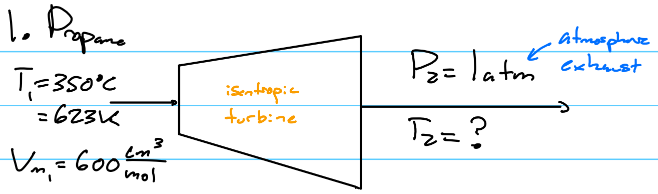
ECHE363 Homework 7 - Due 03/28/25 **Trevor Swan (tcs94)**

1. Propane



VdW EoS:

$$P = \frac{RT}{V_m - b} - \frac{a}{V_m^2}$$

$$a = 92\times10^5 \frac{atm \cdot cm^6}{mol^2} \; ; \; b = 91 \frac{cm^3}{mol}$$

(textbook) Propane: $C_{P_m} = R\left(1.213 + \frac{28.785}{10^3}T - \frac{8.824}{10^6}T^2\right)$

$C_{P_m} = C_{V_m} + R$: $C_{V_m} = R\left(1.213 + \frac{28.785}{10^3}T - \frac{8.824}{10^6}T^2\right) - R$

a) Solve w/ $S_m = S_m(T, V_m)$ We won't take a calc. path, no dP term!

Use: $dS_m = \frac{C_{V_m}}{T}dT + \left(\frac{\partial P}{\partial T}\right)_{V_m} dV_m$

$$\Delta S_m = 0 = \int_{"1"}^{"2"} dS_m = 0$$

$$\int_{"1"}^{"2"} dS_m = \int_{"1"}^{"2"} \frac{C_{V_m}}{T}dT + \left(\frac{\partial P}{\partial T}\right)_{V_m} dV_m = \int_{T_1}^{T_2} \frac{C_{P_m} - R}{T}dT + \int_{V_{m_1}}^{V_{m_2}} \frac{\partial}{\partial T}\left[\frac{RT}{V_m - b} - \frac{a}{V_m^2}\right]_{V_m} dV_m$$

$$0 = \int_{623K}^{T_2} \frac{R\left(0.213 + \left(\frac{28.785}{10^3}\right)T - \left(\frac{8.824}{10^6}\right)T^2\right)}{T} dT + \int_{V_{m_1}}^{V_{m_2}} \frac{R}{V_m - b} dV_m$$

$$= R\int_{623K}^{T_2} \frac{0.213}{T} + \frac{28.785}{10^3} - \frac{8.824}{10^6} T \, dT + R\ln(V_m - b)\Big|_{V_{m_1}}^{V_{m_2}}$$

$$0 = \cancel{R}\left[0.213\ln T + \frac{28.785}{10^3}T - \frac{8.824}{2\cdot10^6}T^2\right]_{623K}^{T_2} + \cancel{R}\left[\ln(V_{m_2} - b) - \ln(V_{m_1} - b)\right]$$

$$0 = 0.213\ln\left(\frac{T_2}{623}\right) + \frac{28.785}{10^3}(T_2 - 623) - \frac{8.824}{2\cdot10^6}\left(T_2^2 - 623^2\right) + \ln\left(\frac{V_{m_2} - b}{V_{m_1} - b}\right)$$

Express T_2 in terms of P_2 and V_{m_2}

$$P_2 = \frac{RT_2}{V_{m_2} - b} - \frac{a}{V_{m_2}^2} \Rightarrow T_2 = \left(P_2 + \frac{a}{V_{m_2}^2}\right)\left(\frac{V_{m_2} - b}{R}\right)$$

Continue next! ↪

Plug into expanded expression

$$0 = 0.213\ln\left(\frac{\left(P_2 + \frac{a}{V_{m_2}^2}\right)\left(\frac{V_{m_2} - b}{R}\right)}{623}\right) + \frac{28.785}{10^3}\left(\left[\left(P_2 + \frac{a}{V_{m_2}^2}\right)\left(\frac{V_{m_2} - b}{R}\right)\right] - 623\right) - \frac{8.824}{2\cdot10^6}\left(\left(\left(P_2 + \frac{a}{V_{m_2}^2}\right)\left(\frac{V_{m_2} - b}{R}\right)\right)^2 - 623^2\right) + \ln\left(\frac{V_{m_2} - b}{V_{m_1} - b}\right)$$

Substitute and solve numerically w/ Wolfram

$P_2 = 1 atm$; $V_{m_1} = 600 \frac{cm^3}{mol}$ $R = 8.314 \frac{m^3 \cdot Pa}{mol \cdot K} \cdot \frac{1{,}000{,}000 cm^3}{1 m^3} \cdot \frac{1 atm}{101325 Pa}$

$a = 92\times10^5 \frac{atm \cdot cm^6}{mol^2}$ $= 82.05 \frac{cm^3 \cdot atm}{mol \cdot K}$

$b = 91 \frac{cm^3}{mol}$

$$V_{m_2} = 36{,}622.2 \frac{cm^3}{mol}$$

$$\boxed{T_2 = 175.3°C}$$

$$T_2 = \left(P_2 + \frac{a}{V_{m_2}^2}\right)\left(\frac{V_{m_2} - b}{R}\right) - 273$$

$$= \left(1 + \frac{92\times10^5}{36622.2^2}\right)\left(\frac{36622.2 - 91}{82.05}\right) - 273 = 175.29°C$$

b) Solve w/ $S_m = S_m(T, P)$

Use: $dS_m = \frac{C_{p,m}}{T}\,dT - \left(\frac{\partial V_m}{\partial T}\right)_P dP$

$$P = \frac{RT}{V_m - b} - \frac{a}{V_m^2}\ ;\quad T = \left(P + \frac{a}{V_m^2}\right)\left(\frac{V_m - b}{R}\right)$$

$$a = 42\times 10^5\ \frac{atm\cdot cm^6}{mol^2}\ ;\quad b = 91\ \frac{cm^3}{mol}$$

Triple Product Rule

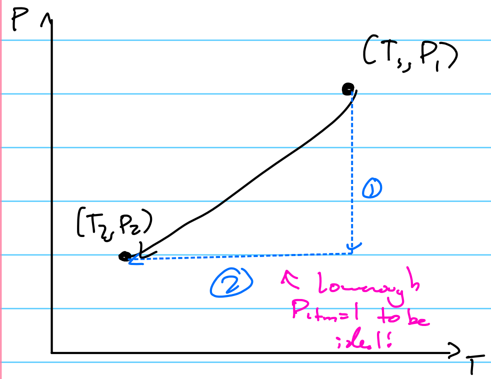
$$-1 = \left(\frac{\partial T}{\partial P}\right)_{V_m}\left(\frac{\partial V_m}{\partial T}\right)_P\left(\frac{\partial P}{\partial V_m}\right)_T$$

$$\left(\frac{\partial V_m}{\partial T}\right)_P = \frac{-1}{\left(\frac{\partial T}{\partial P}\right)_{V_m}\left(\frac{\partial P}{\partial V_m}\right)_T}$$

$$\left(\frac{\partial T}{\partial P}\right)_{V_m} = \frac{\partial}{\partial P}\left[\left(P + \frac{a}{V_m^2}\right)\left(\frac{V_m - b}{R}\right)\right]_{V_m} = \frac{V_m - b}{R}$$

$$\left(\frac{\partial P}{\partial V_m}\right)_T = \frac{\partial}{\partial V_m}\left[\frac{RT}{V_m - b} - \frac{a}{V_m^2}\right]_T = \frac{2a}{V_m^3} - \frac{RT}{(V_m - b)^2}$$

$$\Rightarrow \left(\frac{\partial V_m}{\partial T}\right)_P = \frac{-1}{\left(\frac{V_m - b}{R}\right)\left(\frac{2a}{V_m^3} - \frac{RT}{(V_m-b)^2}\right)} = -\frac{\left(\frac{R}{V_m - b}\right)}{\left(\frac{2a}{V_m^3} - \frac{RT}{(V_m-b)^2}\right)}$$



$$\Delta S_m = \int_{T_1}^{T_2} \frac{R\left(1.213 + \frac{28.785}{10^3}T - \frac{8.824}{10^6}T^2\right)}{T}\,dT - \int_{P_1}^{P_2} - \frac{\left(\frac{R}{V_m - b}\right)}{\left(\frac{2a}{V_m^3} - \frac{RT}{(V_m-b)^2}\right)}\,dP = 0$$

For VdW EoS @ const. temperature

$$dP = \left[\frac{2a}{V_m^3} - \frac{RT}{(V_m-b)^2}\right] dV_m$$

Derived from $\left(\frac{\partial P}{\partial V_m}\right)_T$ above

$$\Delta S = \int_{T_1}^{T_2} \frac{R\left(1.213 + \frac{28.785}{10^3}T - \frac{8.824}{10^6}T^2\right)}{T}\,dT + \int_{V_{m_1}}^{V_{m_2}} \frac{\left(\frac{R}{V_m - b}\right)}{\cancel{\left(\frac{2a}{V_m^3} - \frac{RT}{(V_m-b)^2}\right)}}\cancel{\left[\frac{2a}{V_m^3} - \frac{RT}{(V_m-b)^2}\right]} dV_m$$

$$0 = \int_{T_1}^{T_2} \frac{\cancel{R}\left(1.213 + \frac{28.785}{10^3}T - \frac{8.824}{10^6}T^2\right)}{T}\,dT + \int_{V_{m_1}}^{V_{m_2}} \frac{\cancel{R}}{V_m - b}\,dV_m$$

$$0 = 1.213\ln\left(\frac{T_2}{623}\right) + \frac{28.785}{10^3}\left(T_2 - 623\right) - \frac{8.824}{2\cdot 10^6}\left(T_2^2 - 623^2\right) + \ln\left(\frac{V_{m_2} - b}{V_{m_1} - b}\right)$$

This is the same as equation ☆ on the first page!

→ Make the same substitutions, plug into mol form to get T_2

$T_2 = \left(P_2 + \frac{a}{V_{m_2}^2}\right)\left(\frac{V_{m_2} - b}{R}\right)$

$P_2 = 1\ \text{atm}$; $V_{m_1} = 600\ \frac{cm^3}{mol}$ $R = 82.05\ \frac{cm^3 \cdot atm}{mol \cdot K}$

$a = 92 \times 10^5\ \frac{atm \cdot cm^6}{mol^2}$

$b = 91\ \frac{cm^3}{mol}$

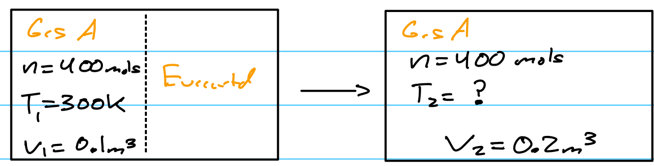
$$0 = 0.213 \ln\left(\frac{\left(P_2 + \frac{a}{V_{m_2}^2}\right)\left(\frac{V_{m_2} - b}{R}\right)}{623}\right) + \frac{28.785}{10^3}\left(\left[\left(P_2 + \frac{a}{V_{m_2}^2}\right)\left(\frac{V_{m_2} - b}{R}\right)\right] - 623\right) - \frac{8.824}{2 \cdot 10^6}\left(\left(\left(P_2 + \frac{a}{V_{m_2}^2}\right)\left(\frac{V_{m_2} - b}{R}\right)\right)^2 - 623^2\right) + \ln\left(\frac{V_{m_2} - b}{V_{m_1} - b}\right)$$

$\Rightarrow V_{m_2} = 36{,}622.2\ \frac{cm^3}{mol} \longrightarrow T_2 = \left(1 + \frac{92 \times 10^5}{36622.2^2}\right)\left(\frac{36622.2 - 91}{82.05}\right) - 273 = 175.29\,°C$

They match!

$\boxed{T_2 = 175.3\,°C}$

2. Adiabatic, Rigid

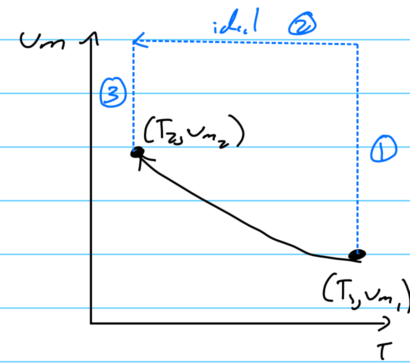


$$P = \frac{RT}{V_m - b} - \frac{a}{T V_m^2}$$

$a = 40 \frac{J \cdot K \cdot m^3}{mol^2}$; $b = 3\times10^{-5} \frac{m^3}{mol}$

$C_{V,m}^{ideal} = 1.5R$

Hypothetical path w/ $T - V_m$



Mole Balance:

$\frac{dn}{dt} = 0$ (closed)

$n_1 = n_2 = n = 400$ mols

$$V_{m_1} = \frac{0.1}{400} = .00025 \frac{m^3}{mol}$$

$$V_{m_2} = 2V_{m_1} = 0.005 \frac{m^3}{mol}$$

$$P_1 = \frac{8.314 \cdot 300}{.00025 - 3\times10^{-5}} - \frac{40 \frac{J\cdot K \cdot m^3}{mol}}{300 \cdot .00025^2}$$

$$= 9203939.4 \ Pa$$

$$= 9.20 \ MPa$$

First Law: $dU + \underbrace{\cancel{dE_k}}_{\text{neglig.}\to 0} + \cancel{dE_p}^{\,0} = \underbrace{\cancel{\delta Q}^{\,0}}_{\text{adiabatic}} + \cancel{\delta W}^{\,0}$ Rigid $\to dU = 0 \Rightarrow \Delta U_m = 0$

$$\Delta U_m = 0 = \Delta U_{m①} + \Delta U_{m②} + \Delta U_{m③}$$ Use Hypothetical path above

Use: $$dU_m = C_{V,m} dT + \left[T\left(\frac{\partial P}{\partial T}\right)_{V_m} - P\right] dV_m$$

① Const $T = T_1$, $V_{m_1} \to V_m^{ideal} \approx \infty$

$$\Delta U_{m①} = \left[T\left(\frac{\partial P}{\partial T}\right)_{V_m} - P\right] dV_m$$ write in terms of V_m w/ EoS

$$\left(\frac{\partial P}{\partial T}\right)_{V_m} = \frac{\partial}{\partial T}\left[\frac{RT}{V_m - b} - \frac{a}{T V_m^2}\right]_{V_m} = \frac{R}{V_m - b} + \frac{a}{T^2 V_m^2}$$

$$\Rightarrow \Delta U_{m①} = \int_{V_{m_1}}^{V_m^{id}} \left[T_1\left(\cancel{\frac{R}{V_m - b}} + \frac{a}{T_1^2 V_m^2}\right) - T_1\left(\cancel{\frac{R}{V_m - b}} + \frac{a}{T_1^2 V_m^2}\right)\right] dV_m$$

$$= \int_{V_{m_1}}^{V_m^{id}} \frac{2a}{T_1 V_m^2} dV_m = \int_{0.00025}^{\infty} \frac{2(40)}{300 V_m^2} dV_m \overset{\text{wolfram}}{=} 1066.67 \frac{J}{mol}$$

③ Const $T = T_2$, $V_m^{ideal} \approx \infty \to V_{m_2}$

$$\Delta U_{m③} = \int_{V_m^{id}}^{V_{m_2}} \left[T_2\left(\cancel{\frac{R}{V_m - b}} + \frac{a}{T_2^2 V_m^2}\right) - T_2\left(\cancel{\frac{R}{V_m - b}} + \frac{a}{T_2^2 V_m^2}\right)\right] dV_m$$

$$= \int_{V_m^{id}}^{V_{m_2}} \frac{2a}{T_2 V_m^2} dV_m = \frac{2a}{T_2}\int_{\infty}^{0.0005} \frac{1}{V_m^2} dV_m \overset{\text{wolfram}}{=} -160{,}000 \ \frac{1}{T_2} \ \frac{J}{mol \cdot K}$$

② Const V_m, $T_1 \rightarrow T_2$

$$\Delta U_{m_{②}} = C_{v,m}\,dT \Rightarrow \Delta U_{m_{②}} = \int_{T_1}^{T_2} 1.5R\,dT = 1.5R(T_2 - 300)$$

Combine ΔU expressions

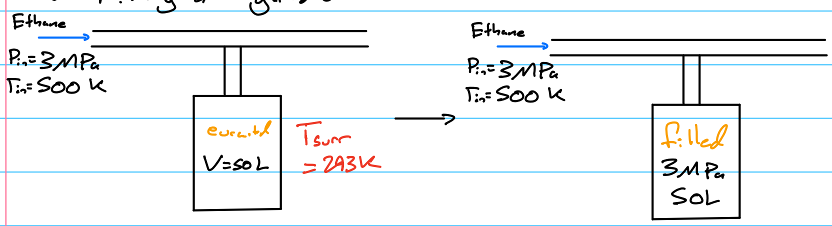
$$\Delta U_m = 1066.67 + 1.5R(T_2 - 300) - \frac{160{,}000}{T_2} = 0$$

Plot to solve for T_2

$T_2 = 263.2$

$$\boxed{T_2 = 263.2\,K}$$

3. Filling a Cylinder



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

$$B' = -2.8\times10^{-8}\ \frac{m^3}{J}$$

a) Find T_2 immediately after closing

I will assume adiabatic - don't know how to control $\dot{Q}$

First Law: $\frac{d}{dt}(U + \cancel{E_k} + \cancel{E_p}) = \dot{n}_{in} h_{m,in} - \cancel{\dot{n}_{out} h_{m,out}} + \cancel{\dot{Q}} + \cancel{\dot{W}_s}$ ($\dot{n}_{out}$: only entering; $\dot{Q}$: assumed; $\dot{W}_s$: no shaft work)

$$\frac{dU}{dt} = \dot{n}_{in} h_{m,in} \Rightarrow dU = h_{m,in}\, dn$$

$$\int_{U_1}^{U_2} dU = \int_{n_1}^{n_2} h_{m,in}\, dn \qquad \cancel{n_2} U_{2m} - \cancel{n_1 U_{1m}} = h_{m,in}(\cancel{n_2} - \cancel{n_1})$$ (initially empty)

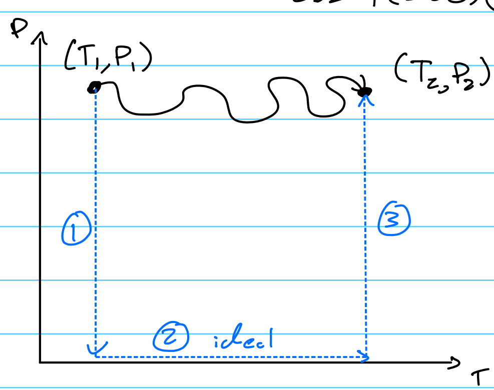
$$\Rightarrow \boxed{U_{2m} = h_{m,in}}$$

enthalpy definition

$$\Rightarrow U_{2m} = U_{in,m} + P_{in} V_{in,m} \rightarrow U_2 - U_{in,m} = P_{in}V_{in,m} \rightarrow \int_{U_{in,m}}^{U_{2m}} dU_m = P_{in} V_{in,m}$$ ← constant

EoS: $P_{in} V_{m,in} = RT(1 + B'P)$

$$= 8.314(500)(1 + [-2.8\times10^{-8}](3\times10^6 Pa)) = \boxed{3807.81\ \frac{J}{mol}}$$



U_{sc}: $$dU_m = \left[c_{P,m} - P\left(\frac{\partial V_m}{\partial T}\right)_P\right]dT - \left[T\left(\frac{\partial V_m}{\partial T}\right)_P + P\left(\frac{\partial V_m}{\partial P}\right)_T\right]dP$$

$$\left(\frac{\partial V_m}{\partial T}\right)_P = \frac{\partial}{\partial T}\left[\frac{RT}{P}(1 + B'P)\right]_P = \frac{R}{P}[1 + B'P]$$

$$\left(\frac{\partial V_m}{\partial P}\right)_T = \frac{\partial}{\partial P}\left[\frac{RT}{P}(1 + B'P)\right]_T = \frac{\partial}{\partial P}\left[\frac{RT}{P} + RTB'\right]_T = -\frac{RT}{P^2}$$

$$\Rightarrow dU_m = \left[c_{P,m} - \cancel{P}\left(\frac{R}{\cancel{P}}[1 + B'P]\right)\right]dT - \left[T\left(\frac{R}{P}[1 + B'P]\right) + \cancel{P}\left(-\frac{RT}{P^{\cancel{2}}}\right)\right]dP$$

$$= \left[c_{P,m} - R(1 + B'P)\right]dT - \left[\frac{RT}{P}[\cancel{1} + B'P] - \cancel{\frac{RT}{P}}\right]dP$$

$$dU_m = \left[c_{P,m} - R(1 + B'P)\right]dT - [RTB']dP$$

① Const $T = T_{in}$, $P_{in} \rightarrow P_{low} \approx 0$

$$\Delta U_{m①} = \int_{P_{in}}^{P_{low}} -[RTB']dP = -RTB'(P_{low} - P_1) = -(8.314)(500)(-2.8\times10^{-8})(0 - 3\times10^6 Pa)$$

$$= \boxed{-349.188\ \frac{J}{mol}}$$

③ Const $T = T_2$, $P_{low} \rightarrow P_2 = 3MPa$

$$\Delta U_{m③} = -RTB'(P_2 - P_{low}) = -(8.314)(T_2)(-2.8\times10^{-8})(3\times10^6 Pa - 0) = \boxed{0.698\ T_2}$$

② Const $P = P_{low}$, $T_{in} \to T_2$

$$dU_m = \left[c_{P,m} - R(1+\underbrace{B'\cancel{P}}_{P_{low}\approx 0})\right]dT = \left[c_{P,m} - R\right]dT$$

$$\Delta U_{m②} = \int_{T_{in}}^{T_2} (C_{P,m} - R)\,dT$$

Appendix: $C^{ideal}_{P,m} = R\left(1.131 + \frac{19.225}{10^3}T - \frac{5.561}{10^6}T^2\right)$

$$= \int_{T_{in}}^{T_2} \left(R\left(1.131 + \frac{19.225}{10^3}T - \frac{5.561}{10^6}T^2\right) - R\right)dT$$

$$= R\int_{T_{in}}^{T_2} \left(0.131 + \frac{19.225}{10^3}T - \frac{5.561}{10^6}T^2\right)dT$$

$$= R\left[0.131(T_2 - 500) + \frac{19.225}{2\cdot 10^3}(T_2^2 - 500^2) - \frac{5.561}{3\cdot 10^6}(T_2^3 - 500^3)\right]$$

Combine into one equation, use wolfram to solve

From $P_{in}V_{m,in}$ expression

$dU_m = P_{in}V_{m,in}$

$$\Delta U_m = -349.188\,\frac{J}{mol} + 0.698\,T_2 + 8.314\left[0.131(T_2 - 500) + \frac{19.225}{2\cdot 10^3}(T_2^2 - 500^2) - \frac{5.561}{3\cdot 10^6}(T_2^3 - 500^3)\right] = 3807.81\,\frac{J}{mol}$$

$T_2 = 552.118$ $\boxed{T_2 = 552.118\text{ K}}$

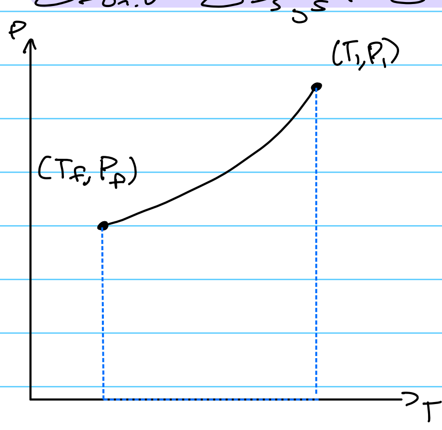
b) Find ΔS_{univ} given final state equilibrates to $T_{surr} = 293K$

$$V_{m_2} = \frac{RT_2}{P_2}(1 + B'P_2) = \frac{8.314\cdot 552.118}{3\times 10^6}\left(1 - 2.8\times 10^{-8}(3\times 10^6)\right) = 0.0014\,\frac{m^3}{mol}$$

$$P_f = \frac{RT_f}{V_{m_2}}(1 + B'P_f) = \frac{8.314\cdot 293}{0.0014}\left(1 - 2.8\times 10^{-8}P_f\right)$$

$$P_f = 1740001.429 - 0.04872\,P_f \implies P_f = 1659166.758\text{ Pa} = 1.66\text{ MPa}$$

$\Delta S_{univ} = \Delta S_{sys} + \Delta S_{surr}$



Use: $dS_{sys_m} = \frac{C_{P,m}}{T}dT + \left(\frac{\partial V_m}{\partial T}\right)_P dP$

$\left(\frac{\partial V_m}{\partial T}\right)_P = \frac{R}{P}\left[1 + B'P\right]$ From Previous page

$$\implies dS_{sys_m} = \frac{C_{P,m}}{T}dT + \frac{R}{P}\left[1 + B'P\right]dP$$

① Const $T=T_i$, $P_i \to P_{low} \approx 0$

$$\Delta S_{m_{①}} = \int_{P_i}^{P_{low}} \frac{R}{P}\left[1+B'P\right]dP = \int_{P_i}^{P_{low}} \frac{8.314}{P}\left(1-2.8\times10^{-8}P\right)dP$$

$$= R\left(\left[\ln(P_{low}) - \ln(P_i)\right] - 2.8\times10^{-8}\left(P_{low}-P_i\right)\right)$$

③ Const $T=T_f$, $P_{low} \to P_f$

$$\Delta S_{m_{③}} = \int_{P_{low}}^{P_f} \frac{R}{P}\left[1+B'P\right]dP = \int_{P_{low}}^{P_f} \frac{8.314}{P}\left(1-2.8\times10^{-8}P\right)dP$$

$$= R\left(\left[\ln(P_f) - \ln(P_{low})\right] - 2.8\times10^{-8}\left(P_f - P_{low}\right)\right)$$

Combine ① and ③ to eliminate undefined behavior

$$\Delta S_{m_{①}} + \Delta S_{m_{③}} = R\left(\left[\ln(P_{low}) - \ln(P_i)\right] - 2.8\times10^{-8}\left(\cancel{P_{low}}^{0} - P_i\right)\right) +$$

$$R\left(\left[\ln(P_f) - \ln(P_{low})\right] - 2.8\times10^{-8}\left(P_f - \cancel{P_{low}}^{0}\right)\right)$$

$$= R\left[\cancel{\ln(P_{low})} - \ln(P_i) + 2.8\times10^{-8}(P_i) + \ln(P_f) - \cancel{\ln(P_{low})} - 2.8\times10^{-8}(P_f)\right]$$

$$= R\left[\ln\left(\frac{P_f}{P_i}\right) + 2.8\times10^{-8}\left(P_i - P_f\right)\right] = -4.42$$

② Const $P = P_{low}$, $T_i \to T_f$

$$\Delta S_{m_{②}} = \int_{T_i}^{T_f} \frac{C_{pm}}{T}dT = \int_{500}^{293} \frac{R\left(1.131 + \frac{19.225}{10^3}\cancel{T} - \frac{5.561}{10^6}T^{\cancel{2}}\right)}{\cancel{T}}dT$$

$$= R\int_{500}^{293} \frac{1.131}{T} + \frac{19.225}{10^3} - \frac{5.561}{10^6}T\,dT$$

$$= R\left[1.131\ln\left(\frac{293}{500}\right) + \frac{19.225}{10^3}\left[293-500\right] - \frac{5.561}{10^6}\left[293^2 - 500^2\right]\right] = -34.3169$$

$$\Rightarrow \Delta S_{sys_m} = -34.3169 - 4.42 = -39.24\ \frac{J}{mol\cdot K}$$

Energy balance on Surroundings

$$dU + \underbrace{\cancel{dE_k} + \cancel{dE_p}}_{\text{negligible}} = \underbrace{\cancel{\delta W}}_{\text{no work}} + \delta Q \Rightarrow \Delta u = Q$$

enthalpy $\rightarrow \Delta h_m - \Delta(Pv)_m = Q_m$ use ideal $c_{p,m}$, v_m is constant

$$\int_{T_i}^{T_f} R\left(1.131 + \frac{19.225}{10^3}T - \frac{5.561}{10^6}T^2\right)dT - v_m \underbrace{\Delta P}_{P_f - P_i} = q_m$$

$$R\left[1.131(T_f - T_i) + \frac{19.225}{2\cdot 10^3}(T_f^2 - T_i^2) - \frac{5.561}{3\cdot 10^6}(T_f^3 - T_i^3)\right] - 0.0014\left((1.66 - 3.00)\times 10^6\right)$$

$$\Rightarrow q = -11650.4 \ \frac{J}{mol} = -q_{surr}$$

$$\Rightarrow \Delta S_{surr_m} = \frac{11650.4}{243K} = 34.7623 \ \frac{J}{mol\cdot K}$$

$$n = \frac{1}{0.0014 \frac{m^3}{mol}} \cdot (50L \times 10^{-3}) \doteq 35.71 \ mol$$

Calculate ΔS_{univ}

$$\Delta S_{univ} = 35.71 mol (34.7623 - 34.24) = 18.65 \ \frac{J}{K}$$

$$\boxed{\Delta S_{univ} = 18.65 \ \frac{J}{K}}$$

4. Answer the following reflection questions (5 points):

   a. What about the way this class is taught is helping your learning?

   b. What about the way this class is taught is inhibiting your learning?

A) There was nothing that changed between this week's homework and the previous assignment. The focus on examples and discussion during class is helping my learning greatly. I have found the use of examples and long explanations helpful in solving the homework problems. This combined with the enthusiasm shown by Dr. Warburton makes the class interesting and engaging. The lack of busy work also keeps homework interesting.

B) There is nothing inhibiting my learning at this stage in the class. I think it would be helpful if there was echo 360 for the class, but I only really see this useful if I had to skip class one day. I haven't needed to yet this semester, but it could be useful for others in the future. This class seems built on helping learning, and there isn't much to complain about or comment on!