}} - \frac{m}{\rho_{H_2O}} = 0.15$$

$$m = \frac{0.15 \times 0.92}{0.08}$$

$\therefore$ $$H_{lost} = H_{gained}$$

$\Rightarrow$ $$15 \times S \times 100 = \frac{0.15 \times 0.92}{0.08} \times 80$$

$$S = 0.092\,\text{cal / gm}^{\circ}\text{C}$$

Q6 **A simple seconds pendulum is constructed out of a very thin string of thermal coefficient of linear expansion $\alpha = 20 \times 10^{-4}\ /\ ^{\circ}C$ and a heavy particle attached to one end. The free end of the string is suspended from the ceiling of an elevator at rest. The pendulum keeps correct time at 0°C. When the temperature rises to 50°C, the elevator operator of mass 60kg being a student of Physics accelerates the elevator vertically, to have the pendulum correct time. Find the apparent weight of the operator when the pendulum keeps correct time at 50°C. (Take g = 10 m/s²)**

Sol:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

When the temperature is raised length changes to $l(1+\alpha\Delta T)$

when the lift accelerates upwards

$$g_{eff} = g + a$$

new period of pendulum,

$$T' = 2\pi\sqrt{\frac{l(1+\alpha\Delta T)}{g+a}}$$

$\Rightarrow$ $$T' = T \Rightarrow g\frac{(1+\alpha\Delta T)}{(g+a)} = 1$$

or $$a = g\alpha\Delta T = 10 \times 20 \times 10^{-4} \times 50 = 1\ \text{m / sec}^2$$

$$w_{eff} = m(g+a) = 60(10+1) = 660\,\text{N}$$

Q7 **Two rods having length l_1 and l_2, made of materials with the linear coefficient of expansion α_1 and α_2, were welded together. The equivalent linear expansion coefficients for the obtained rod :-**

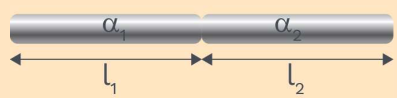
Sol:

$$l_1(1+\alpha_1\Delta T)+l_2(1+\alpha_2\Delta T)=l_f$$

$$l_1 = l_1 + l_2 + (l_1 + \alpha_1 + l_2\alpha_2)\Delta T$$

$$l_f = (l_1 + l_2)\left(1+\frac{l_1\alpha_1 + l_2\alpha_2}{l_1 + l_2}\Delta T\right)$$

Q8 **Steam at '100°C' is passed into '1.1' kg of water contained in a calorimeter of water equivalent '0.02' kg at '15°C' till the temperature of the calorimeter and its contents rises to '80°' C . The amount of mass of the steam condensed in kilogram is :**



Sol: Heat released by steam = heat gained by water and calorimetry

$mL + m \times S\ (100 - 80) = (1.1 + 0.02) \times S \times (80 - 15)$

$m \times 540 + 20\ m = 1.12 \times 65$

$m = 0.130$ kg.

Q9 **Earth receives '1400' W/m² of solar power . If the solar energy falling on a lens of area '0.2' m² is focused on to a block of ice of mass 280 grams, the time taken to melt the ice will be ______ minutes.**
(Latent heat of fusion of ice = 3.3×10^5 J/kg)

Sol: Energy given by the sun = $1400 \times 0.2 \times t$

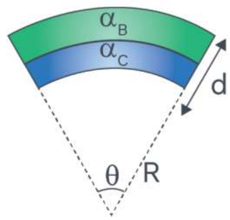
Energy required to melt the ice = $280 \times 10^{-3} \times 3.3 \times 10^5$

$1400 \times 0.2 \times t = 280 \times 10^{-3} \times 3.3 \times 10^5$

$t = 330$ sec.

Q10 **A bimetallic strip is formed out of two identical strips, one of brass and the other of copper. The coefficients of linear expansion of the two metals are α_B and α_C. On heating, the temperature of the strips goes up by ΔT and the strip bends to form an arc of radius of curvature R. Then R is:**

Sol: **Sol.** Let l_0 be the initial length of each strip before heating.
Length after heating will be



$$l_B = l_0(1+\alpha_B \Delta T) = (R+d)\theta \text{ and}$$

$$l_C = l_0(1+\alpha_C \Delta T) = R\theta$$

$$\therefore \quad \frac{R+d}{R} = \left(\frac{1+\alpha_B \Delta T}{1+\alpha_C \Delta T}\right)$$

$$\therefore \quad 1+\frac{d}{R} = 1+(\alpha_B - \alpha_C)\Delta T \quad \text{[From binomial expansion]}$$

$$\therefore \quad R = \frac{d}{(\alpha_B - \alpha_C)\Delta T}$$

or $$R \propto \frac{d}{\Delta T} \text{ and } R \propto \frac{1}{|\alpha_B - \alpha_C|}$$

Q11 **A ‘50’ gm lead bullet, specific heat ‘0.02’ cal/gm is initially at ‘30°C’. It is fired vertically upwards direction with a speed of ‘840’ m/sec & on returning to the starting level strikes a cake of ice at ‘0°C’. How much ice is melted . Assume that all energy is spent in melting only.**
[Latent heat of ice = 80 cal/gm]

Sol: Heat released by bullet = heat gained by ice

$$\Rightarrow \quad \frac{1}{2}mv^2 + mS\Delta\theta = m'L$$

$$\Rightarrow \quad \frac{1}{2}\times(50\times10^{-3})\times(840)^2\times\frac{1}{4.2}+50\times0.02\times(30-0) = m'\times 80$$

m’ = 52.875 gm

Q12 **The temperature of '100' gm of water is to be raised from '24°C' to '90°C' by adding steam to it. Find out the mass of the steam required for this purpose .**

Sol: Heat released by steam = Heat absorbed by water

$m_1L + m_1 \times S\,(100 - 90) = m_2 \times S\,(90 - 24)$

$540\ m_1 + 10\ m_1 = 66\ m_2$

$\Rightarrow \quad m_1 = \dfrac{66 \times 100}{550} = 12\,\text{gm}$

Q13 **An electrical heating coil was placed in a calorimeter containing 360 gm of water at 10°C. The coil expand energy at the rate of 90 watt. The water equivalent of the calorimeter and the coil is 40 gm. Calculate what will be the temperature of water after 10 minutes.**
[J = 4.2 Joules/cal.]

Sol: Energy supplied by coil = heat gain by water and calorimetry

$\Rightarrow \quad Pt = (m_1 + w) \times S\,\Delta\theta$

$\Rightarrow \quad 90 \times (10 \times 60) = (360 + 40) \times 4.2 \times (\theta - 10)$

$\theta = 42.14°C$

Q14 **The brass scale of a barometer gives correct reading at '0°C'. Coefficient of thermal expansion of brass is 0.00002/° C. The barometer reads 75 cm at 27° C. What is the correct atmospheric pressure at 27°C?**

Sol:

$h = h_0\,(1 + \alpha\Delta\theta)$

$h = 75\{1 + 0.00002 \times 27\}$

$h = 75.0405$ cm

Q15 **A clock with an iron pendulum keeps correct time at '20°C'. How much will it lose or gain in a day if the temperature changes to '40°C'? (Coefficient of cubical expansion of iron = 0.000036/° C)**

Sol: Loss or gain in time due to thermal expansion

$$\Delta t = \frac{1}{2} \times \Delta\theta \times t \times \alpha \qquad (\alpha = 0.000036 / °C)$$

t = duration time

1 day = 24 × 3600 sec.

$$\therefore \quad \Delta t = \frac{1}{2} \times 0.000036 \times 20 \times 24 \times 3600$$

$$\Delta t = 31.104 \text{ sec}$$

Note : If we increase temperature then time period increases and watch becomes slow.

MIND MAP

Heat	Temperature
Heat is the form of energy transferred between two or more systems and its surrounding by virtue of temperature difference.	Temperature is the thermal state of the body which would determine the direction of flow of heat when this body is placed in contact with another body.

Change of state - During the change of phase, temperature remains constant but heat is being supplied to the body

- Latent heat of fusion (L_f)

  Solid $\xrightarrow{Q=mL_f}$ Liquid
- Latent heat of Vapourisation (L_v)

  LIquid $\xrightarrow{Q=mL_v}$ Vapour
- Latent heat of Sublimation (L_s)

  Solid $\xrightarrow{Q=mL_s}$ Gas

Thermal expansion - Increase in confriguration of a solid with increasing temperature

- Linear Expansion

  $L = L_0(1 + \alpha\,\Delta T)$
- Superficial Expansion

  $A = A_0(1 + \beta\,\Delta T)$
- Volume Expansion

  $V = V_0(1 + \gamma\,\Delta T)$

Relation between

α, β and γ

$\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$

Principle of Calorimetry

- It is based on the law of conservation of energy

  Heat lost by one body = Heat gained by other body

Thermometry - A branch of physics deals with the measurement of tempertaure is known as thermometry

- Conversion of temperature scale

  $\frac{C}{5} = \frac{F - 32}{9} = \frac{K - 273}{5} = \frac{R}{4}$

  Where C = Celsius, F = Fahrenheit
  K = Kelvin, R = Reamur
- Triple point of water

  Temperature and pressure at which all the time phases of water exits in equilibrium T_c = 293.16 K

Heat Capacity - The amount of heat absorbed by a given amount of substance to change the temperature by unity

- Molar Specific Heat

  The amount of heat required to raise the temperature of one mole of a substance by unity

  $C = \frac{\Delta Q}{n\Delta T}$
- Specific Heat Capacity

  The amount of heat required to raise the temperature of 1g of substance by 1°C

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