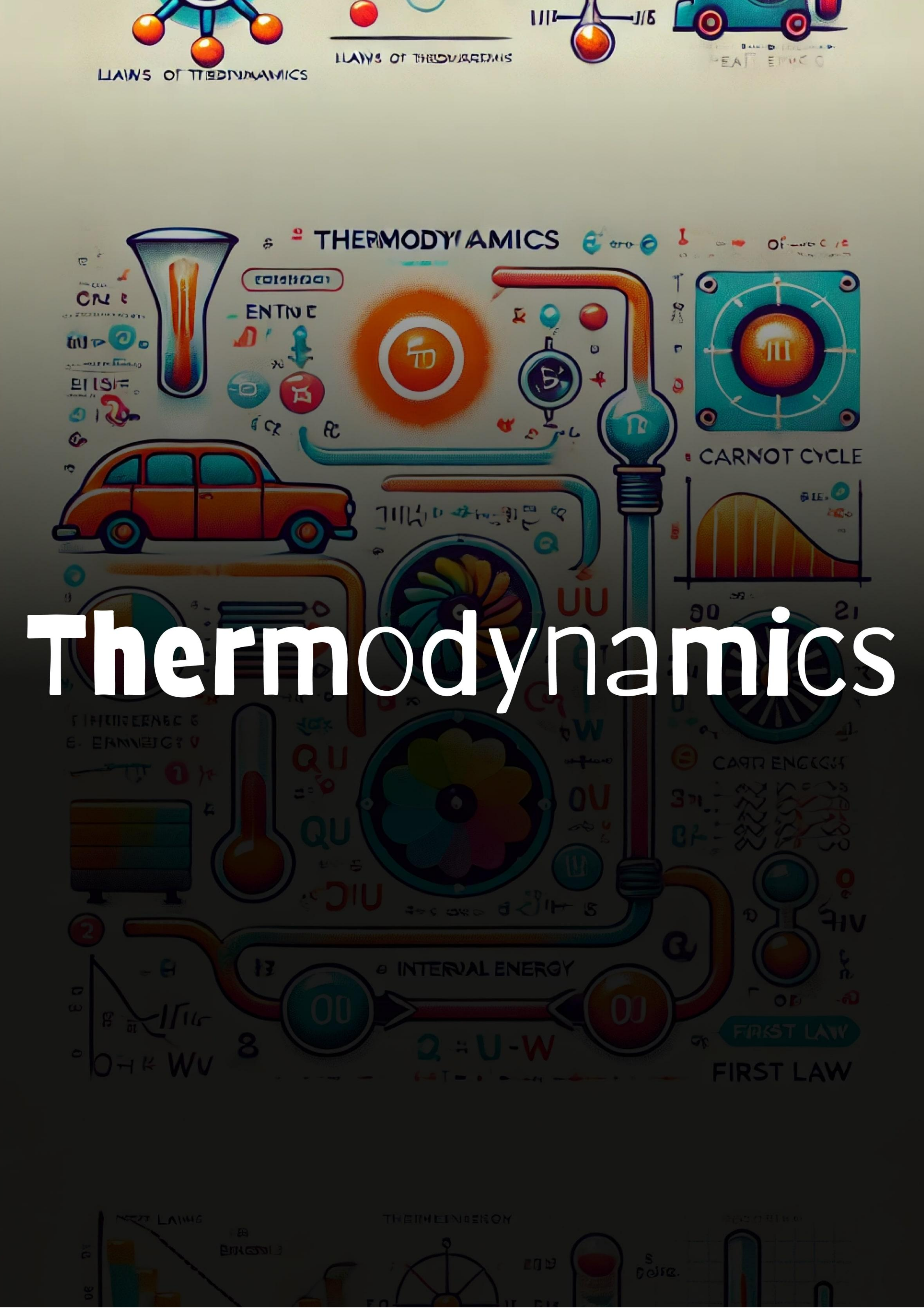
Thermodynamics



THERMODYNAMICS

Everything around and except system is called surrounding

TYPE OF SYSTEM

Open system, Closed system, isolated system.

Through a boundary mass can't be interchanged

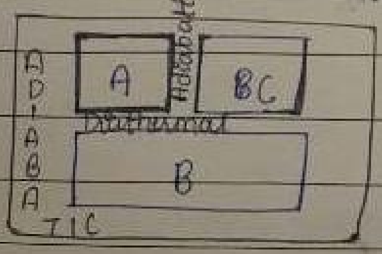
Boundaries	Exchange of heat
1) Adiabatic	✗
2) Diathermal	✓

Thermal equilibrium of two body

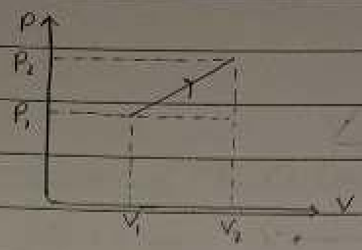
If heat transfers between 2 system is not in process, i.e. their temp^r is same then the 2-system are said to be in thermal equilibrium

Zeroth law of thermodynamics

According to Zeroth law of thermodynamics if A and B are in thermal equilibrium B and C are in thermal equilibrium then A and C will also be in thermal equilibrium



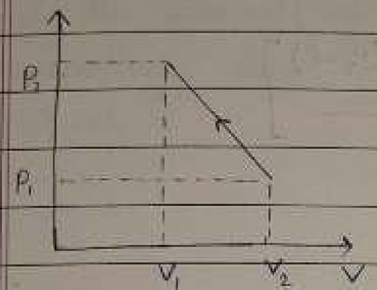
$W = 0$



$Work = +ve = \left[(V_2-V_1)P_1 + \frac{1}{2}(P_2-P_1)(V_2-V_1)\right]$

$\Rightarrow V_2-V_1\left[P_1 + \frac{P_2}{2} - \frac{P_1}{2}\right]$

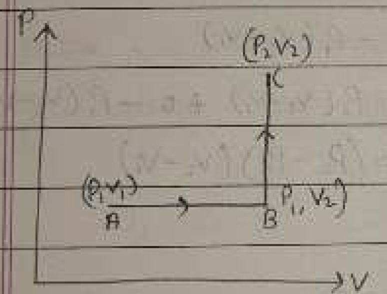
$\Rightarrow \frac{(V_2-V_1)(P_1+P_2)}{2}$



$W = -ve = \left[\frac{1}{2}(P_1+P_2)(V_2-V_1)\right]$

$W_{A\to B} + W_{B\to C} = 0 + P_2(V_2-V_1)$

$\Rightarrow +P_2(V_2-V_1)$

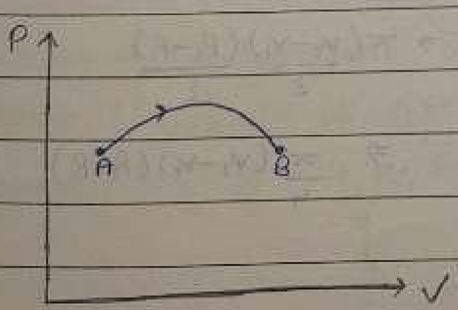


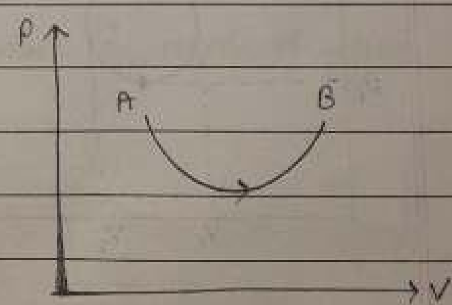
$W_{A\to C} = W_{A\to B} + W_{B\to C}$

$\Rightarrow P_1(V_2-V_1) + 0$

$\Rightarrow P_1(V_2-V_1)$

Q





→ Work is continuously increasing

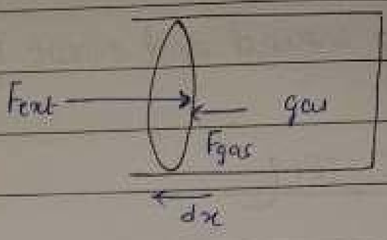
Work is continuously increasing

WORK

→ depends upon path does not use to define state of gas

Work done by gas = $F_{gas}\,dx$

$\Rightarrow PA\,dx$



Work done by gas $\Rightarrow P\,dV$

During expansion

$V_f > V_i$

$\Delta V = +ve$

$\therefore W = +ve$

During compression

$\Delta V = -ve$

$\therefore W = -ve$

INDICATOR

$dW = PdV$

$P = const^n$

$\int dW = \int PdV$

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

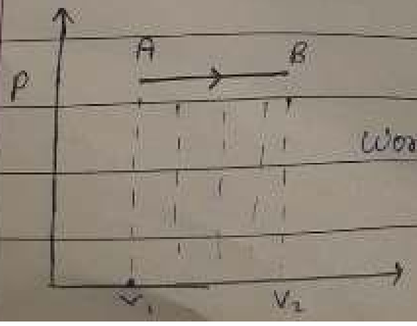
$W = P\Delta V$

$P =$ variable

$\int dW = \int_{V_1}^{V_2} PdV$

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

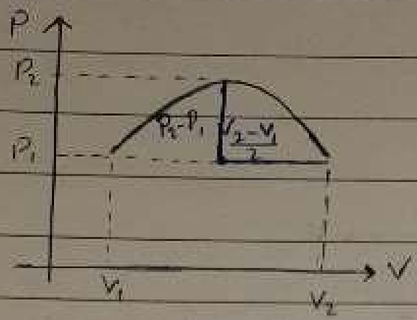
INDICATOR DIAGRAM



Work $= \int PdV =$ Area

Work $= P(V_2 - V_1)$

Q

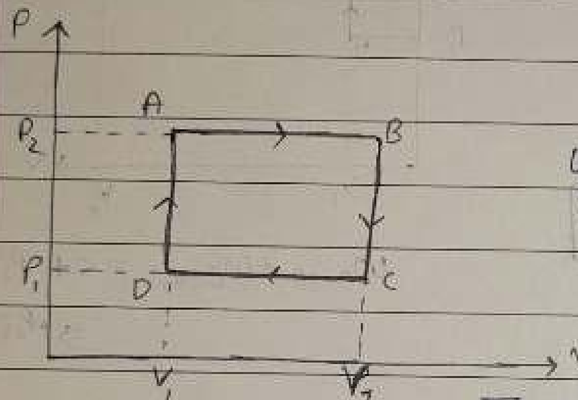


$$\text{Work done} = \left[P_1(V_2-V_1) + \frac{\pi\left(\frac{V_2-V_1}{2}\right)(P_2-P_1)}{2} \right]$$

$$\text{Area of semi ellipse} = \frac{\pi R_1 R_2}{2}$$

$$\text{Work done} \rightarrow \left[P_1(V_2-V_1) + \frac{\pi\frac{(V_2-V_1)}{2}(P_2-P_1)}{2} \right]$$

Q



Work from

$A \rightarrow B = +P_2(V_2-V_1)$

$B \rightarrow C = D \rightarrow A = 0$

$C \rightarrow D = -P_1(V_2-V_1)$

Total work $= P_2(V_2-V_1) + 0 - P_1(V_2-V_1) + 0$

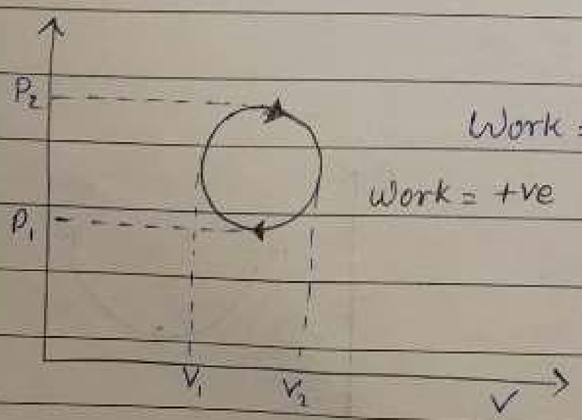
$\Rightarrow (P_2-P_1)(V_2-V_1)$

Total work done = Area of loop

If Clockwise work done = +ve

If Anticlockwise loop work done = -ve

Q

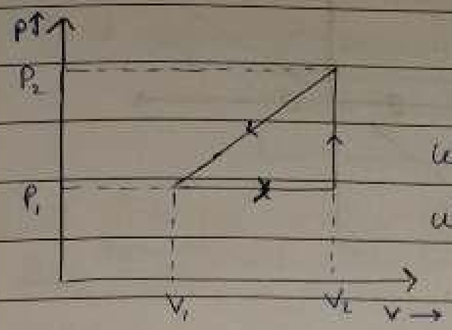


Work $= \pi R_1 R_2$

Work = +ve $\Rightarrow \pi \frac{(V_2-V_1)}{2} \frac{(P_2-P_1)}{2}$

$\Rightarrow \frac{\pi}{4}(V_2-V_1)(P_2-P_1)$

Q

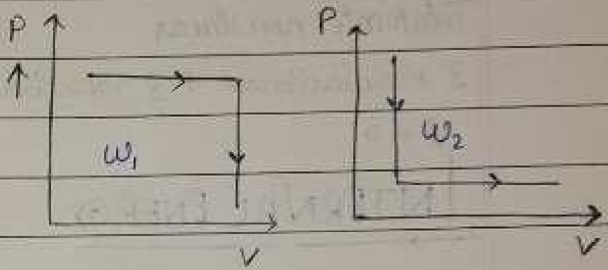


$Work = \frac{1}{2}(P_2 - P_1)(V_2 - V_1)$

$Work = -ve$

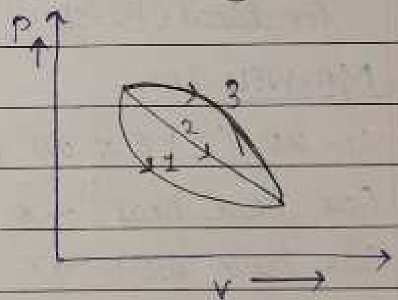
Q In the following figure two indicator diagrams are shown. If the amount of work done in them are W_1 and W_2 respectively, then.

⇒ $W_1 > W_2$



Q In the following figure A certain mass of gas traces three paths 1, 2, 3 from state A to state B. If the work done by the gas along these paths are W_1, W_2 and W_3 respectively then

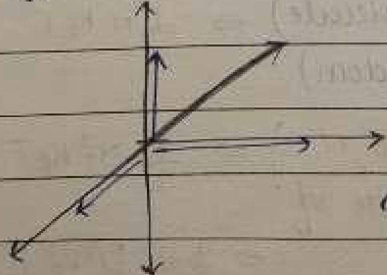
Ans $W_3 > W_2 > W_1$



DEGREE OF FREEDOM

Number of independent ways of motion in terms of which K.E. of ~~motion~~ molecule is defined.

Monoatomic → Eg → Ne, He, Ar



f = 3 translational degree of freedom

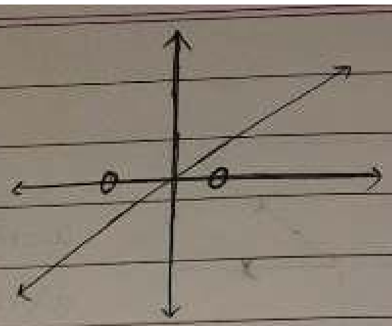
0 → Rotational degree of freedom

Total f = 3

Diatomic

$f = 3$ translational $+ 2$ Rotational

$\Rightarrow 5$



Triatomic ~~collinear~~ linear

→ CO_2

$O = C = O$

$f_{net} = 5$ ($3 \rightarrow$ Translational $+ 2$ Rotational)

Triatomic non linear

3 translational + 3 rotational

$f = 6$

- At very temp^r D.O.F. of Diatomic gas $= 3+4$ $\Rightarrow 7$ ← Vibrational degree of freedom.
- At very temp^r Vibrational degree of freedom = given

INTERNAL ENERGY

- It depends upon temperature
- Does not depend upon path
- $U = K.E + P.E$

  for ideal ($P.E = 0$)

MAXWELL LAW.

$U = K.E$ (Σ K.E. of all molecules due to all type of degree of freedom)

Gas have heat → ✗

Gas have work → ✗

Gas have internal energy → ✓

$U \propto$ temp^r $\propto$ No. of molecules $\propto$ ~~to~~ degree of freedom

U (Internal energy of 1 molecule due to 1 degree of freedom) $\Rightarrow \frac{1}{2} K_B T$

U (Internal energy of N molecule due to 1 degree of freedom) $\Rightarrow \frac{1}{2} N K_B T$

U (Internal energy due to N molecules ; of f degree of freedom) $\Rightarrow \frac{1}{2} N f K_B T$

$\Rightarrow$ ~~$\frac{1}{2} N f$~~ $\frac{1}{2} \left(N f \frac{R}{N_A}\right) T \Rightarrow \frac{1}{2} \eta f R T$

$K_B = \frac{R}{N_A}$

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U (total internal energy due to n moles of f degree of freedom)

$$\Delta U = \frac{1}{2} nR\Delta T f$$

Q Find internal energy of n mole of diatomic gas due to translational motion.

⇒ $K.E. = \frac{1}{2} nR3T = \frac{3}{2} nRT$ Ans

$$C_m = \frac{dQ}{dt\, n} \quad (\text{J/mol K})$$

CGS → $\frac{cal}{mol\ K}$

$$S = \frac{dQ}{dt\, m}$$

$$\frac{C_m}{S} = \frac{dQ}{dt\,n} \cdot \frac{dt\,m}{dQ} = \frac{m}{n} \times MM$$

$$C_m = MM \times S$$

Molar heat capacity

→ At constant pressure

$$C_p = \left[\frac{dQ}{dt\, n}\right]_P$$

→ At constant volume

$$C_v = \left[\frac{dQ}{dt\, n}\right]_{v = const^n}$$

$$C_p - C_v = R$$

$$\frac{C_p}{C_v} = \gamma$$

→ Adiabatic exponent
→ Unit and dimensionless

* **Q** If C_p and C_v denote the specific heats (per unit mass of an ideal gas of molecular weigh M) then

Ans

$C_p' = m C_p$

$C_v' = m C_v$

$C_p' - C_v' = R$

$m C_p - m C_v = R$

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

At constant volume

$dQ = nC_v dT$

By 1st law of thermodynamics at constn volume

$dQ = dU + dW$ (Volume = constn, $dV = 0$, $dW = 0$)

$\therefore dQ = dU$

$\Rightarrow nC_v dT = \frac{R}{2} f \, n \, dT$

$C_v = \frac{Rf}{2}$

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

$dU = nC_v dT$ | MR ratta

$\frac{C_p}{C_v} = \gamma \qquad C_p = C_v \gamma$

$C_p - C_v = R$

$C_v\gamma - C_v = R$

$C_v(\gamma - 1) = R$

$C_v = \frac{R}{\gamma - 1}$

$\frac{Rf}{2} = \frac{R}{\gamma - 1}$

$\frac{2}{f} = \gamma - 1$

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

	D.O.F.	C_v	C_p	γ
Monoatomic	3T + 0R = 3	3R/2	5R/2	5/3 = 1.66
Diatomic	3T + 2R = 5	5R/2	7R/2	7/5 = 1.4
Triatomic (linear)	3T + 2R = 5	5R/2	7R/2	7/5 = 1.4
Triatomic (non-linear)	3T + 3R = 6	3R	4R	4/3 = 1.33
Diatomic (at higher tempr)	3T + 2R + 2V = 7	7R/2	9R/2	9/7

Q A polyatomic gas with n degrees of freedom has a mean energy per molecule given by.

Ans $\frac{1}{2} K_B n \Delta T$

Q The value of $\gamma \left(= \frac{C_P}{C_V}\right)$ for hydrogen, helium and another ideal diatomic gas x (whose molecules are rigid but have an additional vibrational mode), are respectively equal to

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

$\Rightarrow \frac{7}{5}, \frac{5}{3}, \frac{9}{7}$

Q The amount of heat energy required to raise the tempr of 1g of Helium at NTP from T_1 to T_2.

Ans $dQ = n C_V \Delta T$ (assume) ↳ ~~Volume constant~~

$d\theta = \frac{1}{4} \times \frac{3R}{2} (T_2 - T_1) \times \frac{N_A}{N_A}$

$\Rightarrow \frac{3}{8} K_B N_A (T_2 - T_1)$

* **Q** The molar ~~heat capa~~ specific heat at constant pressure of an ideal gas is $\left(\frac{7}{2}\right) R$. The ratio of specific heat at constant pressure to that at constant volume is.

Ans $C_P = \frac{7}{2} R$

$\therefore C_V = \left(\frac{7-1}{2}\right) R = \frac{5}{2} R$

$\frac{C_P}{C_V} = \frac{M S_P}{M S_V} = \frac{7}{5}$ Ans

Q The gas mixture consists of 2 moles of O_2 and 4 moles of Ar at tempr T. Neglecting all vibrational mode, what is the total internal energy.

Ans $U_{net} = U_{(O_2)} + U_{Ar}$

$\Rightarrow \frac{1}{2} n_{O_2} f_{O_2} RT + \frac{1}{2} n_{Ar} f_{Ar} RT$

$\Rightarrow \frac{1}{2} \times 2 \times 5RT + \frac{1}{2} \times \frac{2}{4} \times 3RT$

$\Rightarrow 11RT$ Ans

Q If the ratio of the specific heat of a gas at constant pressure to that of constant volume is γ, the change in internal energy of a mass of gas, when the volume of gas changes from V to $2V$ at constant pressure.

Ans $du = nC_v\Delta T$

$PV = nRT$

$P\Delta V = nR\Delta T$

$\therefore \Delta V = \Delta T$

$\therefore du = \frac{nR(2T-T)}{\gamma-1} = \frac{nRT}{\gamma-1} = \frac{PV}{\gamma-1}$

$$\therefore \boxed{du = \frac{PV}{\gamma-1}}$$

GAS MIXTURE

A gas having n_1 no of mole of C_{v_1} molar heat capacity is mixed with n_2 mole of C_{v_2} gas then find molar heat capacity of mixture of gas.

$(C_v)_{mix} = \frac{n_1C_{v_1} + n_2C_{v_2}}{n_1+n_2}$ $\qquad (\gamma)_{mix} = 1 + \frac{2}{f_{mix}}$

$(C_P)_{mix} = \frac{n_1C_{P_1} + n_2C_{P_2}}{n_1+n_2}$ $\qquad (\gamma)_{mix} = \frac{(C_P)_{mix}}{(C_v)_{mix}}$

$(f)_{mix} = \frac{n_1f_1 + n_2f_2}{n_1+n_2}$ $\qquad \gamma = \frac{n_1\gamma_1 + n_2\gamma_2}{n_1+n_2}$ ✗

1st LAW OF THERMODYNAMICS

↳ Based on conservation of energy

$$\boxed{dQ = dw + du}$$

$dQ = +ve$ heat given to system

$dQ = -ve$ heat taken from system

$dU = +ve$ Increase in internal energy
$dU = -ve$ decrease in internal energy
$dW = +ve$ Work done by gas
$dW = -ve$ Work done on gas

Q A system is given 400 calories of heat and 1000 Joule of work is done by the system, then the change in internal energy of the system will be.

Ans $dQ = 400cal = 1680J$

$dU = dQ - dW$

$\Rightarrow 1680 - 1000$

$\Rightarrow 680J$ Ans

Q The internal energy change in a system that has absorbed 2kcal of heat and done 500J of work is.

Ans $du = dq - dw$

$\Rightarrow 2000 \times 4.2 - 500$

$\Rightarrow (8400 - 500)J$

$\Rightarrow 7900J$

Q 110 Joule of heat is added to gaseous system whose change in I.E is 40J, then amount of external work done

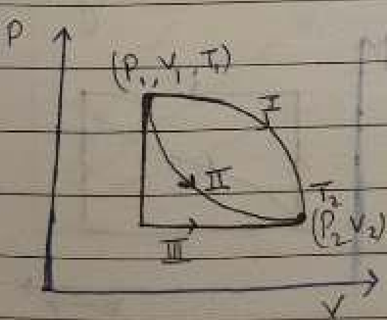
Ans $dQ = dU + dW$

$dW = 110 - 40 = 70J$ Ans

Q First law of thermodynamics is a consequence of?

→ Energy

$PV = nRT$ → for Ideal gas

Q 

dU_1 = Change in internal energy in 1st path

dU_2 = " " " in 2nd "

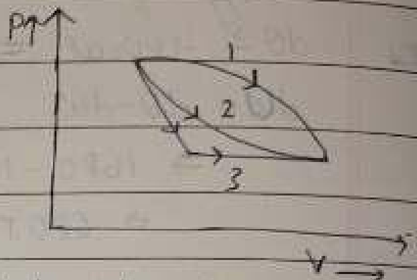
dU_3 = " " " in 3rd "

$dU_1 = dU_2 = dU_3$ ($\because \Delta T =$ constn)

↳ $\frac{1}{2} nfR\Delta T$

Q An ideal gas goes from state A to state B via three different processes as indicated in the P-V diagram -

If Q_1, Q_2, Q_3 indicate the heat absorbed by the gas along three processes and U_1, U_2, U_3 indicate the change in internal energy along the three processes respectively then -



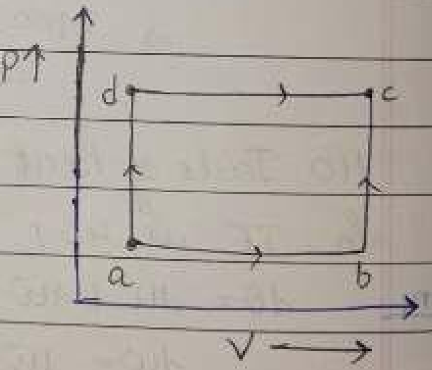
Ans $U_1 = U_2 = U_3$

as $dW_1 > dW_2 > dW_3$

$\therefore dQ_3 < dQ_2 < dQ_1$

Q The system is taken from state a to state ~~abc~~ c by two paths adc and abc shown in the figure. The internal energy at a is $U_a = 10J$. Along the path adc the amount of heat absorbed $dQ_1 = 50$ J and the work obtained $dW_1 = 20J$ whereas along the path abc the heat absorbed $dQ_2 = 36J$. The amount of work done along the path abc is

Ans ΔU in both the case will be same



$\therefore dQ_1 - dW_1 = dQ_2 - dW_2$

$\Rightarrow 50 - 20 = 36 - dW_2$

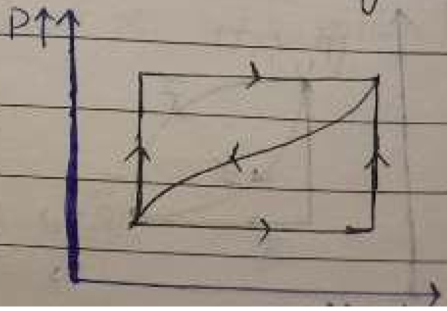
$\Rightarrow 30 - 36 = -dW_2$

$dW_2 = 6J$ Ans

Q When a system is taken from state i to state f along the path iaf, it is found that Q = 50 cal and W = 20 cal. Along the path ibf Q = 36 cal. Work along path ibf is.

Ans $50 - 20 = 36 - W$

$W = 6J$



Gay - Lussac Law → By K.T.G $P \propto T$

a) Isochoric Process

➤ If a system undergoes change from A to B such that volume remains constant i.e. under the isochoric process

$$\boxed{A} \xrightarrow{\text{Isochoric}} \boxed{B}$$

(P_1, T_1, V) (P_2, T_2, V)

Volume = constant

$dV = 0$

$dW = 0$

By 1st law of thermodynamics

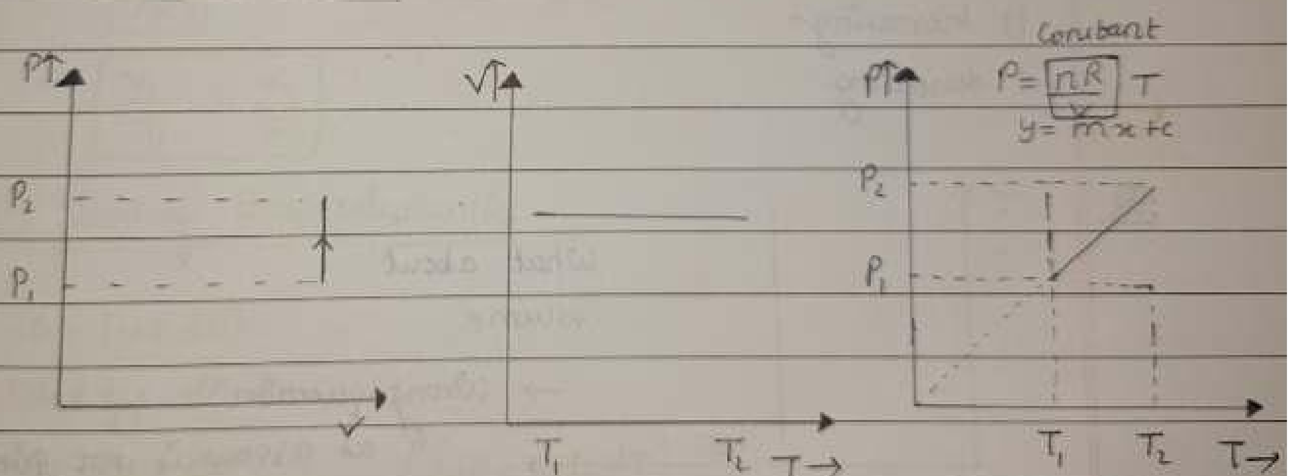
$dQ = dU + dW^{\,0}$

$\boxed{dQ = dU}$

By K.T.G

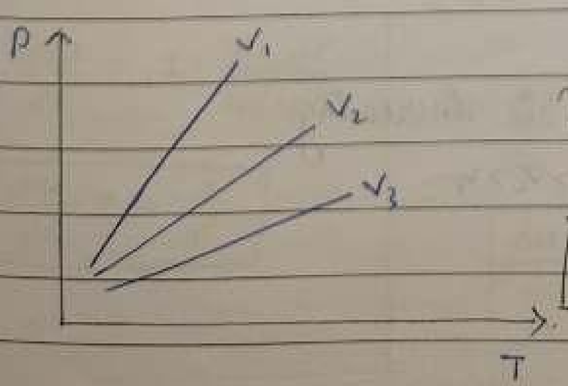
$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Graph for Isochoric



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

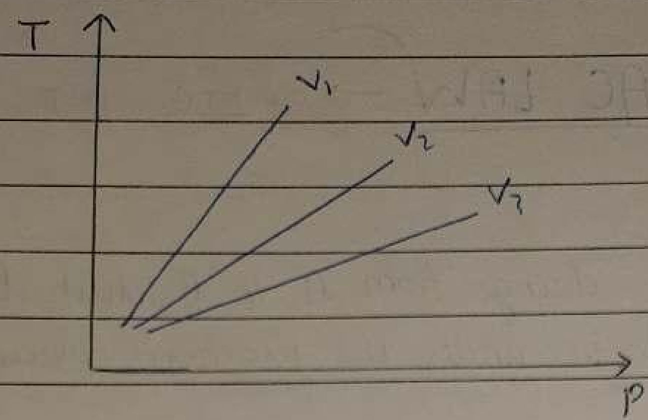
Q



Then find relation b/w V_1, V_2, V_3

$\Rightarrow V_3 > V_2 > V_3$

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

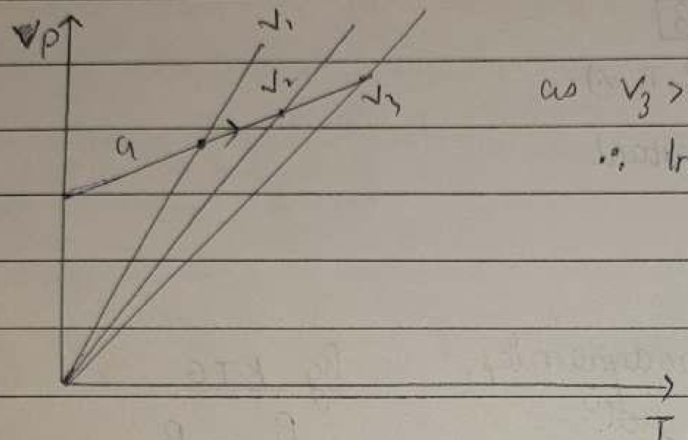


$T = \frac{V}{nR} P$

Slope $\propto V$

$\therefore V_1 > V_2 > V_3$

Q



as $V_3 > V_2 > V_1$

$\therefore$ In line a volume is increasing

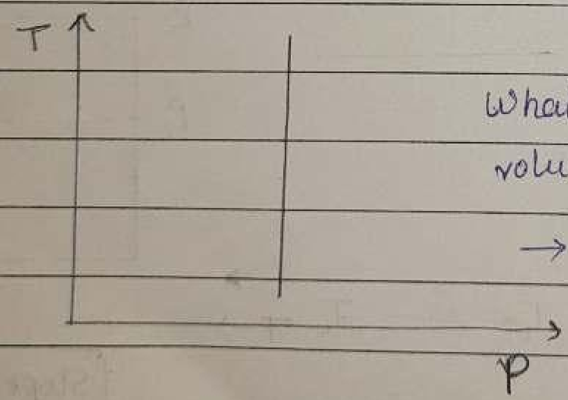
Q→ Volume is

a) Constant

b) Increasing

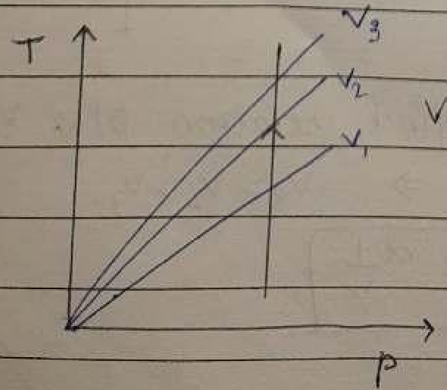
c) decreasing

Q



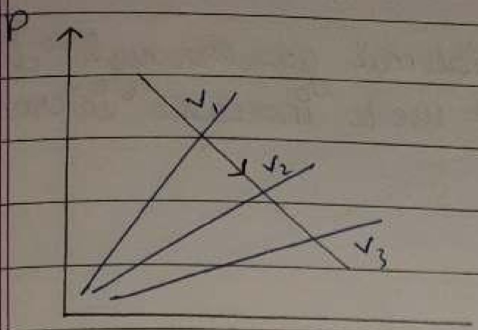
What about volume

→ Wrong question as arrow is not given.



Volume is increasing

$V_3 > V_2 > V_1$



$V_3 > V_2 > V_1$

$\therefore$ Volume is increasing

OR $\downarrow PV = (nR)T \uparrow$

$\hookrightarrow$ Constant

$\therefore V \uparrow\uparrow$

b) **ISOBARIC PROCESS**

If a system undergoes change from A to B such that pressure remains constant i.e. under the isobaric process.

$$\boxed{A} \xrightarrow[\text{process}]{\text{Isobaric}} \boxed{B}$$

(P_1, V_1, T_1) $\qquad$ (P_1, V_2, T_2)

$PV = nRT$

$V = \left(\frac{nR}{P}\right)T \rightarrow$ constant

$V = KT$

$\boxed{V \propto T}$

$$\boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$

1st Law of thermodynamics

$dQ = dU + dW$

divided by dQ both side

$1 = \frac{dU}{dQ} + \frac{dW}{dQ}$

$\left([dQ = nC_p dT] \text{ यहाँ} \right.$
$\left. (dU = nC_v dT) \rightarrow \text{always valid} \right)$

$\frac{dW}{dQ} = 1 - \frac{nC_v dT}{nC_p dT}$

$$\boxed{\frac{dW}{dQ} = 1 - \frac{1}{\gamma}}$$

$1 = \frac{dU}{dQ} + 1 - \frac{1}{\gamma}$

$$\boxed{\frac{dU}{dQ} = \frac{1}{\gamma}}$$ MR Ratta

$$\boxed{dU = \frac{dQ}{\gamma}}$$

Q Heat is given to the 4 mole diatomic gas through isobaric process then find fraction of heat use to increases internal energy.

Ans $\frac{dU}{dQ} = \frac{1}{\gamma} = \frac{5}{7}$ Ans

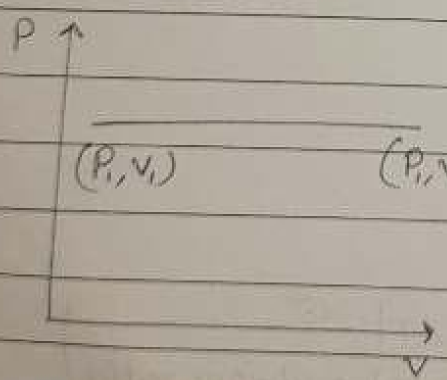
Q Heat given to the triatomic linear gas at constn pressure is 50 J then find work done?

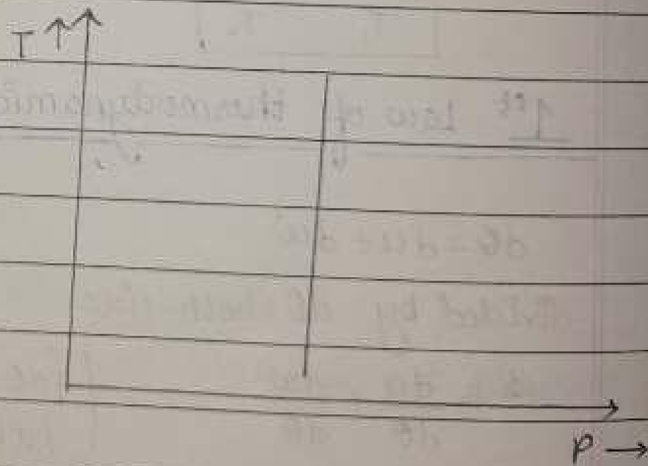
Ans $\frac{dW}{dQ} = 1 - \frac{1}{\gamma}$

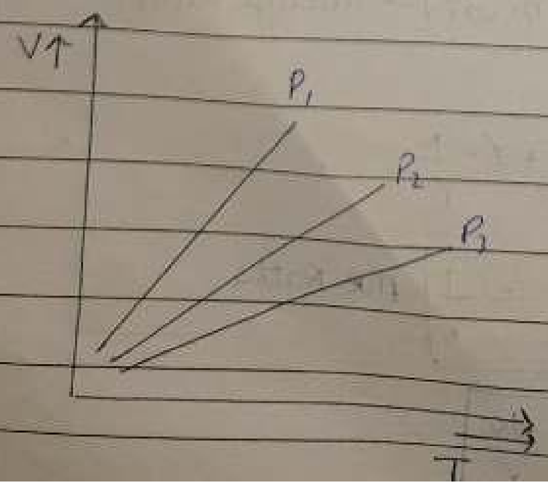
$dW = dQ\left(1 - \frac{1}{\gamma}\right)$

$\Rightarrow 50\left(1 - \frac{5}{7}\right) = \frac{50 \times 2}{7} = \frac{100}{7}$ J

GRAPH FOR ISOBARIC





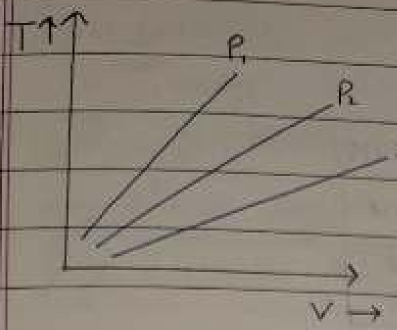


$PV = nRT$

$V = \frac{nR}{P} T$

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

$P_3 > P_2 > P_1$



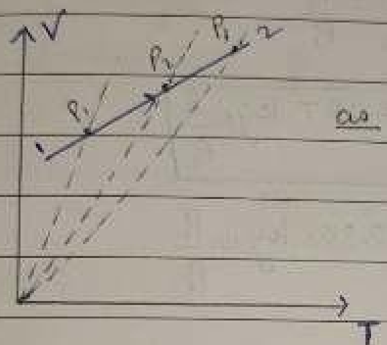
$\boxed{P_1 > P_2 > P_3}$

$PV = nRT$

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

Slope $\propto P$

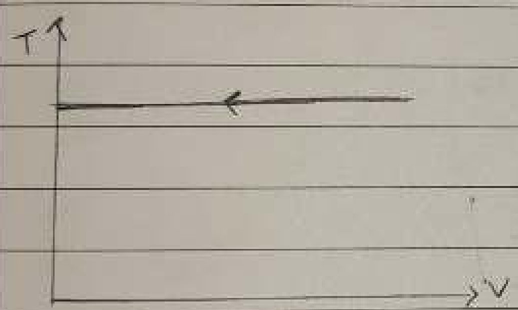
Q Pressure in the graph



as $P_3 > P_2 > P_1$

$\therefore$ Pressure is increasing

Q



$PV = nRT$ constant

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

$\therefore$ Pressure is increasing.

3) ISOTHERMAL PROCESS

BOYLE'S LAW $\longrightarrow$ T = constant $\Delta T = 0$ $\Delta U = 0$

reversible

PV = constⁿ

By 1st Law of thermodynamics

$dQ = dU + dW$

- Heat flow with very small amount $\boxed{dQ = dW}$

- For ideal gas

$P_1 V_1 = P_2 V_2$

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

Work in Isothermal Process

$\int dw = \int P\,dV$ (Pressure is not constant)

$W = \int P\,dV$

$PV = nRT$

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

$W = \int_{V_1}^{V_2} \frac{nRT}{V}\,dV$

$W = nRT \int_{V_1}^{V_2} \frac{1}{V}\,dV$

$W = nRT\left[\log_e V\right]_{V_1}^{V_2}$

$W = nRT\left[\log_e V_2 - \log_e V_1\right]$

$\boxed{W = nRT \log_e \frac{V_2}{V_1}}$

$W = 2.303\, nRT \log_{10}\left(\frac{V_2}{V_1}\right)$

$\Rightarrow \boxed{W = 2.303\, nRT \log_{10} \frac{V_2}{V_1}}$

$\boxed{\Delta\theta = 2.303 \log nRT \log_{10} \frac{V_2}{V_1}}$

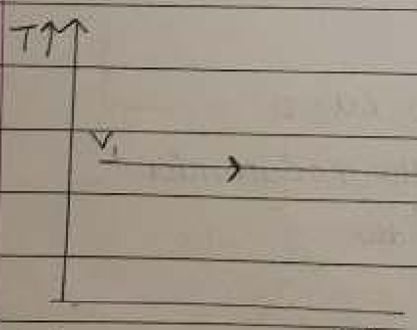
As $P_1V_1 = P_2V_2$

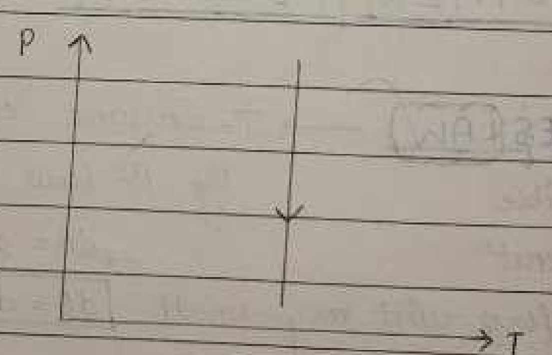
$\frac{V_1}{V_2} = \frac{P_2}{P_1}$

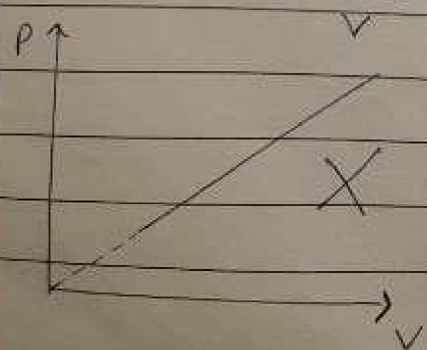
$\therefore \boxed{W = nRT \log_e \frac{P_1}{P_2}}$

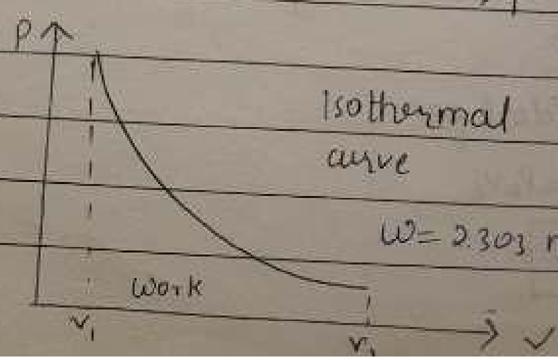
$W = +2.303\, nRT \log_{10} \frac{P_1}{P_2}$

Graph









$W = 2.303\, nRT \log_{10} \frac{V_2}{V_1}$

LOG CONCEPT

$2^3 = 8$ (2 → power, 3 → power, 8 → result)

~~log $2^8 = 3$~~ $\log_2 8 = 3$

log 8 on the base 2 = 3

ANTI-LOG

$y = \log_e x$

taking anti log ⇒ log के concept को power मे convert करना

$e^y = x$

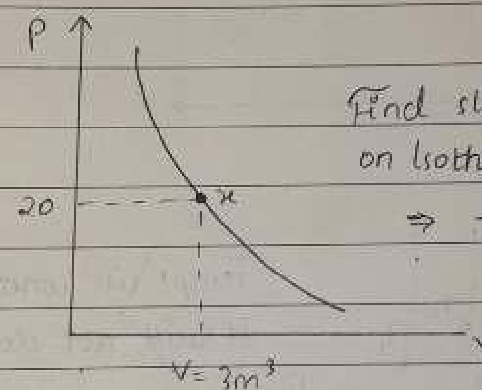
$P = \frac{nRT}{V}$

$\frac{dP}{dV} = nRT\frac{dV^{-1}}{dV}$

$\frac{dP}{dV} = nRT(-1V^{-2})$

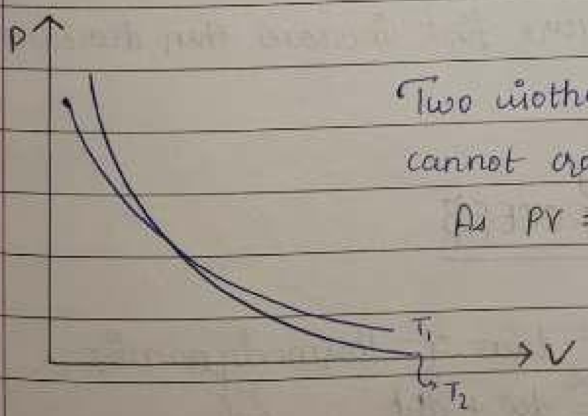
$\frac{dP}{dV} = -\frac{nRT}{V \times V}$ ($\frac{nRT}{V}$ → P)

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



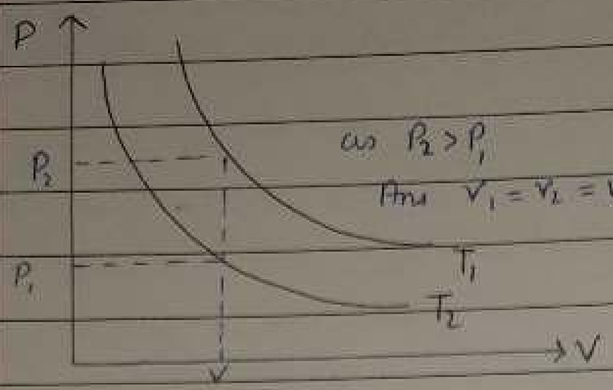
Find slope at point x on Isothermal curve

$\Rightarrow -\frac{20 \text{ atm}}{3 m^3}$



Two isothermal curve cannot cross each other.

As PV = will not be constant then.

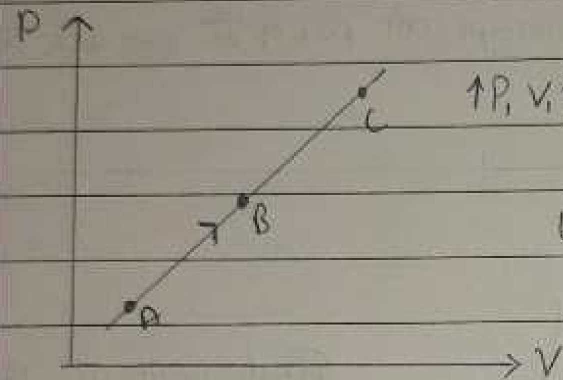


as $P_2 > P_1$
And $V_1 = V_2 = V$

And $P_2 V = T_1$
$P_1 V = T_2$
as $P_2 V > P_1 V$
$\therefore T_1 > T_2$

then $T_1 > T_2$

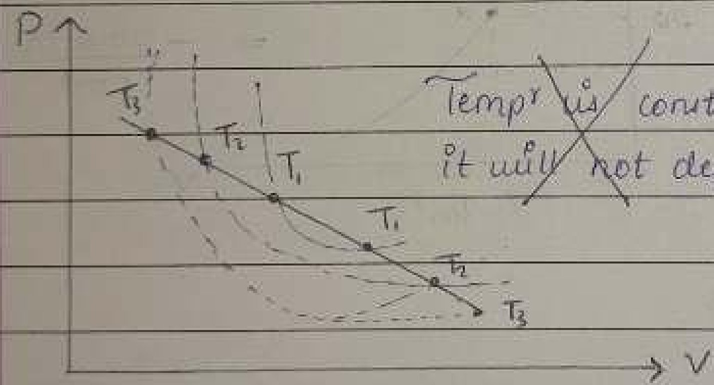
Q



$\uparrow P, V \uparrow = nRT \uparrow$

What about tempr ? ↑

Q



~~Tempr is constn~~
~~it will not depend on arrow.~~

as $T_1 > T_2 > T_3$
$\therefore$ Temperature first increases then decreases.

ADIABATIC PROCESS

No Heat transfer

1st Law of thermodynamics

$\cancel{dQ}^{\to 0} = dw + du$

$\boxed{dw = -du}$

EXPANSION	
$V_2 > V_1$	$Work = -du = -nC_v dT$
$dw = +ve$ Tyre का	$= -\frac{nR}{\gamma-1} dT$
$+ve = -du$ फटना	$\boxed{Work = \frac{nRdT}{1-\gamma}}$
Tempr ↓	$W = \frac{nR(T_2-T_1)}{1-\gamma}$
COMPRESSION	
$V_2 < V_1$ volume ↓	$W = \frac{nRT_2 - nRT_1}{1-\gamma}$
$dw = -ve$	
$du = +ve$	$\boxed{W = \frac{P_2V_2 - P_1V_1}{1-\gamma}}$ → MR ratta
Temp ↑	

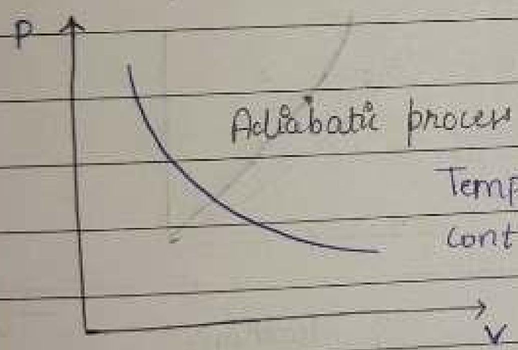
Typre में हवा भरना

GRAPH

$PV^\gamma = const^n$

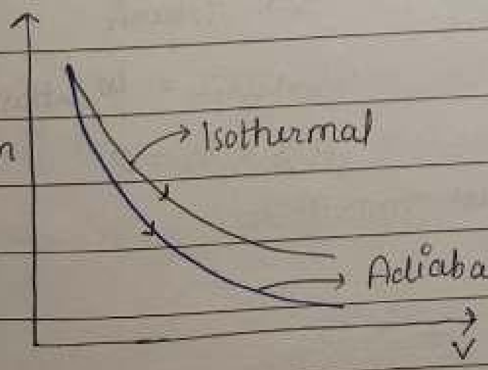
$P \propto \frac{1}{V^\gamma}$ $(\gamma > 1)$

Slope $= -\gamma\left(\frac{P}{V}\right)$



Tempr is not constn

Slope for isothermal



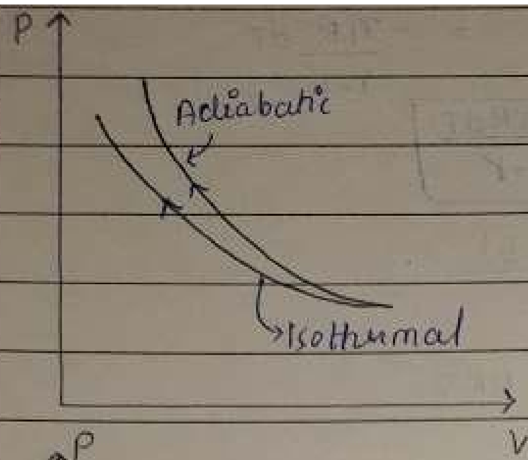
(in Expansion)

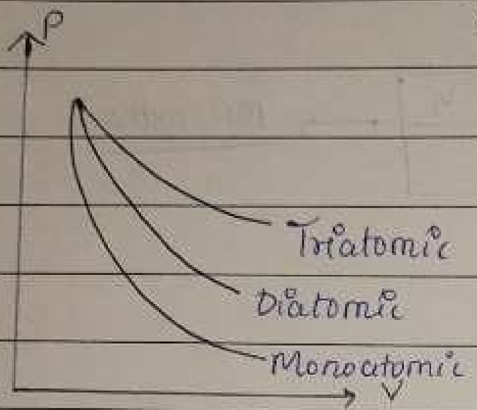
$PV = const^n$

$\frac{\Delta P}{P} = -\frac{\Delta V}{V}$

slope $\frac{\Delta P}{\Delta V} = -\frac{P}{V}$

ompression

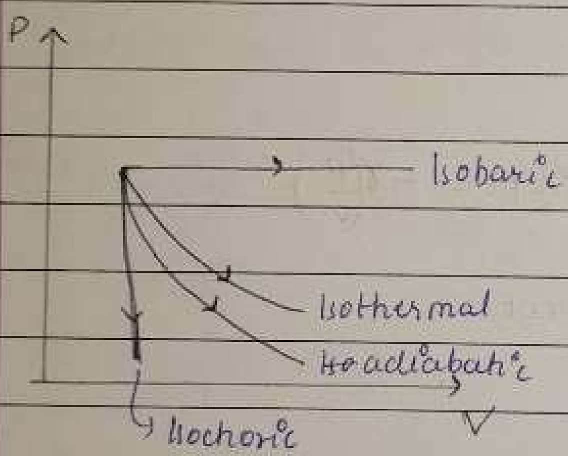


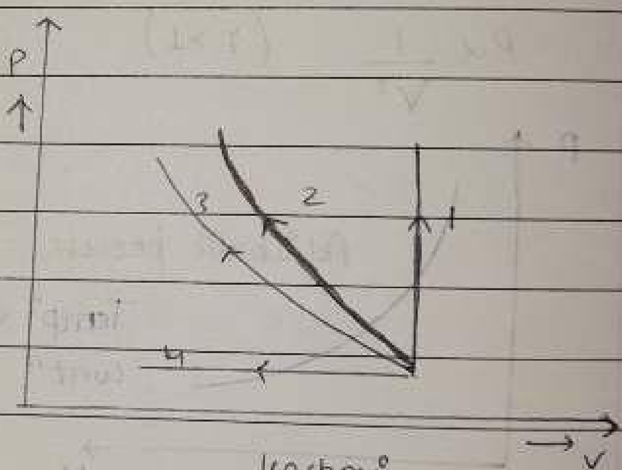


Slope for adiabatic process

Slope $= -\gamma\left(\frac{P}{V}\right)$

$\gamma_T < \gamma_D < \gamma_m$





$W_{isobaric} > W_{isothermal} > W_{adiabatic}$

$W_{isochoric} = 0$

1 – Isochoric
2 → Adiabatic
3 → Isothermal
4 → Isobaric

$W_{isobaric} < W_{isothermal} < W_{Adiabatic}$

$W_{isochoric} = 0$

Q Work done during V_1 to V_2 is maxm in
a) Isothermal
b) Adiabatic
c) Isochoric
d) Can't say.

Adiabatic Process

Compression	Expansion
V↓	V↑
$dV = -ve$	$dV = +ve$
$dU = +ve$	$dU = -ve$
$dW = -ve$	$dW = +ve$
$U \Rightarrow \uparrow$	$U \rightarrow \downarrow$
Temp$^r \rightarrow \uparrow$	Temp$^r \rightarrow \downarrow$

Q The ratio of the slopes of adiabatic and isotherm of P/V graph is.

Ans → $\frac{\gamma P / V}{P / V} = \gamma : 1$

Q In a thermodynamic process, pressure of a fixed mass of a gas is changed in such a manner that the gas molecules gives out 20J of heat and 10J of work is done on the gas. If the initial internal energy of the gas was 40J, then the final internal energy was.

Ans $d\theta = -20$

$dW = -10$

$d\theta = dW + dU$

$dU = -20 + 10 = -10 = U_f - U_i$

$U_f = -10 + 40 = 30J$ Ans

Q If Q, E, W denote respectively the heat added, change in internal energy and the work done in a closed cyclic process then which of these will follow.

Ans $\Delta E = 0$

Q A cylinder of fixed capacity 44.8 L contains 2 moles of He gas at STP, what is the amount of heat needed to raise the tempr of the gas in the cylinder by 20°C

Ans $Q = nC_v dT$ ($\because$ V = constant, $W = 0$, $\therefore dQ = dU$)

$Q = 2 \times \frac{3}{2} \times 20 \times R = 60R$

$\Rightarrow 60 \times 8.314$

498.84 J

Q A gas is compressed at a constant pressure of 50 N/m² from a volume of 10m³ to 4m³. Energy of 100 Joule is then added to gas by heating, its internal energy is.

Ans $dU = dQ - dW$

$\Rightarrow 100 - (-50 \times 6)$

$\Rightarrow 400$ J Ans

Q An ideal gas is taken through a cyclic thermodynamic process through four steps. The amounts of heat involved in these steps are $Q_1 = 5960$ J, $Q_2 = -5585$ J, $Q_3 = -2980$ J, $Q_4 = 3645$ J respectively. The corresponding works involved are $W_1 = 2200$ J, $W_2 = -825$ J, $W_3 = -1100$ J, and $W_4 = ??$

Ans $dQ = dW + dU^{\to 0}$

$\therefore Q_{total} = W_{total}$

$5960 - 5585 - 2980 + 3645 = 2200 - 825 - 1100 + W_4$

$\Rightarrow$ ~~7000 =~~ $1040 = 275 + W_4$

$W_4 = 765$ J Ans

Q (i) If heat is added to the system, its temp must always increase

(ii) If +ive work is done by the system in thermodynamic process, its volume must increase.

Which is true

Ans (ii) only.

Q If $\gamma = 2.5$ and volume is equal to $\frac{1}{8}$ times to the initial volume then pressure P' is equal to (initial pressure = P) for adiabatic.

Ans $PV^{\gamma} = \text{const}^n$

$\Rightarrow P_1V_1^{\gamma} = V_2^{\gamma}P_2$ $\quad \frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}$

$\Rightarrow$ ~~$PV^{2.5} = \left(\frac{V}{8}\right)^{2.5} P'$~~

$\frac{P_1}{P_2} = \left(\frac{V}{8V}\right)^{\gamma}$

$\Rightarrow$ ~~$PV^{5/2} = \left(\frac{V}{8}\right)^{5/2} P'$~~

$P \cdot 8^{5/2} = P'$

$\Rightarrow$ ~~$P^5\ P = \frac{1}{8^{5/2}} P'$~~

$P' = P(2)^{\frac{3\times5}{2}}$

$P' \Rightarrow P\,2^{15/2}$ Ans

~~$P' = P$~~

Q A gas is being compressed adiabatically. The specific heat of the gas during compression is.

Ans $S = \frac{dQ}{m\Delta T}$ $\quad dQ = 0$

$\therefore S = 0$

Q A cycle tyre burst suddenly. This presents an

→ Adiabatic process.

Q The adiabatic elasticity of hydrogen gas ($\gamma = 1.4$) at NTP is

Ans $\frac{-\Delta P}{\frac{\Delta V}{V}} = \beta$ $\quad PV^{\gamma} = \text{constant}$

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

$-\frac{\Delta P}{\Delta V} = \frac{\beta}{V}$

$\frac{dP}{dV} = \frac{-P\gamma}{V}$ — ②

$\frac{\Delta P}{\Delta V} = \frac{-\beta}{V}$ — ①

From ① and ②

$\frac{-P\gamma}{V} = \frac{-\beta}{V}$ $\quad \beta = P\gamma$

Answer $\Rightarrow \beta = P\gamma = 1.4 \times 1\text{atm}$

$\Rightarrow 1.4\times10^5 \frac{N}{m^2}$

Q In an isothermal reversible expansion if the volume of 96 gm of oxygen at 27°C is increased from 70 l to 140 l, then work done by the gas will be.

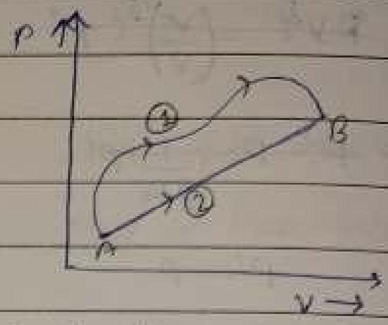
Ans $W = +2.303\, nRT \log \frac{V_2}{V_1}$

$\Rightarrow 2.303 \times \frac{96}{32} \times 300\, R \log_{10} \frac{140}{70}$

$\Rightarrow 2.303 \times 900\, R \log_{10} 2$

Q. A system is taken from state A to state B along two different paths 1 and 2. The heat absorbed and work done by the system along these two paths are Q_1, Q_2 and W_1 and W_2 respectively then.

Ans. $Q_1 - W_1 = Q_2 - W_2$



Q. Which of the following is correct for the work done in for the same initial and final state?

Ans.
a) Adiabatic > Isothermal > Isobaric
b) Adiabatic < Isobaric > Isothermal
c) Adiabatic < Isothermal > Isobaric
d) None of these ✓

GRAPH FOR ADIABATIC PROCESS

$PV^\gamma = \text{constant}$

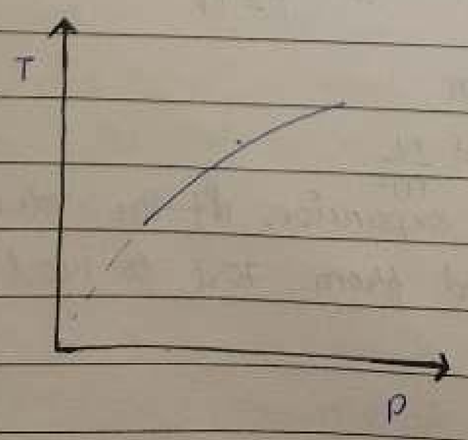
$PV = nRT$

$V = \frac{T}{P}(nR)$ → constant

∴ $P\left(\frac{T}{P}\right)^\gamma = \text{const}^n$

$P^{1-\gamma} T^\gamma = \text{const}^n$

$\boxed{T^\gamma = P^{\gamma-1}}$ → For adiabatic



$\gamma > 1$

∴ $T^\gamma = P^{\gamma-1}$

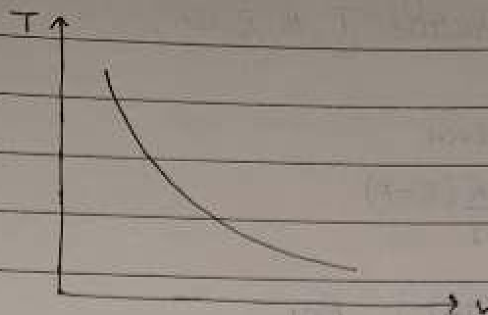
$PV^{\gamma} = const^n$

$PV = nRT$

$\left(\frac{T}{V}\right)V^{\gamma} = const^n$

$TV^{\gamma-1} = const^n$

$T = V^{1-\gamma}$



Q Work done per mol in an isothermal change is.

→ $RT \log_e \frac{V_2}{V_1}$

Q A cylinder of fixed capacity 44.8 L contains 2 moles of He gas at STP. What is the amount of heat needed to raise the tempr of gas in the cylinder by 20°C.

Ans $V = 44.8L$ $\quad dQ = dU$

$n = 2$ $\quad = \frac{1}{2}nfRdT = \frac{1}{2} \times 2 \times 3 \times 8.314 \times 20$

$\Rightarrow 498840 = 498.84$ J

Q An ideal gas at a pressure of 1 atm pressure and tempr of 27°C is compressed adiabatically until its pressure becomes 8 times the initial pressure, then the final tempr is $(\gamma = 3/2)$

Ans $PV^{\gamma} = const^n$

~~$PV = nRT$~~ $\quad P\left(\frac{T}{P}\right)^{\gamma} = \text{constant}$

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

$\therefore$ ~~$TV^{\gamma-1} = \text{constant}$~~ $\quad P^{1-\gamma}T^{\gamma} = \text{constant}$

$$\frac{P_1^{1-\gamma}}{P_2^{1-\gamma}} = \frac{T_2^{\gamma}}{T_1^{\gamma}}$$

$$\Rightarrow \left(\frac{P}{8P}\right)^{1-\gamma} = \left(\frac{T_2}{T_1}\right)^{\gamma}$$

$$\Rightarrow 8^{\gamma-1} = \frac{(T_2)^{\gamma}}{(300)^{\gamma}}$$

$$\Rightarrow 8^{\frac{1}{2}}\, 300^{3/2} = (T_2)^{3/2}$$

$$\Rightarrow 8^{\frac{1}{3}}\, 300 = T_2$$

$T_2 = 2 \times 300$

$\Rightarrow 600K$

$\Rightarrow 327$ °C

Q The amount of work done in an adiabatic expansion from temperature T to T_1 is

Ans $dw = -du$

$dw = -nC_v dt$

$dw = -\frac{nR(T_1 - T)}{\gamma - 1}$

$\Rightarrow \frac{R(T - T_1)}{\gamma - 1}$ Ans

Q An ideal gas has volume V_0 at 27°c. It is heated at constant pressure so that its volume becomes $2V_0$. The final tempr is

→ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$\Rightarrow \frac{2V_0}{V_0} = \frac{T_2}{300}$

$T_2 = 600K = 327°C$

Q The adiabatic elasticity of hydrogen gas ($\gamma = 1.4$) at NTP is

Ans $\beta = \gamma P = 1.4 \times 10^5 \ N/m^2$

POLYTROPIC PROCESS

$PV^x = const^n$

$x \rightarrow$ Polytropic constant
↳ may be anything

$$\boxed{Work(W) = \frac{nRdT}{1-x}}$$

Molar heat capacity

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

$C_m = \frac{R}{\gamma - 1} + \frac{R}{1-x}$

[$q = \Delta U + W$

$nCdT = \frac{nf}{2}RdT + \frac{nRdT}{1-x}$

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

Q If Pressure is proportional to (Volume)^2 then find molar heat capacity for mononatomic gas

Ans $C_m = \frac{R}{\gamma-1} + \frac{R}{1-x}$

$P \propto V^2$

$PV^{-2} = \text{const}^n$ $\boxed{x=-2}$

$\Rightarrow \frac{R}{\frac{5}{3}-1} + \frac{R}{1+2} = \frac{3R}{2} + \frac{R}{3} = \frac{11R}{6}$

Q During an adiabatic process the process of a gas is found to be proportional to the cube of its temp^r. The ratio of C_p/C_v for the gas is:

Ans $PV^{\gamma} = \text{constant}$

$PV = nRT$

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

$P\frac{T^{\gamma}}{P^{\gamma}} = K$

$P^{1-\gamma}T^{\gamma} = K$

$P^{\gamma-1} \propto T^{\gamma}$

$P \propto T^{\frac{\gamma}{\gamma-1}}$

Given $P \propto T^3$

$\therefore \frac{\gamma}{\gamma-1} = 3$

$\gamma = 3\gamma - 3$

$2\gamma = 3$

$\gamma = \frac{3}{2}$ **Ans**

Q A perfect gas is found to obey the relation $PV^{3/2} = K$. Considering an adiabatic process, if such a gas initially at a temp^r T, is compressed to half of its initial volume, then its final temp^r will be

Ans $PV^{3/2} = K$

$\frac{T}{V}V^{3/2} = K$

$TV^{1/2} = K$

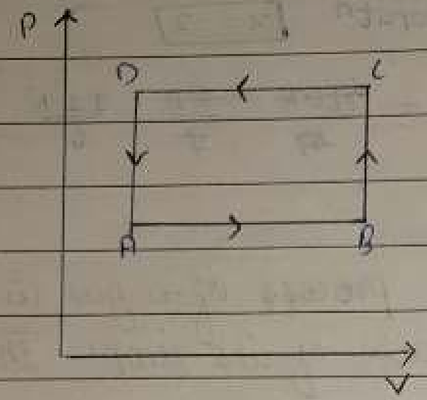
$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{1/2}$

$\frac{T}{T_2} = \left(\frac{1}{2}\right)^{1/2}$

$T_2 = \sqrt{2}\,T$ **Ans**

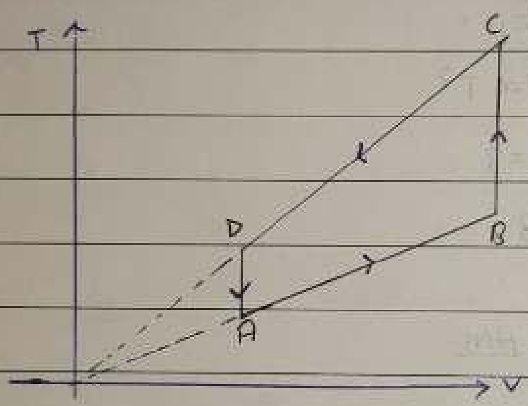
GRAPH CONVERSION

Q



Draw T-V graph

→



A → B ⇒ P → constant

↑V ∝ T↑

B → C ⇒ Volume → constⁿ

↑P ∝ T↑

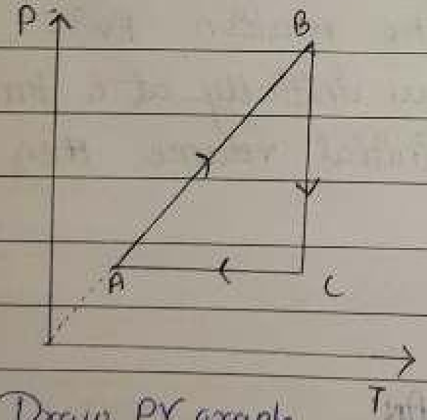
C → D ⇒ Pressure → constⁿ

↓V ∝ T↓

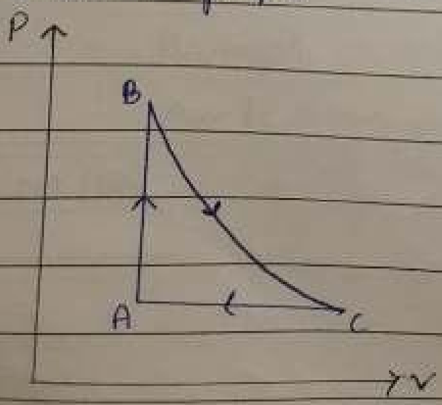
D → A ⇒ Volume constⁿ

↓P ∝ T↓

Q



Draw PV graph



A → B

P ∝ T · V → constant

B → C T = constant

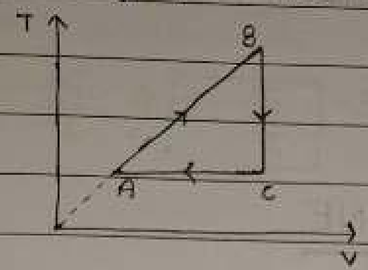
$\downarrow P \propto \frac{1}{V\uparrow}$

A → B P → constant

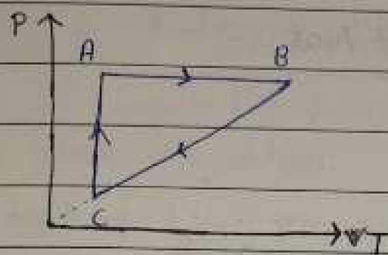
↓V ∝ T↓

Q Convert $\left(\frac{T}{V}-\frac{V}{T}\right)$ graph into (P–T) graph

Ans



→



A → B

$T \propto V$, P = constant, T ↑

B → C

V = constant, T ↓

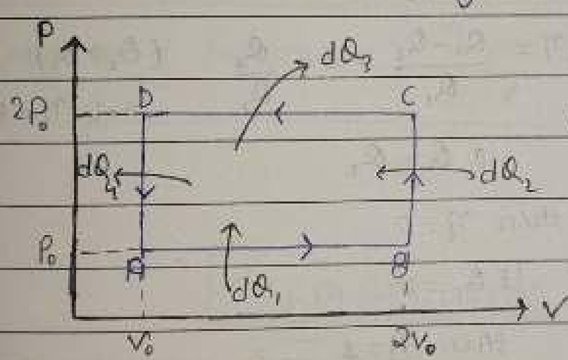
$\downarrow P \propto T \downarrow$

C → A

T = constant

PV = constant

★ Q EFFICIENCY = $\frac{\text{Work}}{\text{total heat given}}$



Work done $= P_0V_0$

The gas is monoatomic

A → B	B → C	C → D	D → A
dw = +ive	dw = 0	dw = −ive	dw = 0
du = +ive	du = +ive	du = −ive	du = −ive
∴ dQ_1 = +ive	dQ_2 = +ive	dQ_3 = −ive	dQ_4 = −ive

$T_A = \frac{P_0V_0}{nR}$ $T_B = \frac{P_0 2V_0}{nR}$ $T_C = \frac{2P_0 2V_0}{nR}$ $T_D = \frac{2P_0V_0}{nR}$

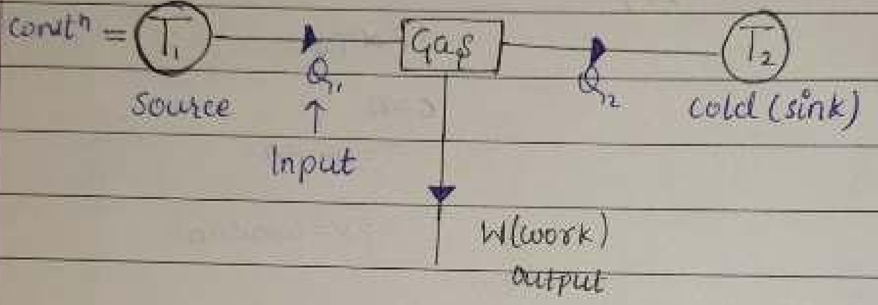
$$\text{Efficiency} = \frac{P_0V_0}{dQ_1 + dQ_2} = \frac{P_0V_0}{nC_p dT + nC_v dT} = \frac{P_0V_0}{n\frac{5}{2}R\frac{P_0V_0}{nR} + n\frac{3}{2}R\frac{2P_0V_0}{nR}} = \frac{2}{11}$$

In %age = $\frac{2}{11} \times 100 = \frac{200}{11}$ % Ans

HEAT ENGINE

Input is given in the form of heat.

→ Convert heat into work :-



η (efficiency) = $\frac{Work}{Q_1}$
↳ Dimensionless

$$\boxed{\eta = \frac{W}{Q_1} \times 100}$$

$Q_1 = W + Q_2$

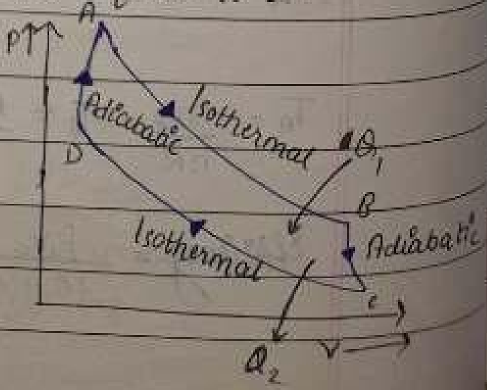
$\eta = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$ $(Q_2 > Q_1)$
↳ ∴ η = +ive

if $Q_1 = Q_2$
then $\eta = 0$
If $Q_2 = 0$
then $\eta = 1$

CARNOT ENGINE

→ Which have maxm possible efficiency but not equal to 1.

→ A → B → Isothermal
B → C → Adiabatic
C → D → Isothermal
D → A → Adiabatic



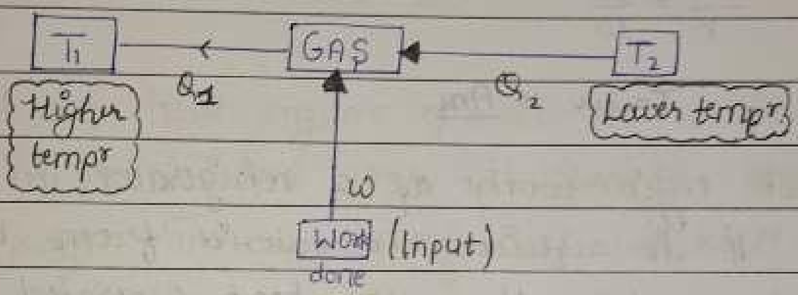
$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$$

$$\eta = 1 - \frac{Q_2}{Q_1} \Rightarrow \boxed{1 - \frac{T_2}{T_1}} \quad \text{Ans}$$

HEAT PUMP

→ Convert work (in the form of electrical energy) into heat.

→ gives heat at higher temperature

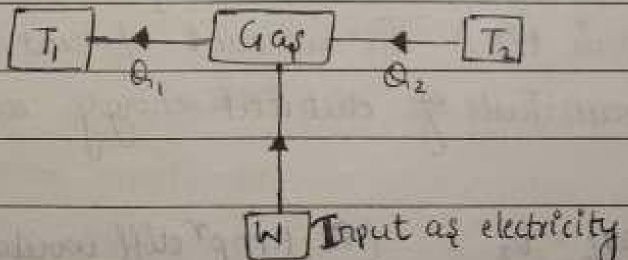


$$\boxed{\text{Coefficient of Performance} = \frac{\text{Output}}{\text{Input}} = \frac{Q_1}{W}}$$

REFRIGERATOR

→ Convert work into heat

→ Take heat from lower tempr



$$\text{Coefficient of performance} = \frac{\text{Output}}{\text{Input}} = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} = \beta$$

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

Q A Carnot engine has same efficiency between (i) 100K and 500K and (ii) TK and 900K. The value of T is..

Ans $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{100}{500} = 1 - \frac{T}{900}$

$T = \frac{900}{5} 180 = 180K$ **Ans**

Q A carnot engine has an efficiency of 40% when the sink tempr is 27°C. The source tempr is.

Ans $\eta = \frac{40}{100} = 1 - \frac{300}{T}$

$\frac{300}{T} = \frac{6}{10}$

$T = 500\ K$ **Ans**

Q A carnot engine works as a refrigerator in between 250K and 300K. If it acquires 750 calories from heat source at low temperature, then the heat generated at higher temperature (in calories) will be.

Ans $\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$

$\frac{Q_1}{750} = \frac{300}{250}$

$Q_1 = 900$ calorie

Q The temperature inside a refrigerator is t_2 °C and the room temperature is t_1°C. The amount of heat delivered to the room for each joule of electrical energy consumed ideally will be

Ans $W = 1\ J$

$\eta = \frac{t_2 + 273}{t_1 - t_2} \quad \frac{Q_2}{W}$ (As tempr diff would be same)

$\frac{(t_2+273)}{t_1 - t_2} \quad \frac{Q_1 - W}{W} = \frac{Q_1 - 1}{1}$

Q A carnot engine having an efficiency of $\frac{1}{10}$ as heat the engine is used as a refrigerator. If the work done is on the system is 10J the amount of energy absorbed from the reservoir at lower tempr is.

Ans
$$\frac{1}{10} = 1 - \frac{T_2}{T_1} \qquad Q_2 = ?$$

$$\frac{T_2}{T_1} = \frac{9}{10}$$

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

$$\beta = \frac{Q_2}{\omega} = \frac{T_2}{T_1 - T_2}$$

$$\frac{\omega}{Q_2} = \frac{T_1 - T_2}{T_2}$$

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

$$\frac{10}{Q_2} = \frac{10}{9} - 1$$

$Q_2 = 90J$ Ans

Q Two Carnot engine A and B are operated in series. The engine A receives heat from the source at temp T_1 and rejects the heat to the sink at tempr T. The second engine B receives the heat at temp T and rejects to its sink at temp T_2, for what value of T the efficiencies of the two engines equal.

Ans

$$(T_1) \xrightarrow{(A)} (T) \xrightarrow{(B)} (T_2)$$

$$\cancel{1} - \frac{T}{T_1} = \cancel{1} - \frac{T_2}{T}$$

$$T^2 = T_1 T_2$$

$$T = \sqrt{T_1 T_2} \quad \text{Ans}$$

Q A scientist says that the efficiency of his heat engine which work at source tempr 127°C and sink temp 27°C is 26%, then

Ans $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{400} = 0.25 = 25\%$

∴ It is impossible.

Q The (W/Q) of a Carnot engine is $\frac{1}{6}$, now the tempr of sink is reduced by 62°C, then this ratio becomes twice, therefore the initial tempr of the sink and source respectively is.

Ans $\frac{1}{6} = 1 - \frac{T_2}{T_1}$

$\frac{T_2}{T_1} = \frac{5}{6}$

$T_2' = T_2 - 62$

$\frac{1}{6} \times 2 = 1 - \frac{T_2 - 62}{T_1}$

$\frac{1}{3} = 1 - \frac{T_2 - 62}{T_1}$

$\frac{2}{3} = \frac{T_2}{T_1} - \frac{62}{T_1}$

$\frac{2}{3} = \frac{5}{6} - \frac{62}{T_1}$

$\frac{62}{T_1} = \frac{1}{6}$

$T_1 = 372 K = 99°C$

$T_2 = 37°C$ Ans

Q A refrigerator works between 4°C and 30°C. It is required to remove 600 calories of heat every second in order to keep the tempr of the refrigerated space constant. The power required is.

Ans $\beta = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$

$\beta \quad \frac{600 \times 4.2}{W} = \frac{277}{303 - 277}$

$W = 236.5 J$

$P = \frac{W}{t} = \frac{236.5}{1} = 236.5 W$

Shivalal

$$\frac{(t_2+273)}{t_1-t_2} 1 = Q_1$$

$$Q_1 = \frac{t_1+273}{t_1-t_2}$$

Q If the system takes 100 cal heat, releases 80 cal to sink. If source temp is 127°C find the sink temp.

Ans $\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$

$$\frac{100}{80} = \frac{400}{T_2}$$

$T_2 = 320K = 47°C$ Ans

Q An ideal gas heat engine operates in a Carnot engine between 227°C and 127°C. It absorbs 6 Kcal at the higher tempr. The amount of heat (in kcal) converted into work is equal to.

Ans $\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$

$\frac{6}{Q_2} = \frac{500}{400}$ $Q_2 = 4.8$ kcal

$Q_1 = Q_2 + W$

$W = Q_1 - Q_2 = 1.2$ Kcal

Q The efficiency of Carnot engine is 50% and temp of sink is 500K. If temp of source is kept constant and its efficiency is raised to 60% then the required tempr of sink will be.

Ans $\frac{1}{2} = 1 - \frac{500}{T_1}$ $\frac{6}{10} = 1 - \frac{T}{1000}$

$\frac{500}{T_1} = \frac{1}{2}$ $T_1 = 1000$ $\frac{4}{10} = \frac{T}{1000}$

$T = 400K$ Ans

Q A carnot engine whose sink is at 300K has an efficiency of 40%. By how much should be the temperature of source be increased so as to increase its ~~temperature~~ by 50% of original efficiency?

Ans $\frac{40}{100} = 1 - \frac{300}{T_1}$

$\frac{6}{10} = \frac{300}{T_1}$

$T_1 = 500\ K$

Now efficiency is increased by

$50\% = 0.4 + 0.4 \times \frac{50}{100} = 0.6$

$\therefore \frac{6}{10} = 1 - \frac{300}{T_1}$

$\frac{4}{10} = \frac{300}{T_1}$

$T_1' = 750$

$T_1' - T_1 = 250\ K$ **Ans**

KINETIC THEORY OF GASES

- Kinetic theory of gases is based on the molecular picture of matter. According to which.

1) A given amount of gas is a mixture of very large number of identical molecules of the order of Avogadro's number.

2) The molecules are moving randomly in all directly.

3) At ordinary tempr and pressure, the size of the molecules is very small as compared to the distances between them. Thus, the interaction between them is negligible. Hence, they move according to Newton's law of attraction

4) The molecules do not exert force of attraction or repulsion on each other, except during collisions.

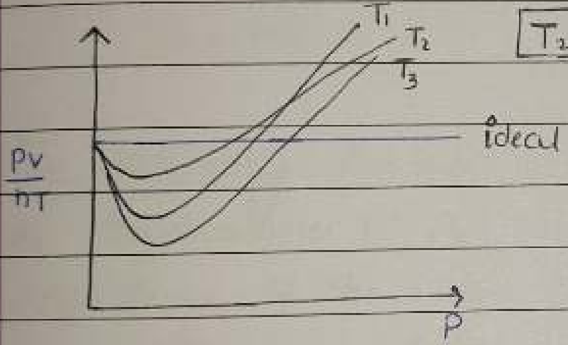
5) The collisions of molecules against each other or with

the walls of the container are perfectly elastic. Such that the momentum and the K.E. of the molecules are conserved during collision, though their velocities change.

Q A given sample of an ideal gas occupies a volume V at a pressure P and absolute temperature T. The mass of each molecule of the gas is m. Which of the following gives the density of gas?

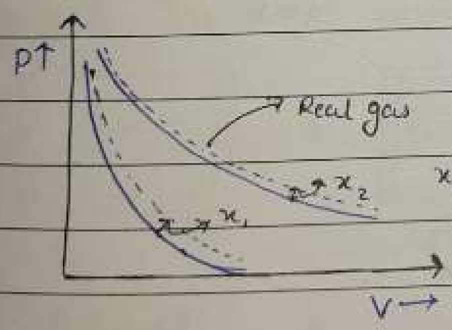
Ans $d = \frac{PM}{RT} = \frac{PmN_A}{RT} = \frac{Pm}{KT}$ $\left(\frac{R}{N_A} = K\right)$

Q A real gas behaves as an ideal gas at
→ Very low pressure and high temp^{r}



$T_2 > T_1 > T_3$ Ans

Graph which is near to ideal graph has higher temperature since real gas behaves as ideal gas at higher temp.



$x_1 > x_2$ As temp ↑ difference b/w isothermal curve of Real gas & ideal gas shortens.

Q A gas is filled in a vessel at 27°C. To what temp^{r} should it be heated in order that $\frac{1}{3}$rd of the gas may escape out.

Ans $\frac{2n_i}{3} = n_f$

$P = const^n$ (as vessel is open)

$V = const^n$

Open vessel ⇒ P, V = constant

Closed vessel ⇒ V constant, n constant

$PV = nRT$

$n_1T_1 = n_2T_2$

$n_i\, 300 = \frac{2}{3} n_i\, T_2$

$T_2 = 450K$

Q The percentage change in the pressure of a given mass of a gas filled in a container at constant temperature is 100%. Calculate the %age change in its volume.

Ans $P_i = P$

$P_f = 2P$

As $PV = const^n$

$\therefore V_f = \frac{V_i}{2}$ $\therefore$ 50% change

Q A gas is filled in a vessel at a certain tempr and at a pressure of 80 cm of mercury. At the same temp, more gas is filled in the vessel so that its mass increases by 60%. Determine the resultant pressure in the vessel.

Ans T, V = constant

$PV = nRT$

$P \propto n$

$n_1 = n$ $P_1 = 80\rho g$

$n_2 = 1.6n$ $P_2 = x\rho g$

$\frac{P_1}{n_1} = \frac{P_2}{n_2}$

$\frac{80\rho g}{n} = \frac{x\rho g}{1.6n}$

$x = 128$ cm of Hg

Q Boyle's law is obeyed by

→ Ideal gas of constant mass and tempr

Q For an ideal gas the fractional change in its volume per degree rise in temperature at constant pressure is equal to (in terms of T, where T is absolute temperature of gas)

MR trick	My method
$V \propto T$	$V_t = V_0 + \frac{V_0 t}{273 = T}$
$\frac{\Delta V}{V} = \frac{\Delta T}{T}$	$\frac{V_t - V_0}{V_0 t} = \frac{1}{T}$
$\frac{\Delta V}{V \Delta T} = \boxed{T^{-1}}$	$\frac{V_t - V_0}{V_0 t} = \boxed{T^{-1}}$

Ans

Q The rise in temp^r of a given mass of an ideal gas at constant pressure and at temp^r 27°C to double its volume is

Ans $V \propto T$

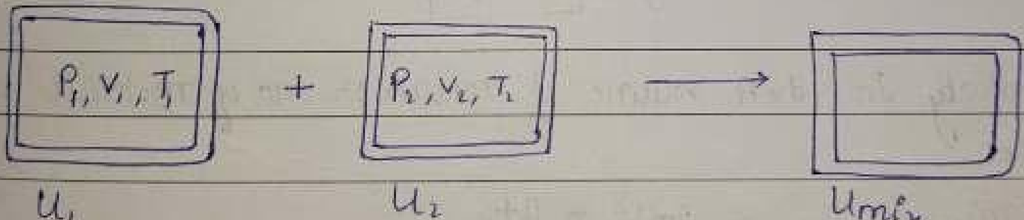
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $\Delta T = 300K = 300°C$ ~~$\Rightarrow 27°C$~~

$\frac{V}{300} = \frac{2V}{T_2}$

$T_2 = 600K$

Q Two thermally insulated vessels 1 and 2 are filled with air at temperatures (T_1, T_2), volume (V_1, V_2) and pressure (P_1, P_2) respectively. If the valve joining the two vessels is opened, the temp^r inside the vessel at equilibrium will be.

Ans



$\frac{f}{2} n_1 R T_1 + \frac{f}{2} n_2 R T_2 = \frac{f}{2}(n_1 + n_2) R\, T_{mix}$

$n_1 T_1 + n_2 T_2 = (n_1 + n_2) T_{mix}$

$\frac{P_1 V_1}{R T_1} T_1 + \frac{P_2 V_2}{R T_2} T_2 = \left(\frac{P_1 V_1}{R T_1} + \frac{P_2 V_2}{R T_2}\right) T_{mix}$

$\Rightarrow \frac{P_1 V_1 + P_2 V_2}{\frac{P_1 V_1}{T_1} + \frac{P_2 V_2}{T_2}} = T_{mix}$ Ans

Q If E is the energy density of an ideal gas, then the pressure of the ideal gas is.

Ans $KE = \frac{3}{2}PV$

$\frac{K.E}{V} = E$

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

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

Q A gas at a pressure P_0 is contained in a vessel, if the masses of all the molecules are halved and their velocities is doubled, then the resulting pressure P will be

Ans $P = \frac{1}{3}mn\bar{v}^2$

$m' = \frac{m}{2}$

$\bar{v}' = 2v$

$P = \frac{1}{3}\frac{m}{2}4\bar{v}^2 = 2P_0$ Ans

Q Four molecules of a gas have speeds 1, 2, 3 and 4 km/s. The value of the rms speed of the gas molecules is.

Ans $V_{rms} \rightarrow$ Root mean square speed

Root mean square velocity is '0' for all gases

V_{Avg} = Avg velocity is '0' for every gas

Due to random motion.

$\therefore V_{rms} = \sqrt{\frac{1^2+(2)^2+(4)^2+(3)^2}{4}} = \sqrt{\frac{15}{2}}$ Km/s Ans

$P = \frac{1}{3}mn\bar{v}^2$

$3P = \frac{N m}{V}\bar{v}^2$

$3P = \frac{M}{V}\bar{v}^2$

$3P = \rho\bar{v}^2$

↳ it is the mean of square of the velocity of gas molecules

$\sqrt{\frac{3P}{\rho}} = \sqrt{\bar{v}^2}$

↳ Root of mean of square of the velocity of gas molecules

$V_{rms} = \sqrt{\frac{3P}{\rho}}$

$V_{rms} = \sqrt{\frac{3RT}{M}}$ Ans

$\therefore P_{avg} = 2mnv_x^2 \times \frac{1}{2}$ (Here $\frac{1}{2}$ is multiplied to find average force)

$P_{avg} = mnv_x^2$

Also since the particle is having velocity in x, y, z axis

$\therefore V = v_x\hat{i} + v_y\hat{j} + v_z\hat{k}$

$V^2 = v_x^2 + v_y^2 + v_z^2$

Now if we consider $v_x = v_y = v_z$

then $v^2 = 3v_x^2$

$v_x^2 = \frac{v^2}{3}$

$\therefore \boxed{P_{avg} = \frac{1}{3} mn_0 \bar{v}^2 \text{ Ans}}$ $n_0 \rightarrow$ no. density

KINETIC INTERPRETATION OF TEMPERATURE

The pressure exerted by an ideal gas is given by

$P = \frac{1}{3} n_0 m \bar{v}^2$

$P = \frac{1}{3} \frac{N}{V} m \bar{v}^2$

$PV = \frac{1}{3} N m \bar{v}^2$

KE of 1 mole

$N = N_A$

$PV = \frac{1}{3} \frac{N_A m \bar{v}^2 \times 2}{\times 2} = \frac{1}{3 \times 2} M\bar{v}^2 \times 2 = \frac{1}{3} KE \times 2$

$\boxed{K.E = \frac{3}{2} P.V}$ → Ratta. (Not for 1 mole but is universally applied)

Energy density ← $\boxed{\frac{K.E}{V} = \frac{3P}{2}}$ → Because Pressure is due to translational degree of freedom.

$K.E = \frac{3}{2} nRT$ (for 1 mole) $= \frac{3}{2} RT$

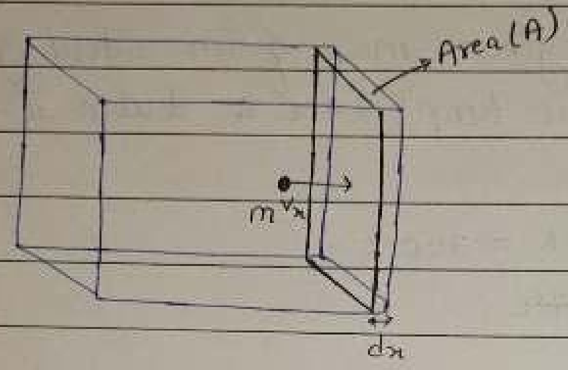
$K.E = \frac{3}{2} N_A K_B T$

$\frac{K.E}{N_A} = \frac{3}{2} K_B T$

PRESSURE OF AN IDEAL GAS.

$$\boxed{P = \frac{1}{3} m n_0 \bar{v}^2}$$

→ n_0: no. of molecules / volume



Let a molecule of mass m having a velocity v_x in x axis collides elastically with the walls of the container then change in momentum of that molecules of gas is

→ $(dp) = 2m v_x$

↳ 1 mole. change in momentum

Now if in volume V of container there are N molecules of gas then its number density $\boxed{n_0 = \frac{N}{V}}$

Similarly in $dx A$ volume of container no. of molecule will be $n\, dx A$

$\therefore (dp)_{\text{total molecules in } A dx \text{ volume of container}} = 2m v_x n A dx$

$$\frac{dp}{dt} = 2m v_x n A \frac{dx}{dt}$$

$$F = 2m v_x n A v_x$$

$$\frac{F}{A} = 2m v_x^2 n$$

$$P = 2m v_x^2 n$$

Since it is not necessary all at time all the gas molecules are colliding with walls of the container

Q The mean rotational K.E. of diatomic molecule at tempr T is.

Ans $K.E = \frac{1}{2} k_B T$

$K.E = \frac{1}{2} f k_B T$

$f = 2$

$k_B T$ **Ans**

Q If the pressure remains constant, find the tempr at which root mean square speed of a gas is half of its value at 27°C.

Ans V_{rms} at 27°C $= \sqrt{\frac{3R \times 300}{M}}$

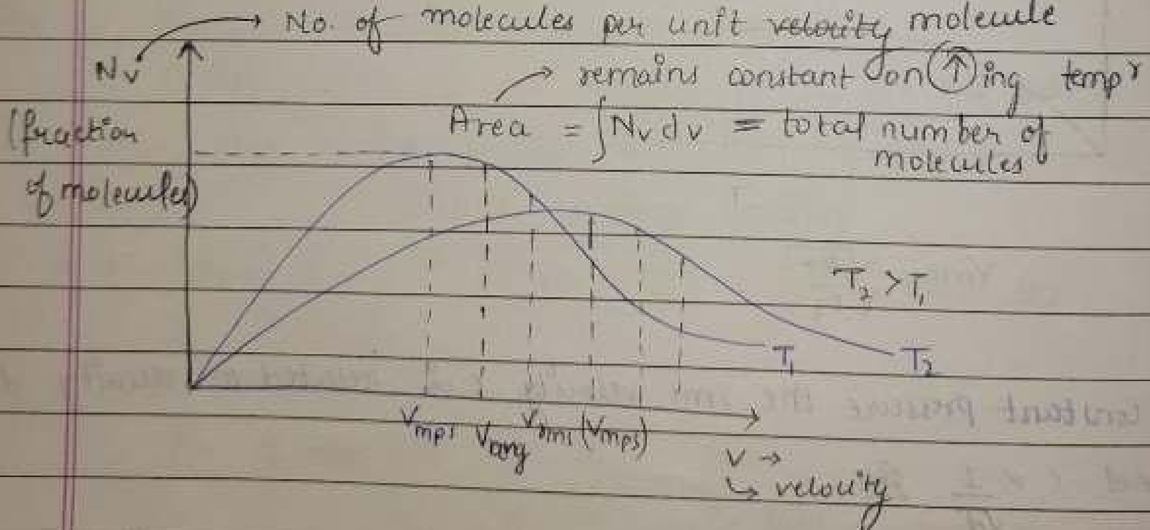
Now $\left(\frac{1}{2}\sqrt{\frac{3R \times 300}{M}}\right)^2 = \left(\sqrt{\frac{3R}{M}T}\right)^2$

$\frac{1}{4} \times 300 = T$

$T = 75\,K$

$= 75 - 273 = -198°C$ **Ans**

MAXWELL BOLTZMAN LAW



MEAN FREE PATH

Avg distn b/w two collision

↳ Avg distn a molecule can travel before colliding.

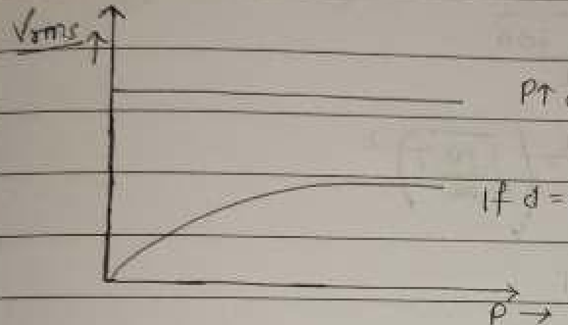
$$V_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_BT}{m}}$$ (m → Mass of one molecule)

$$V_{Avg} = \sqrt{\frac{8P}{\pi\rho}} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8k_BT}{\pi m}}$$

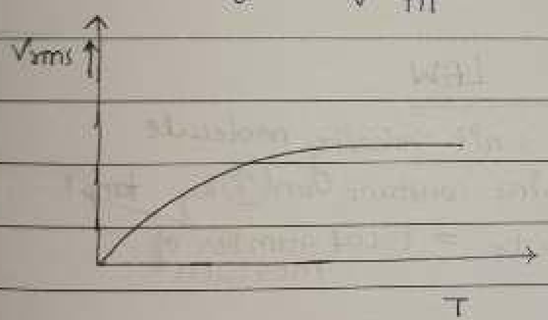
$$V_{mps} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2P}{\rho}} = \sqrt{\frac{2k_BT}{m}}$$

$$V_{mps} : V_{Avg} : V_{rms} = \sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3}$$

$$\boxed{V_{mps} > V_{Avg} > V_{rms}}$$



$$V = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3PV}{m}} \quad (T = const^n)$$



$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

Q At constant pressure the rms velocity c is related to density d as

Ans ~~d ∝~~ $c \propto \frac{1}{\sqrt{d}}$ Ans

Q The rms speed of the molecules of enclosed gas is v. What will be the rms speed if pressure is doubled keeping tempr same?

→ v $\quad V_{rms} = \sqrt{\frac{3RT}{m}}$

$$\lambda = \frac{1}{\sqrt{2}\, n_0 \pi d^2} = \frac{1}{\sqrt{2}\frac{N}{V}\pi d^2} = \frac{nRT}{\sqrt{2} N \pi d^2 P} =$$

(n_0 → no. density)

$\lambda \propto$ temp^r

$\lambda \propto \frac{1}{\text{Pressure}}$

$\lambda = \frac{m}{\sqrt{2}\pi d^2 \rho}$ (m = mass of each gas molecule) (ρ = density of gas)

$\lambda = \frac{k_B T}{\sqrt{2}\pi d^2 P}$ [For 1 mole]

Q The mean free path of molecules of a gas (radius r) is inversely proportional to.

Ans $\lambda \propto \frac{1}{d^2} \Rightarrow \lambda \propto \frac{1}{r^2}$