

CHE 203  
HW # 8 SOLUTION

1)  $W_{12} = 0$ ,  $W = W_{23} = -P_2(V_3 - V_2) = -R(\bar{T}_3 - \bar{T}_2)$

But  $\bar{T}_3 = \bar{T}_1$ , so  $W = R(\bar{T}_2 - \bar{T}_1)$  — (a)

Also  $W = RT_1 \ln\left(\frac{P}{P_1}\right)$  — (b)

equating (a) and (b), implies that:

$$\ln\left(\frac{P}{P_1}\right) = \frac{\bar{T}_2 - \bar{T}_1}{\bar{T}_1} \quad \begin{array}{l} \bar{T}_1 = 800 \text{ K} \\ \bar{T}_2 = 350 \text{ K} \\ P_1 = 4 \text{ bar} \end{array}$$

$$\Rightarrow P = P_1 \exp\left[\frac{\bar{T}_2 - \bar{T}_1}{\bar{T}_1}\right] = 4 \times \exp(-0.5625) \\ \approx 2.279 \text{ bar}$$

$\therefore P = 2.279 \text{ bar}$

2)  $B = -242.5 \text{ cm}^3/\text{mol}$ ,  $C = 25,200 \text{ cm}^6/\text{mol}^2$

$T = 373.15 \text{ K}$ ,  $P_1 = 1 \text{ bar}$ ,  $P_2 = 55 \text{ bar}$

$$B' = \frac{B}{RT}, \quad C' = \frac{C - B^2}{R^2 T^2}$$

a) Solve virial equation for initial  $V$

Guess:  $V_1 = \frac{RT}{P_1}$  Given  $\frac{P_1 V_1}{RT} = 1 + \frac{B}{V_1} + \frac{C}{V_1^2}$

$V_1 = \text{find}(V_1)$   $V_1 = 30,780 \text{ cm}^3/\text{mol}$

Solve virial equation for final  $V$ .

$$\text{Guess: } V_2 = \frac{RT}{P_2} \quad \text{Given } \frac{P_2 V_2}{RT} = 1 + \frac{B}{V_2} + \frac{C}{V_2^2}$$

$$V_2 = \text{Find}(V_2), \quad V_2 = 241.33 \text{ cm}^3/\text{mol}$$

$$W = - \int_{V_1}^{V_2} P dV \quad \text{--- (1.3)}$$

Eliminate  $P$  from equation (1.3) by the virial equation:

$$\Rightarrow W = -RT \int_{V_1}^{V_2} \left[ 1 + \frac{B}{V} + \frac{C}{V^2} \right] \cdot \frac{1}{V} dV$$

$$\underline{W = 12.62 \text{ kJ/mol}}$$

b) Eliminate  $dV$  from equation (1.3) by the virial equation in  $P$ :

$$dV = RT \left[ \frac{-1}{P^2} + c' \right] dP$$

$$\Rightarrow W = -RT \int_{P_1}^{P_2} \left( -\frac{1}{P} + c'P \right) dP$$

$$\underline{W = 12.6 \text{ kJ/mol}}$$

Note: The answers to (a) & (b) differ because the relations between the two sets of parameters are exact only for infinite series.

$$3) \quad T = 348.15 \text{ K}, \quad P = 15 \text{ bar}, \quad R = 8.314 \text{ J/mol}\cdot\text{K}$$

$$a) \quad B = -194 \text{ cm}^3/\text{mol}, \quad C = 15,300 \text{ cm}^6/\text{mol}^2$$

$$\text{Guess } V = \frac{RT}{P} \quad \text{Given } \frac{PV}{RT} = 1 + \frac{B}{V} + \frac{C}{V^2}$$

$$V = \text{Find}(V) \quad V = \underline{\underline{1722 \text{ cm}^3/\text{mol}}}$$

$$Z = \frac{PV}{RT} \Rightarrow \underline{\underline{Z = 0.893}}$$

$$b) \quad T_c = 318.7 \text{ K}, \quad P_c = 37.6 \text{ bar}, \quad \omega = 0.286$$

$$T_r = \frac{T}{T_c}, \quad P_r = \frac{P}{P_c}, \quad B_0 = 0.083 - \frac{0.422}{T_r^{1.6}}$$

$$B_1 = 0.139 - \frac{0.172}{T_r^{4.2}}, \quad Z = 1 + (B_0 + \omega B_1) \frac{P_r}{T_r}$$

$$\Rightarrow \underline{\underline{Z = 0.899}}, \quad V = \frac{Z \cdot RT}{P}, \quad V = \underline{\underline{1734 \text{ cm}^3/\text{mol}}}$$

$$c) \quad a = \frac{0.42748 R^2 T_c^{2.5}}{P_c}, \quad b = \frac{0.08664 R T_c}{P_c}$$

$$\text{Given } P = \frac{RT}{V-b} - \frac{a}{T^{0.5} V(V+b)}$$

$$V = \text{Find}(V), \quad V = \underline{\underline{1714 \text{ cm}^3/\text{mol}}}$$

$$Z = \frac{PV}{RT} \Rightarrow \underline{\underline{Z = 0.888}}$$

4)

$$T = 298.15 \text{ K}, \quad P = 2.43 \text{ bar}, \quad V_{\text{vap.}} = 16 \text{ m}^3$$

$$T_c = 425.1 \text{ K}, \quad P_c = 37.96 \text{ bar}, \quad \omega = 0.200$$

$$T_r = \frac{T}{T_c}, \quad P_r = \frac{P}{P_c}, \quad \text{mol} = 58.123 \text{ gm},$$

$$R = 8.314 \text{ J/mol}\cdot\text{K}, \quad B_0 = 0.083 - \frac{0.422}{T_r^{1.4}}$$

$$B_1 = 0.139 - \frac{0.172}{T_r^{4.2}}$$

$$V = \frac{RT}{P} + (B_0 + \omega B_1) R \cdot \frac{T_c}{P_c}$$

$$m_{\text{vap.}} = \frac{V_{\text{vap.}}}{V} \Rightarrow \underline{\underline{m_{\text{vap.}} = 98.2 \text{ kg}}}$$