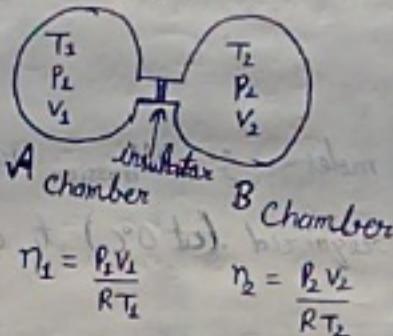


Thermodynamics - I

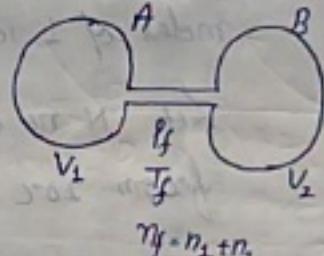
Exercise - 0-II

Solution - I -

Two insulating chamber of gas at T_1 and T_2



⇒ Remove insulator



Insulating Chamber so

$$q_{\text{net}} = 0$$

$$w_{\text{net}} = 0$$

(No work done given)

so According FLOT

$$\Delta U_{\text{net}} = q_{\text{net}} + w_{\text{net}} \Rightarrow \Delta U_{\text{net}} = 0$$

$$\Rightarrow \Delta U_A + \Delta U_B = 0$$

$$\Rightarrow n_1 C_m \Delta T_A + n_2 C_m \Delta T_B = 0$$

$$\Rightarrow n_1 (T_f - T_1) + n_2 (T_f - T_2) = 0$$

$$\Rightarrow T_f = \frac{n_1 T_1 + n_2 T_2}{n_1 + n_2}$$

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

Solution-2

$$\text{moles of } \text{H}_2\text{O(l)} = \frac{500}{18} \text{ moles}$$

$$C_m(\text{H}_2\text{O(l)}) = 75.6 \text{ J/mole K}$$

$\text{H}_2\text{O(l)}$ loss heat and decreasing its temperature decreases from 20°C to 0°C

mass of one ice cube = 9 gm

$$\text{moles of 1 ice cube} = \frac{9}{18} \text{ moles} ; \Delta H_{\text{fusion}}(\text{ice}) = 6 \text{ kJ/mole}$$

Let N no of ice cube required (at 0°C) to convert $\text{H}_2\text{O(l)}$ from 20°C to 0°C

So Heat gain by ice cube (0°C ice to 0°C $\text{H}_2\text{O(l)}$) = Heat loss by $\text{H}_2\text{O(l)}$

$$\Rightarrow N \times n \times \Delta H_{\text{fusion}} = n \cdot C_m(\text{H}_2\text{O(l)}) \cdot \Delta T \quad [20^\circ\text{C} \text{ H}_2\text{O(l)} \text{ to } 0^\circ\text{C}]$$

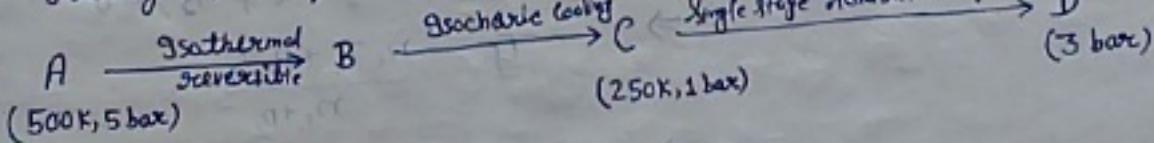
$$\Rightarrow N \times \frac{9}{18} \times 6 \text{ kJ/mole K} = \frac{500}{18} \times 75.6 \text{ J/mole K} (20-0)$$

$$\Rightarrow N = \frac{500 \times 75.6 \times 20 \times 10^3}{9 \times 6 \times 1000} = 14$$

$$\Rightarrow \boxed{N=14}$$

Solution-3

Ideal gas; no of moles $n=2$ moles; $C_v = \frac{3}{2} R$



(A) Path AB is isothermal so $T_B = 500\text{K}$

$$\text{Path BC is isochoric so } P \propto T \Rightarrow \frac{P_B}{P_C} = \frac{T_B}{T_C} \Rightarrow \frac{P_B}{1} = \frac{500}{250} \Rightarrow \boxed{P_B = 2 \text{ bar}}$$

(B) CD path is Adiabatic irreversible (single stage)

$$\text{So } \omega_{CD} = \Delta U_{CD} \quad (\dot{Q}_{CD} = 0)$$

$$\Rightarrow -P_{\text{ext}}(V_D - V_C) = n C_{vm} \Delta T$$

$$\Rightarrow -P_{\text{ext}} \left(\frac{nRT_D}{P_D} - \frac{nRT_C}{P_C} \right) = n - \frac{3}{2} R (T_D - T_C)$$

$$\Rightarrow -3 \left(\frac{T_D}{\frac{3}{2}} - \frac{250}{1} \right) = \frac{3}{2} (T_D - 250)$$

$$\Rightarrow -T_D + 750 = \frac{3}{2} T_D - 375$$

$$\Rightarrow \frac{5T_D}{2} = 1125 = 1.25$$

$$\Rightarrow T_D = 450 \text{ K}$$

$$(C) \Delta H_{CD} = n C_{pm} \Delta T_{CD}$$

$$= 2 \times \frac{5}{2} R (T_D - T_C)$$

$$= \frac{10R}{2} (450 - 250) = 1000 R$$

$$\boxed{\Delta H_{CD} = 1000 R}$$

$$(D) \Delta U_{BC} = n C_{vm} \Delta T_{BC}$$

$$= 2 \times \frac{3}{2} R (T_C - T_B)$$

$$= 2 \times \frac{3}{2} R (250 - 500)$$

$$= -750 R$$

$$\boxed{\Delta U_{BC} = -750 R}$$

Solution-4-

For real gas $(2 \text{ bar}, 40 \text{ lit}, 300\text{K}) \xrightarrow[\text{irreversible}]{\text{Adiabatic}} (4 \text{ bar}, 30 \text{ lit}, 300\text{K})$

$$(T_1 - T_2) \frac{\partial \Sigma \mu}{\partial T} = \left(\frac{\partial \mu_{20}}{\partial T} - \frac{\partial \mu_{40}}{\partial T} \right) \text{against } P_{\text{ext}} = 4 \text{ bar}$$

$$w_{\text{gas}} = -P_{\text{ext}} \Delta V$$
$$(273 - 30) \frac{\partial \Sigma \mu}{\partial T} = -4 \text{ bar} \cdot (30 \text{ lit} - 40 \text{ lit})$$

$$= +40 \text{ bar-lit}$$
$$273 - 30 \frac{\partial \Sigma \mu}{\partial T} = 4000 \text{ J} \quad (1 \text{ bar-lit} = 100 \text{ J})$$

Now $\Delta U = w_{\text{gas}}$ ($w_{\text{gas}} = 0$; Adiabatic)
 $\Rightarrow \Delta U = 4000 \text{ J}$

Enthalpy change

$$\Delta H = \Delta U + (P_2 V_2 - P_1 V_1)$$

$$= 4000 \text{ J} + (4 \text{ bar} \times 30 \text{ lit} - 2 \text{ bar} \times 40 \text{ lit})$$

$$= 4000 \text{ J} + (120 - 80) \text{ lit bar}$$

$$= 4000 \text{ J} + 40 \times 100 \text{ J}$$

$$\boxed{\Delta H = 8000 \text{ J}} \quad \boxed{4000 \text{ J} = \Delta U}$$

Solution-5-

(A) Enthalpy $H = f(P, V, T, n)$; for a given no. of moles P can be replaced in form of V, T so Enthalpy can be written as $H = f(V, T)$ [No physical and chemical change]

(B) Enthalpy $H = U + PV$ where U = Internal energy and absolute value of U can not be determined as it is sum of all type of energy.

So absolute value of H can not be also determined

(C) Isothermal expansion of ideal gas against vacuum

$$\Delta T = 0 ; \Delta U = 0$$

$$P_{ext} = 0 ; W = 0$$

$$\Delta S = Q + W$$

$$Q = 0$$

(D) At constant temperature of ideal gas

$$V \propto T$$

If V decreases, T Decreases (Compression)

Solution-6-

(A) Adiabatic expansion $Q = 0$; $\Delta U = Q + W$

$$\Rightarrow W = \Delta U \quad [\text{So } W \neq \Delta H]$$

(B) For adiabatic process

$$W_{\text{reversible}} = \Delta U = n C_{vm} \Delta T \quad (\text{For ideal gas})$$

or
irreversible

If ΔT will be same then magnitude of W will be same

(C) Adiabatic reversible expansion

$$T V^{\gamma-1} = K \Rightarrow T = \frac{1}{V^{\gamma-1}} \quad [\gamma > 1]$$

$V \uparrow, T \downarrow$

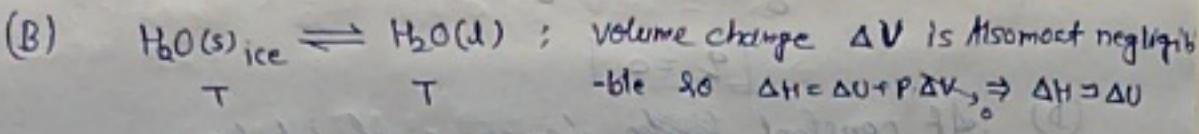
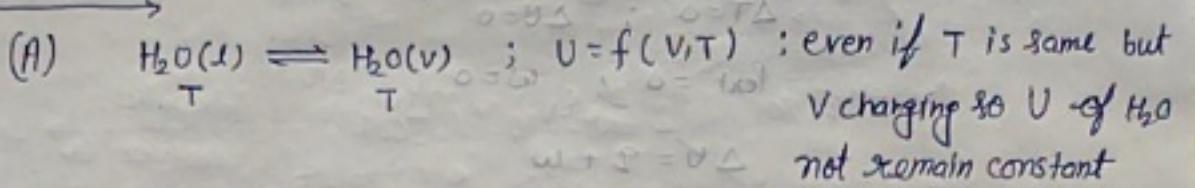
(D) For same change in volume far expansion $[\Delta U = n C_{vm} \Delta T]$

$$\Delta T_{\text{Isobaric}} > \Delta T_{\text{Adiabatic}} \quad \text{So} \quad \Delta U_{\text{Isobaric}} > \Delta U_{\text{Adiabatic}}$$

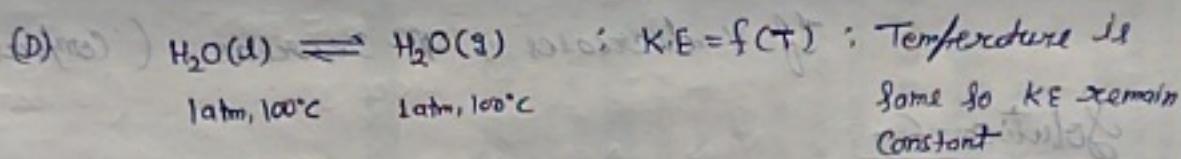
$$\text{For Isobaric} \quad T_f = T_i \left(\frac{V_2}{V_1} \right)^{\frac{1}{\gamma}} ; P = \text{constant} ; \Delta T > 0 \quad [\text{far expansion}]$$

$$\text{For Adiabatic} \quad T_f = T_i \left(\frac{V_2}{V_1} \right)^{1/\gamma} ; [T_i V_1^{\gamma-1} = T_2 V_2^{\gamma-1}] ; \Delta T < 0 \quad [\text{far expansion}]$$

Solution-7



(C) $C_m = f(T) \text{ ie } C_m(T) = a + bT + cT^2 + \dots$



Solution-8

For ideal gas, volume doubled From, $P, V, T \quad KE = E$ (let)

(A) Isothermal expansion

$$T_f = T = \text{Constant}$$

$$\text{Kinetic energy } [E_1 = E] \quad (\text{as } KE = f(T))$$

(B) Adiabatic expansion

T_f decreases from $T \quad [T_f < T \quad \text{Adiabatic expansion}]$

$$\text{so Kinetic Energy } [E_2 < E]$$

(C) Insulated ($\tau=0$) ; free expansion ($\omega=0$)

$$\text{so } \Delta U = \tau' + \omega' \Rightarrow \Delta U = 0 \Rightarrow nC_m \Delta T = 0$$

$$[T_f = T] \Rightarrow \Delta T = 0 \text{ so } T_f = T$$

(D) Isobaric expansion

$$P \text{ constant} \Rightarrow V \propto T$$

$$V \uparrow, T \uparrow \text{ so } T_f > T \text{ so Kinetic energy } [E_4 > E]$$

$$\text{so } [E_4 > E_1 = E_3 > E_2]$$

Solution-9 -

Statement-1 Enthalpy of an ideal gas given as

$$\Delta H = nC_{pm} \Delta T ; \text{ At constant temperature}$$

$$\Delta T = 0, \text{ so } \Delta H = 0 \quad (\text{True})$$

Statement-2 Enthalpy of an ideal gas is function of
 $H = f(P, V, T)$ for given amount of gas
So $H = f(P, T)$ only is (False)

Solution-10 -

Statement-1 Due to adiabatic expansion, the temperature of an ideal gas always decreases (false)

Because in adiabatic free expansion

$$\omega = 0$$

$$q = 0$$

$$\Rightarrow \Delta U = q + \omega$$

$$\Rightarrow \Delta U = 0$$

$$\Rightarrow nC_{vm} \Delta T = 0$$

$$\Rightarrow \Delta T = 0 \Rightarrow \boxed{T_1 = T_2}$$

In above case temperature remains same also.

Statement-2 For an Adiabatic process $\Delta U = \omega$ (True)

Adiabatic $q = 0$

$$\Delta U = q + \omega \quad (\text{from FLOT})$$

$$\Delta U = \omega$$

Match the column

Solution - 11 \Rightarrow Work in Any process given as $\omega = - \int_{V_1}^{V_2} P_{ext} dV$

(A) Reversible Isothermal process for Ideal gas

$$T = \text{Constant} ; P \cdot V = \text{Constant}$$

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

$$W_{\text{Isothermal}}^{\text{(rev)}} = - \int_{V_1}^{V_2} P_{ext} dV \quad [P_{ext} = P_{\text{gas}} = nRT/V] ; W_{\text{Isothermal}}^{\text{(irreversible)}} = -nRT \ln \left(\frac{V_2}{V_1} \right)$$

$$\Rightarrow W_{\text{Isothermal}}^{\text{(irreversible)}} = -nRT \ln \left(\frac{P_1}{P_2} \right) \\ = 2.303 nRT \log_{10} \left(\frac{P_2}{P_1} \right)$$

A \rightarrow P, R, S

(B) Reversible Adiabatic process : $q = 0$

$$\omega = \Delta U = nC_v m \Delta T$$

$$\omega = nC_v m (T_2 - T_1)$$

Also

$$\omega = - \int_{V_1}^{V_2} P_{ext} dV \quad (P_{ext} = P_{\text{gas}})$$

B \rightarrow Q, S

(C) Irreversible Adiabatic process : $q = 0$

$$\omega = \Delta U = nC_v m \Delta T$$

$$\omega = nC_v m (T_2 - T_1)$$

Also $\omega = - \int_{V_1}^{V_2} P_{ext} dV$

C \rightarrow Q, S

(D) Irreversible Isothermal process

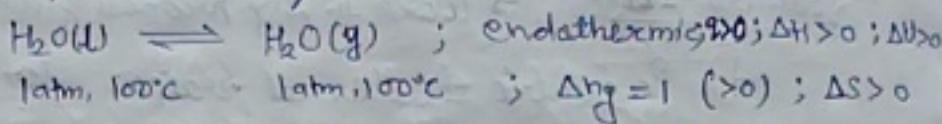
$$T = \text{Constant}$$

$$\omega = - \int_{V_1}^{V_2} P_{ext} dV$$

D \rightarrow S

Solution - 12

(A) Isothermal vapourisation of H_2O at $100^\circ C$ & 1 atm ; $\Delta T = 0$



Normal Boiling Point $\Delta G = 0$ at equilibrium.

$$\Delta G = 0$$

$$\text{Adiab.} \quad \Delta V > 0 \\ \omega < 0$$

$A \rightarrow P$

(B) Isothermal reversible expansion of an ideal gas

$$\Delta T = 0$$

$$\Delta U = (nC_{Vm} \Delta T)_{\text{for ideal gas}} = 0$$

$$\Delta H = (nC_{Vm} \Delta T)_{\text{for ideal gas}} = 0$$

$$\Delta U = q + \omega$$

$$q = -\omega = -nRT \ln\left(\frac{V_2}{V_1}\right)$$

$$V_2 > V_1 \text{ (expansion)}$$

$$\omega < 0$$

$$q > 0$$

$B \rightarrow P, Q, R$

(C) Adiabatic free expansion of ideal gas ; $q = 0$ (Adiabatic)
 $\omega = 0$ (free expansion)

$$\Delta U = q + \omega$$

$$\Delta U = 0 \Rightarrow (nC_{Vm} \Delta T)_{\text{ideal gas}} = 0 \\ \Rightarrow \Delta T = 0$$

$$\Delta H = 0 \Rightarrow nC_{Vm} \Delta T = 0$$

$C \rightarrow P, Q, R, S, T$

(D) Isochoric heating of an ideal gas ; $\omega = 0$ ($\Delta V = 0$) isochoric)
 $q > 0$ (Heating)

$$\Delta T > 0 ; \Delta U > 0 ; \Delta H > 0$$

$D - T$

MATCH THE LIST

(ii) 5, 4, 1, 2, 3

Solution - 13 →

Assuming for ideal gas

$$(P) \text{ Isothermal process (reversible)} \Rightarrow [PV = K] ; PV_1 = PV_2$$

$$T = \text{constant} ; \Delta T_{\text{co}} \Rightarrow \Delta U_{\text{co}} ; W = - \int_{V_1}^{V_2} P_{\text{ext}} dV = -nRT \ln\left(\frac{V_2}{V_1}\right)$$

$$\Rightarrow W = +2.303 nRT \log_{10}\left(\frac{P_1}{P_2}\right)$$

$$\text{So } q = -W = 2.303 nRT \log_{10}\left(\frac{P_1}{P_2}\right)$$

[P → 1]

$$(Q) \text{ Adiabatic process (reversible)} ; q = 0 ; [PV^\gamma = K]$$

[Q → 2]

$$(R) \text{ Isochoric process} ; V = \text{constant} \Rightarrow \Delta V = 0 \Rightarrow W = 0$$

Area under p-V curve = 0

$$q = \Delta U = nC_V m \Delta T$$

[R → 4]

$$(S) \text{ Isathermal irreversible process} ; T = \text{constant} ; \Delta T = 0$$

$$PV = \text{constant} ; \Delta U = 0 ; \Delta H = 0 ; q = -W$$

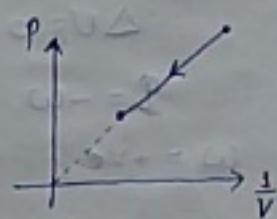
$$W = - \int_{V_1}^{V_2} P_{\text{ext}} dV = - P_{\text{ext}} (V_2 - V_1)$$

$$\text{So } q = -W = P_{\text{ext}} (V_2 - V_1)$$

[S → 3]

Solution - 14

(P) In fig. (i)



[P → 1, 4, 5]

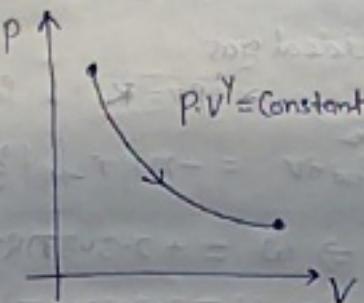
$$P \propto \frac{1}{V} \Rightarrow PV = \text{constant}$$

Isothermal $\Delta T = 0$

$$\Delta U = nC_V m \Delta T = 0$$

In process $\frac{1}{V}$ decreasing
 $\Rightarrow V$ increasing (Expansion)
 \Rightarrow Work done by system
 \Rightarrow Heat absorbed by system ($q = -W$)

(Q) In fig (ii)

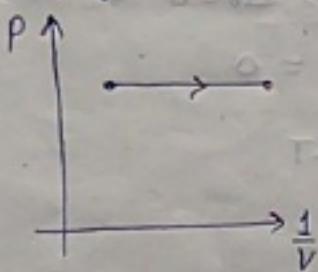


process following Adiabatic reversible path $\Rightarrow \delta Q = 0$ $\Delta U = \omega$

process following expansion (V -Increasing)
so work done by system? $\omega < 0$ ($\Delta V > 0$)

$$\boxed{Q \rightarrow U}$$

(R) In fig (iii)



$P = \text{Constant}$ (\Rightarrow Isobaric path)

$\frac{1}{V}$ Increasing ; $V \rightarrow \text{Decreasing}$

$$\Delta V < 0$$

 $\omega > 0$

Work done on system.

$$\omega = -nR\Delta T > 0$$

Isobaric
 $\Delta T < 0$

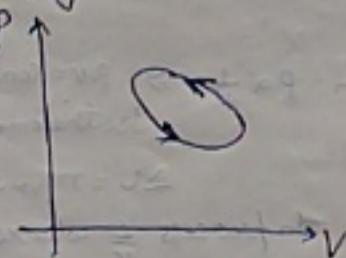
$$Q = nC_m \Delta T$$

 < 0

Heat rejected by system.

$$\boxed{R \rightarrow 2,3}$$

(S) In fig (iv)



Cyclic process

$\Delta U = 0$ (State function)

$$Q = -\omega$$

$\omega = +ve$ (Anti-clock wise)

$\omega = +$ Area under PV

so work done on system

And $Q = -\omega = -ve$ (Heat rejected by system)

$$\boxed{S \rightarrow 2,35}$$