

* Thermodynamics-1 *

Exercise-S-1

Solution-1

(a) no of moles $n=1$

Pressure, $P_{\text{ext}} = 1 \text{ atm} \Rightarrow \boxed{\text{Pext} = 0}$ (Exposed to evacuated bulb)

$$\Delta V = V_2 - V_1 = 100 \text{ lit} - 10 \text{ lit} = 90 \text{ lit}$$

$$W_{\text{gas}} = -P_{\text{ext}} \cdot \Delta V = -0 \text{ atm} \times 90 \text{ lit} = 0 \Rightarrow \boxed{W_{\text{gas}} = 0}$$

(b) no of moles, $n=1$

$$P_{\text{ext}} = 1 \text{ atm}$$

$$\Delta V = V_2 - V_1 = 5 \text{ lit} - 1 \text{ lit} = 4 \text{ lit}$$

$$W_{\text{gas}} = -P_{\text{ext}} \Delta V = -1 \text{ atm} \times 4 \text{ lit} = -4 \text{ lit atm}$$

$$\boxed{W_{\text{gas}} = -4 \text{ lit atm}}$$

Solution-2

$$P_{\text{ext}} = 1 \text{ atm}$$

$$V_i(\text{H}_2\text{O}) = 18 \text{ ml} ; d = 1 \text{ gm/ml} ; m(\text{H}_2\text{O}) = 18 \text{ gm} ; n(\text{H}_2\text{O}) = 1$$

Vapourisation of $\text{H}_2\text{O(l)}$ take place at 373 K



$$V_i = 18 \text{ ml} \\ 1 \text{ atm}$$

$$V_f \\ 1 \text{ atm}$$

$$\text{for } \text{H}_2\text{O(g)} \quad P \cdot V = n R T$$

$$1 \text{ atm} \times V_f = 1 \times 0.0821 \times 373$$

$$V_f = 30000 \text{ ml} = 30 \text{ lit}$$

so work done

$$W = -P_{\text{ext}} \Delta V$$

$$= -1 \text{ atm} \times (V_f - V_i)$$

$$= -1 \text{ atm} \times (30 \text{ L} - 18 \text{ ml})$$

$$= -1 \text{ atm} \times 30 \text{ lit}$$

$$\Rightarrow \boxed{W = -30 \text{ lit atm}}$$

Solution-3

1-300 K & 1 atm

(i) CO_2 : Total degree of freedom = $3 \times \text{atomicity} = 3 \times 3 = 9$

Translational degree of freedom = 3

Rotational degree of freedom = 2 [CO_2 is linear]

Vibrational degree of freedom = $9 - (3+2) = 4$

(ii) SO_2 : Total degree of freedom = $3 \times 3 = 9$

Translational degree of freedom = 3

Rotational degree of freedom = 3 [SO_2 is bent]

Vibrational degree of freedom = $9 - 3 - 3 = 3$

(iii) He : Total degree of freedom = $3 \times 1 = 3$

Translational degree of freedom = 3

Rotational and vibrational degree of freedom = 0

(iv) NH_3 : Total degree of freedom = $3 \times 4 = 12$

Translational degree of freedom = 3

Rotational degree of freedom = 3 [NH_3 , non linear]

Vibrational degree of freedom = $12 - 3 - 3 = 6$

Solution-4

Heat loss, $Q = -65 \text{ J}$

work done on system, $\omega = +20 \text{ J}$

from first law of thermodynamics

$$\begin{aligned}\Delta U &= Q + \omega \\ &= -65 \text{ J} + 20 \text{ J} \\ &= -45 \text{ J}\end{aligned}$$

$$\boxed{\Delta U = -45 \text{ J}}$$

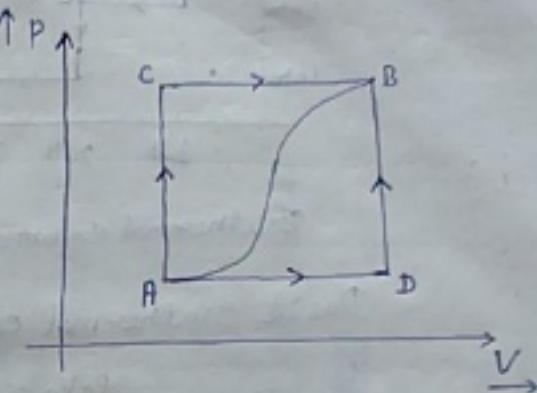
Solution - 5

Given $q_{ACB} = +80 \text{ J}$ (Heat flow into system)

$w_{ACB} = -30 \text{ J}$ (System work)

for internal energy change

$$\begin{aligned}\Delta U_{ACB} &= q_{ACB} + w_{ACB} \\ &= 80 \text{ J} - 30 \text{ J} \\ &= 50 \text{ J}\end{aligned}$$



(a) $w_{ADB} = -10 \text{ J}$ (work done by system)

$$\Delta U_{ADB} = \Delta U_{ACB} = 50 \text{ J} \quad (\text{U is state function})$$

and $\Delta U_{ADB} = q_{ADB} + w_{ADB}$

$$50 \text{ J} = q_{ADB} - 10 \text{ J} \Rightarrow q_{ADB} = +60 \text{ J}$$

(b) $w_{BA} = +20 \text{ J}$ (work done on system, along curve path)

$$\Delta U_{BA} = \Delta U_{BCA} = -\Delta U_{ACB} = -50 \text{ J} \quad (\text{U is state function})$$

$$q_{BA} = \Delta U_{BA} - w_{BA} = -50 \text{ J} - 20 \text{ J} = -70 \text{ J}$$

$q_{BA} = -70 \text{ J}$ (Heat loss by system along curve path)

(c) $U_D - U_A = 110 \text{ J} = \Delta U_{AD}$

$$\Delta U_{ADB} = \Delta U_{AD} + \Delta U_{DB}$$

$$50 \text{ J} = 40 \text{ J} + \Delta U_{DB}$$

$$\boxed{\Delta U_{DB} = 10 \text{ J}}$$

$$w_{ABB} = -10 \text{ J} = w_{AD} + w_{DB}$$

$$\Rightarrow w_{AD} = -10 \text{ J} \quad (w_{DB} = 0, \text{isochoric})$$

For path AD

$$\Delta U_{AD} = q_{AD} + w_{AD}$$

$$110 \text{ J} = q_{AD} - 10 \text{ J}$$

$$\boxed{q_{AD} = +50 \text{ J}}$$

For path DB

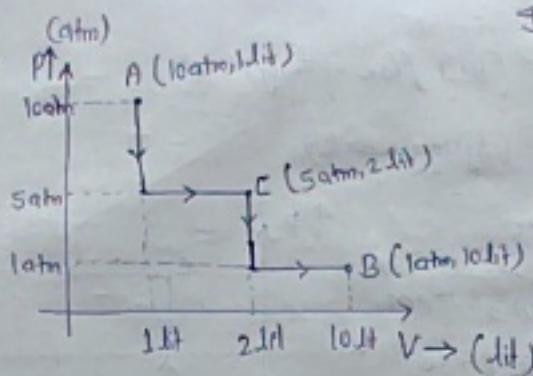
$$\Delta U_{DB} = 10 \text{ J}$$

$$w_{DB} = 0$$

$$\boxed{q_{DB} = \Delta U_{DB}}$$

$$\boxed{q_{DB} = +10 \text{ J}}$$

Solution-6



Ideal gas

Isothermal

$$\text{So } \Delta U_{A \rightarrow B} = 0$$

$$\text{Or } q_{A \rightarrow B} = -w_{A \rightarrow B}$$

Isothermal expansion, 1st against 5 atm then against 1 atm

Due to Isothermal expansion, T is constant means

$$P_A V_A = P_C V_C$$

$$10 \times 1 = 5 \times V_C \Rightarrow V_C = 2 \text{ lit}$$

Total Area under P-V curve

$$\begin{aligned} A &= 5 \times (2-1) + 1 \times (10-2) \\ &= 13 \text{ lit atm} \end{aligned}$$

So work done on gas $w_{A \rightarrow B} = -A = -13 \text{ lit atm}$ (Expansion)

$$\text{Now } q_{A \rightarrow B} = -w_{A \rightarrow B} = +13 \text{ lit atm}$$

Solution-7

Isothermal compression of 2 mole ideal gas from (1 bar, 2 lit) to 2 bar

for minimum work is $w_{\text{rev}} < w_{\text{irr}}$ in comp

$$\begin{aligned} w_{\text{rev, isothermal}} &= -nRT \ln\left(\frac{V_2}{V_1}\right) \\ &= -P_1 V_1 \ln\left(\frac{P_2}{P_1}\right) \\ &= -1 \text{ bar} \times 2 \text{ lit} \ln\left(\frac{2 \text{ bar}}{1 \text{ bar}}\right) \\ &= -2 \text{ lit bar} \cdot \ln\left(\frac{1}{2}\right) \\ &= +2 \times 100 \times 0.7 \\ &= 140 \text{ J} \end{aligned}$$

Solution - 8.

(i) 2 moles ideal gas at (2 bar, 4 lit) reversibly, isothermally compress to 20 bar

$$\begin{aligned}
 W_{\text{rev, isothermal}} &= -nRT \ln\left(\frac{V_2}{V_1}\right) \\
 &= -P_1 V_1 \ln\left(\frac{P_2}{P_1}\right) \quad [\text{Isothermal } P_1 V_1 = nRT = P_2 V_2] \\
 &= -(2 \text{ bar} \times 4 \text{ lit}) \ln\left(\frac{2 \text{ bar}}{20 \text{ bar}}\right) \\
 &= -8 \text{ liter bar} \ln\left(\frac{1}{10}\right) \\
 W_{\text{rev, isothermal}} &= 18.42 \text{ bar lit}
 \end{aligned}$$

(ii)

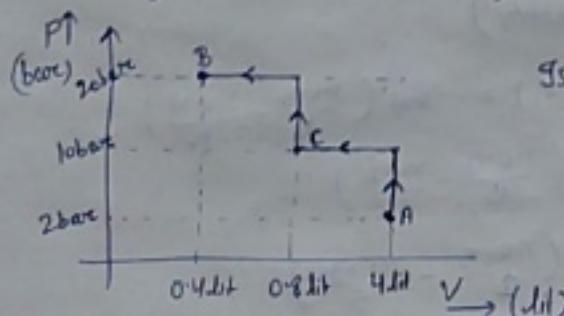
2 moles ideal gas at (2 bar, 4 lit), isothermally compress in single stage against constant force $P_{\text{ext}} = 20 \text{ bar}$

so it is irreversible process

$$\begin{aligned}
 W_{\text{irr, isothermal}} &= -P_{\text{ext}} (V_2 - V_1) \\
 &= -P_{\text{ext}} \left(\frac{nRT}{P_2} - \frac{nRT}{P_1} \right) \\
 &= -P_{\text{ext}} \left(\frac{P_1 V_1}{P_2} - \frac{P_1 V_1}{P_1} \right) \quad [nRT = P_1 V_1 \text{ Isothermal}] \\
 &= -20 \text{ bar} \left(\frac{2 \text{ bar} \times 4 \text{ lit}}{20 \text{ bar}} - 4 \text{ lit} \right) \\
 &= -20 \text{ bar} (-3.6 \text{ lit})
 \end{aligned}$$

$$W_{\text{irr, isothermal}} = 72 \text{ bar lit}$$

(iii) 2 moles ideal gas at (2 bar, 4 lit) compress, isothermally in 2 step
1st against 10 bar then against 20 bar to 20 bar pressure.



$$\begin{aligned}
 \text{Isothermal } & P_1 V_1 = P_2 V_2 = P_3 V_3 \\
 2 \text{ bar} \times 4 \text{ lit} &= 10 \text{ bar} \times V_2 = 20 \text{ bar} \times V_3 \\
 \Rightarrow V_2 &= 0.8 \text{ lit} \\
 \Rightarrow V_3 &= 0.4 \text{ lit}
 \end{aligned}$$

$$\begin{aligned}
 &\text{total Area under P-V curve, } A \\
 &= 10 \text{ bar} \times (4 - 0.8) \text{ lit} + 20 \text{ bar} \times (0.8 - 0.4) \text{ lit} \\
 &= 40 \text{ bar lit}
 \end{aligned}$$

$$\text{so } W = +A = 110 \text{ bar lit}$$

Solution-9

A monoatomic ideal gas ($\gamma = \frac{5}{3}$) compresses adiabatically irreversibly from 4 lit to 1 lit against 1 bar

$$\begin{aligned} W_{\text{irr}} &= -P_{\text{ext}}(V_2 - V_1) - \cancel{\text{heat}} \\ &= -1 \text{ bar} (1 \text{ lit} - 4 \text{ lit}) \\ &= +3 \text{ bar lit} \\ &= 300 \text{ J} \quad (1 \text{ bar lit} = 100 \text{ J}) \end{aligned}$$

Adiabatic process $q = 0$

$$\begin{aligned} \Delta U &= W \\ \Rightarrow \Delta U &= 300 \text{ J} \end{aligned}$$

for ideal gas $\frac{\Delta H}{\Delta U} = \gamma$

$$\Delta H = \frac{5}{3} \times 300 = 500$$

$$\boxed{\Delta H = 500 \text{ J}}$$

Solution-10

2 moles ideal diatomic gas ($C_{Vm} = \frac{5}{2} R$)

$$n = 2$$

$$C_{Vm} = \frac{5}{2} R ; \gamma = \frac{7}{5}$$

$$P_{\text{ext}} = 5 \text{ atm}$$

Adiabatic irreversible expansion from 300 K, 5 atm to 2 atm

So $\boxed{q = 0}$ (Adiabatic)

$$\text{Now } \Delta U = W = -P_{\text{ext}}(V_2 - V_1) = -P_{\text{ext}} \left(\frac{nRT_2}{P_2} - \frac{nRT_1}{P_1} \right)$$

$$n C_{Vm} (T_2 - T_1) = -P_{\text{ext}} \left(\frac{nRT_2}{P_2} - \frac{nRT_1}{P_1} \right)$$

$$\Rightarrow n \times \frac{5}{2} R (T_2 - 300) = -1 \left(\frac{nR \times T_2}{2} - \frac{nR \times 300}{5} \right)$$

$$\Rightarrow \frac{5}{2} T_2 - 750 = -\frac{T_2}{2} + 60 \Rightarrow T_2 = 270$$

$$\text{Now } \Delta U = n C_{Vm} \Delta T = W_{\text{Adiab}}$$

$$\Rightarrow \boxed{\Delta U = W_{\text{Adiab}} = 2 \times \frac{1}{2} R \times (270 - 300) = -150R}$$

$$\text{And } \Delta H = n C_{Pm} \Delta T$$

$$= 2 \times \left(\frac{5}{2} R + R \right) \times (270 - 300) \quad [C_{Pm} - C_{Vm} = R]$$

$$\boxed{\Delta H = -210R}$$

Solution-11

$$Y = \frac{4}{3}; \text{ no of moles } n = 1$$

Adiabatic expansion (1 step) from 400K; 10 atm to 1 atm

$$\text{Here } P_{\text{ext}} = P_2 = 1 \text{ atm}$$

$$\text{For Adiabatic } \omega = \Delta U \quad (\gamma = 1)$$

$$-P_{\text{ext}}(V_2 - V_1) = n C_{Vm} \Delta T$$

$$-P_{\text{ext}} \left(\frac{nRT_2}{P_2} - \frac{nRT_1}{P_1} \right) = n \frac{R}{\gamma-1} (T_2 - T_1)$$

$$\Rightarrow -1 \left(\frac{T_2}{1} - \frac{400}{10} \right) = \frac{(T_2 - 400)}{\frac{4}{3} - 1}$$

$$\Rightarrow -T_2 + 40 = \frac{3}{4} T_2 - 1200$$

$$\Rightarrow T_2 = \frac{1240}{\frac{7}{4}} = 310 \text{ K}$$

$$\omega_{\text{Adiab, irr}} = n C_{Vm} \Delta T$$

$$= 1 \times \frac{R}{\gamma-1} (T_2 - T_1)$$

$$= 1 \times \frac{8.314}{\frac{4}{3} - 1} (310 - 400)$$

$$\boxed{\omega_{\text{Adiab, irr}} = 2244.78 \text{ J}}$$

Solution-12

$$\text{no. of moles } n=1 \quad ; \quad \gamma = 1 + 3/3 = \frac{4}{3}$$

$$T_1 = 300 \text{ K}$$

$$V_1 = V \text{ (Let)}$$

$$V_2 = 27V$$

$$C_{Vm} = 25.08 \frac{\text{J}}{\text{mol}\cdot\text{K}} \text{ for } O_2$$

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

$$T_2 = T_1 \cdot \left(\frac{V_1}{V_2}\right)^{\gamma-1} = 300 \left(\frac{V}{27V}\right)^{\frac{4}{3}-1} = 300 \left(\frac{1}{3^3}\right)^{\frac{1}{3}} = 100 \text{ K}$$

$$\boxed{T_2 = 100 \text{ K}}$$

$$(b) \text{ Adiabatic work } \quad w = \Delta U = n C_{Vm} \Delta T$$

$$= 1 \times 25.08 \times (100 - 300)$$

$$\boxed{w_{\text{adiabatic}} = 5.016 \text{ kJ}}$$

Solution-13

no. of moles $n=2$ moles (ideal gas)

V: Constant

$$C_V = (16.5 + 10^2 T) \frac{\text{J}}{\text{mol}\cdot\text{K}}$$

$$T_1 = 300 \text{ K} ; T_2 = 400 \text{ K}$$

Since $dU = n C_{Vm} dT$ (for ideal gas)

$$\int dU = n \int_{T_1}^{T_2} C_{Vm} dT$$

$$\Delta U = 2 \int_{300}^{400} (16.5 + 10^2 T) dT$$

$$= 2 \left[16.5T + \frac{10^2}{2} T^2 \right]_{300}^{400}$$

$$= 2 [16.5(400 - 300) + \frac{10^2}{2} (400^2 - 300^2)] = 4000 \text{ J}$$

$$\boxed{\Delta U = 4 \text{ kJ}}$$

Solution-14

$$T_1 = 200K ; T_2 = 250K$$

$$P_1 = 2 \text{ atm} ; P_2 = ?$$

$$C_V = 27.5 \frac{\text{J}}{\text{mol}\cdot\text{K}}$$

$$\text{no. of moles } n = 3$$

$$R = 8.3 \text{ J/mol}\cdot\text{K}$$

$$C_{Vm} = \frac{R}{Y-1}$$

$$27.5 = \frac{8.3}{Y-1}$$

$$Y-1 = \frac{8.3}{27.5}$$

$$Y = 1.3 = \frac{4}{3}$$

Reversible Adiabatic, so

$$P_1^{1-Y} T_1^Y = P_2^{1-Y} T_2^Y$$

$$\Rightarrow P_2 = P_1 \left(\frac{T_1}{T_2} \right)^{\frac{Y}{1-Y}} = P_1 \left(\frac{T_1}{T_2} \right)^{\frac{C_{Vm}}{R}}$$

$$= 2 \text{ atm} \left(\frac{200}{250} \right)^{\frac{-35.8}{8.3}} = [C_{Vm} = C_{Vm} + R]$$

$$= 2 \left(\frac{4}{5} \right)^{\frac{-35.8}{8.3}} \left(\left(\frac{4}{5} \right)^{\frac{1}{0.3}} = 2.1 \text{ given} \right)$$

$$= 2 \times 2.1 = 5.22 \text{ atm}$$

$$P_2 = 5.22 \text{ atm}$$

* For Adiabatic $Q = 0$

$$Q = 0$$

$$\omega = \Delta U = n C_{Vm} \Delta T = 3 \times 27.5 \times (250 - 200) = 4125 \text{ J}$$

$$\Rightarrow \boxed{\omega = \Delta U = 4125 \text{ kJ}}$$

$$* \Delta H = n C_{Vm} \Delta T = 3 \times (27.5 + 8.3)(250 - 200) \quad [C_{Vm} = C_{Vm} + R]$$

$$\Delta H = 5312 \text{ J} \Rightarrow \boxed{\Delta H = 5.312 \text{ kJ}}$$

$$* T_1 V_1^{Y-1} = T_2 V_2^{Y-1} \Rightarrow V_2 = V_1 \left(\frac{T_1}{T_2} \right)^{\frac{1}{Y-1}} = \left(\frac{n R T_1}{P_1} \right) \left(\frac{T_1}{T_2} \right)^{\frac{1}{Y-1}}$$

$$\Rightarrow V_2 = \frac{3 \times 0.0821 \times 200}{2} \left(\frac{200}{250} \right)^{\frac{1}{1.3-1}} = 5.619 \times \left(\frac{4}{5} \right)^{\frac{1}{0.3}} = 5.619 \times 2.1 = 11.844 \Rightarrow \boxed{V_2 = 11.844}$$

Solution - 15

no of mole of gas = 1 mole (ideal)

AB → Isobaric

BC → Isochoric

CA → Isothermal

(a) T_1 & T_2

at Point A - use $P_A V_A = n R T_A$

$$20 \text{ atm} \times 1 \text{ lit} = 1 \times 0.0821 \times T_1$$

$$\Rightarrow T_1 = 243.60 \text{ K}$$

at Point B use $P_B V_B = n R T_B$

$$20 \text{ atm} \times 10 \text{ lit} = 1 \times 0.0821 \times T_2$$

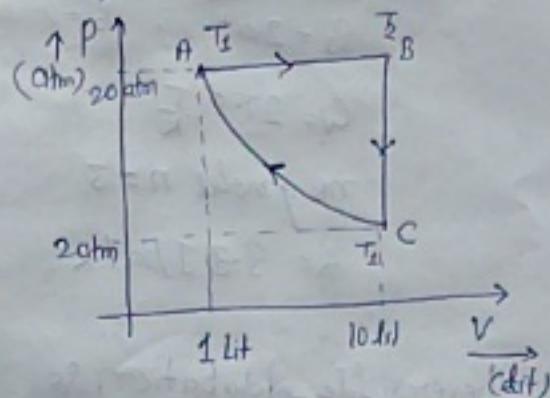
$$\Rightarrow T_2 = 2436 \text{ K}$$

(b) $\boxed{\Delta U_{\text{net}} = 0}$ (Cyclic process, U is state function)

$$\text{So } \boxed{Q_{\text{net}} = -W_{\text{net}}}$$

$$\begin{aligned}
 W_{\text{net}} &= \cancel{W_{AB} + W_{BC} + W_{CA}}^{\text{Isobaric}} + \cancel{Q_{BC} + Q_{CA}}^{\text{Isochoric}} + \cancel{Q_{AB}}^{\text{Isothermal}} \\
 &= -20 \text{ atm} (10 \text{ lit} - 1 \text{ lit}) + 0 + \left[-2.303 n R T_1 \log_{10} \left(\frac{V_A}{V_C} \right) \right] \\
 &= -20 \text{ atm} \times 9 \text{ lit} - 2.303 \times 1 \times 2 \text{ cal} \times 243.60 \log_{10} \left(\frac{1}{10} \right) \\
 &= -180 \text{ lit atm} - 2.3 \times 1 \times 2 \times 243.60 (-\log 10) \text{ cal} \\
 &= -180 \times \frac{101}{4.2} \text{ cal} + 2.3 \times 1 \times 2 \times 243.60 \times 1 \text{ cal} \\
 \boxed{W_{\text{net}} = -3464.24 \text{ cal}}
 \end{aligned}$$

$$\boxed{Q_{\text{ref}} = -W_{\text{net}} = 3264.24 \text{ cal}}$$



Solution-16

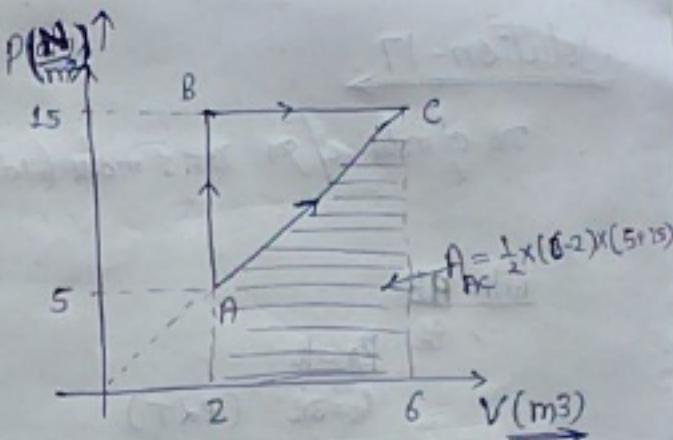
State change A to C followed

by two paths ① AC path

② ABC path

a) Area under PV curve in both

$$A_{\text{path}} < A_{\text{ABC path}}$$



Ans. Area under curve (P-V) is work

$$\therefore W_{\text{ABC}} = - \text{Area}_{\text{ABC}} \quad (\text{Expansion work})$$

$$W_{\text{AC}} = - \text{Area}_{\text{AC}}$$

$$\therefore |W_{\text{ABC}}| > |W_{\text{AC}}|$$

(Least magnitude work is along AC path)

b) $q_{\text{AC}} = +200 \text{ J}$

$$U_A = +10 \text{ J}$$

$$\Delta U_{\text{AC}} = U_C - U_A = U_C - 10 \text{ J} \quad (\text{Ans. } \Delta U_{\text{AC}} = W_{\text{AC}} + q_{\text{AC}})$$

$$\Rightarrow \Delta U_{\text{AC}} = -\frac{1}{2} \times (6-2) \times (5+15) \frac{\text{N} \cdot \text{m}^3}{\text{J}} + 200 \text{ J}$$

$$\Rightarrow U_C - 10 \text{ J} = -\frac{1}{2} \times 4 \times 20 \text{ J} + 200 \text{ J}$$

$$\Rightarrow U_C - 10 \text{ J} = -40 \text{ J} + 200 \text{ J}$$

c) $W_{\text{AB}} = 0$ (isobaric)

$$U_C = 170 \text{ J}$$

$$\Delta U_{\text{AB}} = 10 \text{ J}$$

$$\therefore \Delta U_{\text{AB}} = q_{\text{AB}} + W_{\text{AB}}$$

$$10 \text{ J} = q_{\text{AB}} + 0$$

$$\Rightarrow q_{\text{AB}} = +10 \text{ J}$$

Solution-17

no of mole of gas $n = 1$ mole (ideal gas)

Path AB

$$P_A = P_0$$

$$P_B = 3P_0 \quad (P \propto T)$$

$$\omega_{AB} = 0 \quad (\text{isochoric})$$

Path BC

$$PT = \text{constant}$$

$$P_B T_B = P_C T_C$$

$$3P_0 \times 300 = P_0 \times T_C$$

$$T_C = 900 \text{ K}$$

$$PT = \text{constant} \Rightarrow P \cdot \left(\frac{PV}{nR} \right) = \text{constant} \Rightarrow \boxed{PV^{\frac{1}{2}} = k}$$

$$PV^x = k'$$

$$\omega_{BC} = \frac{nR\Delta T}{x-1}$$

$$= \frac{1 \times 2 \text{ cal} \times (T_C - T_B)}{\frac{1}{2} - 1} = \frac{1 \times 2 \text{ cal} \times (900 - 300)}{-\frac{1}{2}}$$

$$\omega_{BC} = -2400 \text{ cal}$$

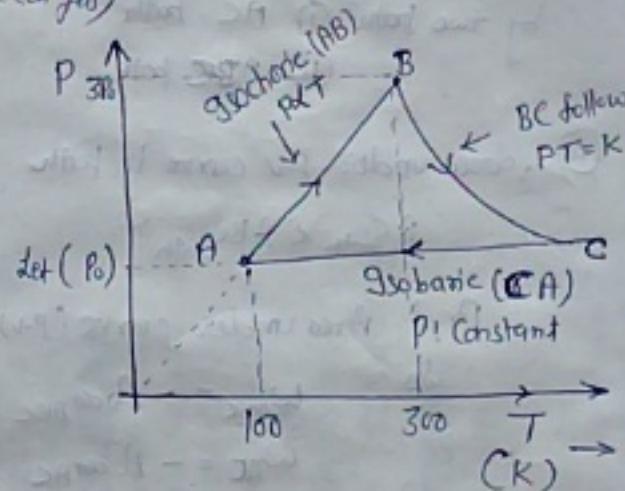
Path CA

Isobaric path

$$\omega_{CA} = -nR\Delta T_{CA} = -1 \times 2 \text{ cal} \times (100 - 900) = +1600 \text{ cal}$$

$$\begin{aligned}\omega_{\text{net}} &= \omega_{AB} + \omega_{BC} + \omega_{CA} \\ &= 0 - 2400 + 1600\end{aligned}$$

$$\boxed{\omega_{\text{net}} = -800 \text{ cal}}$$

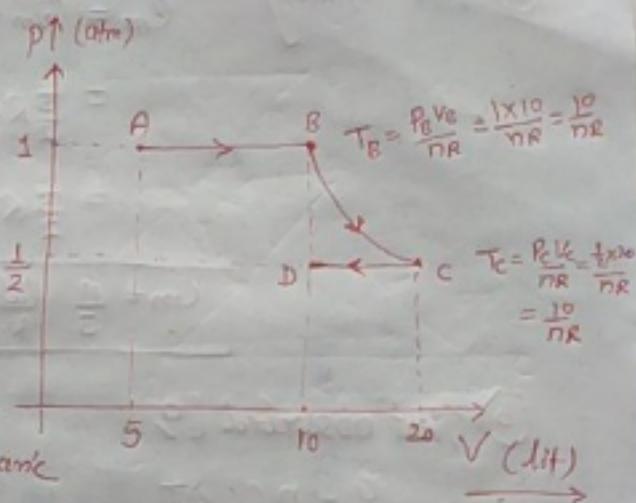


Solution-18

Since $T_B = T_C$ so it is
assume as Isothermal
path

$$W_{ABCD} = W_{AB} + W_{BC} + W_{CD}$$

\downarrow
Subanic \downarrow Isothermal \downarrow Subanic



$$= -1 \text{ atm} (10-5) \text{ lit} - nRT \ln\left(\frac{V_C}{V_B}\right) - \frac{1}{2} \text{ atm} (10-20) \text{ lit}$$

$$= -5 \text{ lit/atm} - P_B V_B \ln\left(\frac{V_C}{V_B}\right) + 5 \text{ lit/atm}$$

$$= -1 \times 10 \ln\left(\frac{20}{10}\right)$$

$$= -10 \times \ln 2 \text{ lit/atm} = -10 \times 0.693 = 7 \text{ lit/atm}$$

$$\boxed{W_{\text{sub}} = 7 \text{ lit.atm}}$$

Solution-19

no of moles of gas, $n = 1$ mole (ideal), monoatomic

Initial state T_1 , V_1

$$V_1 = 1 \text{ lit}$$

Final state $T_2 = ?$

$$V_2 = 2 \text{ lit}$$

Process following path $\frac{P}{V^2} = \text{Constant}$

$\boxed{PV^{-2} = \text{Constant}}$; By comparing a polytropic

path $PV^x = \text{Constant}$

$$\boxed{x = -2}$$

④ Heat capacity $C_m = C_{vm} + \frac{R}{1-x}$

$$= \frac{3}{2}R + \frac{R}{1-(2)} = \frac{11}{6}R$$

$$= \frac{11}{2}R + \frac{R}{3} = \frac{11}{6}R = \frac{11}{3} \text{ Cal/K.mole}$$

$$C_m = \frac{11}{3} \frac{\text{Cal}}{\text{K.mole}}$$

b) Heat absorbed (q)

$$q = n C_m \Delta T$$

$$q = 1 \times \frac{11}{3} \frac{\text{Cal}}{\text{K.mol}} (800 - 100)$$

$$= \frac{11}{3} \times (800 - 100)$$

$$= 2566.67 \text{ Cal}$$

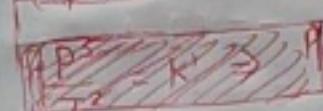
$$q = 2566.67 \text{ Cal}$$

For T_2

$$\frac{P}{V^2} = K \Rightarrow \frac{nRT}{V^3} = K$$



$$\frac{T}{V^3} = K'$$



$$\frac{T_1}{V_1^3} = \frac{T_2}{V_2^3}$$

$$\Rightarrow T_2 = T_1 \left(\frac{V_2}{V_1}\right)^3$$

$$= 100 \left(\frac{2}{1}\right)^3$$

$$T_2 = 800 \text{ K}$$

c) Work

$$w = \frac{nR \Delta T}{K-1} \quad (\text{For Polytropic})$$

$$= 1 \times 2 \text{ cal} \times \frac{(800 - 100)}{-2 - 1}$$

$$w = -466.67 \text{ Cal}$$

d)

$$\Delta U = q + w$$

$$= 2566.67 - 466.67 = 2100 \text{ Cal}$$

$$\Rightarrow \boxed{\Delta U = 2100 \text{ Cal}}$$

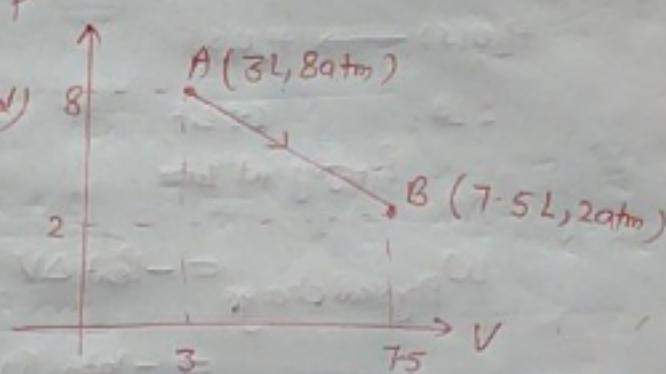
Solution - 20

no. of moles of gas $\Rightarrow n=1$ (ideal)

$$W_{AB} = - \text{Area under } P-V$$

$$= -\frac{1}{2}(7.5-3) \text{ lit} \times (2+8) \text{ atm}$$

$$W_{AB} = -22.5 \text{ atm lit}$$



$$\Delta U_{AB} = n(C_v m \Delta T) = n \frac{R}{Y-1} (T_2 - T_1) = \frac{1}{Y-1} (nRT_2 - nRT_1)$$

$$= \frac{P_2 V_2 - P_1 V_1}{Y-1}$$

$$= \frac{2 \text{ atm} \times 7.5 \text{ lit} - 8 \text{ atm} \times 3 \text{ lit}}{\frac{5}{3} - 1}$$

$$= -\frac{27}{2} \text{ Jit atm}$$

$$\Delta U_{AB} = -13.5 \text{ Jit atm}$$

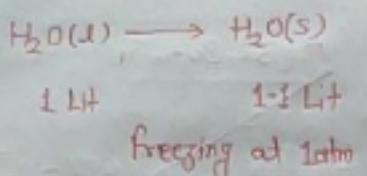
$$\therefore \Delta U_{AB} = q_{AB} + W_{AB}$$

$$\Rightarrow q_{AB} = \Delta U_{AB} - W_{AB}$$

$$= -13.5 \text{ Jit atm} - (-22.5 \text{ lit atm})$$

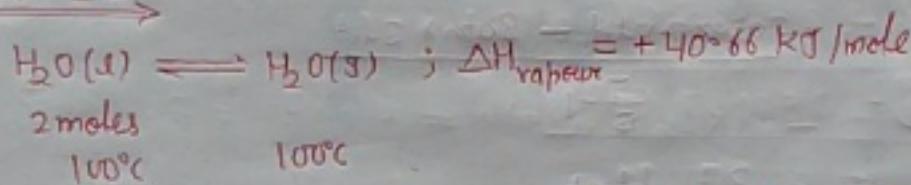
$$q_{AB} = 9 \text{ atm lit}$$

Solution - 21



$$\begin{aligned} w_{\text{Physical change}} &= -P_{\text{ext}} \Delta V \\ &= -1 \text{ atm} \cdot (1-1 \text{ lit} - 1 \text{ lit}) \\ &= -0.1 \text{ lit atm} \\ &= -0.1 \times 10^3 \text{ J} \\ \boxed{w} &= -10.13 \text{ Joule} \end{aligned}$$

Solution - 22



$$\Delta H = \Delta U + \Delta n g RT \Rightarrow \Delta U = \Delta H - \Delta n g RT$$

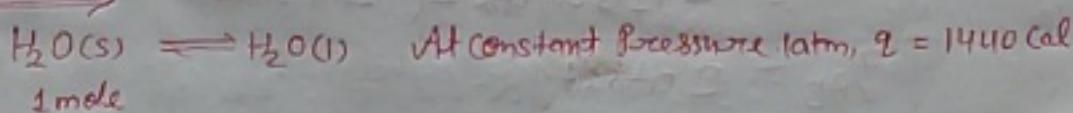
$$= 40.66 - 1 \times 8.314 \frac{\text{kJ}}{\text{mol K}} \times 373$$

$$\Delta U = 37.56 \text{ kJ/mole}$$

\downarrow for 1 mole

$$\text{So } \boxed{\Delta U_{\text{for 2 moles}} = 2 \times 37.56 = 75.12 \text{ kJ}}$$

Solution - 23



$$V_{\text{H}_2\text{O(s)}} = 0.0156 \text{ lit} \quad V_{\text{H}_2\text{O(l)}} = 0.018 \text{ lit}$$

For solid and liquid cases, we assume almost negligible volume and pressure change occurs so $\boxed{\Delta H = \Delta U = 1440 \text{ cal}}$