i) Mean free path (λ):

It is the avg. distance b/w 2 collission is called mean free path.

$$\lambda = \frac{\lambda_1 + \lambda_2 + \lambda_3 \; \ldots \; \lambda_N}{N}$$

$$\boxed{\lambda = \frac{1}{\sqrt{2}\pi d^2 n}} \qquad \because n = \frac{N}{V}$$

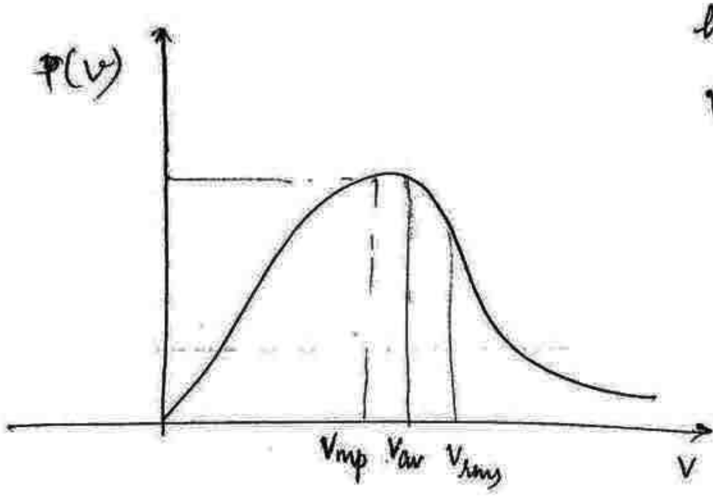
ii) speed of gas molecules:

$$\frac{R}{M} = \frac{N_A K}{m N_A} = \frac{K}{m}$$

$$V_{rms} = \sqrt{\frac{3RT}{M_w}} = \sqrt{\frac{3KT}{m}}$$

$$V_{av} = \sqrt{\frac{8RT}{\pi M_w}} = \sqrt{\frac{8}{\pi}\frac{KT}{m}}$$

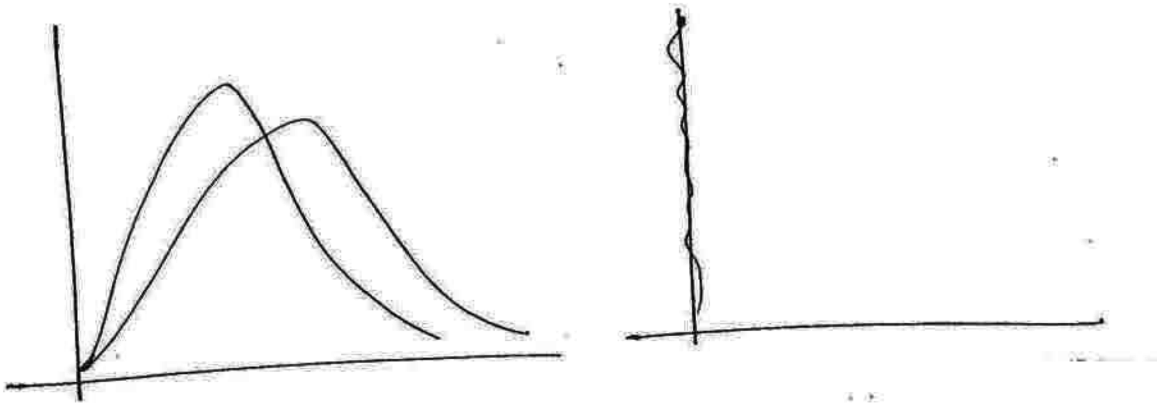
$$V_{mp} = \sqrt{\frac{2RT}{M_w}} = \sqrt{\frac{2KT}{m}}$$



here, $p(v)$ is the velocity distribution function.

If the graph is b/w $p(v)$ and v then its
area = 1

If the graph is b/w $NP(v)$ and v, then its
area = N



Q) Find ~~the~~ V_{rms} of H_2 gas at 300 K

$$= \sqrt{\frac{3RT}{M_w}} = \sqrt{\frac{3 \times 8.31 \times 300}{2 \times 10^{-3}}}$$

$$= 1960 \text{ m/s}$$

Q) Find the temp at which H_2 gas will escape from the earth surface

$$\sqrt{\frac{3RT}{M_w}} = 11.2 \text{ km/s}$$

$$\therefore \sqrt{\frac{3 \times 8.31 \times T}{2 \times 10^{-3}}} = (11.2 \times 10^3)$$

iii) $$\boxed{PV = \frac{1}{3}(mN)V_{rms}^2}$$

$$V_{rms} = \sqrt{\frac{3KT}{m}} \qquad PV = \frac{1}{3}(mN)\left(\frac{3KT}{m}\right) = NKT$$

iv) $$\boxed{KE = \frac{1}{2}(mN)V_{rms}^2}$$

iv) ~~stt~~ If we write the expression of total energy for a gas molecule, then the no. of terms with quadratic degree is called degree of freedom

a) Translation

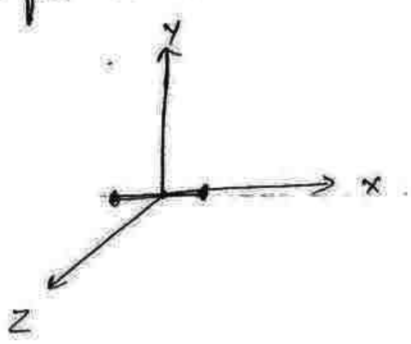
$$K_T = \frac{1}{2}mv^2 \Rightarrow \frac{1}{2}m\left(V_x^2 + V_y^2 + V_z^2\right)$$

$$\therefore K_T = \frac{1}{2}mV_x^2 + \frac{1}{2}mV_y^2 + \frac{1}{2}mV_z^2$$

$$\boxed{f_T = 3}$$

b) Rotational

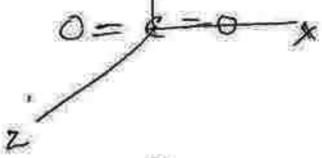
2 for linear and 3 for non-linear



$$\boxed{f_R = 2}$$

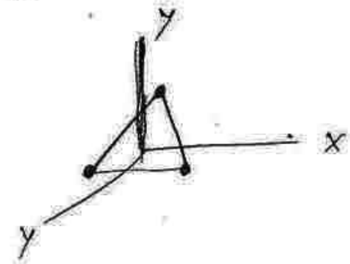
$$K_R = \frac{1}{2}I_y\omega_1^2 + \frac{1}{2}I_z\omega_2^2$$

eg: CO_2 , H_2O_2



$\boxed{f_R = 2}$

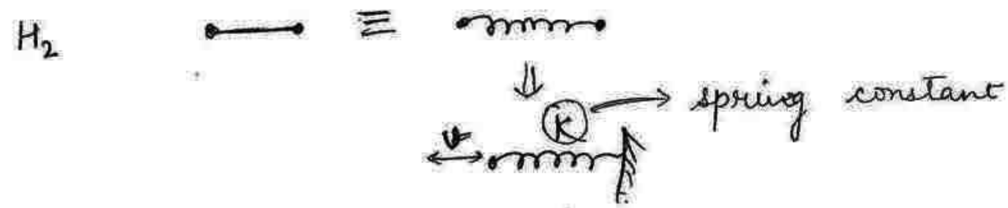
eg: SO_2 , O_3.



$\boxed{f_R = 3}$

c) Vibrational:

for <u>one mode</u> of vibration, there are 2 degree of freedom.



$$E_v = KE_v + PE_v$$

$$= \left(\frac{1}{2}\mu v^2\right) + \left(\frac{1}{2}Kx^2\right) \qquad \boxed{f_v = 2}$$

At 0 K temp, energy due to translational motion and rotational motion but dt due to vibration is not zero. if we assume 2 be 0 then we can ~~catu~~ find velocity in pos^n together which is not possbi

i) for monoatomic (He, Ne, Ar) $\boxed{f=3}$

ii) diatomic (H_2, N_2, O_2) $f_T = 3$, $f_R = 2$

if $T < 800$ K $f_V = 0$ $\boxed{f = 5}$

if $T > 800$ K $f_V = 2$ $\boxed{f = 7}$

iii) ~~[illegible]~~ for CO_2, $f_T = 3$, $f_R = 2$, $f_V = 2$ $\therefore \boxed{f=7}$

iv) Non-linear polyatomic

$f_T = 3$ $f_R = 3$ $\boxed{f=6}$

equipartition:

Total energy of a gas molecule is equally distributed in its all degree of freedom and for each degree of freedom, its value is $\boxed{\frac{1}{2}KT}$ $\therefore$ Internal energy of ideal gas $\Rightarrow$

$$\boxed{U = \frac{f}{2} NKT = \frac{f}{2} nRT}$$

$$\Delta U = \frac{f}{2} nR\Delta T$$

Q) Two moles of H_2 and 4 moles of He are mixed at 300 K, find energy of the mixture

$2H_2 + 4He$

$\frac{5}{2} \times 2R \times 300 + \frac{3}{2} \times 4R \times 300$

Q) gas A (f_1, n_1, T_1) ... gas ...

Find final temp.

$$A(f_1, n_1, T_1) + B(f_2, n_2, T_2)$$

$$U_i = U_f$$

$$\frac{f_1}{2} n_1 R T_1 + \frac{f_2}{2} n_2 R T_2 = \frac{f_1}{2} n_1 R T + \frac{f_2}{2} n_2 R T$$

$$T = \left(\frac{f_1 n_1 T_1 + f_2 n_2 T_2}{f_1 n_1 + f_2 n_2} \right)$$

vi) Molar specific heat

a) $Q = ms\Delta t$

$Q = nc\Delta t$

$\therefore ms\cancel{\Delta t} = nc\cancel{\Delta t}$

$\therefore \cancel{m}s = \frac{\cancel{m}}{M} c$

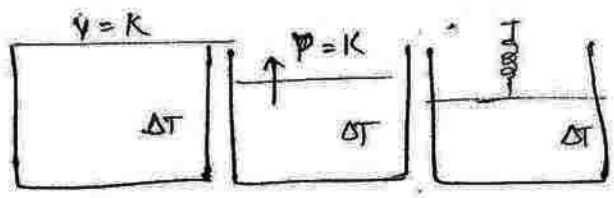
$$\boxed{C = MS}$$

Molar specific heat = Molecular weight × specific heat

b) A gas has infinite no of specific heat

$$\boxed{C = \frac{Q}{n\Delta T}} \longrightarrow \text{process dependent}$$

Q_1



$$\boxed{C_1 < C_2 < C_3}$$

c) Molar specific heat at constant pressure :

$$C_v = \frac{Q_v}{n\Delta T} = \frac{\Delta U}{n\Delta T}$$

$$\therefore C_v = \frac{\frac{f}{2} n R \Delta T}{n\Delta T}$$

$$\therefore C_v = \frac{fR}{2}$$

d) Molar specific heat at constant ...

$$C_p = \frac{Q_p}{n\Delta T} = \frac{W + \Delta U}{n\Delta T} = \frac{P\Delta V + \Delta U}{n\Delta T}$$

$$= \frac{\cancel{n}R\cancel{\Delta T} + \frac{f}{2}\cancel{n}R\cancel{\Delta T}}{\cancel{n}\cancel{\Delta T}} = \boxed{C_p = R + C_v}$$

$\therefore \boxed{C_p - C_v = R}$ $\quad \therefore \quad M_{cp} - M_{cv} = R$

$\therefore \boxed{C_p - C_v = \frac{R}{m}}$ Specific heat

e) $\gamma = C_p / C_v \qquad \gamma = \frac{C_v + R}{C_v} \qquad \therefore \gamma = 1 + \frac{R}{C_v}$

$\therefore \boxed{\gamma = 1 + \frac{2}{f}}$

$$\boxed{C_v = \frac{fR}{2} = \frac{R}{\gamma - 1}}$$

f) $PV^x = K$

$$\boxed{C = C_v + \frac{R}{1-x}}$$

g) C_p, C_v and γ for gaseous mixture:

T: n_1, C_{v_1} T: n_2, C_{v_2} T: $n_1 + n_2$, C_v

$U_i = U_f$

$n_1 C_{v_1} T + n_2 C_{v_2} T = (n_1 + n_2) C_v T$

$$\therefore \boxed{C_v = \frac{n_1 C_{v_1} + n_2 C_{v_2}}{n_1 + n_2}}$$

$C_p = C_v + R$

$$\therefore \boxed{\frac{n_1 C_{p_1} + n_2 C_{p_2}}{n_1 + n_2}} \qquad \boxed{\gamma = \frac{C_p}{C_v}}$$

$$(n_1+n_2)C_v = n_1 C_{v_1} + n_2 C_{v_2}$$

$$\left(\frac{n_1+n_2}{\gamma-1}\right) R = \frac{n_1 R}{\gamma_1 - 1} + \frac{n_2 R}{\gamma_2 - 1}$$

$$\boxed{\frac{n_1+n_2}{\gamma-1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}}$$

$\because PV^x = K \quad \therefore$

$x = 1$ Isothermal

$x = 0$ Isobaric

$x = \gamma$ Adiabatic

$x = \infty$ Isochoric

Q) 2 moles of H_2 is mixed with 4 moles of He. Find C_p, C_v and γ for the mix.

2 moles of H_2 + 4 moles of He

$$C_v = \frac{n_1 C_{v_1} + n_2 C_{v_2}}{n_1 + n_2}$$

$$\therefore C_v = \frac{2 \times \frac{5R}{2} + 4 \times \frac{3R}{2}}{2+4} = \frac{11R}{6}$$

$$\therefore C_p = \frac{17R}{6} \qquad \gamma = \frac{17}{11}$$

Q) Around 300 K for CO_2 $C_V = 29.7$ J/mole K.

Find dergee of free of freedom of CO_2

$$\because \quad C_V = \frac{fR}{2}$$

$$\therefore \quad f = \frac{C_V 2}{R} = \frac{2 \times 29.7}{8.31}$$

$$\therefore \quad \boxed{f = 7} \quad (T = 3,\ R = 2,\ V = 2)$$

Q) Find molar specific heat of He in the following process.

a) $PV^2 = K$ b) $PT = K$ c) $TV = K$

~~b)~~ a) $PV^2 = K$ $(\because x = 2)$

$$\therefore C = C_V + \frac{R}{1-x}$$

$$= \frac{3}{2}R + \frac{R}{1-2} = \frac{R}{2}$$

b) $PT = K$

$$P\left(\frac{PV}{nR}\right) = K \quad \Rightarrow \quad P^2 V = nRK$$

$$PV^{1/2} = K_1 \quad \therefore x = 1/2 \quad \therefore C = C_V + \frac{R}{1-x}$$

$$\therefore C = \frac{3}{2}R + 2R = \frac{7}{2}R$$

c) $TV = K$ $\therefore \left(\frac{PV}{nR}\right)V = K \Rightarrow PV^2 = nRK$

$x = 2$

$$\therefore C = C_V + \frac{R}{1-x} \Rightarrow \frac{3}{2}R + \frac{R}{1-2} = \frac{R}{2}$$

Q) Find the amount of heat required to raise the temp of 2 mole H_2 by 50 K

a) when vol^m is constant

b) when pres. is constant

c) when $PV^3 = K$

a) $Q = nC_v\Delta T$

$$= 2 \times \frac{5}{2}R \times 50 = 250R$$

b) $Q = nC_p\Delta T$

$$2 \times \left(\frac{5}{2}R + R\right) \times 50 \Rightarrow 2 \times \frac{7R}{2} \times 50 = 350R$$

c) $PV^3 = K$ $(x = 3)$

$$\therefore C = C_v + \frac{R}{1-x}$$

$$\frac{5R}{2} + \frac{R}{1-3} \Rightarrow \therefore C = 2R$$

$$\therefore Q = nC\Delta T \Rightarrow 200R$$

In general, specific heat doesn't depends on Temp.