EXPANSION OF SOLIDS

1. TEMPERATURE :

a. It is the thermal condition of a body which determines its ability to transfer heat to other bodies

b. Relation between celsius and Fahrenheit scales is $F = \frac{9}{5}C + 32$

c. General relation for any arbitrary scale of temeprature.

$$\frac{S - L.F.P}{U.F.P - L.F.P} = \text{Constant}$$

Where 's' is reading on a scale.

2. Linear expansion:

$$\alpha = \frac{l_2 - l_1}{l_1(t_2 - t_1)}$$

α :Coefficient of linear expansion.

$l_2 - l_1$: : Increase in length

$t_2 - t_1$: : Increase in Temperature.

3. Superficial or areal expansion:

$$\beta = \frac{a_2 - a_1}{a_1(t_2 - t_1)}$$

β : Coefficient of areal expansion

$a_2 - a_1$:Increase in area

$t_2 - t_1$: in crease in Temperature.

4. Volume Expansion:

$$\gamma = \frac{V_2 - V_1}{V_1(t_2 - t_1)}$$

γ : Coefficient of volume expansion

$V_2 - V_1$: Increase in volume

$t_2 - t_1$: Increase in temperature

5. Relation between α, β and γ

$$\alpha : \beta : \gamma = 1 : 2 : 3$$

α, β and γ are measured $/^0C$.

6. Variation of density of solids,

$d_0 = d_t (1 + \gamma t)$

d_0 and d_t are densities at 0^0C and t^0C respectively.

γ coefficient of volume expansion.

EXPANSION OF LIQUIDS

1. Liquids have definite volume, but do not have definite Shape. So they have only cubical expansion.

2. When liquid is heated in a container the container also expands. Hence liquids have two types of cubical expansion.

3. On heating liquids expand. The expansion is more than that for solids.

4. There are two coefficients of expansion for a liquid.
   i) Coefficient of apparent expansion.
   ii) Coefficient of real expansion.

5. Coefficient of apparent expansion (γ_a) : -

The coefficient of apparent expansion of a liquid is the ratio of the apparent increase in the volume of the liquid per degree rise of temperature to its. Original volume.

a. $\boldsymbol{\gamma}_a = \frac{v_2 - v_1}{v_1(t_2 - t_1)} /^0 C$

b. $v_2 = v_1 \left[1 + \gamma_a (t_2 - t_1)\right]$

Where v_2 - v_1 = apparent increase in volume

$(t_2 - t_1)$ = Increase in temperature.

v_1 = volume at $t_1{}^0C$

v_2 = volume at $t_2{}^0C$

6. Coefficient of real expansion (γ_r) :

The coefficient of real expansion of a liquid is the ratio of the real increase in volume of the liquid to its original volume per 1^0C rise of temperature.

(ie) $\gamma_r = \frac{v_2 - v_1}{v_2(t_2 - t_1)} /^0 C$

v_2 - v_1 = real increase in volume

t_2 - t_1 = increase in temperature.

v_1 = volume at $t_1{}^0C$

v_2 = volume at $t_2{}^0C$

7. Coefficient of apparent expansion and Coefficient of real expansion units $/^0C$ or /k.

8. Relation between γ_a & γ_r :

$$\gamma_r = \gamma_a + \gamma_g \,(\text{or})$$

$$\gamma_r = \gamma_a + 3\alpha \;\left[\because \gamma_g = 3\alpha\right]$$

Where α is the coefficient of linear expansion

9. γ_a is determined using specific gravity bottle method.

$$\gamma_a = \frac{\text{mass of the liquid expelled}}{\text{mass of the liquid remained x temp. difference}}$$

$$= \frac{m_1 - m_2}{m_2(t_2 - t_1)} = \frac{w_2 - w_3}{(w_2 - w_1)(t_2 - t_1)}$$

Where m_1 mass of the liquid at $t_1{}^0C$
Where m_2 mass of the liquid at $t_2{}^0C$
And w_1 = mass of the specific gravity bottle
w_2 = mass of the bottle + liquid at $t_1{}^0C$
t_1 = Initial temperature
w_3 = mass of bottle + liquid at $t_2{}^0C$
t_2 = Final temperature

10. As the temperature of liquid increases its density decreases.

11. Variation of density of liquid with temperature

$$d_2 = \frac{d_1}{1 + \gamma_r (t_2 - t_1)} \,(\text{or})\, d_t = \frac{d_0}{1 + \gamma_r t}$$

d_1 is the density of liquid at $t_1{}^0C$
d_2 is the density of liquid at $t_2{}^0C$
γ_r coefficient of real expansion,

12. Coefficient of real expansion of a liquid in terms of density

$$\gamma_r = \frac{d_1 - d_2}{d_2 (t_2 - t_1)} /^0 C$$

Where d_1 is density of liquid at $t_1{}^0C$
Where d_2 is density of liquid at $t_2{}^0C$

13. Anomalous expansion of water: Generally all liquids expand on heating but pure water contracts from 0^0C to 4^0C temperature. This peculiar behaviour of water is called Anomalous expansion of water.

14. Density of water is maximum at 4^0C (or) 277 K And minimum volume at 4^0C (or) 277K

15. Anomalous expansion of water can be demonstrated with Hopes apparatus (or) dilatometer.

EXPANSION OF GASES

1. Gases do not posses finite size and fixed shape. But they posses pressure.
2. While doing experiments, a gas must be taken in a closed container.
3. four parameters which define the state of a gas are P, V, T and n.
4. Pressure of a gas is measured by
   a. manometer Bourdon's gange (highpressure)
   b. M C leod gange (low pressure)
   c. Fortin's barometer (measuring atmospheric pressure).

5. A moderate fall in the barometer reading indicates an incoming rain and a sudden fall predicts a storm.

6. As we go up in the atmosphere, atmospheric pressure decreases.

7. A balloon bursts as it reaches higher altitudes because of decreases of atmospheric pressure.

8. Volume of the gas is measured using a gas burette or eudiometer.

9. Boyle's law : At constant temperature, the pressure of a given mass of a gas is inversely proportional to its volume.

(ie) $P \,\alpha\, \frac{1}{v} \;or\; pv = k$ if n & T are const.

$$\Rightarrow \quad p_1 v_1 = p_2 v_2$$

10. **Charles I law :** When the pressure of a gas is kept constant the volume of a given mass of gas is proportional to absolute temperature.

(ie) $\frac{v}{T}$ = constant if n and p are held fixed.

$$\Rightarrow \quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

11. **Charle's II law :** At constant volume, the pressure of a given mass of a gas is directly proportional to its absolute temperature.

$$\left(ie\right)\ P\alpha T\left(or\right)\ \frac{P}{T}=court\ \ \left(or\right)\frac{P_1}{T_1}=\frac{P_2}{T_2}$$

12. When heat is given to a gas, both its volume and pressure undergo changes.
$\therefore$ A gas has two different coefficients of expansion

   a. The coefficient of expansion of a gas at constant pressure called volume coefficient (α) of a gas
   b. The coefficient of expansion of a gas at constant volume called pressure coefficient .(β) of a gas.

13. Volume coefficient of a gas : volume coefficient of a gas is the ratio increase in its volume per degree rise of the temperature to its volume at 0^0C when the pressure is kept constant

$$\alpha=\frac{v_t-v_0}{v_0 t}(or)\alpha=\frac{v_2-v_1}{v_1 t_2-v_2 t_1}$$

14. Pressure coefficient of a gas : (β): Pressure coefficient of a gas is the ratio of its increase in pressure per degree rise of temperature to its pressure at 0^0C. Keeping the volume constant.

$$\beta=\frac{p_t-p_0}{p_0 t}(or)\beta=\frac{p_2-p_1}{p_1 t_2-p_2 t_1}.$$

15. Relation between α *and* β: For all gases

$$\alpha=\beta=\frac{1}{273.15}=0.00367/^0 C$$

16. If two vessels of same capacity containing a gas at T_1^0 K and T_2^0K and at pressures P_1 and P_2 atm are connected then the common pressure 'P' will be P = $\left(\frac{P_1T_2+P_2T_1}{T_1+T_2}\right)$

17. **Ideal gas equations is :** $\frac{\text{PV}}{\text{T}}=\text{R}$ Where P is the pressure, V is the volume of 1 gm mole of a gas, T is the absolute temperature and R is the universal gas constant.
R = 8.31 Joule /gm/^{0}K
= 2 cal/gm/mole/^{0}K

18. From gas equation $\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$

19. If d is the density of the gas $\frac{P}{dT}$ = Constant

(or) $\frac{P_1}{d_1T_1}=\frac{P_2}{d_2T_2}$

20. According to mayor's equation the pressure exterted by a gas is P = nKT
Where n is the no. of molecules per unit volume and k is the Boltzmann's constant

K = 1.38 x 10^{-27} J/k and K = $\frac{R}{N}$ where N = 6.02 x 10^{23} molecules per mole. And N is the avagadro's number.

21. The gas equation for unit mass of a gas is pv = rT.

22. The relation between R and r is R = Mr.
Where M is the molecular weight. Number of moles in a gas n = m/M.

23. Vander walls gas equation for a real gas is $\left(P+\frac{a}{v^2}\right)$ (v - b) = RT where a and b are constents.

24. If the volume (v) and temp (T) of a gas constant, then $P\alpha m\ \ (or)\ \frac{p_1}{m_1}=\frac{p_2}{m_2}$

25. Absolute zero : It is the temperature at which the volume of a gas becomes zero at constant pressure (or) pressure becomes to zero at counstant volume.

Ideal gas or perfect gas

An ideal gas or perfect gas is that gas which strictly obeys the gas law, (such as Boyle's law, Charle's law, Gay Lussac's law, etc.)

i. The size or the molecule of a gas is zero.

ii. There is no force of attraction or repulsion amongst the molecules o the gas

Assumptions of Kinetic Theory of Gases

1. A gas consists of a very large number of molecules (of the order of Avogadro's number, 10^{23}), which are perfect elastic spheres.
2. The size of the gas molecules of very small as compared to the distance between them.
3. The molecules of do not exert any force of attraction or repulsion on each other, except during collision.
4. The collision of the molecules with themselves and with the wall of the vessel are perfectly elastic.
5. A molecules moves along a straight lien between two successive collision and the average straight.
6. The collisions are almost instantaneous.

Expression for pressure due to an ideal gas

$$P = \frac{1}{3} mnC^2$$

$$P = \frac{1}{3}\frac{M}{V}C^2 = \frac{1}{3}\rho C^2$$

Relation between pressure and kinetic energy of the gas

From kinetic theory of gases, the pressure P exerted by an ideal gas of density ρ and rms velocity of its gas molecule C is given by

$$P = \frac{1}{3}\rho C^2$$

$$P = \frac{2}{3}E$$

Average kinetic energy per molecule of the gas

$$M = m \times N_A$$

$$P = \frac{1}{3}\rho C^2 = \frac{1}{3}\frac{M}{V}C^2 \text{ or } PV = \frac{1}{3}MC^2$$

$$\frac{1}{2}MC^2 = \frac{3}{2}RT$$

$\therefore$ Average K.E of translation of one mole of the gas $= \frac{1}{2}MC^2 = \frac{3}{2}RT$

$$\therefore \frac{1}{2}mC^2 = \frac{3}{2}\left(\frac{R}{N_A}\right)T = \frac{3}{2}k_BT$$

$\therefore$ Average K.E of translation of one mole of the gas= $\frac{1}{2}mC^2 = \frac{3}{2}k_BT$

Kinetic Interpretation of temperature

$$PV = \frac{1}{3}MC^2$$

$$\frac{1}{3}MC^2 = RT$$

$$C^2 = \frac{2RT}{M} \text{ or } C^2 \propto T$$

$$C \propto \sqrt{T} \text{ or } \sqrt{T} \propto C$$

Avogardro's law

It states that equal volumes of all gases under identical conditions of temperature and pressure contain the same number of molecules.

$$n_1 = n_2$$

(f) Graham's law of diffusion

It states that the rates of diffusion of two gases are inversely proportional to the square roots of their dustiest.

(g) Dalton's Law of partial Pressure

$$p_1 + p_2 + p_3 + ... = P$$

Mot probable speed, mean speed and RMS speed of gas molecules

(a) Most probable speed $a = \sqrt{\frac{m}{2\pi k_B T}}$

and $b = \frac{m}{2k_BT}$

Most probable speed of the molecules of a gas as that speed which is possessed by maximum fraction of total number of molecules of the gas.

$$C_{m.p} = \sqrt{\frac{2k_B T}{m}}$$

(b) Mean speed or Average speed

Mean speed or Average speed is the average speed with which a molecule of the gas moves.

$$C_{av} = \frac{C_1 + C_2 + ...C_n}{n}$$

$$C_{av} = \sqrt{\frac{8k_B T}{m\pi}}$$

(c) Root Mean square speed

Root mean square speed of gas molecules is defined as the square root of the mean of the squares of the random velocities of the individual moles of a gas.

$$C_{rms} = \sqrt{\frac{C_1^2 + C_2^2 + ...C_n^2}{n}}$$

$$C_{rms} = \sqrt{\frac{3k_b T}{m}}$$

Degrees of Freedom

The number of degrees of freedom of a dynamical system is defined as the total number of co-ordinates or independent quantities required to describe completely the position and configuration of the system.

$$N = 3A - R$$

i. Mono atomic Gases

ii. Di atomic Gases. : $N = 3 \times 2 - 1 = 5$

iii. Tri atomic gases. : $N = 3 \times 3 - 2 = 7$

Law of Equipartition of energy

According to this law, for any dynamical system in thermal equilibrium, the total energy is distrusted equally amongst all the degrees of freedom, and the energy ass-ociated with each molecule per degree of freedom is ½ k_BT, where k_B is Boltzmann constant and T is temperature of the system.

$$E_t = \frac{1}{2}mv_x^2 + \frac{1}{2}mv_y^2 + \frac{1}{2}mv_z^2$$

Determination of γ from the degree of freedom

$$\gamma = \left(1 + \frac{2}{n}\right)$$