

1) Both O_2 and N_2 are diatomic gases. $\therefore \gamma = 1.4$ (or $\frac{7}{5}$) = $\frac{C_p}{C_v}$

RECALL: $C_p = C_v + R$

From definition of γ

$$C_v = \frac{5}{7} C_p$$

Substitute

$$\begin{aligned} C_v &= \frac{5}{7} (C_v + R) \\ &= \frac{5}{7} C_v + \frac{5}{7} R \end{aligned}$$

Solve for C_v

$$C_v - \frac{5}{7} C_v = \frac{5}{7} R$$

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

$$C_p = \frac{5}{2} R + R = \frac{7}{2} R$$

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- 2.) GIVEN: i) $V_1^{\text{TOT}} = 1 \text{ m}^3 = 1000 \text{ L}$, $V_2^{\text{TOT}} = 5V_1^{\text{TOT}}$
 ii) Diatomic, Ideal Gas
 iii) $P_1 = 1000 \text{ k}$, $T_1 = 600 \text{ K}$

Find T_2 , P_2 , W^{TOT} , ΔU^{TOT} , ΔH^{TOT} , Q^{TOT}

a) Reversible isothermal process ($dT=0$)

$$\Delta U = \int C_V dT = 0 \Rightarrow Q^{\text{TOT}} = -W^{\text{TOT}}$$

$$\Delta H = \int C_P dT = 0$$

P_2 : For I.G. $P_1 V_1 = P_2 V_2$ (isothermal)

$$P_2 = P_1 \left(\frac{V_1}{V_2} \right) = P_1 \left(\frac{1}{5} \right) = 200 \text{ kPa}$$

$$W = -RT \ln \frac{V_2^{\text{TOT}}}{V_1^{\text{TOT}}} = -8.314 \left(\frac{\text{J}}{\text{mol K}} \right) 600 \text{ K} \ln 5$$

$$= -8029 \frac{\text{J}}{\text{mol}}$$

No of moles?

$$P_1 V_1^{\text{TOT}} = n R T_1$$

$$n = \frac{P_1 V_1^{\text{TOT}}}{R T_1} = \frac{1000 \text{ kPa} \cdot 1000 \text{ L}}{8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol K}} \cdot 600 \text{ K}}$$

$$= 200.5 \text{ mol}$$

$$W^{\text{TOT}} = 200.5 \text{ mol} \cdot 8029 \frac{\text{J}}{\text{mol}} (= -Q^{\text{TOT}})$$

$$= -1609814 \text{ J} = 1,609 \text{ kJ. } (= -Q^{\text{TOT}})$$

2. (cont)

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b) Adiabatic, reversible process ($dQ=0$)
Diatomic I.G. $\gamma = 1.4$

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

$$T_2 = 600 \text{ K} \left(\frac{1 V_1^{\text{TOT}}}{5 V_1^{\text{TOT}}} \right)^{0.4} = 315.2 \text{ K}$$

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$P_2 = P_1 \left(\frac{V_1}{V_2} \right)^{\gamma} = 1000 \text{ kPa} \left(\frac{1}{5} \right)^{1.4} \\ = 105 \text{ kPa}$$

(NOTE: T_2 AND P_2 ARE LESS FOR
ADIABATIC PROCESS THAN FOR ISOTHERMAL
PROCESS BECAUSE OF ADIABATIC COOLING
 $Q_{\text{ISOTHERMAL}}^{\text{TOT}} = +1,609 \text{ kJ}$ TO KEEP T CONST
 $Q_{\text{ADIABATIC}}^{\text{TOT}} = 0 \Rightarrow$ HENCE $T \downarrow$)

$$\Delta U^{\text{TOT}} = n \cdot \Delta U = n \cdot (C_V \Delta T) \\ = 200.5 \text{ mol} \times \frac{5}{2} R (315.2 - 600) \text{ K} \\ = 200.5 \text{ mol} \times \frac{5}{2} \left(8.314 \frac{\text{J}}{\text{mol K}} \right) (315.2 - 600) \text{ K}$$

2) (cont.)

B4

$$\begin{aligned}\Delta U^{\text{TOT}} &= 200.5 \text{ mol} \times -5919.6 \text{ J/mol} \\ &= -1,187 \text{ kJ.}\end{aligned}$$

FOR ADIABATIC PROCESS FROM 1ST LAW

$$\Delta U = W.$$

$$\therefore \boxed{W^{\text{TOT}} = -1,187 \text{ kJ}}$$

ALSO

$$\begin{aligned}W^{\text{TOT}} &= \frac{1}{\gamma-1} (P_2 V_2^{\text{TOT}} - P_1 V_1^{\text{TOT}}) \\ &= \frac{1}{0.4} \left((105 \text{ kPa})(5000 \text{ L}) - (1000 \text{ kPa})(1000 \text{ L}) \right) \\ &= 1,187.5 \text{ kJ}\end{aligned}$$

$$\begin{aligned}\Delta H &= C_p \Delta T = \frac{7}{2} R (315.2 - 600) \\ &= \frac{7}{5} \Delta U = \gamma \cdot \Delta U \\ &= -8287.4 \text{ J/mol}\end{aligned}$$

$$\begin{aligned}\Delta H^{\text{TOT}} &= 200.5 \text{ mol} \times -8287.4 \text{ J/mol} \\ &= -1,662 \text{ kJ}\end{aligned}$$

3.) REVERSIBLE ISOTHERMAL COMPRESSION
FROM P₁ TO P₂

$$W = - \int P dV$$

$$Z = \frac{PV}{RT} = 1 + B'P$$

$$PV = RT(1 + B'P)$$

$$P(V - B'RT) = RT$$

$$P = \frac{RT}{V - B'RT}$$

$$W = - \int_{V_1}^{V_2} \frac{RT}{(V - B'RT)} dV$$

(Recall T constant
dT = 0)

$$= -RT \int_{V_1}^{V_2} \frac{dV}{(V - B'RT)}$$

$$= -RT \left[\ln(V - B'RT) \right]_{V_1}^{V_2}$$

$$= -RT \ln \left(\frac{V_2 - B'RT}{V_1 - B'RT} \right)$$

Changes the amount of work required depending on value B'

Ex) Methylene chloride

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$$\overline{B} = -0.242 \frac{\text{L}}{\text{mol}}$$

$$B' = \frac{\overline{B}}{RT} \quad \text{Eq'n 3.13a from Text}$$

$$\circ\circ \quad B'RT = \frac{\overline{B}}{RT} \times RT = \overline{B}$$

$$W = -RT \ln \left(\frac{V_2 - \overline{B}}{V_1 - \overline{B}} \right)$$

Use reverse of problem 2a

Need $V \left(\frac{\text{L}}{\text{mol}} \right) ?$

$$V_2 = \frac{1000 \text{ L}}{200.5 \text{ mol}} = 4.99 \frac{\text{L}}{\text{mol}}$$

$$V_1 = \frac{5000 \text{ L}}{200.5 \text{ mol}} = 24.9 \frac{\text{L}}{\text{mol}}$$

Now

$$\begin{aligned} W &= -8.314 \frac{\text{J}}{\text{mol K}} \times 600 \text{ K} \times \ln \left(\frac{4.99 - 0.242}{24.9 - 0.242} \right) \\ &= +8218 \frac{\text{J}}{\text{mol}} \end{aligned}$$

versus $8029 \frac{\text{J}}{\text{mol}}$ for I.G. compression.