THERMAL PROPERTIES OF MATTER

Heat and Temporature :-

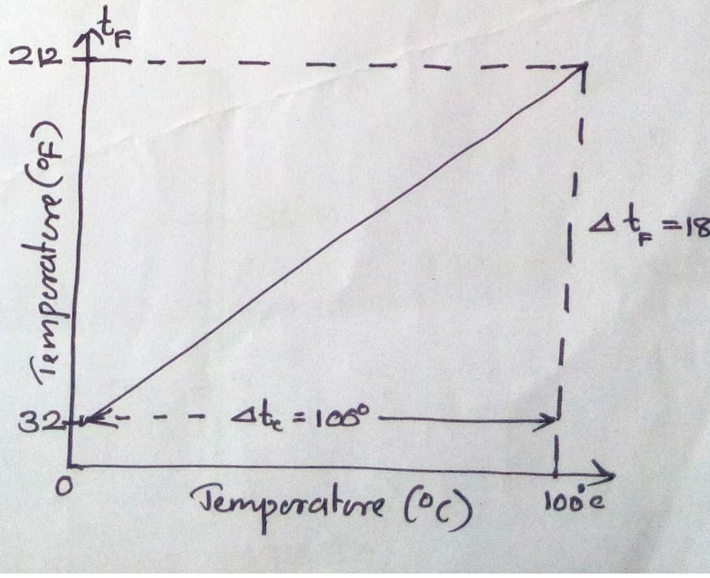
Temperature is the relative measure of hotness or coldness. Heat is the form of energy transferred between two (or more) systems or a system and its sorroundings by virtue of temperature difference. The SI unit of heat energy is Joule while that of temperature is Kelvin.

Measurement of temperature

A measure of temperature is obtained using a thermometer. For the defenition of any standard scale, two fixed reference points are needed. The ice point and the steam point are two convenient fixed points and are known as the freezing and boiling points.

	Fahrenheit scale	Celcius Scale
Ice point	$32^\circ F$	$0^\circ c$
Steam point	$212^\circ F$	$100^\circ c$

$$\frac{t_f - 32}{180} = \frac{t_c}{100}$$



Ideal gas equation and absolute temperature.

Boyle's law ⇒ $V \propto \frac{1}{P}$ ⇒ $PV =$ a constant

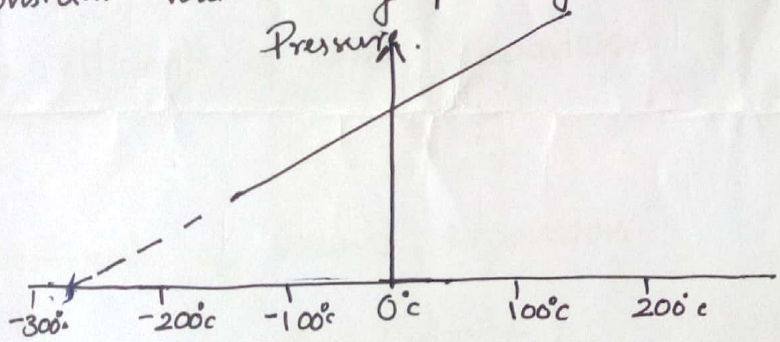
Charle's law ⇒ $V \propto T$ ⇒ $\frac{V}{T} =$ a Constant

$$\frac{PV}{T} = \text{a Constant}$$

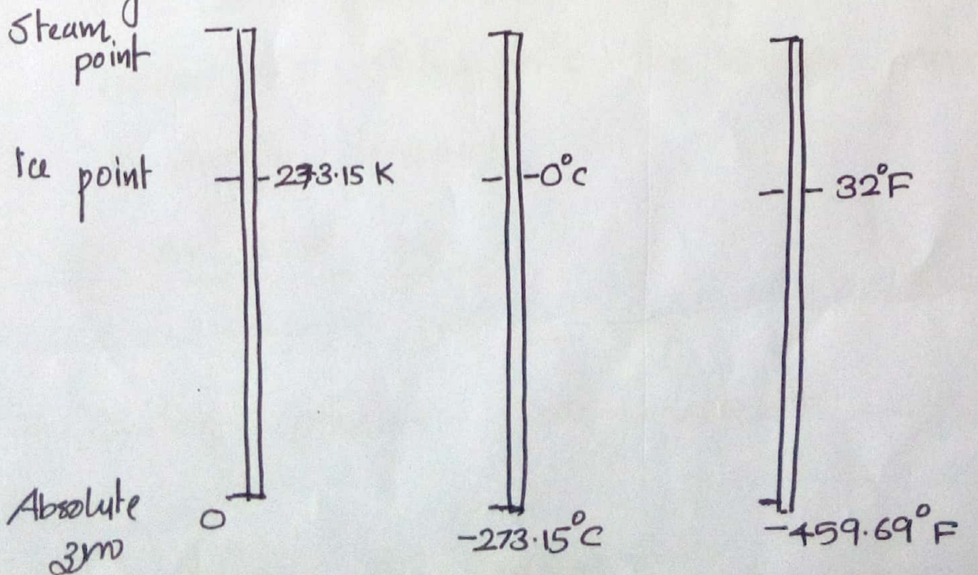
$PV = \mu RT$, ideal gas equation

Where μ is the number of moles in the sample of gas and R is the universal gas constant $R = 8.31 J/mol K$

The variation of pressure with temperature of a gas at constant volume is graphically shown in the figure.



The absolute minimum temperature of an ideal gas is called absolute zero. $(-273.15°C) = 0K$



$TK = t°c + 273.15$

Thermal expansion

The increase in the dimension of a body due to the increase in its temperature is called thermal expansion. The expansion in length is called linear expansion, expansion in area is called area expansion, expansion in volume is called volume expansion.

Co-efficient of linear expansion

$$\frac{\Delta l}{l} \propto T \Rightarrow \frac{\Delta l}{l} = \alpha_l \Delta T$$

$$\alpha_l = \frac{\Delta l}{l} \times \frac{1}{\Delta T}$$

Co-efficient of area expansion

$$\alpha_a = \frac{\Delta a}{a} \times \frac{1}{\Delta T}$$

Coefficient of volume expansion

$$\alpha_v = \frac{\Delta V}{V} \times \frac{1}{\Delta T}$$

Note:- The volume of a given amount of water decreases as it is cooled from room temperature, until its temperature reaches 4°c. Below 4°c, the volume increases, and therefore the density decreases.

α_v for an ideal gas *

$$PV = \mu RT \quad \text{—— (1)}$$

At Constant pressure, $P\Delta V = \mu R \Delta T$ —— (2)

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

ie $\alpha_v = \frac{1}{T}$, for ideal gas

At $0^\circ c$, $\alpha_v = 3.7 \times 10^{-3}\ K^{-1}$

Relation between α_l and α_v

Consider a cube of length l, that expands equally in all direction, when its temperature increases by ΔT. We have

$$\Delta l = \alpha_l \, l \, \Delta T$$

$$\Delta V = (l + \Delta l)^3 - l^3$$

$$\simeq 3 l^2 \Delta l$$

$$= 3 l^3 \alpha_l \Delta T$$

$$= 3 V \alpha_l \Delta T$$

$$\frac{\Delta V}{V} \cdot \frac{1}{\Delta T} = 3 \alpha_l$$

$$\alpha_v = 3 \alpha_l$$

IIIly $\alpha_a = 2 \alpha_l$

Thermal stress

When the thermal expansion of a rod is prevented by fixing its ends rigidly, the corresponding stress set up in the rod is called thermal stress.

Specific heat Capacity.

The quantity of heat required to warm a given substance depends on

(i) its mass

(ii) change in temperature ΔT

(iii) Nature of the substance.

Heat Capacity :- The quantity of heat required to raise the temperature of a body by 1K is called its heat capacity.

$$S = \frac{\Delta Q}{\Delta T}$$, Where ΔQ is the amount of heat supplied and ΔT is the change in temperature.

Specific heat capacity :- The quantity of heat required to raise the temperature of 1kg of a substance through 1K is called its specific heat capacity.

$$s = \frac{S}{m} = \frac{1}{m}\frac{\Delta Q}{\Delta T}$$

Molar Specific heat capacity :- The quantity of heat required to raise the temperature of 1 mol of a substance through 1K is called its molar specific heat capacity.

$$C = \frac{S}{\mu} = \frac{1}{\mu}\frac{\Delta Q}{\Delta T}$$

Its unit is $J\ mol^{-1}\ K^{-1}$

Note: Molar specific heat capacity at constant pressure is denoted by C_p and that at constant volume is denoted by C_v

Calorimetry

A system is said to be isolated if no exchange or transfer of heat occurs between the system and its sorroundings. When different parts of an isolated system are at different temperature, a quantity of heat transfer from the part at higher temperature to the part at lower temperature. The heat lost by the part at higher temperature is equal to the heat gained by the part at lower temperature.

Calorimetry means the measurement of heat. A device in which heat measurement can be made is called a calorimeter.

Change of state

The change of state from solid to liquid is called melting and from liquid to solid is called fusion.

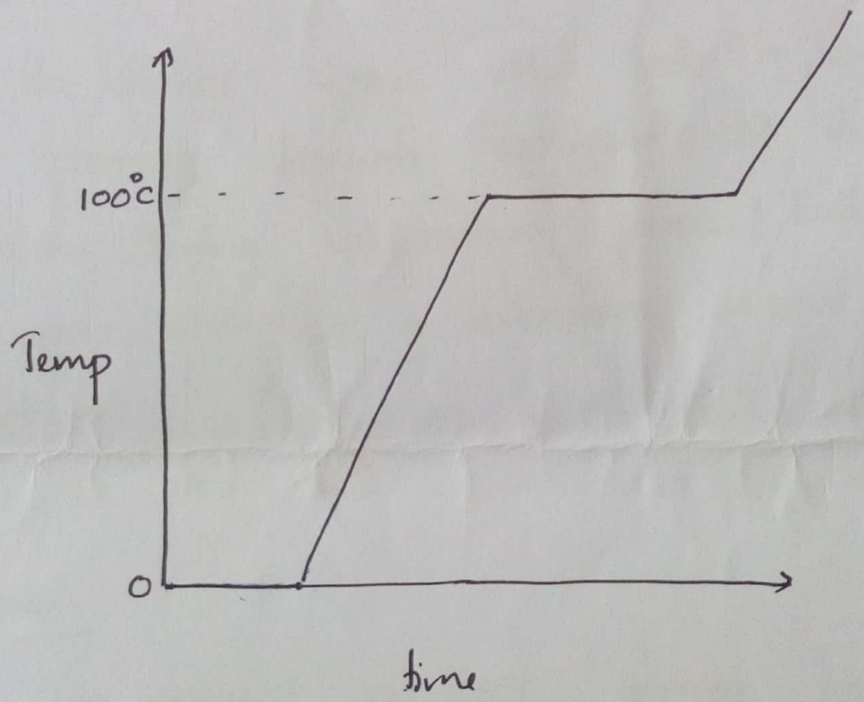
"Both the solid and liquid states of the substance co-exist in thermal equilibrium during the change of state from solid to liquid"

The temperature at which the solid and liquid states of the substance in thermal equilibrium with each other is called its melting point. The melting point of substance at standard atmospheric pressure is called normal melting point.

Melting point depends on

(i) Nature of the substance

(ii) Pressure.



Note: The phenomonon of refreezing is regelation

The change of state from liquid to vapour (or gas) is called vaporisation.

The liquid and vapour states of the substance co-exist in thermal equilibrium, during the change of state from liquid to vapour. The temperature at which the liquid and and the vapour states of the substance coexist is called its boiling point.

Note: Boiling point increases with the increase in pressure.

- Cooking is difficult on hills
- Pressure cooker

The boiling point of a substance at standard atmospheric pressure is called normal boiling point.

Sublimation

The change from solid state to vapour state without passing through the liquid state is called sublimation. During sublimation process, both the solid and vapour states of a substance co exist in thermal equilibrium.

Eg: Dry ice (solid CO_2)

Latent heat

The amount of heat energy ~~transferred~~ per unit mass transferred during change of state of the substance is called latent heat of the substance for the process.

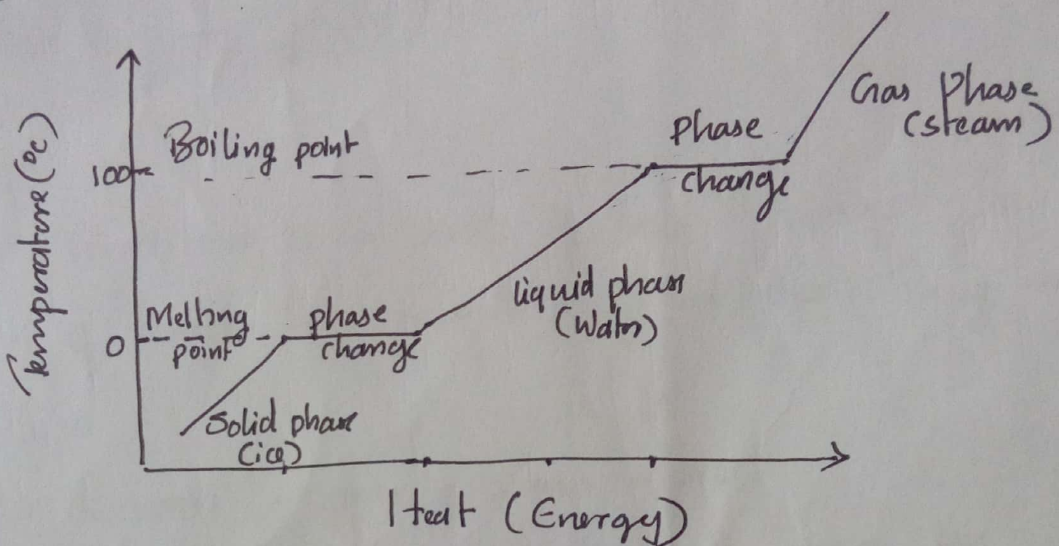
$$L = \frac{Q}{m}$$

unit is J/Kg

It depends on

(i) Nature of substance
(ii) Pressure.

The latent heat for a solid - liquid state change is called latent heat of fusion (L_f) and that for a liquid-gas state change is called the latent heat of vaporisation.



Heat transfer

There are three distinct mode of heat transfer: conduction, convection and radiation.

Conduction

Conduction is the mechanism of transfer of heat b/w two adjacent part of a body because of their temperature difference.

At steady state, the rate of flow of heat

$H \propto$ Temperature difference $(T_C - T_D)$

$H \propto A$

$H \propto \frac{1}{L}$

$$H \propto \frac{A(T_C - T_D)}{L}$$

$$H = \frac{KA(T_C - T_D)}{L}$$

Where K is a constant called the thermal conductivity. Its unit is $J s^{-1} m^{-1} K^{-1}$

Convection

Convection is a mode of heat transfer by actual motion of matter. It is possible only in fluids. They are of two types

(i) Natural – gravity plays a role

(ii) Forced – Material is forced to move by a pump or by some other physical means.

Radiation

The transfer of heat without the aid of any physical medium is called radiation. The energy so radiated by electromagnetic wave is called radiant energy.

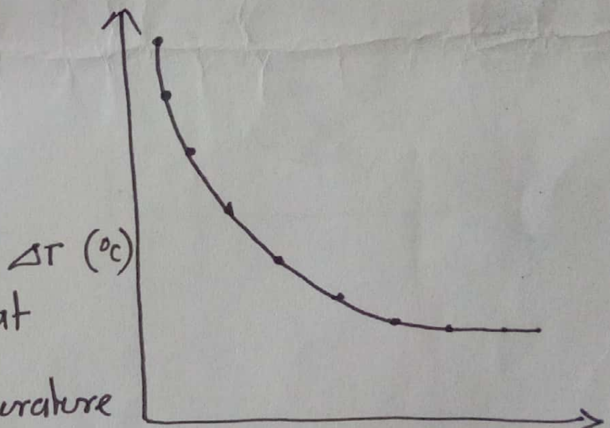
The electromagnetic radiation emitted by a body by virtue of its temperature is called thermal radiation.

When this thermal radiation falls on other bodies, it is partly reflected and partly absorbed. The amount of heat that a body can absorb by radiation depends on the color of the body. Black bodies absorb and emit radiant energy better than bodies of lighter colours.

Newtons law of Cooling

The rate of loss of heat, $-\frac{dQ}{dt}$ of the body is directly proportional to the difference of temperature $\Delta T = (T_2 - T_1)$ of the body and the surroundings

$$-\frac{dQ}{dt} = K(T_2 - T_1) \quad \text{— (1)}$$



Consider a body of mass 'm' and specific heat capacity 's' is at temperature T_2. Let T_1 be the temperature of the surroundings.

If the temperature falls by a small amount dT_2 in time dt,

Then the amount of heat lost

$$dQ = ms\,dT_2$$

$\therefore$ Rate of loss of heat

$$\frac{dQ}{dt} = ms\frac{dT_2}{dt} \quad \text{— (2)}$$

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$\therefore$ from eqn (1) & (2)

$$-ms\frac{dT_2}{dt} = k(T_2 - T_1)$$

$$\frac{dT_2}{T_2 - T_1} = \frac{-K}{ms}\,dt$$

$$\frac{dT_2}{T_2 - T_1} = -\mathcal{K}\,dt \qquad \text{wher } \mathcal{K} = \frac{K}{ms}$$

$$\log_e(T_2 - T_1) = -\kappa t + c$$

$$T_2 = T_1 + e^c e^{-\kappa t}$$

$$\log_e(T_2 - T_1) \propto t$$