THERMAL PHYSICS

14/12/2019

Kinetic Theory of Gases (K.T.G.)

Total Energy of substance (TE)

Mechanical Energy (ME) | Internal Energy (I.E) / U

K.E. → [structured Motion of Molecules] | P.E.

I.K.E → depends on temp. → [Random motion of Molecules] | I.P.E → depends on I.M.F

KTG

→ If IMF of substance = 0 then substance will become Ideal gas (I.G.)

$\therefore$ U (I.E.) = IKE + IPE

For I.G. ⇒ IMF = 0 so, IPE = 0

$\therefore$ $\boxed{U_{of\ IG} = IKE}$ → depends on temp. only

Note :⇒ (1). I.E. of I.G. depends only on temp. ($\because$ IPE = 0).

(2). IT (Isothermal) :— T = const. (Throughout the Process) ⇒ IKE = const.

For I.G. ⇒ U = I.K.E. = const at IT Process.

$\boxed{\text{Change in I.E.} (\Delta U) = 0}$ for I.G. in IT Process.

(3). Phase Change

$$\underset{(100°C)}{\text{Water}} \xrightarrow[\text{Const. P}]{\text{Const. T}} \underset{(100°C)}{\text{Steam}}$$

Phase Change ⇒ IT & IB Process

↳ IT ⇒ T = const. ⇒ I.K.E = const. , but bonds break so IPE ⇒ change

$\boxed{\Delta U = \Delta IPE \neq 0}$ → For Phase Change

(4). Ideal gas follows Ideal gas eqⁿ :→ PV = nRT (I.G.E.) at all possible temp. & Pressure.

(5). Real gas follows Van-der Waal eqⁿ :→ $\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$ at all possible temp. & Pressure.

(6). Real gas follows I.G.E. at high temp., low Pressure and low density

$$\underset{[IMF\ ✓]}{R.G.} \xrightarrow[\rho\downarrow]{T\uparrow;\ P\downarrow} \underset{[IMF\ ✗]}{I.G.}$$

(7). Absolute Zero temp. is temp. of Zero Energy for Ideal gas.

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(8). Absolute Zero temp. is not temp. of Zero Energy.
$\because$ 0 Kelvin $\Rightarrow$ I.K.E. = 0 but I.P.E. $\neq 0$ $[U \neq 0]$

Notations:- (1). $m \rightarrow$ mass of 1 molecule [Molecule of IG are point mass]
means mass hai but ek point ke form me hai. ($\because$ radius of molecule is neglegible)

(2). $M \rightarrow$ mass of gas sample ($M = mN$).

(3). $N_A \rightarrow$ Avagadro No. (no. of molecule in 1 mole), $N_A = 6.023 \times 10^{23}$ /mole

(4). $N \rightarrow$ Total molecules in sample.

(5). $M_w \rightarrow$ Molecular weight / Molar mass (Mass of 1 mole or N_A molecule)
$[M_w = mN_A]$.

(6). Mole $(n) = \frac{M}{M_w} = \frac{mN}{mN_A} = \frac{N}{N_A}$

(7). $\boxed{R}$ = Universal gas constant $= 8.314$ (or) $\frac{25}{3}$ J/mole-K
$\hookrightarrow$ moles ke liye $= 2$ cal/mole-K
$= 0.0821$ l-atm/mole-K.

(8). $\boxed{K}$ = Boltzmann's constant
$\downarrow$
molecules ke liye
1 mole $\rightarrow R$
N_A molecules $\rightarrow R$
1 molecule $\rightarrow$ $\boxed{\frac{R}{N_A} = K = 1.38 \times 10^{-23} \frac{J}{K}}$

(9). Pressure of gas (P) :$\rightarrow$ S.I unit $\Rightarrow$ Pa (or) N/m^2
1 atm = 760 mmHg = 1.013×10^5 N/m^2

Gas molecules collide with container wall $\Rightarrow$ Change in Momentum $\Rightarrow$ Force $\Rightarrow$ Pressure

(10). Vol^m of gas (V) :$\rightarrow$ S.I. unit $\Rightarrow$ m^3
$\hookrightarrow$ Vol^m of Container

Vol^m of gas molecules $\simeq 0$ because molecules $\Rightarrow$ Point mass (·)
$\downarrow$
radius of molecules = Neglegible
So, vol^m of molecules $= \frac{4}{3}\pi \boxed{r^3} \simeq 0$

(11). At Absolute Zero temp. (0 Kelvin), motion of molecules will get frezed so speed, velocity, momentum, energy, vol^m of gas and it's Pressure becomes Zero.

At NTP & STP ⇒ $T = 0^\circ c = 273\,K$
$P = 1\,atm = 1.013 \times 10^5\,Pa$

Different forms of $\boxed{PV = nRT}$ ①

$n = \frac{N}{N_A}$

$\therefore PV = \frac{N}{N_A} R T$

$\boxed{PV = NKT}$ ②

$n = \frac{M}{M_\omega}$

$\therefore PV = \frac{M}{M_\omega} RT \Rightarrow P = \frac{M}{V} \frac{RT}{M_\omega}$

$\Rightarrow P = \rho \cdot \frac{RT}{M_\omega}$

$\Rightarrow \frac{P}{\rho} = \frac{RT}{M_\omega} = \frac{RT}{m N_A}$

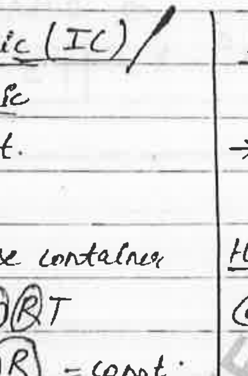
③ $\Rightarrow \boxed{\frac{P}{\rho} = \frac{RT}{M_\omega} = \frac{KT}{m}}$

Different Processes

$\boxed{PV = nRT}$

Isochoric (IC) / Isometric	Isobaric (IB)	Isothermal (IT)	Adiabatic (Ad)
→ V = const.	→ P = const.	→ T = const.	→ No heat exchange b/w system & surrounding
Hint:- Close container	Hint:- Open container OR Movable Piston	Hint:- Conducting container OR metallic wall	~~Hint~~:- $Q = 0$ Insulated container Fast / sudden Process
$PV = nRT$ $\frac{P}{T} = \frac{nR}{V} = const.$ $[P \propto T]$ $\% = \frac{\Delta P}{P_i} \times 100 = \frac{\Delta T}{T_i} \times 100$	$PV = nRT$ $\frac{V}{T} = const.$ $[V \propto T]$ $\% = \frac{\Delta V}{V_i} \times 100 = \frac{\Delta T}{T_i} \times 100$	$PV = nRT$ $PV = const$ $P \propto \frac{1}{V}$ $[P_1V_1 = P_2V_2]$	eg:- Tyre bursting, sound wave Propogation $[PV^\gamma = const.]$

Ques:-



On heating, P & V of gas:—
ⓐ both ↑ ⓑ both ↓ ⓒ P↓ & V↑
ⓓ P↑ & V = Const ⓔ P = const & V↑

→ I.B. ⇒ P = const. so, V ∝ T ⇒ T↑ ⇒ V↑

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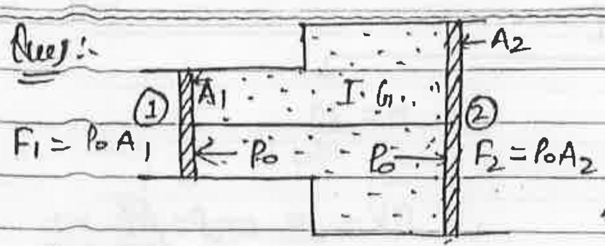
Ques :-



Piston ① & ② are connected with string & can move as well. On heating I.G., piston will move towards :-

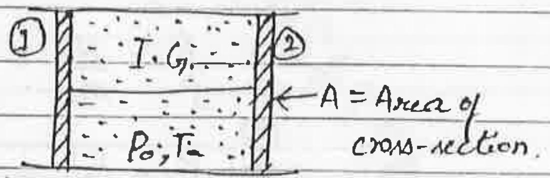
ⓐ Right ⓑ left

ⓒ Won't move ⓓ NOTA

$\therefore A_2 > A_1$

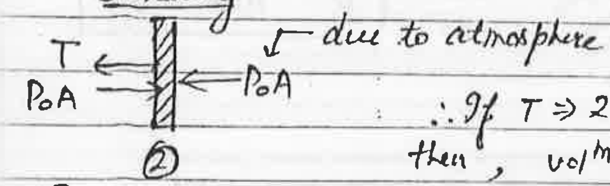
So, $F_2 > F_1$ and hence F_{net} will act towards Right.

Ques :-



If initially system (gas) is at eq^n with atmosphere of P_0 pressure & T_0 temp with string. Now temp. of gas is increased to twice of initial. Then tension in string will be —

Initially



For rest, $T = 0$

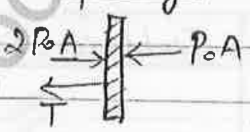
$\therefore$ If $T \Rightarrow 2$ times & Piston won't move then, vol^m = const.

So, $P \propto T$

$T \rightarrow 2$ times

$\Rightarrow P \rightarrow 2P_0$

finally



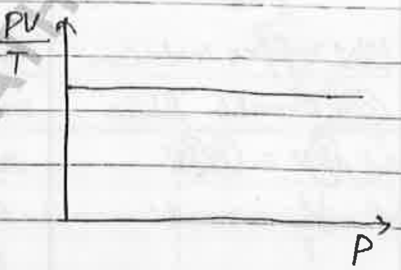
$\Rightarrow 2P_0A = T + P_0A$

$$\boxed{T = P_0A}$$

Ques :- $\frac{PV}{T}$ vs P curve for I.G.?

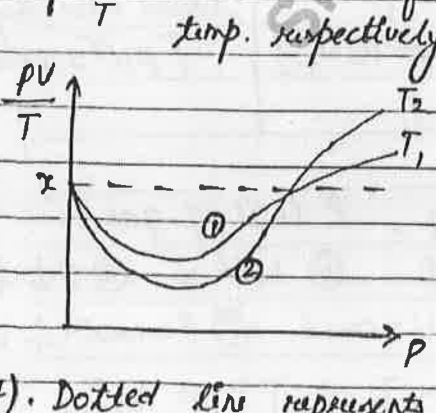
$PV = nRT$

$\frac{PV}{T} = nR = $ const.



NCERT

Ques :- If $\frac{PV}{T}$ vs P curve for 2 gas sample ① & ② as shown at T_1 & T_2 temp. respectively.



(1). Here dotted line represent?

(2). ⓐ $T_1 > T_2$ ⓑ $T_1 = T_2$

ⓒ $T_1 < T_2$ ⓓ NOTA

(3). value of x for 10 g H_2 gas.

(1). Dotted line represents Ideal gas behaviour

(2). ① & ② are real gas

R.G. $\underset{\rho\downarrow}{\xrightarrow{T\uparrow;\ P\downarrow}}$ I.G. ∵ Curve ① is close to Ideal gas behaviour so, $\boxed{T_1 > T_2}$

(3). $x = nR$

$x = \left(\frac{10}{2}\right)_{H_2} \times R = 5R$

Ques:- When temp. of Ideal gas kept in close container is increased by 6°C it's pressure increases by 1%. Then f/o initial temp. of gas in °C.

∴ $P\,\textcircled{V} = \textcircled{n}\,\textcircled{R}\,T$ ∵ close container ⇒ $V = \text{const}$

$\Rightarrow P \propto T$

$$\frac{\Delta P}{P_i} \times 100 = \frac{\Delta T}{T_i} \times 100$$

$$1 = \frac{6K}{T_i} \times 100 \qquad (\because \Delta°C = \Delta K)$$

$$T_i = 600K = 327°C.$$

Imp.

Ques:- Pressure of 1 mole gas depends on it's vol^m as $P = \frac{P_0}{1+\left(\frac{V}{V_0}\right)^2}$ where P_0 & V_0 are constant. F/o decrease in temp. of gas if it is expanded from V_0 to $2V_0$ vol^m.

When $V_1 = V_0$ then $P_1 = \frac{P_0}{2}$ and T_1

$V_2 = 2V_0$ then $P_2 = \frac{P_0}{5}$ and T_2

∵ $PV = nRT$

$T = \frac{PV}{nR}$

Now, $T_1 = \frac{P_0V_0}{2 \times 1 \times R}$ & $T_2 = \frac{2V_0 \times \frac{P_0}{5}}{1 \times R} = \frac{2P_0V_0}{5R}$.

So, $T_1 - T_2 = \Delta T = \frac{P_0V_0}{R}\left(\frac{1}{2} - \frac{2}{5}\right)$

$= \frac{P_0V_0}{10R}$

Imp:

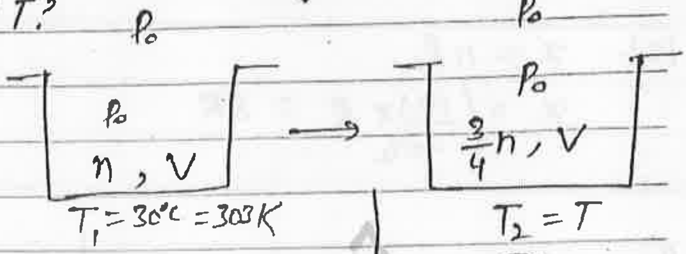
ID

Ques:- Some amount of oxygen gas kept in open container at 30°C. When it is heated upto T temp, 1/4th of gas escaped out of container. Then f/o value of T?

∴ ~~$(P)V = (n)(R)T$~~

~~$V \propto T$~~

~~ΔV~~



$T_1 = 30°C = 303K$ ① $P_0V = nR(303)$ -(I).

$T_2 = T$ ② $P_0V = \frac{3}{4}nR(T)$ -(II)

(I) ÷ (II).

$T \times 1 = \frac{4}{3} \times 303$

$T = 404\ K$ (or) $131°C$.

Ques:-

① 35 Kg N_2 gas at 6atm pressure

↓

② 35 Kg N_2 + x Kg O_2 9atm

If some amount of O_2 gas added in it, pressure of gas becomes 9 atm then f/o amount of O_2 gas added.

For ①, ~~(6atm)~~ $\cancel{V} = \left(\frac{35\ \text{Kg}}{28\ \text{g}}\right) \cancel{RT}$

For ②, $(9\ \text{atm})\ \cancel{V} = \left(\frac{35\ \text{Kg}}{28\ \text{g}} + \frac{x\ \text{Kg}}{32\ \text{g}}\right) \cancel{RT}$

$$\Rightarrow \frac{6}{9} = \frac{\frac{35}{28}}{\frac{35}{28} + \frac{x}{32}}$$

$$\frac{2}{3} = \frac{\cancel{35/28}}{\cancel{35/28}\left(1 + \frac{x}{32} \times \frac{28}{35}\right)}$$

$$2 + \frac{28x}{16 \times 35} = 3$$

$$\frac{28x}{16 \times 35} = 1$$

$$x = \frac{16 \times 35}{28} = 20\ \text{kg}$$

Ques!- Temp. of air in open room of Vol^m 30m^3 is increased from 17°C to 27°C due to sunshine! If no. of molecules before and after heating in room are n_i & n_f. Then $n_f - n_i$ will be–

$V = 30m^3$

$T_i = 17°C = 290K$

$T_f = 27°C = 300K$

$P = 10^5 Pa$

$$\therefore n_i = \frac{P_iV_i}{KT} = \frac{PV}{K(290)}$$

$$\therefore n_f = \frac{PV}{K(300)}$$

$$\text{Noo, } n_f - n_i = \frac{PV}{K}\left(\frac{1}{300} - \frac{1}{290}\right)$$

$$= \frac{10^5 \times 30}{1.38 \times 10^{-23}}\left(\frac{1}{300} - \frac{1}{290}\right)$$

$$= \frac{10^5 \times 30 \times 10}{1.38 \times 10^{-23} \times 300 \times 290}$$

$$= 2.5 \times 10^{25}$$

Ques!- 2 moles H_2 gas and 1 mole N_2 gas kept in a container at NTP. Then f/o– ① Equivalent molar mass of mixture ② Density of mixture.

①
$$Mwt_{mix} = \frac{m_{mix}}{n_{mix}}$$

$$= \frac{2 \times 2 + 1 \times 28}{2+1} = \frac{32}{3} g$$

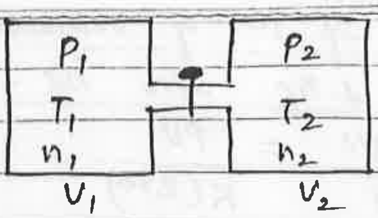
② $\rho = ?$

$$\left(\frac{P}{\rho}\right)_{mix.} = \left(\frac{RT}{Mw}\right)_{mix}$$

$$\frac{10^5}{\rho_{mix.}} = \frac{8.314 \times 273}{\frac{32}{3} \times 10^{-3}}$$

$$\rho_{mix} = \frac{10^5 \times 32 \times 10^{-3}}{25 \times 273} \frac{Kg}{m^3} \quad \text{(or)} \quad \frac{g \times \cancel{10^3}}{L \times \cancel{10^3}} = \frac{g}{L}$$

Ques:-



When stopper is removed temp. and Pressure becomes T & P respectively then $\frac{P}{T} = ?$

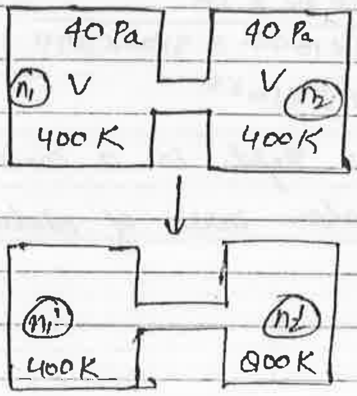
Apply conservation of moles;-

$$n_1 + n_2 = n_1' + n_2'$$

$$\frac{P_1V_1}{\cancel{R}T_1} + \frac{P_2V_2}{\cancel{R}T_2} = \frac{PV_1}{\cancel{R}T} + \frac{PV_2}{\cancel{R}T}$$

$$\frac{P}{T} = \frac{P_1V_1T_2 + P_2V_2T_1}{T_1T_2\,(V_1+V_2)}$$

Ques:-



Two identical vessel filled with gas at 40 Pa pressure at 127°C are connected as shown. If temp. of these vessels are maintained at 127°C & 527°C respectively Then pressure of gas becomes?

$$\therefore n_1 + n_2 = n_1' + n_2'$$

$$\frac{40\cancel{V}}{\cancel{R}(400)} + \frac{40\cancel{V}}{\cancel{R}(400)} = \frac{P\cancel{V}}{\cancel{R}(400)} + \frac{P\cancel{V}}{\cancel{R}(800)}$$

$$\frac{1}{5} = \frac{P}{400} + \frac{P}{800}$$

$$\frac{1}{5} = \frac{3P}{800}$$

$$P = \frac{160}{3} = 53.3\ Pa$$

Ques:- If an Ideal gas follows additional law $T^2V = const.$ Then –
① If it's vol^m increased from V_0 to $2V_0$ then pressure becomes P_0 to ....?
② Graph b/w it's P & T ?

① P & V

$$T^2V = const$$

$$\left(\frac{P^2V^2}{n^2R^2}\right)V = const. \qquad \left(\because T = \frac{PV}{nR}\right)$$

$P^2V^3 = \text{const.}$

$V \rightarrow 2 \text{ times}$

$V^3 \rightarrow 8 \text{ times}$

$P^2 \rightarrow 1/8 \text{ times} \Rightarrow P = \frac{1}{2\sqrt{2}} \text{ times}$

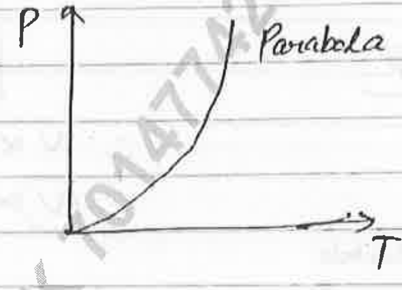
$\Rightarrow P = \frac{P_0}{2\sqrt{2}}$

② P vs T

$T^2V = \text{const.}$

$T^2 \times \frac{nRT}{P} = \text{const.}$

$P \propto T^3$



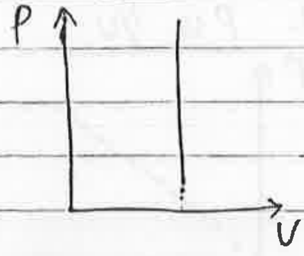
- Graphs

Ⓐ. Isochoric

$V = \text{const.}$

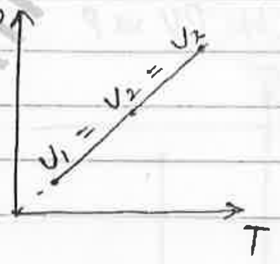
$P \propto T$

(a). P vs V



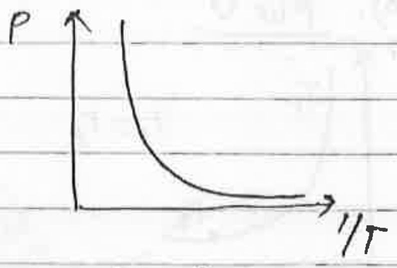
$P\boxed{V} = nRT$

(b). P v/s T



$\therefore P \propto T$

(c). P vs 1/T



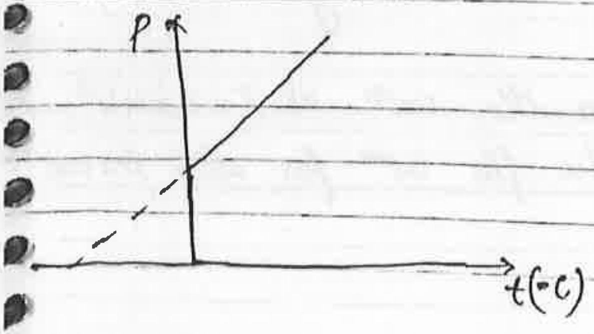
$\therefore P \propto T$

$\boxed{P} \propto \frac{1}{\boxed{1/T}}$

$y \propto \frac{1}{x}$

↳ Rectangular Hyperbola

(d). P v/s t(°C)



$\therefore P = \frac{nRT}{V}$

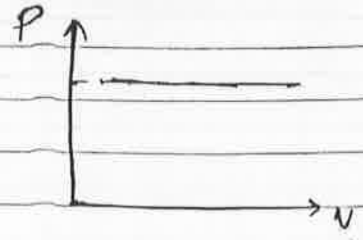
$P = \frac{nR}{V}(t+273)$

$P = \frac{nR}{V}t + \frac{nR}{V}(273)$

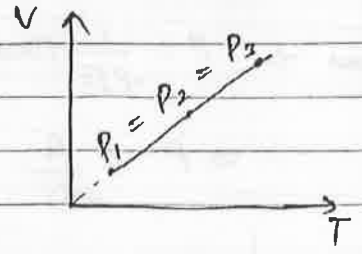
$y = mx + c$

(B) Isobaric

(a). P v/s V

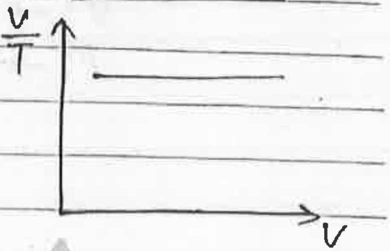


(b). V v/s T



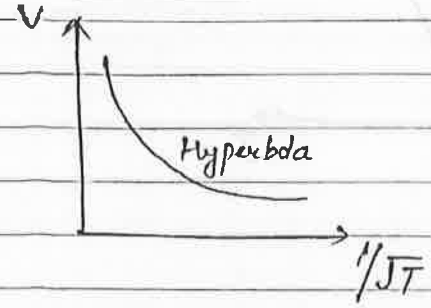
$V \propto T$

(c). V/T v/s V



$\therefore V \propto T \Rightarrow \frac{V}{T} = \text{const.}$

(d). V v/s $\frac{1}{\sqrt{T}}$



$\therefore V \propto T$

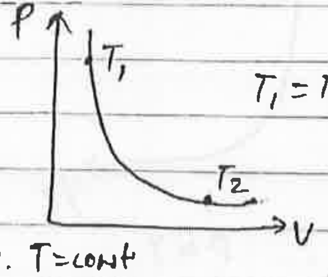
$V \propto \frac{1}{\left(\frac{1}{\sqrt{T}}\right)^2}$

$y \propto \frac{1}{x^2}$

(C) Isothermal

T = const

(a). P v/s V

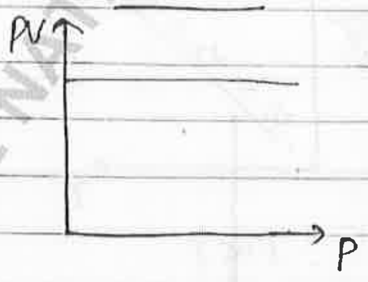


$\therefore T = \text{const}$

$PV = \text{const.}$

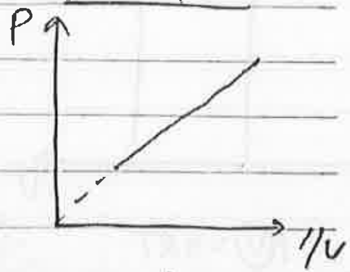
$P \propto \frac{1}{V}$

(b). PV v/s P



$\therefore PV = \text{const.}$

(c). P v/s 1/V



$\therefore P \propto \frac{1}{V}$

$y \propto x$

Imp.

Ques:- If temp. of Ideal gas depends on it's vol^m as $T = T_0 + \alpha V^2$ where T_0 and α are +ve const. Then f/o vol^m for which pressure of gas is min^m.

$$\therefore T = T_0 + \alpha V^2$$

$$\frac{PV}{nR} = T_0 + \alpha V^2$$

$$P = \frac{nRT_0}{V} + \frac{nR\alpha V^{\cancel{2}}}{\cancel{V}}$$

Now, $P = f(V)$

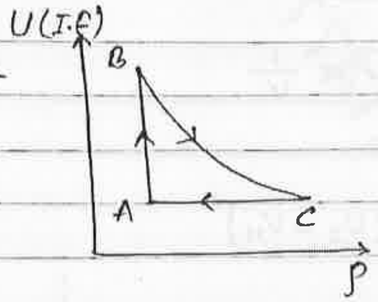
For Maxima (or) Minima,

$$\frac{dP}{dV} = 0 = nRT_0\left(\frac{-1}{V^2}\right) + nR\alpha$$

$$V^2 = \frac{T_0}{\alpha}$$

$$V = \sqrt{\frac{T_0}{\alpha}}$$

Ques:-



If BC is rectangular hyperbola then identify Process $(\because \rho = \frac{m}{V})$

AB ⟶ ρ = const ⇒ V = const So AB = IC

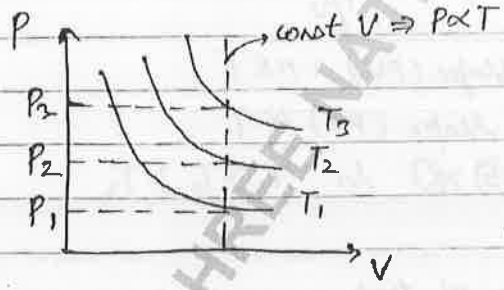
BCA ⟶ U = const ⇒ T = Const So ACA = IT

BCA ⟶ $U \propto \frac{1}{\rho}$

$T \propto \frac{1}{m/V} \Rightarrow V \propto T$

So, BC = IB.

Ques:-



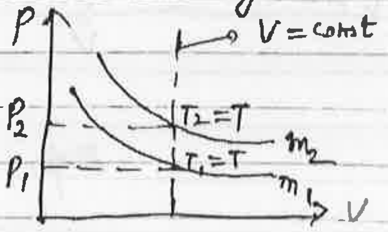
3 IT curve of a gas sample at T_1 & T_2 & T_3 temp., order of temp?

$\therefore P \propto T$

$P_3 > P_2 > P_1 \Rightarrow T_3 > T_2 > T_1$

Ques:- 2 different samples of an I.G. of mass m_1 & m_2 at same temp. change their vol^m and pressure as given in PV curve then –

ⓐ $m_1 = m_2$
ⓑ $m_1 > m_2$
ⓒ $m_1 < m_2$
ⓓ Data Insufficient



V = const ⇒ $PV = nRT$

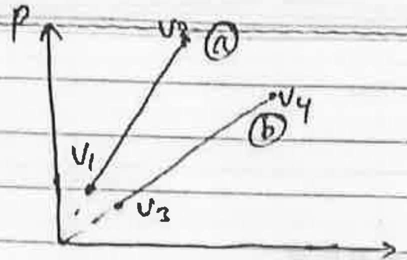
$P \propto n$

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

$P \propto m$

$\Rightarrow P_2 > P_1 \Rightarrow m_2 > m_1$

Ques:-



Here, ① $V_1 = V_2 = V_3 = V_4$

② $V_1 < V_2 < V_3 < V_4$

③ $V_1 = V_2$; $V_3 = V_4$; $V_3 < V_2$

④ $V_1 = V_2$; $V_3 = V_4$; $V_3 > V_2$

ⓐ ⇒ IC $(P \propto T)$ ⇒ $V_1 = V_2$

ⓑ ⇒ IC $(P \propto T)$ ⇒ $V_3 = V_4$

Slope → $\frac{P}{T}$ (or) $\frac{\Delta P}{\Delta T}$ (or) $\frac{dP}{dT}$

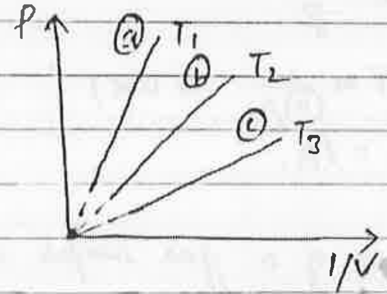
$\because \quad PV = nRT$

Slope $\left(\frac{P}{T}\right) = \frac{nR}{V}$ ⇒ slope $\propto \frac{1}{V}$

Slope of a > b ⇒ $V_a < V_b$

$(V_1 = V_2) < (V_3 = V_4)$

Ques:-



Order of temp.

~~ⓐ ⇒ IT (PV = cons~~

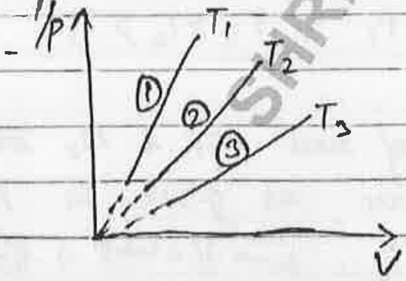
$\therefore$ Slope → $\frac{P}{1/V} = PV$

Slope $(PV) = nRT$

Slope $(PV) \propto T$

Slope of ⓐ > ⓑ > ⓒ so $T_1 > T_2 > T_3$

Ques:-



Order of temp.

$\therefore$ Slope → $\frac{1/P}{V} = \frac{1}{PV}$

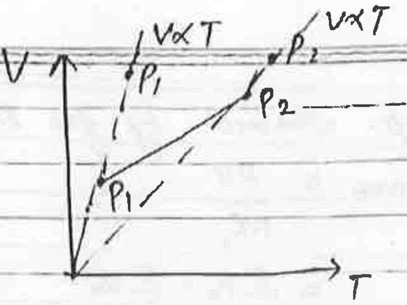
Slope, $\left(\frac{1}{PV}\right) = \frac{1}{nRT}$

Slope $\propto \frac{1}{T}$

Slope of ① > ② > ③

so, $T_3 > T_2 > T_1$

Ques :-



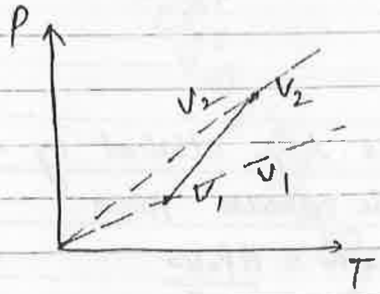
Here, ⓐ $P_1 = P_2$ ⓑ $P_1 > P_2$
ⓒ $P_1 < P_2$ ⓓ NOTA

∴ Slope $\left(\frac{V}{T}\right) = \frac{nR}{P}$

Slope $\propto \frac{1}{P}$

Slope of ① > ② so, $P_1 < P_2$

Ques :-



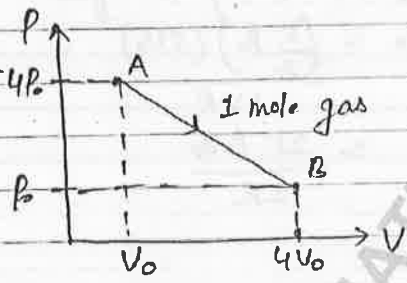
Here, ⓐ $V_1 = V_2$ ⓑ $V_1 > V_2$
ⓒ $V_1 < V_2$ ⓓ NOTA

∴ Slope $\left(\frac{P}{T}\right) = \frac{nR}{V}$

Slope $\propto \frac{1}{V}$

∴ Slope of ② > ① ⇒ $V_2 < V_1$

Ques :-



F/o - ① Temp at A , ② Temp at B

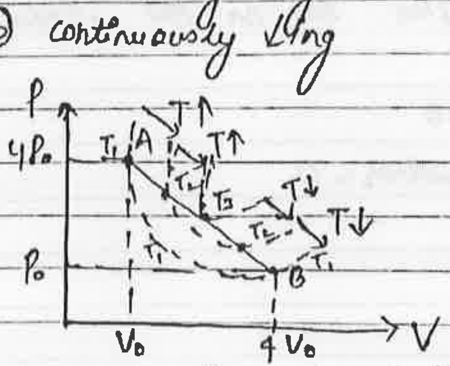
① $T_A = \frac{P_A V_A}{nR} = \frac{4P_0 V_0}{R}$

② $T_B = \frac{P_B V_B}{nR} = \frac{4P_0 V_0}{R}$

∴ $T_A = T_B$

↳ But IT nhi hai. (∵ Rectangular hyperbola nhi hai).

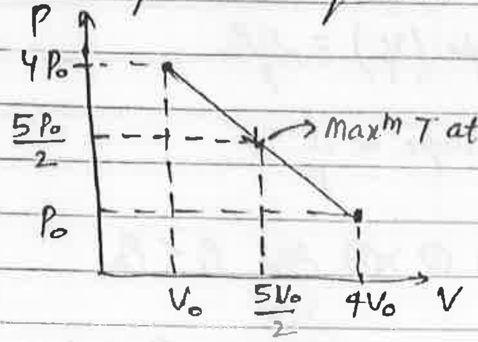
Ques :- In previous question temp. of gas from A to B -
ⓐ continuously ↑ing ⓒ first ↑ then ↓
ⓑ continuously ↓ing ⓓ first ↓ then ↑



$T_2 > T_1$ ⇒ First temp ↑ then ↓ ⇒ Max^m temp. will be at mid. point

KTG = Ex - I ∴ 121 to 155

Ques:- In previous question max^m temp. attained by gas in AB process. ($n = 1$)

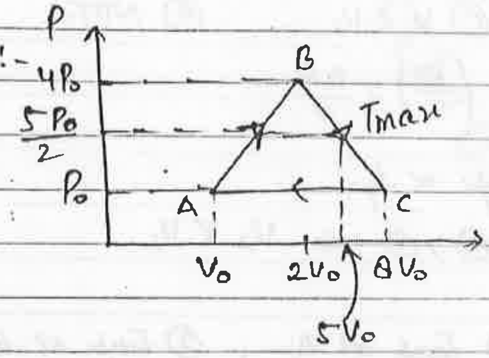


$$\therefore T_{max} = \frac{PV}{nR}$$

$$= \frac{\frac{5}{2}P_0 \times \frac{5}{2}V_0}{1 \times R}$$

$$= \frac{25\ P_0V_0}{4R}$$

Ques:- F/o Max. temp. attained by 1 mole gas in cyclic process ABCA.



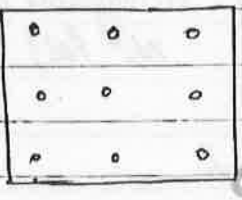
$$\therefore T_B = T_C = \frac{8P_0V_0}{1 \times R}$$

∴ Tmax at mid point of BC Process.

$$T_{max} = \frac{\left(\frac{5}{2}P_0\right)(5V_0)}{1 \times R}$$

$$= \frac{25\ P_0V_0}{2R}$$

- Different speed and velocities of gas sample



(1). Avg. velocity ($\vec{V}_{avg}$)

$$\langle \vec{V} \rangle = \frac{\vec{V}_1 + \vec{V}_2 + \dots\dots \vec{V}_N}{N}$$

∵ If $\vec{v}_1 = 5$ m/sec then koi na koi -5 m/sec wala bhi hoga.

$$\langle \vec{V} \rangle = 0$$

Avg. momentum $= 0$

(2). Avg. speed, V_{avg} or $\langle V \rangle$

$$\langle V \rangle = \frac{V_1 + V_2 + \dots V_N}{N} \neq 0$$

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(3). Mean square speed/velocity.

$$V_{ms} \text{ or } \langle \vec{v} \rangle = \frac{\vec{v}_1^{\,2} + \vec{v}_2^{\,2} + \cdots + \vec{v}_N^{\,2}}{N} \neq 0$$

(4). Root mean square speed

$$V_{Rms} \text{ or } \langle \vec{v}^2 \rangle^{1/2} = \left[\frac{\vec{v}_1^{\,2} + \vec{v}_2^{\,2} + \cdots \vec{v}_N^{\,2}}{N}\right]^{1/2}$$

$$\boxed{V_{ms} = V_{Rms}^2}$$

(5). Most Probable speed

$V_{mp} \Rightarrow$ speed for which no. of molecules are max^m in gas sample.

Note! ⇒

$\langle \vec{v} \rangle = 0$

$\langle \vec{v}^3 \rangle = 0$

$\langle \vec{v}^5 \rangle = 0$

odd $\rightarrow \boxed{0}$

$\langle \vec{v}^2 \rangle \neq 0$

$\langle \vec{v}^4 \rangle \neq 0$

even $\rightarrow \neq 0$

$\langle \vec{v} \rangle^2 = 0$

- Pressure exerted by gas (P)

$$\boxed{P = \frac{1}{3}\underset{\substack{\downarrow \\ \frac{M}{V}}}{\rho} V_{rms}^2}$$

- Root mean square (V_{Rms})

$\because P = \frac{1}{3}\rho V_{rms}^2$

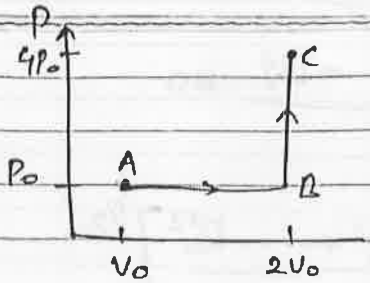
$V_{rms}^2 = \frac{3P}{\rho}$

$$\boxed{V_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3RT}{m_w}} = \sqrt{\frac{3KT}{m}}}$$

↳ It depends on temp. and it's m_w.

$$\therefore \boxed{V_{ms} = V_{rms}^2 = \frac{3P}{\rho} = \frac{3RT}{m_w} = \frac{3KT}{m}}$$

Ques:- F/o ratio of root mean square speed of I.G. at pt. C & A.



$$V_{Rms} \propto \sqrt{\frac{T}{\boxed{m_w}}}$$

$$\therefore\ T_C = \frac{8P_0V_0}{nR} \quad \text{and} \quad T_A = \frac{P_0V_0}{nR}$$

$$\Rightarrow T_C = 8T_A.$$

Now, $$\frac{V_{rms\,C}}{V_{rms\,A}} = \sqrt{\frac{T_C}{T_A}} = \sqrt{\frac{8T_A}{T_A}} = \frac{2\sqrt{2}}{1}$$

Ques:- F/o temp. of He gas molecule so that they are having rms speed as same as that of H_2-gas molecules at NTP

$$(V_{rms})_{He} = (V_{rms})_{H_2}$$

$$\sqrt{\frac{3RT}{4}} = \sqrt{\frac{3R(273)}{2}}$$

$$\frac{T}{4} = \frac{273}{2}$$

$$T = \frac{4 \times 273}{2}$$

$$\left.\begin{aligned} T &= 2 \times 273 \\ T &= 546K \\ T &= 273^\circ C \end{aligned}\right\} \text{(Ans):}$$

Ques:- Find out ratio of mean square speed of He-gas molecules at 2atmp. pressure and 27°c and atomic - H at 1 atm and 127°c.

$$V_{ms} \propto \frac{T}{m_w}$$

$$\frac{(V_{ms})_{He}}{(V_{ms})_H} = \frac{300}{4} \times \frac{1}{400}$$

$$= \frac{3}{16}$$

Ques:- If temp. of N_2-gas molecules having rms speed V_0 is increased upto 4 times of initial in such a way that it dissociates into atomic gas then f/o it's rms speed?

$$\therefore V_{rms} \propto \sqrt{\frac{T}{M_w}}$$

$T \rightarrow 4$ times

$M_w \rightarrow \frac{1}{2}$ times.

So, $V_{rms} \rightarrow \sqrt{\frac{4}{1/2}}$ times.

$V_{rms} \rightarrow \sqrt{8}$ times

$V_{rms} = 2\sqrt{2}\, V_0$.

Ques:- If pressure of an Ideal gas kept in a $\overset{vol^m\ const.}{\text{container}}$ is increased upto twice of initial then it's rms speed becomes.

In container $\rightarrow$ vol^m = const.

So, $P \propto T$

$P \rightarrow 2$ times

$T \rightarrow 2$ times

$\therefore V_{rms} \propto \sqrt{\frac{T}{\boxed{M_w}}} \Rightarrow V_{rms} \rightarrow \sqrt{2}$ times of initial.

- Escape speed (V_{es})

$(V_{es})_{earth} = 11.2$ Km/s
$= 11.2 \times 10^3$ m/s

If $(V_{rms})_{gas} > (V_{es}) \Rightarrow$ Atmosphere absent
eg :⇒ Moon.

If $(V_{rms})_{gas} < V_{es} \Rightarrow$ Atmosphere present.
eg.⇒ Earth.

*** ⇒ If temp. of Earth is ↑ed then H_2 gas will escape out first.

Ques:- F/o min^m temp. of any gas to escape out from Earth?

To escape out :→ $V_{rms} \geq V_{es}$

min^m condition :→ $V_{rms} = V_{es} = 11.2 \times 10^3$ m/sec.

$$\sqrt{\frac{\boxed{3R} T_{min}}{M_w}} = 11.2 \times 10^3$$

$$25\, T_{min} = \overset{5}{\cancel{125}} \times 10^6 \times M_w \rightarrow kg$$

$$T_{min} = 5 \times 10^6 \times 10^{-3} \times M_w \rightarrow g$$

$$\boxed{T_{min} = \frac{10^4}{2} \times M_w \rightarrow g}$$

$$\therefore (T_{min})_{H_2} = \frac{10^4}{2} \times 2 = 10^4 \text{ K}$$

$$(T_{min})_{N_2} = \frac{10^4}{2} \times 28 = 14 \times 10^4 \text{ K.}$$

Note:⇒ (1). $V_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3RT}{M_w}} = \sqrt{\frac{3KT}{m}} = 1.73\sqrt{\frac{KT}{m}}$

$\Rightarrow V_{ms} = V_{rms}^2$

(2). V_{avg} or $\langle v \rangle = \sqrt{\frac{8P}{\pi\rho}} = \sqrt{\frac{8RT}{\pi M_w}} = \sqrt{\frac{8KT}{\pi m}} = 1.59\sqrt{\frac{KT}{m}}$

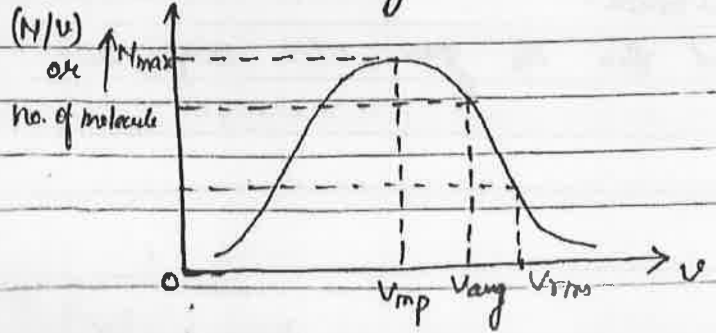
(3). $V_{mp} = \sqrt{\frac{2P}{\rho}} = \sqrt{\frac{2RT}{M_w}} = \sqrt{\frac{2KT}{m}} = 1.414\sqrt{\frac{KT}{m}}$

(4). $V_{sound} = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M_w}}$ $\quad 1 < \gamma < 2$

For a gas sample:→

$V_{rms} > V_{avg.} > V_{mp.}$ $\quad R > A > M$

- Maxwell's velocity distribution Curve



Total no. of molecules = Area of Curve

KTG = Ex. I - 122 to 180

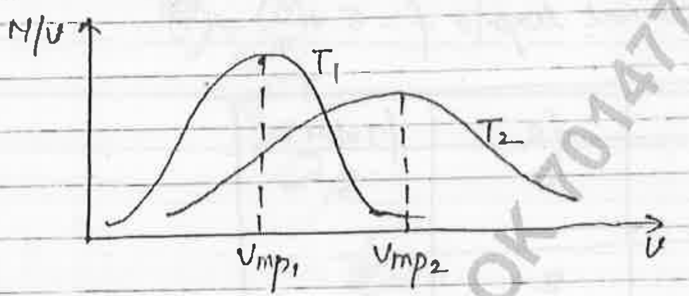
→ If temp. of gas sample is increased then :-

- → $V_{rms} \uparrow$
- → $V_{avg} \uparrow$
- → $V_{mp} \uparrow$

$\Big\} \rightarrow \propto \sqrt{T}$

- → $V_{ms} \uparrow \Rightarrow \propto T$
- → Peak ↓ (∵ Area same rakhne ke liye)
- → Area of curve ⇒ const. (∵ No. of molecules)

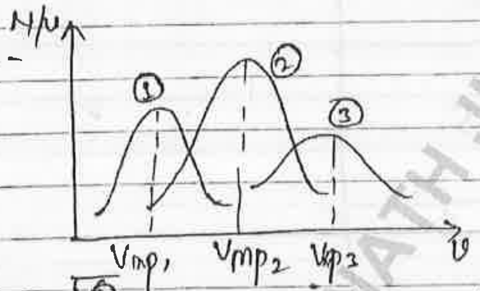
eg.:- If a gas sample is heated from T_1 to T_2



$V_{mp_2} > V_{mp_1}$
↓
$\propto \sqrt{T}$

$\boxed{T_2 > T_1}$

Que:-



Given distribution curve of different gas kept in a container.

(T = const)

ⓐ $H_2, O_2\ N_2$

ⓑ O_2, H_2, N_2

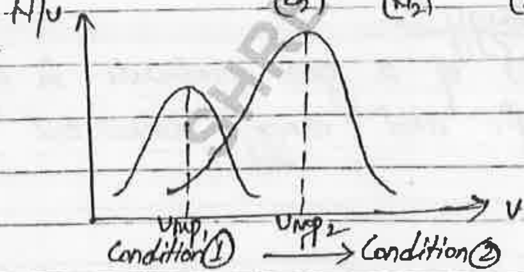
[✓ ⓒ O_2, N_2, H_2]

ⓓ H_2, N_2, O_2

$\therefore V_{mp} \propto \sqrt{\frac{1}{m_\omega}}$ $\therefore V_{mp_3} > V_{mp_2} > V_{mp_1}$

$\underset{(O_2)}{M_{\omega_1}} < \underset{(N_2)}{M_{\omega_2}} < \underset{(H_2)}{M_{\omega_3}}$

Que:-



ⓐ Gas is being heated

ⓑ Gas is being cooled

[✓ ⓒ Gas is being heated and some gas added into it.]

ⓓ Gas is being heated and some gas leaked out of container

$\because V_{mp} \propto \sqrt{\frac{T}{\boxed{m_\omega}}}$

$\underbrace{T_2 > T_1}_{\hookrightarrow \text{heating}}$ and Area ↑ means $\underbrace{\text{no. of molecules} \uparrow}_{\downarrow}$

some gas added into it.

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- Degree of Freedom (D.O.f) / f :→

→ 3 types of Motion:—

(1). Translatory D.O.f (f_T)

(2). Rotational D.O.f (f_R)

(3). Vibrational D.O.f (f_V) ⇒ Only at very high temp.

$$\begin{tikzcd} & f_V = 2 \arrow[dl] \arrow[dr] & \\ KE & & PE \end{tikzcd}$$

Exception :→ CO ↓
shows vibration even at
normal temp. ⇒ $f = 5 + \underset{\uparrow \, f_V}{\textcircled{2}} = \textcircled{7}$.

Gas	f_T	f_R	f_{Total}
Monoatomic (He, Ne, etc)	3	0	3
Diatomic (H_2, N_2, etc).	3	2	5
Polyatomic			
(1). linear (C_2H_2, CO_2)	3	2	5
(2). Non-linear (NH_3, CH_4)	3	3	6

- Maxwell's law of equipartition of Energy.

→ A/c to internal energy (total KE) of a gas molecule is equally distributed among it's all D.O.f. and energy associated to 1 D.O.f is $\frac{1}{2}KT$.

1 molecule → energy associated to 1 D.O.f $= \frac{1}{2}KT$

" " f D.O.f $= \frac{f}{2}KT$

N molecules → " " " $= \frac{f}{2}NKT$

n moles → " " " $= \frac{f}{2}nRT$

→ Translatory K.E. = $\frac{f_T}{2}nRT \Big/ \frac{f_T}{2}NKT \Big/ \frac{f_T}{2}PV$

→ Rotational K.E. = $\frac{f_R}{2}nRT \Big/ \frac{f_R}{2}NKT \Big/ \frac{f_R}{2}PV$

→ I.E. (total K.E.) = $\frac{f}{2}nRT \Big/ \frac{f}{2}NKT \Big/ \frac{f}{2}PV$

Note :⇒ ①. KE $\xrightarrow{\text{means}}$ Translatory KE ⇒ $\frac{\overset{\nearrow 3}{f_T}}{2}(nRT/NKT/PV)$

② Avg. $\xrightarrow{\text{means}}$ per mole or per molecule value ⇒ n or N = 1

③ Avg. KE $\xrightarrow{\text{means}}$ Avg. of translatory KE

$$3 \leftarrow \frac{f_T}{2} \times \underset{1}{\underset{\downarrow}{n}}RT \Big/ \underset{1}{\underset{\downarrow}{N}}KT$$

④ Any type of K.E. (If n or N const.) ∝ T.

Ques:- F/o following for H_2 gas at T_0 temp.

①. I.E. of 10 molecule = $\frac{f}{2}NKT = \frac{5}{2} \times 10\,KT_0 = 25\,KT_0$

② Translatory KE of 10 molecule = $\frac{f_T}{2}NKT = \frac{3}{2} \times 10\,KT_0 = 15\,KT_0$

③. Avg. KE. of 20 mole = $\frac{f_T}{2}\overset{1}{\overset{\uparrow}{n}}RT = \frac{3}{2}RT_0$

④ Ratio of translatory KE and Rotational KE. of gas

$$\frac{\text{Trans. K.E}}{\text{Rotat. KE}} = \frac{\frac{f_T}{2}nRT}{\frac{f_R}{2}nRT} = \frac{f_T}{f_R} = \frac{3}{2}$$

⑤ Fraction of I.E. in form of translational KE at very high temp.

$$\frac{\text{Trans. KE}}{\text{I.E}} = \frac{\frac{f_T}{\cancel{2}}\cancel{nRT}}{\frac{f}{\cancel{2}}\cancel{nRT}} = \frac{f_T}{f} = \frac{3}{5+2} = \frac{3}{7}$$

Ques:- If I.E. of n_1 mole He gas at T_0 temp. is 3 times of that of n_2 mole H_2 gas at $2T_0$ temp. Then $\frac{n_1}{n_2} = ?$

$$\therefore \frac{(IE)_{He}}{(IE)_{H_2}} = \frac{\frac{f_{He}}{\cancel{2}} n_1 \cancel{R} \cancel{T_0}}{\frac{f_{H_2}}{\cancel{2}} n_2 \cancel{R} (2\cancel{T_0})}$$

$$\frac{\cancel{3}\,\cancel{(IE)_{H_2}}}{\cancel{(IE)_{H_2}}} = \frac{\cancel{3} \times n_1}{5 \times n_2 \times 2}$$

$$\frac{n_1}{n_2} = \frac{10}{1}$$

Ques:- 2 mole H_2 gas & 4 mole CH_4 gas kept in a container at T_0 temp. F/o internal energy of mix.

$$\therefore (IE)_{mix} = (IE)_{H_2} + (IE)_{CH_4}$$

$$= \frac{3}{2} \times 2RT_0 + \cancel{4}\,\frac{6}{2} \times 4RT_0$$

$$= 17RT_0$$

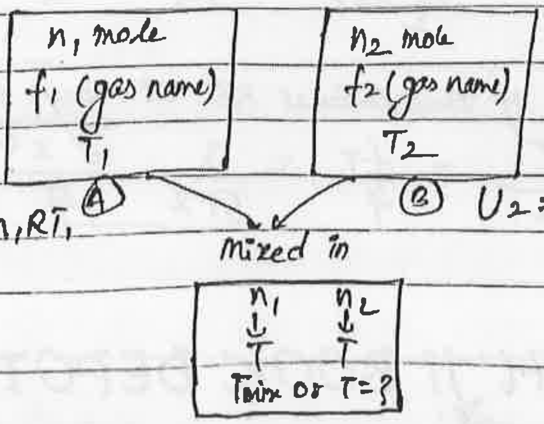
Ques:- Avg. KE. of 10 mole H_2 gas at 27°C is E then f/o it's avg. KE of 20 mole at 127°C temp.

$$\text{Avg. KE.} = \frac{3}{2} \times ① \times RT$$

$$\text{Avg KE} \propto T. \Rightarrow \frac{E}{E_2} = \frac{300}{400}$$

$$E_2 = \frac{4}{3}E.$$

Ques:-



$$U_1 = \frac{f_1}{2} n_1 R T_1$$

$$U_2 = \frac{f_2}{2} n_2 R T_2$$

$\therefore U_{mix} = \frac{f_1}{2}n_1RT + \frac{f_2}{2}n_2RT = \frac{f_1}{2}n_1RT_1 + \frac{f_2}{2}n_2RT_2$

$$\Rightarrow \boxed{T_{mix} = T = \frac{n_1f_1T_1 + n_2f_2T_2}{n_1f_1 + n_2f_2}}$$

If $f_1 = f_2$

eg:- Ⓐ $\rightarrow H_2 \Rightarrow f = 5$

Ⓑ $\rightarrow H_2 \Rightarrow f = 5$

then, $\left[T_{mix} = \frac{n_1T_1 + n_2T_2}{n_1 + n_2} \right]$

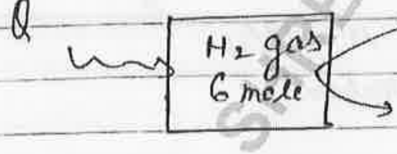
Ques:- 2 mole of He gas at 27°C mixed with 1 mole of H_2 gas at 127°C in a container then f/o temp. of mixture.

$$T_{mix} = \frac{2 \times 3 \times 300 + 1 \times 5 \times 400}{2 \times 3 + 1 \times 5}$$

$$T_{mix} = \frac{3800}{11} = 345.45\ K$$

$$= 72.45°C.$$

Ques:- 6 mole N_2 gas kept in a container at T_0 temp. When some amount of heat energy supplied to it, 2 out of 6 moles dissociates into atomic gas and temp. of gas remains same. Then f/o amount of energy supplied to it!



Diatomic $(N_2) = 4$ moles

Monoatomic $= 2 \times 2 = 4$ moles

Now, $Q = ~~U_f~~\ U_f - U_i$ — ①

$\therefore U_f = \frac{3}{2} \times 4RT_0 + \frac{5}{2} \times 4RT_0$

$U_f = 16RT_0$.

$\therefore U_i = \frac{5}{2} \times 6RT_0 = 15RT_0$.

Now, $Q = 16RT_0 - 15RT_0 = RT_0$

Ques:- If in previous question N molecules of N_2 gas kept in container and n molecules out of N dissociates into atomic gas then f/o heat energy supplied to it?

$$\therefore U_i = \frac{5}{2}\times NKT_0$$

N_2 gas → 2n monoatomic

N_2 gas → N−n diatomic

$$\therefore U_f = \frac{3}{2}(2n)KT_0 + \frac{5}{2}(N-n)KT_0$$

$$U_f = 3nKT_0 + \frac{5}{2}NKT_0 - \frac{5}{2}nKT_0$$

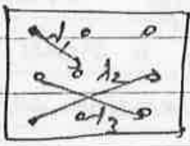
$$U_f = \frac{nKT_0}{2} + \frac{5}{2}NKT_0$$

Now, $Q = U_f - U_i$

$$Q = \frac{nKT_0}{2} + \cancel{\frac{5}{2}NKT_0} - \cancel{\frac{5}{2}NKT_0}$$

Jo dissociate hue hai $\quad Q = \frac{nKT_0}{2}$

- **Mean Free Path (λ_m)** → Distance ⇒ Unit = Å



Avg. distance travelled by gas molecule b/w two consecutive collision.

$$\boxed{\lambda_m = \frac{1}{\sqrt{2}\pi d^2 n}}$$

n → Molecular density $n = N/V$

d → diameter of molecule

$$\lambda_m = \frac{V}{\sqrt{2}\pi d^2 N}$$

$$\boxed{\lambda_m = \frac{KT}{\sqrt{2}\pi d^2 P}} \qquad \left\{\begin{array}{l} \because PV = NKT \\ \frac{V}{N} = \frac{KT}{P} \end{array}\right\}$$

$$o\xrightarrow[V_{avg}]{\lambda_m}- - - - - o \quad [1\ \text{collision}]$$

time taken in 1 collision $\quad \therefore t = \frac{\text{distance}}{\text{speed}} = \frac{\lambda_m}{V_{avg}}$.

Ex-I → 122 → 212

$$t = \frac{\lambda_m}{V_{avg}} \qquad \lambda_m \rightarrow \frac{kT}{\sqrt{2}\pi d^2 p} \qquad V_{avg} \rightarrow \sqrt{\frac{8RT}{\pi M_w}}$$

∵ t sec ⟶ 1 collision

collision per sec ⇒ $1/t$

collision frequency $(f_c) = \frac{1}{t} = \frac{V_{avg}}{\lambda_m} \rightarrow \sqrt{\frac{T}{M_w}}$

∵ $T \rightarrow$ same

$$\boxed{\text{No. of collision per sec} \propto \frac{1}{\sqrt{M_w}}}$$

21/12/2019

[redacted]

- Specific Heat (s or C)

→ Amount of heat required to change the temp. of 1 mole or unit mass by 1°C or 1 Kelvin is k/n as specific heat of substance.

Specific heat (s or c)

$Q = ms\Delta T$ ↓

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

Unit → $\frac{J}{Kg\text{-}K}$

gm sp. heat

$Q = nC\Delta T$ ↓

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

unit → $\frac{J}{mol\text{-}K}$

molar sp. heat.

Relation b/w C & S

$$\because \; C = \frac{Q}{n\Delta T} = \frac{Q}{M\Delta T} M_w$$

$$\boxed{C = S \times M_w}$$

∴ Unit mass → specific heat (s)

m mass → Heat capacity

$H_c = ms$

$Q = \underbrace{ms}\Delta T$ ↓ $H_c = \frac{Q}{\Delta T}$

$Q = \underbrace{nc}\Delta T$ ↓ $H_c = nc = \frac{Q}{\Delta T}$

→ Molar mass → mass of 1 mole

Molar heat capacity → H_c of 1 mole

$H_c = nc = 1 \times c$

$\Rightarrow H_c = c$

Note :⇒ (1). Specific heats of solids & liquids depends on nature of material that's why they are having unique value (single value of their specific heat).

eg. - $S_{water} = 1 \frac{cal}{g\,°c}$, $S_{Ice} = 0.5 \frac{cal}{g\,°c}$

But specific heat of gases depends upon process, that's why gases have infinite no. of specific heat.

- Sp. heat of I.G. in different Process

(1). IC

$C_v = \frac{(Q)_v}{n\Delta T} \Rightarrow \boxed{Q = nC_v\Delta T}$

→ sp. heat at const. vol^m

$\therefore \boxed{C_v = \frac{f}{2}R}$

(2). IB

$C_p = \frac{(Q)_p}{n\Delta T} \Rightarrow \boxed{Q = nC_p\Delta T}$

$C_p = ?$

\# Mayer's Relation

$\boxed{C_p - C_v = R}$ → valid for only I.G.

↓

Molar sp. heat

If gm. sp. heat given :-

$S_p \times M_w - S_v \times M_w = R$

$\boxed{S_p - S_v = \frac{R}{M_w}}$

↓

gm. sp. heat

Que):- If $C_p - C_v = a$ for H_2 gas and $C_p - C_v = b$ for N_2 gas then f/o relation b/w a & b if ① C_p & C_v are molar sp. heat ② C_p & C_v are gm. sp. heat.

① H_2

$C_p - C_v = a$

$R = a$

N_2

$C_p - C_v = b$

$R = b$

$\Rightarrow a = b$

② H_2

$C_p - C_v = a$

$\frac{R}{2} = a$

$R = 2a$

N_2

$C_p - C_v = b$

$\frac{R}{28} = b$

$R = 28b$

$\Rightarrow a = 14b.$

Que:- If a gas sample follows $\overset{\to R.G.}{C_p - C_v = 1.06R}$ at P_1 & T_1 state and it follows $\underset{\hookrightarrow I.G.}{C_p - C_v = 1.00R}$ at P_2 & T_2 state then -

ⓐ $P_1 > P_2$; $T_1 > T_2$

ⓑ $P_1 < P_2$; $T_1 < T_2$

ⓒ $P_1 < P_2$; $T_1 > T_2$

~~ⓓ~~ $P_1 > P_2$; $T_1 < T_2$

$$R.G. \xrightarrow{T\uparrow;\ P\downarrow} I.G.$$

$$P_1 \quad > \quad P_2$$

$$T_1 \quad < \quad T_2$$

Que:- If C_p & C_v of a gas sample are respectively 0.2 & 0.15 $\frac{cal}{g°C}$ then f/o — ① it's $M\omega$, ② it's D.O.f

① ~~$C_p - C_v = \frac{0.2\,R}{M\omega}$~~

~~$M\omega = \frac{C_p - C_v}{R} = \frac{0.2 - 0.15}{2}$~~

① $C_p - C_v = \frac{R}{M\omega}$

$M\omega = \cancel{C_p - C_v}\ \frac{R}{C_p - C_v}$

$M\omega = \cancel{0.2 - 0.1}\ \frac{2}{0.2 - 0.15}$

$M\omega = \frac{2}{0.05} = 40g$

② $C_v = \frac{f}{2} R$

$\downarrow$

$[0.15 \times M\omega] = \frac{f}{\cancel{2}} \times \cancel{2}$

$f = 0.15 \times 40$

$f = 6.0$

$f = 6$

Que:- If C_p & C_v of an I.G. are 425 & 215 $\frac{J}{Kg\text{-}K}$ respectively then it's density at STP.

⇒ IB

$\because C_p - C_v = R$

$C_p = C_v + R$

$C_p = \frac{f}{2}R + R \Rightarrow \boxed{C_p = \left(\frac{f}{2}+1\right)R}$

(3). IT

$C = \frac{Q}{n\Delta T \to 0} = \infty$

$\boxed{C_{IT} = \infty}$ → Not defined

$\therefore Q = n\overset{\infty}{\cancel{C}}\Delta T$

↳ formula not defined for IT.

(4). Ad.

$C = \frac{\overset{\to 0}{\cancel{Q}}}{n\Delta T} \Rightarrow \boxed{C_{Ad} = 0}$

Note: ⇒ ① ∵ IE ⇒ $U = \frac{f}{2}nRT$

$U = nC_vT$

↓ If $T\uparrow \Rightarrow U\uparrow$

Chang in I.E. ← $\boxed{\Delta U = nC_v\Delta T}$

↳ Same formula for Process

↳ ΔU is state function.

②. $Q = nC\Delta T$

Q — IC → $Q = nC_v\Delta T$

IB → $Q = nC_p\Delta T$

Polytropic → $Q = nC_{poly}.\Delta T$

→ Heat is Path function.

(5).** Polytropic Process ($PV^x = $ const).

If $x = 0 \Rightarrow P = $ const. ⇒ IB ⇒ $C = C_p$

If $x = 1 \Rightarrow PV = $ const. ⇒ IT ⇒ $C = \infty$

If $x = \gamma \Rightarrow PV^{\gamma} = \text{const.} \Rightarrow \text{Ad.} \Rightarrow C_{Ad} = 0$

eg:⇒ $\underset{\downarrow}{\textcircled{T}} \propto V^2 \Rightarrow$ Polytropic

$\frac{PV}{nR} \propto V^3 \Rightarrow PV^{-2} = \text{const.}$

$\Rightarrow x = -2$

$$\therefore \boxed{C_{poly} = C_V + \frac{R}{1-x}}$$

$$\therefore \boxed{Q_{poly.} = nC_{poly.}\Delta T}$$

$$\therefore \boxed{\Delta U = nC_V\Delta T}$$

Ques!- 1 mole He gas follow $PV^3 = \text{const}$ process then flo-

① Molar heat capacity of gas in given process

② Heat supplied & change in I.E. of gas to ↑ its temp. by 10°C.

$\therefore PV^3 = \text{const.}$

$\Rightarrow x = 3$

① $C = C_V + \frac{R}{1-x}$

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

$C = \frac{3}{2}R - \frac{R}{2}$

$\boxed{C = R}$

② $\therefore Q = nC\Delta T$

$Q = 1 \times R \times 10$

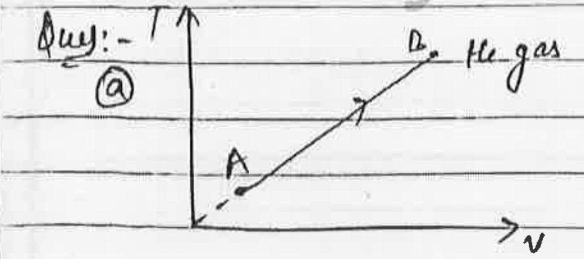
$Q = 10R$ (OR) 20 Cal.

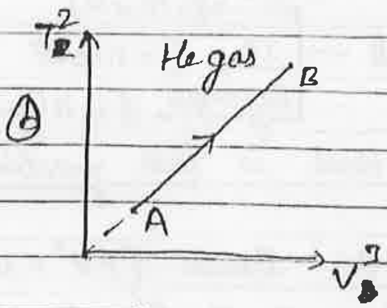
$\therefore \Delta U = nC_V\Delta T$

$\Delta U = 1 \times \frac{3}{2}R \times 10 = 15R$ (OR) 30 Cal.

{∴ Molar Hc = nC = 1×R = R}.

Ques:- ⓐ





Molar heat capacity of gas in ⓐ and ⓑ process.

ⓐ. $T \propto V \Rightarrow$ IB.

Ex-I = 228, 224, 247, 251, 255,
Ex-II = 2, 3, 5, 9, 13, 18, 30, 31, 35, 36, 37, 38, 40,
47, 51, 53, 59, 60, 65, 66, 71, 76, 78, 85, 88,
89, 95, 97, 103, 106, 108

$\therefore$ Molar Hc $= nC_p = 1 \times \frac{5}{2}R = \frac{5}{2}R$.

(b). $T^2 \propto V^3$

$$\frac{P^2V^2}{(nR)^2} \propto V^3$$

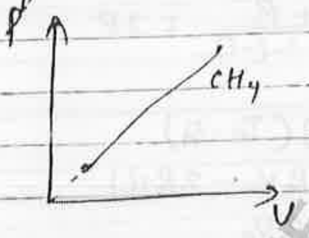
$$P^2V^{-1} = \text{const}$$

$$PV^{-1/2} = \text{const} \qquad \Rightarrow x = -1/2$$

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

$$C = \frac{3}{2}R + \frac{R}{1-(-1/2)} = \frac{13R}{6}$$

Ques:- If P-V curve of 1 mole methane gas is straight line passing through origin with it's initial temp T_0 then f/o amount of heat supplied to it to increase it's rms speed of gas molecules upto twice of initial and change in internal energy in it.



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

$$C = \frac{6}{2}R + \frac{R}{1-(-1)}$$

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

$P \propto V \Rightarrow$

$PV^{-1} = \text{const}$

$x = -1$

$\therefore V_{rms} \propto \sqrt{\frac{T}{M_0}}$

$V_{rms} \rightarrow 2$ times

$T \rightarrow 4$ times

$\Delta T = 3T_0$

Now, $Q = nC\Delta T$

$$Q = 1 \times \frac{7R}{2} \times 3T_0 = \frac{21}{2}RT_0$$

$\therefore \Delta U = nC_V\Delta T$

$= 1 \times (3R) \times (3T_0)$

$= 9RT_0$

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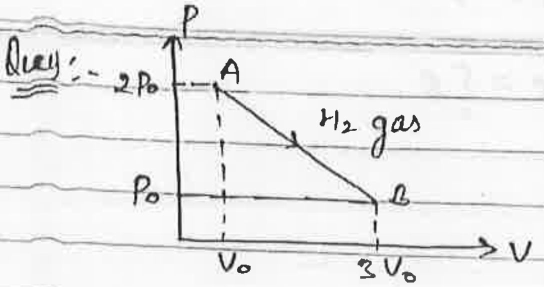
Ques:-



F/o change in I.E. of H_2 gas in AB process.

$\therefore \Delta U = nC_v\Delta T$

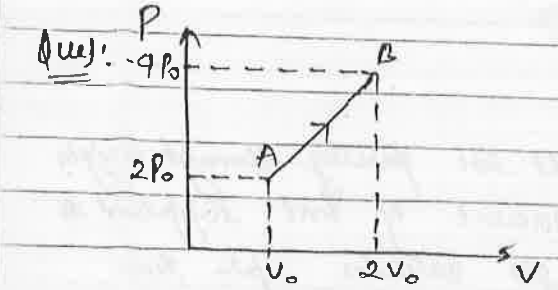
$= n \times \frac{5}{2}R\,[T_B - T_A]$

$= \frac{5}{2}[P_BV_B - P_AV_A]$

$= \frac{5}{2}[3P_0V_0 - 2P_0V_0]$

$= \frac{5}{2}P_0V_0$

Ques:-



F/o heat absorbed and ΔU in AB process for He gas.

$\therefore P \propto V$

$PV^{-1} = \text{const.} \Rightarrow x = -1$

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

$C = \frac{3}{2}R + \frac{R}{1-(-1)} = 2R.$

Now, $\therefore Q = nC\Delta T$

$Q = n(2R)(T_B - T_A)$

$Q = 2(8P_0V_0 - 2P_0V_0)$

$Q = 12P_0V_0$

$\therefore \Delta U = nC_v\Delta T$

$= n \times \frac{3}{2}R\,(T_B - T_A)$

$= \frac{3}{2}(8P_0V_0 - 2P_0V_0)$

$= 9P_0V_0$

Ques:- 2 mole He gas & 1 mole CH_4 gas kept in container. F/o amount of heat given to mix. and it's ΔU to ↑ it's temp. by 30°C if - ① container is closed
② container is open

① close container ⇒ IC.

$\therefore \Delta U_{mix} = \underset{\downarrow}{\Delta U_{He}} + \underset{\downarrow}{\Delta U_{CH_4}}$

$= nC_v\Delta T + nC_v\Delta T$

$= 2 \times \frac{3}{2}R \times 30 + 1 \times 3R \times 30$

$= 180R.$

$\therefore Q = \underset{\downarrow}{Q_{He}} + \underset{\downarrow}{Q_{CH_4}}$

$= nC_v\Delta T + nC_v\Delta T$

$= 180R.$

② Open container ⇒ IB.

$\therefore \Delta U_{mix} = \Delta U_{He} + \Delta U_{CH_4}$

$= nC_v\Delta T + nC_v\Delta T$

$= 180R.$

$\therefore Q = nC_p\Delta T + nC_p\Delta T$

$Q = 2 \times \frac{5}{2}R \times 30 + 1 \times 4R \times 30$

$Q = 270R.$

- γ (Adiabatic exponent) ⇒ $PV^{\textcircled{\gamma}}$

→ Ratio of specific heat at constant 'P' and constant 'V'.

→ $\boxed{\gamma = \frac{C_p}{C_v}} = \frac{C_v + R}{R} = 1 + \frac{R}{C_v} = 1 + \frac{R}{\frac{f}{2}R} = 1 + \frac{2}{f}$

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

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

→ $\boxed{C_v = \frac{f}{2}R = \left(\frac{2}{\gamma - 1}\right)\frac{R}{2} = \frac{R}{\gamma - 1}}$

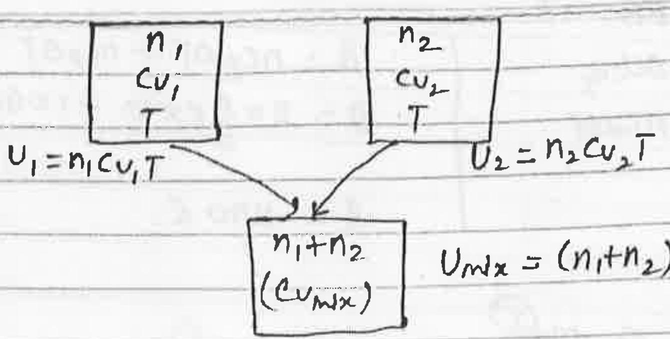
→ $\boxed{C_p = \gamma C_v = \gamma\left(\frac{R}{\gamma - 1}\right)}$

# Gas	$C_v = \frac{f}{2}R$	$C_p = C_v + R$	$\gamma = \frac{C_p}{C_v}$
Monatomic	$\frac{3}{2}R$	$\frac{5}{2}R$	$\frac{5}{3} \doteq 1.66$
Diatomic	$\frac{5}{2}R$	$\frac{7}{2}R$	$\frac{7}{5} = 1.4$
Polyatomic (i). Linear	$\frac{5}{2}R$	$\frac{7}{2}R$	$\frac{7}{5} = 1.4$
(ii). Non-linear	$\frac{6}{2}R = 3R$	$4R$	$\frac{4}{3} = 1.33$

γ_{max} → Monoatomic

$\boxed{1 < \gamma < 2}$

Note : ⇒



$U_1 = n_1 C_{V_1} T$ $\qquad$ $U_2 = n_2 C_{V_2} T$

$U_{mix} = (n_1+n_2)\, C_{V_{mix}}\, T$

$\because U_1 + U_2 = U_{mix}$

So, $\boxed{C_{V_{mix}} = \frac{n_1 C_{V_1} + n_2 C_{V_2}}{n_1+n_2}}$ and $\boxed{C_{P_{mix}} = \frac{n_1 C_{P_1} + n_2 C_{P_2}}{n_1+n_2}}$

OR

$\boxed{C_{P_{mix}} = C_{V_{mix}} + R}$

$\therefore \boxed{\gamma_{mix} = \frac{C_{P_{mix}}}{C_{V_{mix}}}}$

Ques:- 1 mole H_2 gas and 2 mole He gas mixed in container then –
ⓐ $C_{V_{mix}} = ?$ ⓑ $C_{P_{mix}} = ?$ ⓒ $\gamma_{mix} = ?$

① $C_{V_{mix}} = \frac{n_1 C_{V_1} + n_2 C_{V_2}}{n_1+n_2} = \frac{1 \times \frac{5}{2}R + 2 \times \frac{3}{2}R}{1+2}$

$\Rightarrow C_{V_{mix}} = \frac{11R}{6}$

② $C_{P_{mix}} = \frac{11R}{6} + R = \frac{17R}{6}$

③ $\gamma_{mix} = \frac{C_{P_{mix}}}{C_{V_{mix}}} = \frac{\frac{17R}{6}}{\frac{17R}{6}} = \frac{17}{11} = 1.54$

Imp.

Ques:- 1 mole I.G. $(\gamma = \frac{5}{3})$ and 1 mole I.G. $(\gamma = 4/3)$ are mixed in container then γ of mix ?

~~$\therefore \gamma_{mix} = 1 \therefore \gamma = \frac{5}{3} = \frac{C_P}{C_V} \Rightarrow C_V = \frac{3}{8}$~~

$\therefore \gamma = \frac{5}{3} \Rightarrow$ Monoatomic $\Rightarrow C_V = \frac{3}{2}R.$

$\therefore \gamma = \frac{4}{3} \Rightarrow$ Non-linear $\Rightarrow C_V =$ ~~[illegible]~~ $3R$

$$\therefore C_{V_{mix}} = \frac{1 \times \frac{3}{2}R + 1 \times 3R}{1+1} = \frac{9}{4}R$$

$$\therefore C_{P_{mix}} = \frac{9}{4}R + R = \frac{13}{4}R$$

Now, $\gamma_{mix} = \frac{13/4 R}{9/4 R} = \frac{13}{9} = 1.44$

Ques!- Pressure of an I.G. in adiabatic process is proportional to 4th power of it's absolute temp. then I.G. would be

ⓐ H_2

ⓑ He

ⓒ Mixture of He & H_2

ⓓ CH_4

$\therefore$ – ~~$P^4 V^\gamma = \text{const}$~~.

~~$P V^{1/4} = \text{const}$~~

~~$\Rightarrow \gamma = \frac{1}{4}$~~

$\therefore$ Ad. $\longrightarrow$ $PV^\gamma = \text{const}$.

$P \propto T^4$ (Ad.)

$P \propto \frac{P^4 V^4}{(nR)^4}$

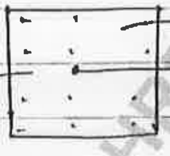
$P^3 V^4 = \text{const}$

$P V^{4/3} = \text{const}$. $\Rightarrow \gamma = 4/3 = 1.33$

$\downarrow$

Polyatomic (Non-linear)

Ques!-



→ In Thermal Physics

F/o – ① Energy of gas wrt C.O.M. of container

② Energy of gas wrt ground

① $E = U = \frac{f}{2} nRT = \frac{3}{2} nRT_0$

② $E = U + K$

$$= \underbrace{\frac{3}{2} nRT_0}_{\text{depends on temp.}} + \underbrace{\frac{1}{2} M V_c^2}_{\text{depends on structured Motion of Molecule}}$$

Ques!:- If I.E. of I.G. given by $U = 5 + 2PV$ then Ideal gas would be - ⓐ H_2 ⓑ He ⓒ CH_4 [✓ ⓓ mix. of He & H_2]

M-Ⓘ $\therefore U = 5 + 2PV$

$$\Delta U = 0 + 2nR\Delta T$$

$$\cancel{n}C_v \cancel{\Delta T} = 2\cancel{n}R\cancel{\Delta T}$$

$$C_v = 2R.$$

$$\therefore C_p = 2R + R = 3R.$$

$$\therefore \gamma = \frac{3R}{2R} = \underset{\text{Mixture.}}{\underset{\downarrow}{\boxed{1.5}}}$$

OR

M-Ⓘⓘ $\therefore 2PV = \frac{f}{2}nRT$

$$2nRT = \frac{f}{2}nRT$$

$$f = 4$$

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

$$\gamma = 1 + \frac{2}{4} = \underset{\text{Mixture.}}{\underset{\downarrow}{\boxed{1.5}}}$$

Ques!:- If I.E. of gas $U = a + bPV$, then γ of gas?

$$\Delta U = 0 + bnR\Delta T$$

$$\cancel{n}C_v \cancel{\Delta T} = b\cancel{n}R\cancel{\Delta T}$$

$$C_v = bR.$$

$$\therefore C_p = bR + R = R(b+1).$$

$$\text{Now, } \gamma = \frac{\cancel{R}(b+1)}{b\cancel{R}} = \frac{b+1}{b}$$

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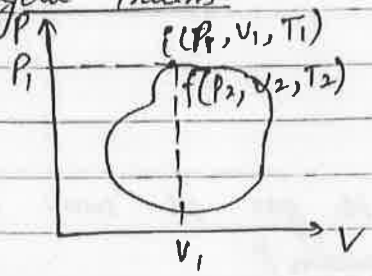
THERMODYNAMICS

- Cyclic Process



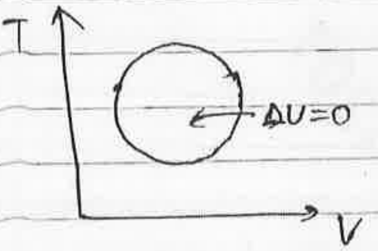
Initial state ≡ Final state

$(P_1, V_1, T_1) \equiv (P_2, V_2, T_2)$

$\because T_1 = T_2$ [$\because$ IE(U) $\propto$ T].

$\therefore U_1 = U_2$

$\Delta U = 0$ [For Cyclic Process].

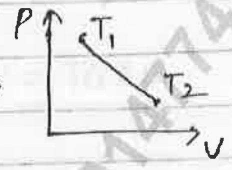


$\because \Delta U = 0 \rightarrow$

$\rightarrow$ Cyclic ($\because T_i = T_f$)

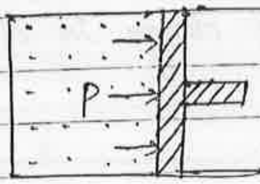
$\rightarrow$ IT $\Rightarrow \Delta U = nC_v\cancel{\Delta T}^{0} = 0$

$\rightarrow$



If $T_1 = T_2$
$\Rightarrow \Delta U = 0$

- W.D. in Thermodynamic Process



$$W_{\text{by gas}} = \int_{V_1}^{V_2} P dV$$

① IB

$P = \text{const}$

$$\therefore W = \int_{V_1}^{V_2} P dV$$

$$W = P\int_{V_1}^{V_2} dV = P(V_2 - V_1)$$

$$\boxed{\begin{aligned} &\underline{IB} \rightarrow W_{IB} = P(V_2 - V_1) = nR(T_2 - T_1) \\ &W_{IB} = P\Delta V \text{ or } nR\Delta T \\ &\therefore Q_{IB} = nC_p\Delta T \\ &\therefore \Delta U_{IB} = nC_v\Delta T \end{aligned}}$$

$\because W_{\text{by gas}} = \int P dV$

If $V\uparrow \Rightarrow dV = +ve \Rightarrow W = +ve$ [W.D. by gas] ($V\uparrow$)

If $V\downarrow \Rightarrow dV = -ve \Rightarrow W = -ve$ [W.D. on gas] ($V\downarrow$)

If $V = \text{const}$ (IC) $\Rightarrow dV = 0 \Rightarrow W = 0$

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②
$$\boxed{\begin{aligned} \underline{IC} \rightarrow \; Q_{IC} &= nC_v\Delta T \\ \Delta U_{IC} &= nC_v\Delta T \\ W_{IC} &= 0 \end{aligned}}$$

Ques:- If 400 J energy is supplied to He gas at const. P then f/o W.D. by gas in given process?

$$\therefore \quad Q_{IB} = nC_p\Delta T$$

$$400J = n \times \frac{5}{2} R\Delta T$$

$$nR\Delta T = \frac{\cancel{400}^{80} \times 2}{\cancel{5}} = 160.$$

$$\text{Now,} \quad W = nR\Delta T = 160\ J$$

Ques:- If some amount of CH_4 gas kept in open container $\overset{IB.}{}$ then f/o fraction of heat energy used in form of change in it's internal energy.

$$\therefore \quad Q = nC_p\Delta T \quad \text{—①}$$

$$\therefore \quad \Delta U = nC_v\Delta T \quad \text{—②}$$

② ÷ ①

$$\left(\frac{\Delta U}{Q}\right)_{IB} = \frac{C_p}{C_v} = \frac{1}{\gamma} = \frac{3}{4} \text{ or } 75\%.$$

If $\left(\frac{W}{Q}\right)_{IB}$ was asked then,

$$\left(\frac{W}{Q}\right)_{IB} = \frac{nR\Delta T}{nC_p\Delta T} = \frac{R}{4R} = \frac{1}{4} \text{ or } 25\%.$$

③ · $\underline{IT}$ [$PV = \text{const.}$]

$$W_{IT} \Rightarrow W = \int_{V_1}^{V_2} PdV$$

$$= \int_{V_1}^{V_2} \left(\frac{nRT}{V}\right) dV$$

$$= nRT \ln \frac{V_2}{V_1}$$

(OR) $$\boxed{W = 2.303\,\underbrace{nRT}_{P_1V_1 \text{ or } P_2V_2}\log_{10}\underbrace{\left(\frac{V_2}{V_1}\right)}_{\frac{P_1}{P_2}}}$$ $(\because P_1V_1 = P_2V_2)$

FLOAT : $Q = W + \Delta U$

IT $\rightarrow$ $\Delta U = 0$

$$\Rightarrow \boxed{Q = W = nRT \ln \frac{V_2}{V_1}}$$

④ Adibatic ($PV^{\gamma} = \text{const.}$)

FLOAT : $\overset{Ad}{\cancel{Q}}_{0} = W + \Delta U$

$$\boxed{W_{Ad} = -\Delta U}$$

$$W_{Ad} = -nC_V\Delta T$$

$$W_{Ad} = -n\left(\frac{R}{\gamma-1}\right)(T_2 - T_1)$$

$$\boxed{W_{Ad} = \frac{nR\Delta T}{1-\gamma} \text{ or } \frac{P_2V_2 - P_1V_1}{1-\gamma}}$$

$\because$ $W_{Ad} = -\Delta U$

$\Rightarrow$ $\Delta U = (-)W_{Ad}$.

→ If $V\uparrow \Rightarrow W = +ve \Rightarrow \Delta U = -ve \Rightarrow U\downarrow \Rightarrow T\downarrow$

$[V\uparrow \Rightarrow T\downarrow] \Rightarrow$ Adiabatic cooling

→ If $V\downarrow \Rightarrow W = -ve \Rightarrow \Delta U = +ve \Rightarrow U\uparrow \Rightarrow T\uparrow$

$[V\downarrow \Rightarrow T\uparrow] \Rightarrow$ Adiabatic cooling

⑤. Polytropic ($PV^{x} = \text{const}$).

Ad. ($PV^{\gamma} = \text{const}$) $\Rightarrow$ $W_{Ad} = \frac{nR\Delta T}{1-\gamma}$

Poly. $\rightarrow$ $$\boxed{W_{poly.} = \frac{nR\Delta T}{1-x}}$$

Ques:- Pressure of an I.G. inversely proportional to square root of it's absolute temp. then f/o W.D. in given process to increase temp. of 1 mole gas by 30°C.

$$\therefore P \propto \frac{1}{\sqrt{T}}$$

$$P T^{1/2} = \text{const.}$$

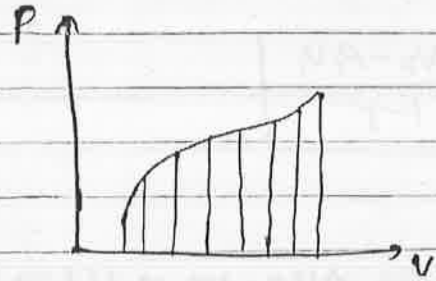
$$P\left(\frac{PV}{nR}\right)^{1/2} \text{ const.}$$

$$P^{3/2} V^{1/2} = \text{const.}$$

$$P V^{1/3} = \text{const.} \quad \Rightarrow x = \frac{1}{3}$$

Now, $W = \dfrac{1 \times R \times 30}{1 - 1/3} = 45R$

- **W.D. in P-V Curve**



$$\therefore W = \int_{V_1}^{V_2} P\,dV$$

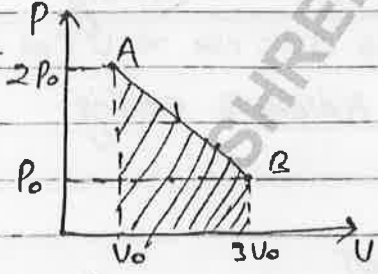
$$\Downarrow$$

$$W = \begin{matrix}\oplus \\ \ominus\end{matrix}\left[\text{Area b/w curve \& vol}^{m} \text{ axis}\right]$$

⊖ → V↓

⊕ → V↑

Ques:-



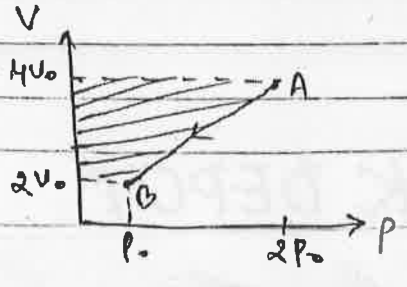
W.D. in AB process.

$$\therefore W = +\left[\frac{1}{2} \times (2P_0 + P_0) \times (3V_0 - V_0)\right]$$

$$W = +\ \frac{1}{\cancel{2}} \times 3P_0 \times \cancel{2}V_0$$

$$W = +3P_0V_0$$

Ques:-



W.D. in AB Process.

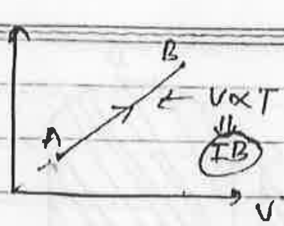
$$\therefore W = -\left[\frac{1}{2} \times (4V_0 - 2V_0) \times (2P_0 + P_0)\right]$$

$$W = -\frac{1}{\cancel{2}} \times \cancel{2}V_0 \times 3P_0 = -3P_0V_0$$

$\therefore$ W.D. $\boxed{\text{on}}$ gas $= 3P_0V_0$

↳ −ve

Ques:-

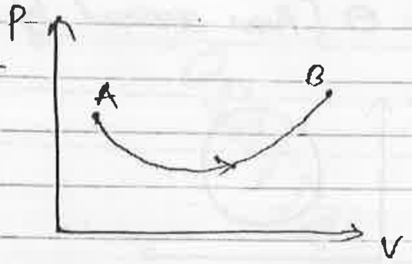


$\left(\frac{W}{Q}\right)$ in AB process in form of γ.

$$\frac{W}{Q} = \frac{\cancel{n}R\Delta T}{\cancel{n}C_p\Delta T} = \frac{R}{\frac{\gamma R}{\gamma - 1}}$$

$$\frac{W}{Q} = \frac{\gamma - 1}{\gamma}$$

Ques:-



W.D. in AB process; —

① continuously ↑
② continuously ↓
③ first ↑ then ↓
④ first ↓ then ↑

$\text{vol}^m \rightarrow \uparrow$ing so $AB \rightarrow W\uparrow$

Imp

Ques:- Some amount of CH_4 gas is expanded upto twice of initial vol^m at const. pressure. It is further processed at constant vol^m until it's pressure becomes 3 times of initial. Then f/o specific heat of CH_4 gas in complete process.

let,
$$\begin{matrix} P_0 \\ V_0 \\ T_0 \end{matrix} \xrightarrow[V \propto T]{IB} \begin{matrix} P_0 \\ 2V_0 \\ 2T_0 \end{matrix} \xrightarrow[P \propto T]{IC} \begin{matrix} 3P_0 \\ 2V_0 \\ 6T_0 \end{matrix}$$

$$Q_{Total} = Q_{IB} + Q_{IC}$$

$$\cancel{n}C[6T_0 - T_0] = \cancel{n} \times C_p[2T_0 - T_0] + \cancel{n}C_v[6T_0 - 2T_0]$$

$$5\cancel{T_0}C = \cancel{T_0}C_p + 4\cancel{T_0}C_v$$

$$5C = 4R + 4 \times 3R$$

$$C = \frac{16R}{5}$$

- W.D. in Cyclic Process

$$W = \int_{V_1}^{V_2} PdV$$

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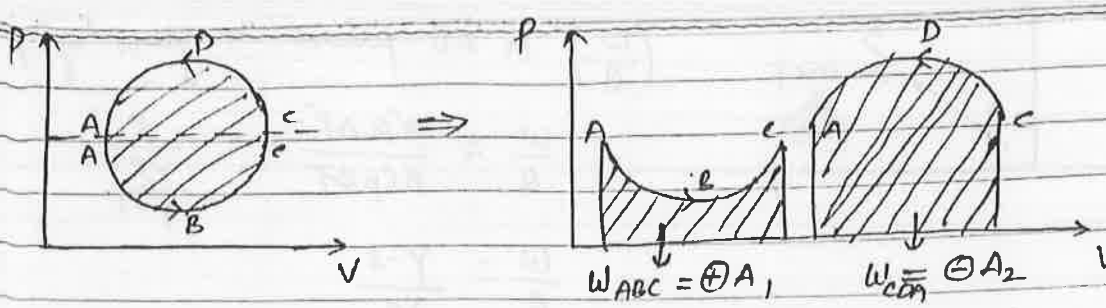
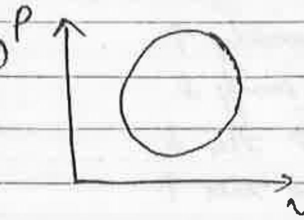


$W_{ABC} = \oplus A_1$ $W_{CDA} = \ominus A_2$

$\therefore$ $W = W_{ABC} + W_{CDA}$

$W = \ominus$ [Area enclosed by circle].

Note ⇒ ①



ACW ⇒ W = -ve

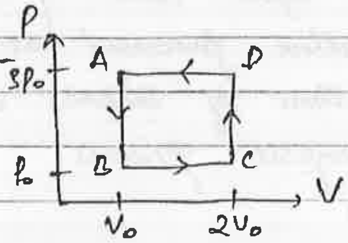
CW ⇒ W = +ve

②

ACW = +ve

CW ⇒ -ve.

Ques :-



P/o - ① W.D. in BC process

$W.D._{BC} = (2V_0 - V_0) \times P_0 = \oplus P_0V_0$

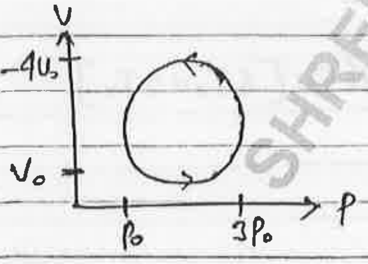
② W.D. on gas in cyclic Process.

$\therefore$ $W_{cycle} = -(2V_0 - V_0) \times (3P_0 - P_0)$

$= -2P_0V_0$

$\therefore$ W.D. on gas $= 2P_0V_0$.

Ques :-



W.D. in cyclic Process.

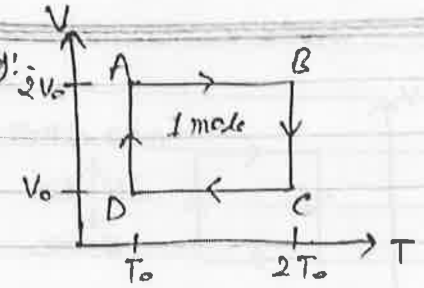
$\therefore$ $W = +\pi ab$

$W = +\pi \frac{(3P_0 - P_0)}{2} \frac{(4V_0 - V_0)}{2}$

$W = \pi\left(\frac{\cancel{2}P_0}{\cancel{2}}\right)\left(\frac{3V_0}{2}\right)$

$W = \frac{3\pi}{2} P_0V_0$

Imp Ques:



W.D. on gas in cyclic process ABCDA?

$$\therefore W = \underset{\downarrow IC}{W_{AB}} + \underset{\downarrow IT}{W_{BC}} + \underset{\downarrow IC}{W_{CD}} + \underset{\downarrow IT}{W_{DA}}$$

$$W = 0 + \left[1 \times R(2T_0) \ln \frac{V_0}{2V_0}\right] + 0 + \left[1 \times R(T_0) \ln \frac{2V_0}{V_0}\right]$$

$$W = -2RT_0 \ln 2 + RT_0 \ln 2$$

$$W = -RT_0 \ln 2$$

$\therefore$ W.D. on gas $= RT_0 \ln 2$.

- FLOT (First Law of Thermodynamics)

→ Law of conservation of energy

→ Valid everywhere

$$Q \longrightarrow \boxed{\text{System}} \xrightarrow{} W \qquad (\uparrow \Delta U)$$

$$\therefore \boxed{Q = W + \Delta U}$$

Q → +ve ⇒ Absorbed

Q → −ve ⇒ Released

$T\uparrow \Rightarrow U\uparrow \Rightarrow \Delta U = +ve$

$T\downarrow \Rightarrow U\downarrow \Rightarrow \Delta U = -ve$

$\therefore W$ → +ve ⇒ $V\uparrow$

W → −ve ⇒ $V\downarrow$

FLOT

Cyclic: → $Q = W + \Delta U^{\to 0} \Rightarrow \boxed{Q = W}$

IT: → $Q = W + \Delta U^{\to 0}$

$Q = W = nRT \ln \frac{V_2}{V_1}$

Adiabatic: → $\cancel{Q}^{\to 0} = W + \Delta U$

$W = -\Delta U$

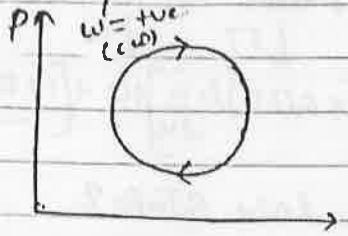
IC: → $Q = \cancel{W}^{\to 0} + \Delta U$

$Q = \Delta U = nC_V\Delta T$

IB: → $Q = W + \Delta U$

Que:- W.O.F. process will release heat?

①



$\because$ cyclic

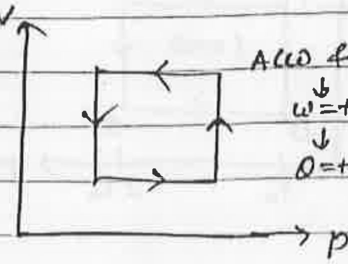
$\Delta U = 0$

$Q = w + \cancel{\Delta U}^{0}$

$Q = w$

$\ominus \quad \ominus$

②



ACW f V-P

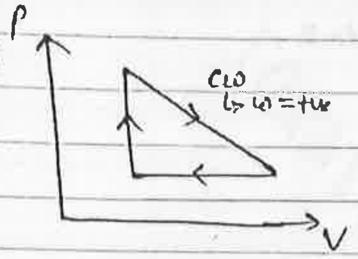
$\downarrow$

$w = +ve$

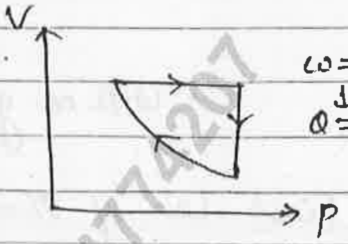
$\downarrow$

$Q = +ve$

③



✓④



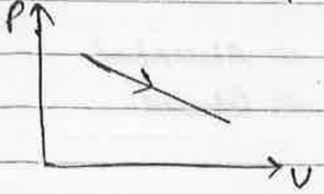
$w = -ve$

$\downarrow$

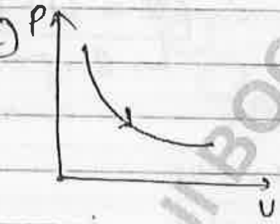
$Q = -ve$

Que:- W.O.F. process (may have) heat absorbed in process equals to shaded area b/w curve and vol^m axis.

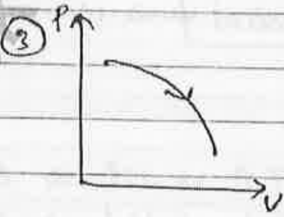
①



②



③



④ All of these

$\because Q = w$

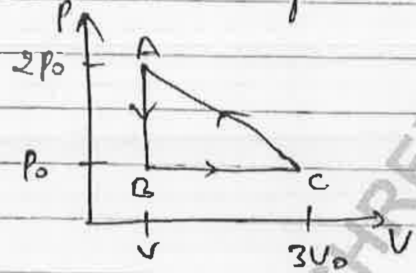
$\downarrow$

$\Delta U = 0$

$T_i = T_f$

$P_iV_i = P_fV_f$

Que:- F/o amount of heat released in cyclic process.



$\because Q = w + \cancel{\Delta U}^{0}$

$Q = w$

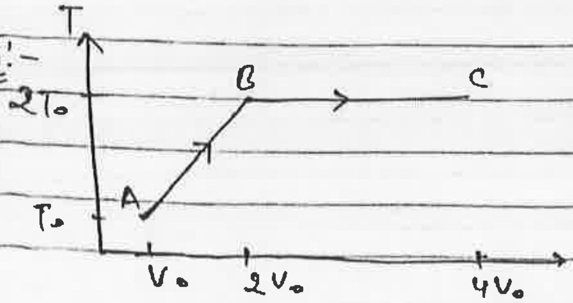
$\therefore w = \ominus \frac{1}{2} \times (3V_0 - V_0) \times (2P_0 - P_0)$

$Q = W = -P_0V_0$

$\therefore$ Heat released $= P_0V_0$

Imp

Que:-



F/o amount of heat absorbed by 2 mole H_2 gas in ABC process.

$AB \rightarrow IB$

$BC \longrightarrow IT$

$$\therefore Q_{ABC} = \underset{\downarrow IB}{Q_{AB}} + \underset{\downarrow IT}{Q_{BC}}$$

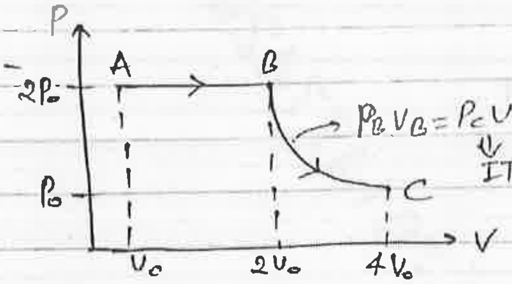
$$Q_{ABC} = nC_p\Delta T + W$$

$$= \cancel{2}\times\frac{7}{\cancel{2}}R(2T_0-T_0) + 2\times R(2T_0)\ln\frac{\overset{2}{\cancel{4}V_0}}{\cancel{2}\cancel{V_0}}$$

$$= 7RT_0 + 4RT_0\ln 2$$

$$= 9.8\,RT_0$$

Ques!-



F/o heat absorbed by the gas in ABC process.

$$\therefore Q = \underset{\downarrow IB}{Q_{AB}} + \underset{\downarrow IT \Rightarrow Q=W}{Q_{BC}}$$

$$Q = nC_p\Delta T + nRT\ln\frac{V_2}{V_1}$$

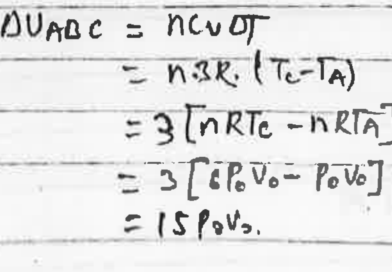
$$Q = n\times\frac{5}{2}R(T_B-T_A) + \underbrace{nRT}\ln\frac{4V_0}{2V_0}$$

$$Q = \frac{5}{2}[4P_0V_0 - 2P_0V_0] + 4P_0V_0\ln 2$$

$$Q = 5P_0V_0 + 4P_0V_0(0.7)$$

$$Q = 7.8\,P_0V_0$$

Ques!-



Heat absorbed by CH_4 gas in ABC process.

$$\therefore Q_{ABC} = \Delta U_{ABC} + W_{ABC} \quad ① \quad (\because FLOT)$$

$$\therefore W_{ABC} = W_{AB} + W_{BC}$$

$$= +\left[\frac{1}{2}\times(P_0+3P_0)\cdot V_0\right] + \frac{1}{2}\left[3P_0+2P_0\right]\times V_0$$

$$= 2P_0V_0 + 2.5\,P_0V_0$$

$$= 4.5\,P_0V_0$$

$$\therefore \Delta U_{ABC} = nC_v\Delta T$$

$$= n3R\cdot(T_C - T_A)$$

$$= 3[nRT_C - nRT_A]$$

$$= 3[6P_0V_0 - P_0V_0]$$

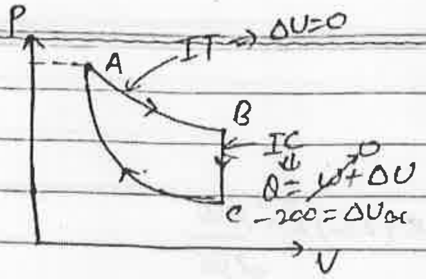
$$= 15P_0V_0.$$

Putting in ①.

$$Q_{ABC} = 15P_0V_0 + 4.5P_0V_0$$

$$= 19.5\,P_0V_0$$

Ques:-



If AB & CA are IT & Adiabatic process respectively and 200 J of heat released in BC process then f/o W.D. on gas in CA process.

$$\therefore \Delta U_{cycle} = \Delta U_{AB} + \Delta U_{BC} + \Delta U_{CA}$$

$$0 = 0 + (-200) + \Delta U_{CA}$$

$$\Delta U_{CA} = 200\,J.$$

$\because$ CA → Ad.

$$W_{CA} = -\Delta U_{CA} = -200\,J.$$

$$\therefore W_{\underset{O}{on}\,gas} = 200\,J \quad \text{(Ans):.}$$

Ques:- When some heat energy is supplied to H_2 gas, heat energy supplied to it becomes 4 times of change in I.E. of gas then molar heat capacity of H_2 in process.

C

$$\therefore Q = 4\,\Delta U$$

$$\cancel{n}C\cancel{\Delta T} = 4\cancel{n}C_V\cancel{\Delta T}$$

$$C = 4C_V = 4 \times \frac{5R}{2}$$

$$C = 10R$$

Ques:- When some amount of heat is supplied to He gas, 40% of it's part used in W.D. then f/o molar heat capacity of He gas in given process.

{ 40% Q → W
Then
60% Q → ΔU }

$$\frac{60}{100} \times Q = \cancel{W}\,\Delta U$$

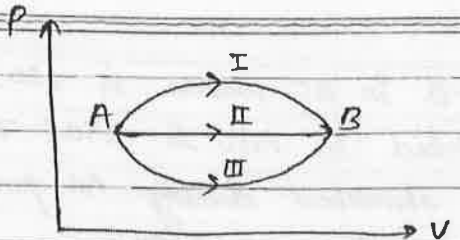
$$\frac{3}{5} \times \cancel{n}C\cancel{\Delta T} = \cancel{n}C_V\cancel{\Delta T}$$

$$C = \frac{5}{3}C_v$$

$$C = \frac{5}{3} \times \frac{3R}{2}$$

$$C = \frac{5}{2}R = 2.5R$$

Ques :-



If a gas sample taken through state A to B via 3 different paths I, II & III. Then order of-

① ΔU of I, II & III

② Work

③ Q(Heat)

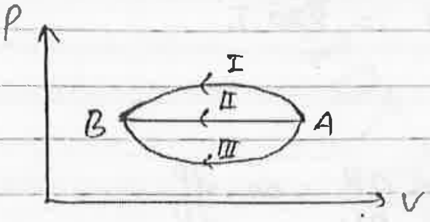
① $\Delta U \rightarrow$ state function so $\Rightarrow \Delta U_I = \Delta U_{II} = \Delta U_{III}$

② Work $\Rightarrow$ I > II > III

③ FLOT $\Rightarrow \uparrow Q = W\uparrow + \underbrace{\Delta U}_{} \rightarrow$ same

so $\Rightarrow Q_1 > Q_2 > Q_3$

Ques :-



Order of all in above question?

① $\Delta U_I = \Delta U_{II} = \Delta U_{III}$

② W $\Rightarrow$ I > II > III

(-ve) $\rightarrow$ so W.D. on gas

③ Q = I > II > III

Ques :- 1 g water at 100°C and 1 atm pressure converting into steam of 100°C. If vol^m of 1g steam at 100°C is 1671 cm³. Then f/o change in internal energy of water during phase change.

$$\underset{1atm}{\text{water}} \xrightarrow[IB]{IT} \underset{1atm}{\text{steam}}$$

$V_1 = 1cm^3$ $\qquad$ $V_2 = 1671 cm^3$

$\therefore Q = mL_v$

$= 1g \times 540 \frac{Cal}{g} = 540 Cal. = 540 \times 4.2 J.$

$\therefore W_{IB} = P(V_2 - V_1)$

$= 10^5 (167 - 1) \times 10^{-6} = 167 J$

$\therefore$ FLOT $\rightarrow$ $Q = W + \Delta U$

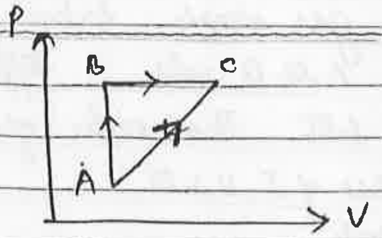
$\Delta U = Q - W$

$= (540 \times 4.2) - 167$

$= 2101 J = 2.1 KJ$

26/12/2019

Ques!-



If W.D. in BC process is 120 J and heat absorbed in ABC is 250 J then f/o heat absorbed during AC process if W.D. during AC is 80 J.

$A \longrightarrow C$

$\Delta U_{ABC} = \Delta U_{AC}$

ABC

$Q = W + \Delta U$

$250 = 120 + \Delta U$

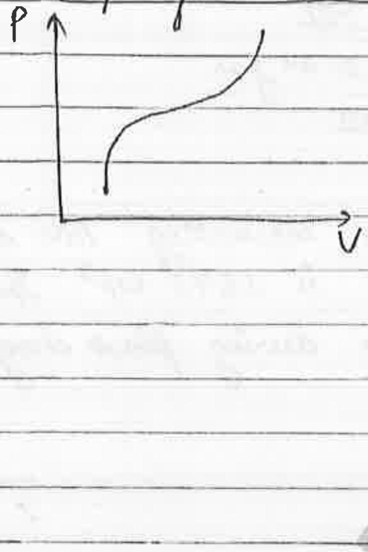
$\Delta U_{ABC} = 130 \Rightarrow \Delta U_{AC}$.

AC ⇒ FLOT

$Q = W + \Delta U$

$Q = 80 + 130 = 210\,J$.

- Slope of P-V Curve



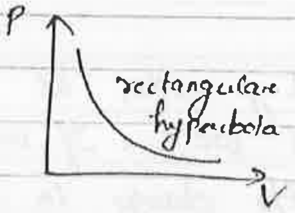
Slope $\longrightarrow \frac{P}{V}$ or $\frac{\Delta P}{\Delta V}$ or $\frac{dP}{dV}$

① IT

$PV^1 = \text{const}$

On diff. w.r.t. 'V'

$P\frac{dV}{dV} + V\frac{dP}{dV} = 0$



$\text{Slope} \leftarrow \boxed{\frac{dP}{dV} = \frac{-P}{V}}$

$P \propto \frac{1}{V^1}$

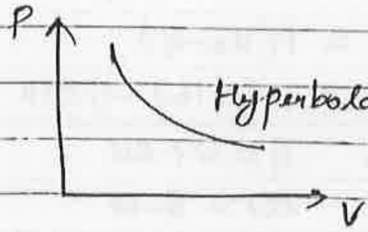
$$\boxed{|\text{slope}|_{IT} = \frac{P}{V}}$$

② Adiabatic

$PV^\gamma = \text{const}$.

On diff. w.r.t. 'V'.

$\frac{dP}{dV} = -\frac{\gamma P}{V}$



$$\boxed{|\text{slope}|_{Ad} = \frac{\gamma P}{V}}$$

$P \propto \frac{1}{V^\gamma}$

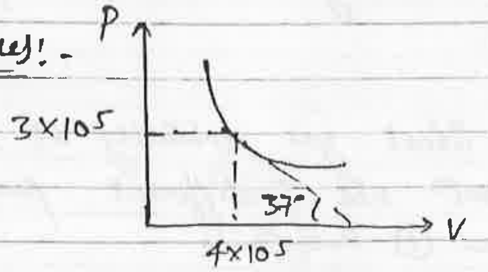
$$\boxed{|\text{slope}|_{Ad} = \gamma\,|\text{slope}|_{IT}}$$

③ Polytropic

$PV^x = \text{const.}$

$$\boxed{\text{Slope} = \frac{dP}{dV} = -x\frac{P}{V}}$$

Ques! -



If P-V curve of gas following PV^n = const. as shown. F/o value of 'n'?

Slope = $\tan(180-37°) = -\tan 37°$.

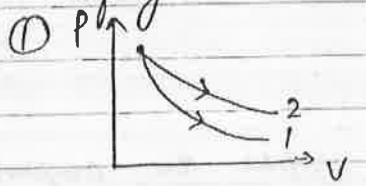
$\cancel{-}n\frac{P}{V} = \cancel{-}\frac{3}{4}$

$n \times \frac{3\times10^5}{4\times10^5} = \frac{3}{4}$

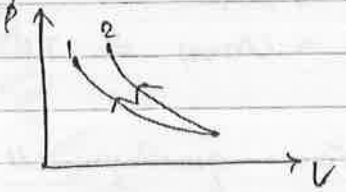
$\boxed{n = 1} \longrightarrow PV^1 = \text{const} \Rightarrow \boxed{\text{IT}}$

Note: ⇒ If given curve are IT & Adiabatic.

①



$|\text{Slope}|_{\underset{\text{Ad.}}{1} > \underset{\text{IT.}}{2}}$



$|\text{Slope}|_{\underset{\text{Ad.}}{2} > \underset{\text{IT.}}{1}}$

- Bulk Modulus (β)

$\therefore \beta = \frac{\Delta P}{\left(-\frac{\Delta V}{V}\right)} \Rightarrow \beta = -V\left(\frac{\Delta P}{\Delta V}\right)$

$\beta = -V[\text{slope of PV curve}]$

So;- $\beta_{IT} = -V\left[-\frac{P}{V}\right] = P$

$\beta_{Ad} = -V\left[-\frac{\gamma P}{V}\right] = \gamma P$

$\beta_{poly.} = -V\left(-\frac{xP}{V}\right) = xP$

Compressibility (C).

$$C = \frac{1}{\beta} \quad \&, \quad \beta_{IT} < \beta_{Ad}$$

$$\Rightarrow \left[C_{IT} > C_{Ad.} \right]$$

→ An ideal gas can be compressed easily in Isothermal process as compared to adiabatic process.

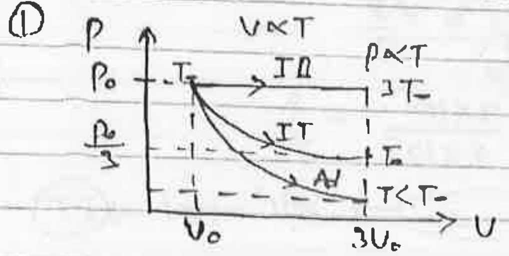
Ques:- 3 different gas samples of an Ideal gas initially at P_0, V_0, & T_0 state expanded upto $3V_0$ vol^m via 3 different processes IB, IT, and Adiabatically. Then – ① P-V Curve

② Order of their final Pressure.

③ Order of their final temp.

④ Order of W.D.

①



&

② $P_{final} \Rightarrow IB > IT > Ad.$

③ $T_{final} \Rightarrow IB > IT > Ad$

④ Order of W.D. ⇒ (Area) ⇒ IB > IT > Ad.

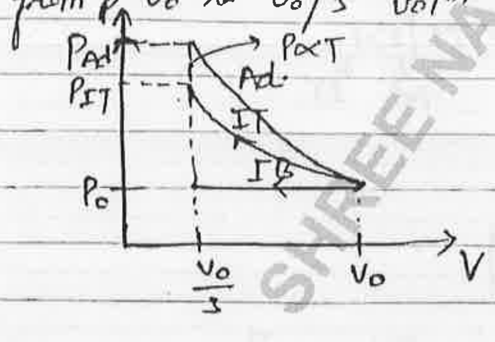
Ques:- If in previous question all the gas samples are compressed from V_0 to $V_0/3$ vol^m then –① P-V Curve

② Order of their final Pressure.

③ Order of their final temp.

④ Order of W.D.

①



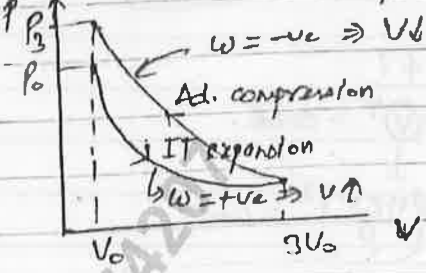
② $P_{final} \Rightarrow P_{Ad} > P_{IT} > P_{IB}$

③ $T_{final} \Rightarrow T_{Ad} > T_{IT} > P_{IB}$

④ Order of $\underset{(-)}{W.D.} \Rightarrow Ad. > IT > IB$

Ques:- If an gas sample of I.G. initially at P_0, V_0 & T_0 state expanded upto $3V_0$ vol^m isothermally. It is furthure compressed back to it's initial vol^m V_0 in adiabatic process. If final pressure becomes P_3 and net work done in process is W. Then –

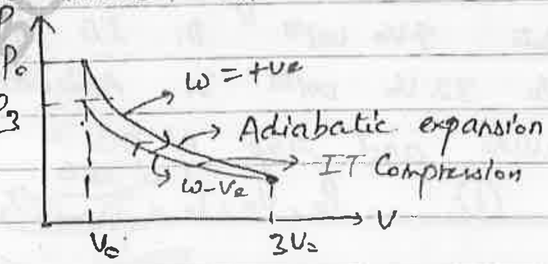
ⓐ $P_3 > P_0$; $W > 0$
ⓑ $P_3 < P_0$; $W < 0$
ⓒ $P_3 < P_0$; $W > 0$
[✓ ⓓ $P_3 > P_0$; $W < 0$]



$\therefore W = W_{IT} + W_{Ad}$
$W = +ve < (-ve)$
$W = -ve \Rightarrow W < 0$

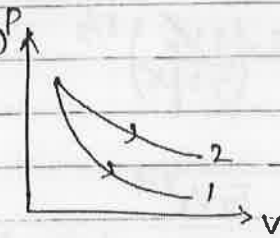
Ques:- If in previous question gas initially expanded adiabatically and then compressed back to initial vol^m IT then –

① $P_3 > P_0$; $W > 0$
② $P_3 < P_0$; $W < 0$
[✓ ③ $P_3 < P_0$; $W > 0$]
④ $P_3 > P_0$; $W < 0$



Ques:- Given curves are adiabatic in nature then f/o suitable optn.

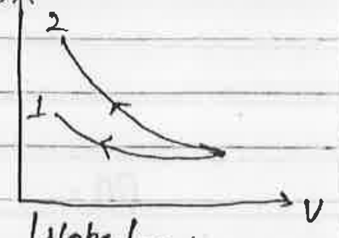
ⓐ. He, Ne
ⓑ, He, H_2
ⓒ. H_2, N_2
ⓓ. H_2, Ne

①


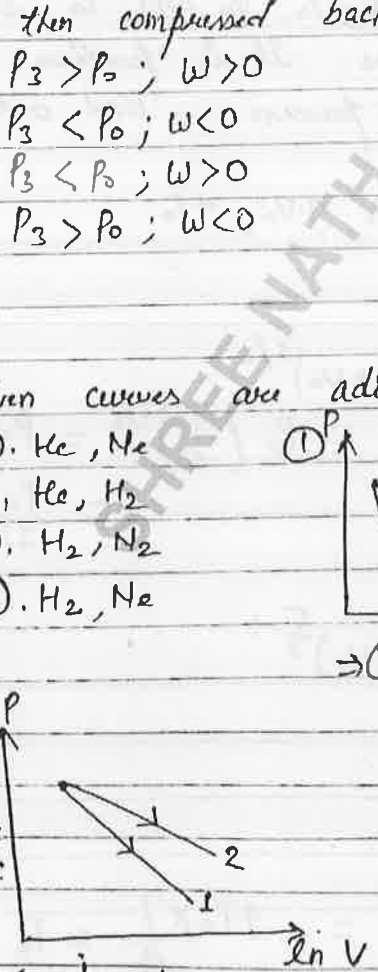
$\Rightarrow$ ⓑ He, H_2

$|slope|_{Ad} = \frac{\gamma P}{V}$

$|slope|_{1>2}$
$\Downarrow$
$\gamma_1 > \gamma_2$
$\gamma_1 \to$ mono, $\gamma_2 \to$ di.

②


$|slope|_{2>1}$
$\downarrow$
$\gamma_2 > \gamma_1$
$\gamma_2 \to$ Mono, $\gamma_1 \to$ di.
ⓓ H_2, Ne

③


$PV^\gamma = const.$
$\ln P + \gamma \ln V = \ln c$
$\underbrace{\ln P}_{y} = \underbrace{-\gamma}_{m} \underbrace{\ln V}_{x} + C$
$\Downarrow$
$|slope| = \gamma \Rightarrow |slope|_{1>2} \to di \Rightarrow$ ⓑ He, H_2
mono

Ex-I = 284

- Different forms of Adiabatic Process.

① P & V

$$\boxed{\left[P_1V_1^{\gamma} = P_2V_2^{\gamma}\right]}$$

② T & V

$$\because \textcircled{P}V^{\gamma} = \text{const.}$$

$$\frac{nRT}{V} \cdot V^{\gamma} = \text{const.}$$

$$TV^{\gamma-1} = \text{const.}$$

$$\Rightarrow \boxed{\left[T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}\right]}$$

③ P & T

$$\because P\textcircled{V}^{\gamma} = \text{const.}$$

$$\downarrow$$

$$P\left(\frac{nRT}{P}\right)^{\gamma} = \text{const.}$$

$$\boxed{P^{1-\gamma}T^{\gamma} = \text{const.} \quad \text{(OR)} \quad PT^{\frac{\gamma}{1-\gamma}} = \text{const.}}$$

④ P & ρ

$$\because PV^{\gamma} = \text{const.}$$

$$P\left(\frac{1}{\rho}\right)^{\gamma} = \text{const.}$$

$$\boxed{P \propto \rho^{\gamma}}$$

Ques:- A monoatomic gas initially at P_0, V_0 and T_0 state expanded upto $4V_0$ vol^m^ in IB process. It is further expanded upto $32V_0$ vol^m^ in Adiabatic process. Find out final pressure and temp. of gas.

① $$P_0, V_0, T_0 \xrightarrow[(V\propto T)]{IB} P_0, 4V_0, 4T_0$$

② (i). $$P_2V_2^{\gamma} = P_3V_3^{\gamma}$$

$$P_0 \times (4V_0)^{5/3} = P_3 \times (32V_0)^{5/3}$$

$$P_3 = P_0 \times \left(\frac{4\cancel{V_0}}{32\cancel{V_0}}\right)^{5/3} = P_0\left(\frac{1}{8}\right)^{5/3} = P_0\left[\left(\frac{1}{2}\right)^{\cancel{3}}\right]^{5/\cancel{3}} = \frac{P_0}{32}$$

(ii). $$T_2V_2^{\gamma-1} = T_3V_3^{\gamma-1}$$

$$4T_0 \times (4V_0)^{\frac{5}{3}-1} = T_3 \times (32V_0)^{\frac{5}{3}-1}$$

$$T_3 = 4T_0\left(\frac{4V_0}{32V_0}\right)^{2/3}$$

$$T_3 = 4T_0 \times \left(\frac{1}{8}\right)^{2/3}$$

$$T_3 = 4T_0 \times \left[\left(\frac{1}{2}\right)^{\cancel{3}}\right]^{2/\cancel{3}} = 4T_0 \times \frac{1}{4} = T_0$$

27/12/2019

Ques:- Air is filled in a tube of wheel of a car at 27°C and 2atm pressure. If the tube is suddenly burst then final temp. of air will be – ($\gamma = 1.5$, $2^{1/3} = 1.251$)

$P_1 = 2\,atm$; $T_1 = 27°C = 300K$

↓

$P_2 = 1\,atm$; $T_2 = ?$

Tyre burst → Ad. $\Rightarrow PT^{\frac{\gamma}{\gamma-1}} = const.$ $\quad \frac{\gamma}{\gamma-1} \rightarrow \frac{1.5}{1-1.5} = -3$

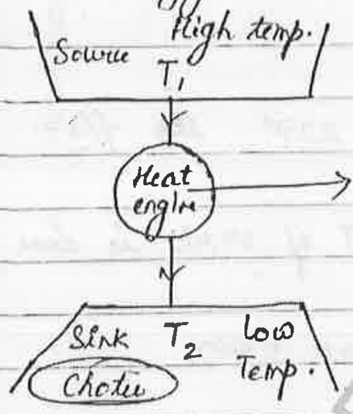
$$\Rightarrow P_1 T_1^{-3} = P_2 T_2^{-3}$$

$$(2)(300)^{-3} = (1)(T_2)^{-3}$$

$$T_2 = \frac{300}{2^{1/3}} = \frac{300}{1.251} = 240K \text{ (or) } -33°C.$$

- Heat Engine (H.E.)

Heat Energy $\xrightarrow{H.E.}$ Mechanical Work (W)



∴ Energy Conservation; –

$$|Q_1| = |W| + |Q_2|$$

$$|W| = |Q_1| - |Q_2|$$

$$\therefore \text{Energy}(\eta) = \frac{O/P}{I/P} \times 100 = \left|\frac{W}{Q_1}\right| \times 100 = \frac{|Q_1| - |Q_2|}{|Q_1|}$$

$$\Rightarrow \boxed{\eta = \left|\frac{W}{Q_1}\right| = 1 - \left|\frac{Q_2}{Q_1}\right|}$$

Carnot Engine : →

$$\left|\frac{Q_2}{Q_1}\right| = \frac{T_2}{T_1}$$

$$\therefore \boxed{\eta_{carnot} = \frac{W}{Q_1} \text{ (or) } 1 - \frac{Q_2}{Q_1} \text{ (or) } 1 - \frac{T_2}{T_1}}$$

* For 100% efficiency

$$\eta_{carnot} = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

For 100%,

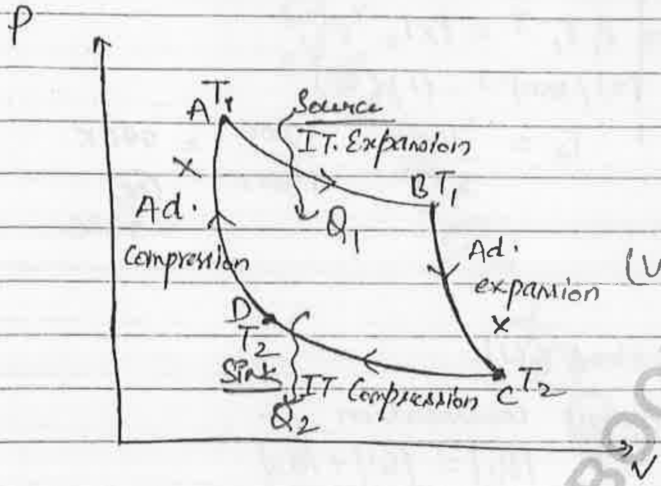
$$\frac{T_2}{T_1} = 0$$

$$\underbrace{T_2 = 0\,Kelvin \qquad T_1 = \infty\,Kelvin}_{\text{Not Possible}}$$

⇒ So 100% efficiency not possible.

Carnot Engine :– In order to maximise efficiency of Heat engine, Carnot suggested a hypothetical engine consiting of four reversible process.

$$4\text{ Processes} \rightarrow \begin{cases} 2IT \rightarrow \begin{cases} IT\text{ Expansion} \\ IT\text{ Compression} \end{cases} \\ 2Ad. \rightarrow \begin{cases} Ad.\text{ Expansion} \\ Ad.\text{ Compression.} \end{cases} \end{cases}$$



Ques:- A carnot engine working b/w 27°c and 227° then f/o –
① It's efficiency
② Amount of heat rejected to sink if 600 J of work is done by it in a single cycle.

① $\therefore \eta = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{500} \times 100 = \frac{2}{5} \times 100 = 40\%$

② $\eta = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1}$

$\frac{600}{Q_1} = 1 - \frac{300}{500} = \frac{2}{5}$

$Q_1 = 1500\ J.$

Now, $|Q_1| = |W| + |Q_2|$

$|Q_2| = 1500 - 600 = 900\ J.$

Ques:- Efficiency of Carnot Engine with 57°c sink temp. is 40%. What should be required change in temp. of it's source to increase

275 K

it's efficiency by 50% of initial ~~by~~ for same sink temp.

$T_2 = 57°C + 273 = 330\,K$

$\therefore \eta = 1 - \frac{T_2}{T_1}$

$\frac{40}{100} = 1 - \frac{330}{T_1}$ — ①

$\therefore \frac{40+20}{100} = 1 - \frac{(T_2)\cancel{+\Delta t}}{(T_1+\Delta t)}$ — ②

② ÷ ①

$\frac{60}{40} = \frac{\cancel{T_1} - \cancel{T_1} + \Delta t}{T_1 - 330}$

$\frac{3}{2} = \frac{\Delta t}{T_1 - 330}$

$3T_1 - 990 = 2\Delta t$

$3(550) - 990 = 2 \times \Delta t$

$\Delta t = \frac{1650 - 990}{2}$

$\Delta t = \frac{660}{2}$

Solving ①

$\frac{2}{5} = \frac{T_1 - 330}{T_1}$

$2T_1 = 5T_1 - 1650$

$3T_1 = 1650$

$T_1 = 550$

Ques:- Efficiency of carnot engine is 1/2. When temp. of it's sink decreases by 150°C it's efficiency becomes 2/3. Then f/o initial temp. of source & sink.

$\therefore \eta_1 = \frac{1}{2} = 1 - \frac{T_2}{T_1}$ — ①

$\therefore \eta_2 = \frac{2}{3} = 1 - \frac{T_2 - 150}{T_1}$ ② $= 1 - \frac{T_2}{T_1} - \frac{150}{T_1} = 1 - \frac{1}{2} - \frac{150}{T_1}$

~~① ÷ ② $\frac{3}{4} = \frac{(T_1 - T_2)/T_1}{T_1 - T_2 + 150}$~~

$\Rightarrow \frac{2}{3} = \frac{1}{2} - \frac{150}{T_1}$

$\Rightarrow T_1 = 900\,K$ or $627°C$

eqⁿ — ① $T_2 = 450\,K$ or $177°C$

Ques:- A heat engine working b/w 27°C and 127°C. It's actual efficiency is 20% then what % of it's maxᵐ possible efficiency is in form of it's actual efficiency.

$\therefore\ \eta_{max} = \left[1 - \left(\frac{300}{900}\right) \times 100\right] = \frac{100}{4} = 25\%.$

Now, $\frac{\eta_{actual}}{\eta_{max}} = \frac{20\%}{25\%} \times 100 = 80\%$

Imp

Ques!- A monoatomic gas expands from V_0 to $8V_0$ vol^m in adiabatic process of Carnot cycle. Then f/o - efficiency of Carnot cycle?

Adibatic $\Rightarrow$ $V_0 \longrightarrow 8V_0$
$(V\uparrow \Rightarrow T\downarrow)$ $\quad \downarrow \quad \downarrow$
$T_1 \quad T_2$

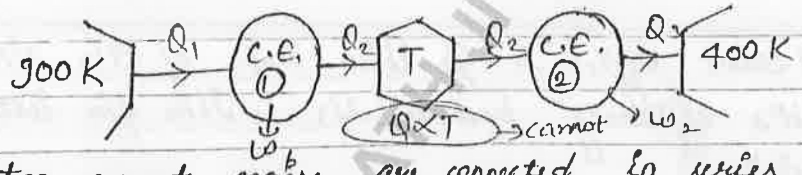
$$\therefore T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$\frac{T_2}{T_1} = \left(\frac{V_0}{8V_0}\right)^{\frac{5}{3}-1}$$

$$\frac{T_2}{T_1} = \frac{1}{4}$$

Now, $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{1}{4} = \frac{3}{4}$ (OR) 75%

Ques!-



If two carnot engine are connected in series. f/o value of 'T' if-

① Both engines are Identical → efficiency same.

② W.D. by both are same..

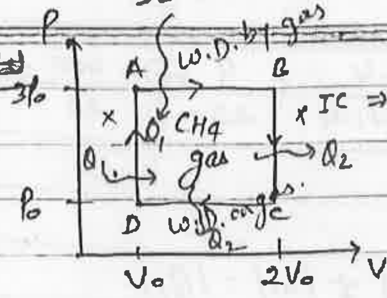
①
$$\eta_1 = \eta_2$$
$$1 - \frac{T}{900} = 1 - \frac{400}{T}$$
$$T(900 - T) = 900(T - 400)$$
$$900T - T^2 = 900T - 360000$$
$$T^2 = 360000$$
$$T = 600\ K$$

②
$$W_1 = W_2$$
$$Q_1 - Q_2 = Q_2 - Q_3$$
$$900 - T = T - 400 \quad (\because Q \propto T)$$
$$2T = 1300$$
$$T = 650\ K$$

$W = +ve$ ↑ $\Delta U = +ve$ } → $Q = +ve$

$IB \Rightarrow V\uparrow \propto T\uparrow$

Ques! –



× $IC \Rightarrow V = const.$
$W = 0$
$P\downarrow \propto T\downarrow$
$\Delta U = -ve$

F/o – ① ΔU_{cyclic}
② W.D. in cyclic Process
③ Heat absorbed in cyclic Process

कुछ भी value बढ़ रही है ⇒ Source
कुछ भी value घट रही है ⇒ sink

$DA \rightarrow P\uparrow$ = Source]
$AB \rightarrow V\uparrow$ = Source]
$BC \rightarrow P\downarrow$ = sink]
$CD \rightarrow V\downarrow$ = sink]

① $\Delta U_{cyclic} = 0 \quad (\because T_i = T_f)$

② W = Area of curve $= +2P_0V_0$

③ FLOT, $Q = W + \Delta U$
$Q = 2P_0V_0 + 0 = 2P_0V_0$

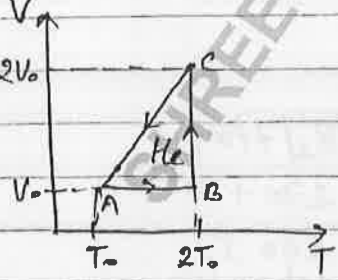
④ Heat absorbed by gas in cyclic process from $\boxed{\text{Source}}$

$$Q_{source} = Q_1 = Q_{DA} + \overset{IB}{Q_{AB}}$$
$$= nC_v\Delta T + nC_p\Delta T$$
$$= n(3R)(T_A - T_D) + n(4R)(T_B - T_A)$$
$$= 3[3P_0V_0 - P_0V_0] + 4[6P_0V_0 - 3P_0V_0]$$
$$= 18P_0V_0.$$

⑤ Efficiency of cycle $(\eta) = \frac{W}{Q_1} \times 100$

$$= \frac{2P_0V_0}{18P_0V_0} \times 100 = 11.1\%$$

Ques! –



F/o efficiency of cycle

Source → AB
→ BC

Sink → CA

$$\therefore \eta = \frac{W}{Q_1} = \frac{\overset{IC}{\cancel{W_{AB}}}^{0} + W_{BC} + W_{CA}}{Q_{AB} + Q_{BC}}$$

$$= \frac{0 + nR(2T_0)\ln\frac{2V_0}{V_0} + nR[T_0 - 2T_0]}{nC_v[2T_0 - T_0] + nR[2T_0]\ln\frac{2V_0}{V_0}}$$

$$= \frac{2\cancel{R}T_0\ln 2 - \cancel{R}T_0}{\frac{3}{2}\cancel{R}[T_0] + 2\cancel{R}T_0\ln 2}$$

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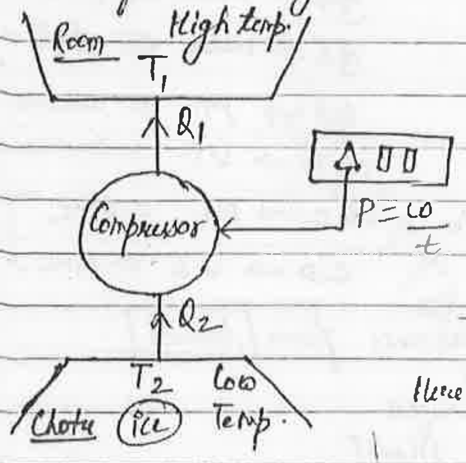
$= \frac{0.4}{1.5+1.4} = \frac{4}{29}$ (or) $\frac{400}{29} \simeq 14\%$

- Refrigerator

Reverse of Carnot Engine



$\therefore |Q_2| + |W| = |Q_1|$

$|W| = |Q_1| - |Q_2|$

C.O.P (β)

Cofficient of Performance (efficiency)

$$\boxed{\beta\uparrow = \frac{Q_2\uparrow}{W\downarrow} = \frac{\overset{Q \propto T}{Q_2}}{Q_1 - Q_2} = \frac{\overset{K}{T_2}}{T_1 - T_2} = \frac{\text{Chotu}}{\text{Temp. diff}^n}}$$

Here, Q_2 = Amount of heat extracted from low temp/ material / refrigerated space.

Q_1 = Amount of heat rejected /expelled in room/ atmosphere.

$\frac{W}{t}$ = Power Rating of Refrigerator

Que:- A Refrigerator working b/w $-3°C$ and ~~100~~ $7°C$. then f/o amount of heat ~~of~~ extracted from refrigerated space and heat rejected to atmosphere if 10 J work done on it in a single cycle.

$T_1 = 7°C + 273 = 280K$

$T_2 = -3 + 273 = 270K.$

① $\frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$

$\frac{Q_2}{10} = \frac{270}{10}$

$Q_2 = 270 J$
↓
extracted.

② $|Q_1| = |Q_2| + |W|$

$= 270 + 10$

$= 280 J.$
↓
ejected in atmosphere.

Que:- A refrigerator working b/w $t_1°C$ & $t_2°C$ where $t_1 > t_2$. F/o amount of heat expelled in atmosphere by refrigerator for per Joule of work done.

(a) t_2/t_1-t_2

(b) t_2+273/t_1-t_2

(c) t_2+273/t_1+t_2

(d) t_1+273/t_1-t_2

$$\therefore \beta = \frac{T_2}{T_1-T_2}$$

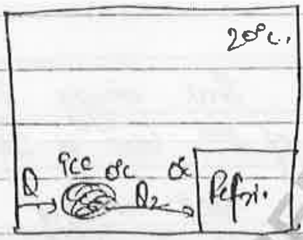
$$\frac{Q_2}{1} = \frac{t_2+273}{(t_1+273)-(t_2+273)}$$

$$Q_2 = \frac{t_2+273}{t_1-t_2}$$

$$\text{Now, } Q_1 = Q_2+W = \frac{t_2+273}{t_1-t_2}+1 = \frac{\cancel{t_2}+273+t_1\cancel{-t_2}}{t_1-t_2} = \frac{t_1+273}{t_1-t_2}$$

Imp.

Ques:- Some amount of ice at 0°C kept in a large chamber of ~~at~~ 20°C. Due to this 20gm ice melting per sec. To just prevent it from melting a refrigerator is used in chamber then f/o required power rating of Refrigerator. (In watt?)



$$\therefore Q = mL_f = 20\times 80 = 1600\ \frac{cal}{sec}$$

$$\therefore Q_2 = Q = 1600\times 4.2\ \frac{J}{sec}$$

$$\therefore \beta = \frac{T_2}{T_1-T_2}$$

$$\frac{Q_2}{W} = \frac{273}{20-0} = 13.65$$

$$\text{per sec} \leftarrow \frac{W}{t} = \frac{Q_2}{13.65} = \frac{1600\times 4.2}{13.6}$$

$$= 492.3\ J/sec.$$

$$\Rightarrow P = 492\ \text{Watt}.$$

- Relation b/w β & η :-

$\beta = \frac{T_2}{T_1 - T_2}$ —① $\beta > 1$

$\eta = 1 - \frac{T_2}{T_1}$ —② $\eta < 1$

From eqⁿ ① & ②

$$\boxed{\beta = \frac{1}{\eta} - 1}$$

Que:- Efficiency of Carnot engine is 1/9. If it is operated in opposite direction amount of heat expelled in atmosphere for for joule of W.D. ?

$$\therefore \beta = \frac{1}{\eta} - 1$$

$$\beta = \frac{1}{1/9} - 1 = 8$$

$$\Rightarrow \frac{Q_2}{W} = 8 \Rightarrow \frac{Q_2}{1} = 8$$

$$\Rightarrow Q_2 = 8$$

$$Q_1 - W = 8$$

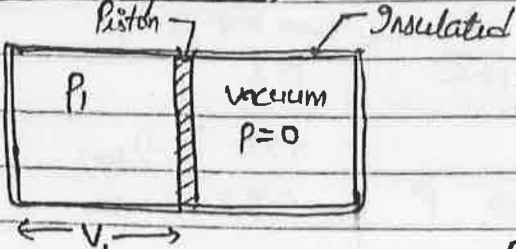
$$Q_1 - 1 = 8$$

$$Q_1 = 9\,J \text{ (Ans)!!}$$

Note:⇒ ①. No device is possible that can convert heat energy into W.D. completely. It is Kalvin-Plank statement of 2nd law of Thermodynamics.

②. No device is possible that can transfer heat energy from low temp. body to high temp. body naturally. It is Claucius-Clappeyron statement of 2nd law of Thermodynamics.

- Free Expansion



∵ Insulated ⇒ Q = 0

Gas expanded but no one is there to oppose

$W_{gas} = 0$

FLOT:- $\cancelto{0}{Q} = \cancelto{0}{W} + \Delta U$

** $\Delta U = 0$

$U_i = U_f$

$T_i = T_f$

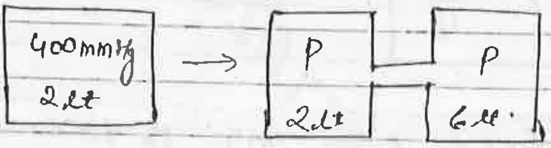
$\boxed{P_1V_1 = P_2V_2}$

Result ! ⇒ $U = \text{const.}$

$T = \text{Const.} \Rightarrow P_1V_1 = P_2V_2$

$W = 0$

Ques:- If some amount of gas kept in container of 2L vol^m at 400 mmHg pressure. If it is connected to another container of 6L capacity then f/o change in pressure of Ideal gas.



∴ Free Expansion

$\overset{U}{\underset{T}{\downarrow}} = \text{const.}$

$P_1V_1 = P_2V_2$

$400 \times 2 = P_2(2+6)$

$P_2 = 100 \text{ mm Hg}$

$\Delta P = 400 - 100 = 300 \text{ mmHg}.$

- Entropy (S) [Randomness / Disorderness]

→ Entropy can be created but can not be destroyed that's why entropy of universe is continuously increasing.

→ When dQ amount of heat is supplied to a substance then change in it's entropy (dS) is given by:- $\boxed{dS = \frac{dQ}{T}}$

$$\Rightarrow \Delta S = \int ds = \int \frac{dQ}{dT}$$

Ⓐ If temp. of substance remains constant.

(i). Phase Change ($Q = mL_v$ or mL_f)

$$\boxed{\Delta S = \frac{Q}{T} = \frac{mL_v \text{ or } mL_f}{T}}$$

(II). IT of I.G.

$$\Delta S = \int \frac{dQ}{T} = \frac{Q}{T} = \frac{W}{T}$$

$$\Delta S = \frac{nR\cancel{T} \ln \frac{V_2}{V_1}}{\cancel{T}} \Rightarrow \boxed{\Delta S = nR \ln \frac{V_2}{V_1}}$$

(B). If temp. of substance varies.

$$\Delta S = \int \frac{dQ}{dT} = \int_{T_1}^{T_2} \frac{msdT}{T}$$

$$\Delta S = ms \int_{T_1}^{T_2} \frac{dT}{T} = ms \ln \frac{T_2}{T_1} \quad \text{(or)} \quad nC \ln \frac{T_2}{T_1}$$

$$\boxed{\begin{array}{l} (\Delta S) \text{ at const. } V \Rightarrow \Delta S = nC_v \ln \frac{T_2}{T_1} \\ \text{at const. pressure} \Rightarrow \Delta S = nC_p \ln \frac{T_2}{T_1} \end{array}}$$

Ques:- 100 gm water is being heated from 20°c to 40°c Then f/o change in entropy of water.

Temp. → variable. $\Rightarrow \Delta S = ms \ln \frac{T_2}{T_1}$

~~= (100) × [illegible]~~

$$= 100gm \times \frac{1 Cal}{g°c} \ln \frac{313}{293}$$

$$= 100 \ln \frac{313}{293} \frac{Cal}{K} \quad \text{(Ans)!.}$$

Ques:- 1 Kg H_2 gas heated from 27°C to 327°C at const. Pressure then f/o - change in entropy of H_2 gas.

$$\therefore \Delta S = nC_p \ln \frac{T_2}{T_1}$$

$$\Delta S = \frac{1000}{2} \times \frac{7}{2} R \ln \frac{600}{300}$$

$$\Delta S = 500 \times \frac{5}{2} R \times \ln 2$$

$$\Delta S = 1750 R \ln 2$$

Ques:- 2.73 Kg ice converting into water at 1 atm pressure. Then f/o change in entropy of ice during phase change.

$$\Delta S = \frac{Q}{T} = \frac{mL_f}{T}$$

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$$\Delta S = \frac{2.73\times10^{3}\ \text{gm} \times 80\ \frac{\text{cal}}{\text{gm}}}{273\ \text{K}} = 800\ \frac{\text{cal}}{\text{K}}$$

Note :⇒ ①. $\because dS = \frac{dQ}{T}$

If $dS = 0 \Rightarrow S = \text{constant}$

i.e., - Adiabatic Process is an Isoentropic Process.

②. If S↑ing ⇒ $dS = +ve \Rightarrow dQ = +ve$ [absorbed]
↳ source.

If S↓ing ⇒ $dS = -ve \Rightarrow dQ = -ve$ [released]
↳ sink.

③ $\because dS = \frac{dQ}{T}$

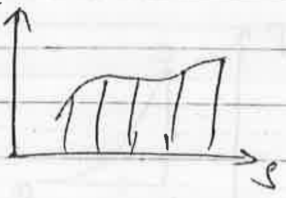
$dQ = T\,dS$

Heat $= Q = \int dQ = \int T\,dS$

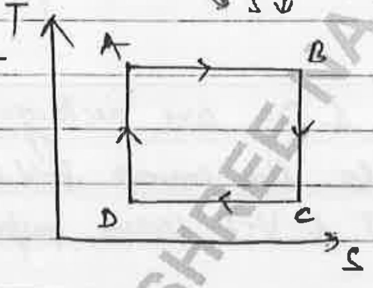
$Q = \pm$ [Area b/w curve & 'S'-axis]

+ → S↑

− → S↓



eg:-



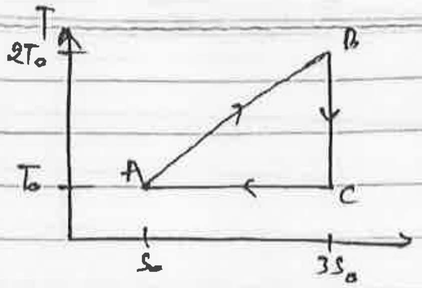
AB → IT ⇒ PV = const.
S↑ ⇒ [source], Q_1 = Area b/w AB & 'S' curve.
↳ Randomness ↑ ⇒ V↑ ⇒ P↓
[PV = const.]

BC → S = const. ⇒ [Adiabatic]
B ⟶ C ⇒ T↓ ⇒ V↑ (Ad.)

CD → S↓ ⇒ [sink].
Q_2 = Area b/w CD & 'S' curve
⇒ work (W) $= \underbrace{Q_1 - Q_2}_{\text{Area enclosed by cycle.}}$

Ex-I = 122 → 207. | Ex-III = 15 to last | Ex-~~III~~ II = Complete KTG & Thermo

Ques:-



F/o efficiency of cycle.

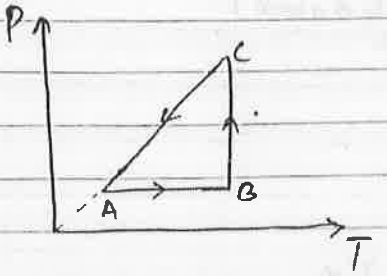
$$\therefore \eta = \frac{W}{Q_1} \xrightarrow{\text{Area}} = \frac{\frac{1}{2} \times 2S_0 \times T_0}{\frac{1}{2} \times (T_0 + 2T_0) \times 2S_0}$$

Q_1 Source → AB Area →

$$\Rightarrow \eta = \frac{T_0 S_0}{3 S_0 T_0}$$

$$\eta = \frac{1}{3} \text{ or } 33.3\%$$

Ques:-



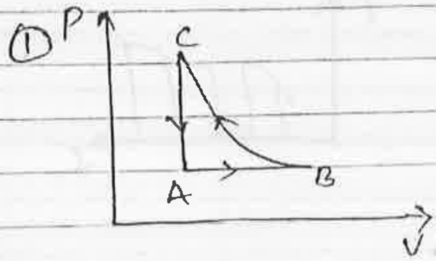
Convert P-T curve into P-V & V-T Curve.

AB → IB ⇒ ↑V ∝ T↑

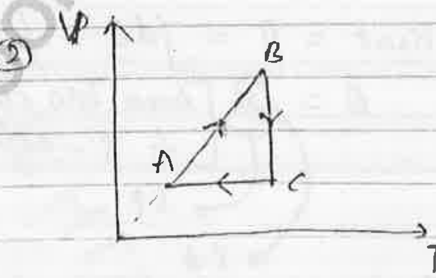
BC → IT ⇒ ↑PV↓ = const.

CA → IC ⇒ ↓P ∝ T↓

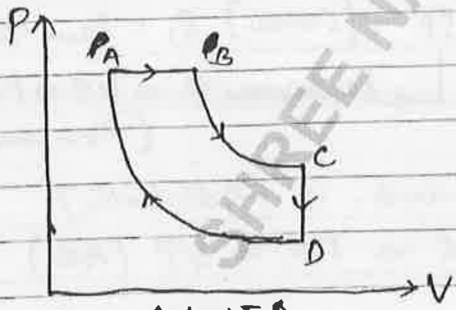
①



②



Ques:-



If BC & DA are rectangular hyperbola then convert P-V curve into P-T & V-T curve respectively

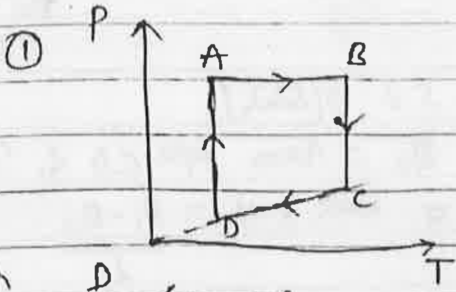
AB → IB ⇒ ↑V ∝ T↑

BC → IT ⇒↓ PV↑ = const

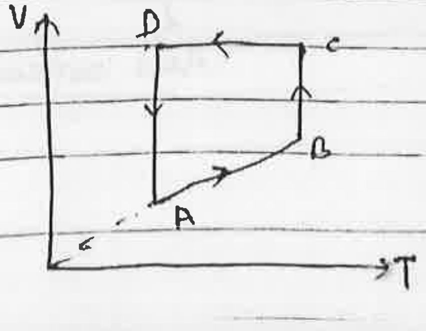
CD → IC ⇒ ↓P ∝ T↓

DA → IT ⇒ ↑PV↓ = const

①



②



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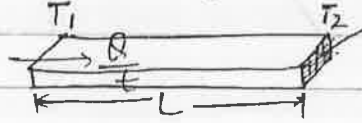
MODE OF HEAT TRANSFER

Conduction	Convection	Radiation
→ In solids mainly. Exception :→ Hg → Due to vibration of molecule → No actual motion of molecules take place. → Slow Process. eg.,- Heating of rod.	→ In fluids [liq. + Gas] → Actual motion of molecules take place. → Due to density difference. → Gravity required for it. eg.,- ①. Heating of water. ②. Heating of atmospheric layer. ③ Sea breeze & land breeze	→ In solid, liq. & gas. (all) → If T > 0 Kelvin then body emitts radiation → No medium required for it. ∵ Radiation are EMW. → Fastest method. eg.,- Heat coming from Sun to Earth through space (vaccum)

- Conduction

Rate of Heat flow through a rod.

$T_1 > T_2$



→ A = Area of Cross-section

$$\therefore \frac{Q}{t} \propto (T_1 - T_2)$$

$$\propto A$$

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

$$\Rightarrow \frac{Q}{t} \propto \frac{A(T_1 - T_2)}{L}$$

$$\Rightarrow \boxed{\frac{Q}{t} = K \frac{A(T_1 - T_2)}{L}}$$

→ Cofficient of Thermal Conductivity

$K \rightarrow \text{unit} = \frac{W}{m\text{-}K}$

$K\uparrow \Rightarrow$ Heat flow ↑

$K \Rightarrow$ Metal > Non-metal

Metal :→ $\boxed{K \Rightarrow Ag > Cu > Au > Al}$

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Ques:- WOF dimensional combination of a rod will give max^m rate of heat flow through it. $r \to$ radius ; $l \to$ length.

ⓐ $r = 2$; $l = 2$
ⓑ $r = 1/2$; $l = 1$
ⓒ $r = 1$; $l = 1/3$
ⓓ $r = 1$; $l = \frac{1}{2}$

$$\therefore \frac{Q}{t} = \frac{K\,Ⓐ\,(T_1 - T_2)}{Ⓛ}$$

$$\Rightarrow \frac{Q}{t} \propto \frac{A}{L} \propto \frac{r^2}{L}$$

Ques:- Rate of heat flow through a rod is 'P'. If this rod is melted and molted again in a new rod of radius 3 times of initial. Then f/o rate of heat flow through it:

Initial rod

~~$P = \frac{\pi r_1^2 (T_1 - T_2)}{l_1}$ —①~~

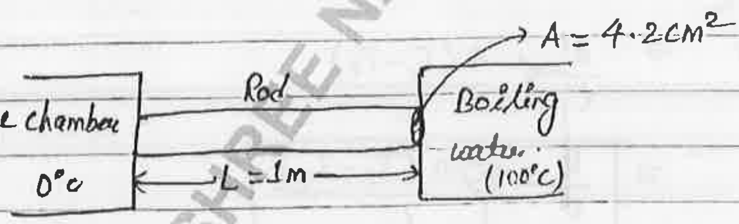
~~$\therefore m_1 = m_2$~~
~~$\rho V_1 = V_2 \rho$~~
~~$\pi r_1^2 \times l_1 = \pi r_2^2 \times l_2$~~
~~$\frac{r_1^2 l_1}{l_2} = \frac{r_2^2}{l_2}$~~

Final rod.

~~$\frac{Q}{t} = \frac{\pi r_2^2 (T_1 - T_2)}{l_2}$~~

~~$\frac{Q}{t} = \frac{\pi r_1^2 l_1}{l_2} (T_1 - T_2)$~~

Ques:-



A rod of length 1m and cross-section area 4.2 cm² connected with ice chamber and boiling water chamber as given If 2.1 Kg ice melting per hour then f/o thermal conductivity of rod?

$$\therefore \frac{Q}{t} = \frac{KA\,(T_1 - T_2)}{l}$$

$$\frac{mL_f}{t} = \frac{K\,(4.2)\times 10^{-4}\,(100 - 0)}{1}$$