

$$H^E = -(4 \text{ kJ/mol}) X_A X_W$$

$$S^E = 0$$

A = A
W = water

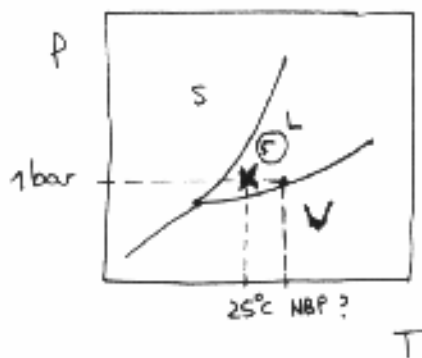
Part a)

Since (5) is pure saturated liquid water, use the steam tables to find P_{chamber} for $T_{\text{chamber}} = 10^\circ\text{C} + 273.15 = 283 \text{ K}$:

$$P_{\text{H}_2\text{O}}^{\text{sat}} @ T = 283 \text{ K} = 1.227 \text{ kPa}$$

$$P_{\text{chamber}} = 0.0123 \text{ atm}$$

Part b)

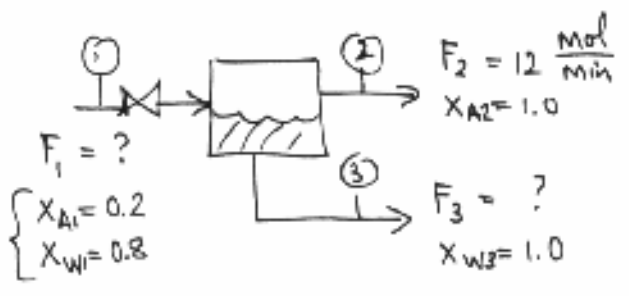


We know that (5) is pure liquid water at 1 atm, 25°C. (i.e. X on S-L-V diagram to left) since NBP is defined as the temperature at which $P_{\text{H}_2\text{O}}^{\text{sat}}(\text{NBP}) = 1 \text{ atm}$,

$$T_{\text{BP}} \geq 25^\circ\text{C}$$

Part c)

◇ Using control volume as shown on p. ①, we perform a mass balance over the chamber:



* OVERALL MB: $F_1 = F_2 + F_3$ — ①

* MB ON A: $X_{A1} F_1 = X_{A2} F_2 + X_{A3} F_3$ — ②

$(0.2) F_1 = (1.0)(12 \text{ mol/min})$

thus, $F_1 = (12/0.2)$
 $= 60 \text{ mol/min} \cdot \left(\frac{1 \text{ min}}{60 \text{ s}}\right)$

so, $F_1 = 1 \text{ mol/s}$

◇ also, from ①,

$F_3 = F_5 = F_1 - F_2$
 $= 1 \text{ mol/s} - \frac{12 \text{ mol/min}}{60 \text{ s/min}}$
 $= 0.8 \text{ mol/s}$

$F_4 = F_2 = \frac{12 \text{ mol/min}}{60 \text{ s/min}}$
 $= 0.2 \text{ mol/s}$

* MB ON W: $X_{W1} F_1 = X_{W2} F_2 + X_{W3} F_3$ — ③

Part d)

$$\dot{W}_{ideal} = \dot{W}_{min} = \dot{W}_{rev}$$

from STVN (16.2):

$$\dot{W}_{ideal} = \Delta(Hin)_{fs} - T_0 \Delta(Sin)_{fs} \quad \text{--- (4)}$$

Using this on the entire system (OVERALL CONTROL VOLUME I):

$$\Delta(Hin)_{fs} = F_5 H_5 + F_4 H_4 - F_1 H_1 \quad \text{--- (5)}$$

$$T_0 \Delta(Sin)_{fs} = T_0 [F_5 S_5 + F_4 S_4 - F_1 S_1] \quad \text{--- (6)}$$

Using the mass balance from part c), we know that:

$$\left. \begin{array}{l} F_5 = F_3 = X_{W1} F_1 \\ F_4 = F_2 = X_{A1} F_1 \end{array} \right\} \text{eqn's (2) \& (3)}$$

Also,

$$\begin{aligned} H_5 &= H_W^{pure}(1 \text{ atm}, 25^\circ\text{C}) \\ H_4 &= H_A^{pure}(1 \text{ atm}, 25^\circ\text{C}) \\ H_1 &= X_{A1} H_{A1} + X_{W1} H_{W1} + H^E \\ &= X_{A1} H_A^{pure}(5 \text{ atm}, 25^\circ\text{C}) + X_{W1} H_W^{pure}(5 \text{ atm}, 25^\circ\text{C}) + H^E \end{aligned}$$

Using the above info in (5):

$$\Delta(Hin)_{fs} = F_5 \left[\cancel{H_W^{pure}(1 \text{ atm}, 25^\circ\text{C})} - \cancel{H_W^{pure}(5 \text{ atm}, 25^\circ\text{C})} \right] + F_4 \left[\cancel{H_A^{pure}(1 \text{ atm}, 25^\circ\text{C})} - \cancel{H_A^{pure}(5 \text{ atm}, 25^\circ\text{C})} \right] - F_1 H^E$$

— since $H, S \neq f(P)$ for liquids

∴ Thus, $\Delta(Hin)_{fs} = -F_1 H^E$ ——— (7)

∴ By similar reasoning

$$T_0 \Delta(Sin)_{fs} = T_0 [F_3 S_5 + F_4 S_6 - F_1 S_1]$$

$$S_5 = S_W^{pure}(1 \text{ atm}, 25^\circ\text{C})$$

$$S_6 = S_A^{pure}(1 \text{ atm}, 25^\circ\text{C})$$

$$S_1 = X_{A1} S_{A1} + X_{A2} S_{A2} - R X_{A1} \ln X_{A1} - R X_{W1} \ln X_{W1} + \cancel{H^E}$$

∴ gives:

$$T_0 \Delta(Sin)_{fs} = RT_0 F_1 [X_{A1} \ln X_{A1} + X_{W1} \ln X_{W1}]$$
 ——— (8)

∴ With:

$$X_{A1} = 0.2$$

$$X_{W1} = 0.8$$

$$H^E = -4(0.8)(0.2)$$

$$= \underline{-0.64 \text{ kJ/mol}}$$

∴ We get:

— from (7), $\Delta(Hin)_{fs} = -(1 \text{ mol/s})(-640 \text{ J/mol})$
 $= +640 \text{ W}$

— from (8), $T_0 \Delta(Sin)_{fs} = (8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}})(298 \text{ K})(1 \frac{\text{mol}}{\text{s}}) [(0.2) \ln(0.2) + (0.8) \ln(0.8)]$
 $= -1,239.8 \text{ W}$

∴ Hence,

$$\dot{W}_{ideal} = 640 - (-1,239.8)$$

$$\dot{W}_{min} = 1.88 \text{ kW}$$

∴ Work must be done in pumping & compression.

Part e)

From SVN, (16.9)

$$\dot{W}_{lost} = T_0 \Delta(S_{in})_{fs} - \dot{Q}$$

where in this case, positive \dot{Q} is considered to be going IN to the system.

rearranging,

$$\dot{Q} = T_0 \Delta(S_{in})_{fs} - \dot{W}_{lost}$$

from part d), $T_0 \Delta(S_{in})_{fs} = -1239.8 \text{ W}$

thus, $\dot{Q} = (-1239.8 \text{ W}) - (4,000 \text{ W})$

$$\dot{Q} = -5.24 \text{ kW}$$

is heat must be removed

Part f)

Start from the relationship between \bar{H}_A and H ; namely

$$\bar{H}_A = \underbrace{H}_{\text{TERM I}} + \underbrace{\left(\frac{\partial H}{\partial X_A}\right) X_W}_{\text{TERM II}} \quad \text{--- (9)}$$

Now,

$$H = H^{REAL} = H^{ID} + H^E$$

TERM I: $H = X_A H_A + X_W H_W - 4 X_W X_A$

$$= X_A H_A + (1 - X_A) H_W - 4(1 - X_A) X_A \quad \text{--- (10)}$$

And term II is found by differentiation of (10):

$$\begin{aligned} \frac{\partial H}{\partial X_A} &= \frac{\partial (10)}{\partial X_A} \\ &= H_A - H_W - 4(-1)X_A - 4(1-X_A)(+1) \\ &= H_A - H_W + 4X_A - 4X_W \end{aligned}$$

TERM II:

$$X_W \left(\frac{\partial H}{\partial X_A} \right) = X_W H_A - X_W H_W + 4X_A X_W - 4X_W^2 \quad (11)$$

\bar{H}_A is found by adding (I) and (II):

$$(I): \quad H = X_A H_A + \cancel{X_W H_W} - \cancel{4X_W X_A}$$

$$(+)\quad (II): \quad X_W \left(\frac{\partial H}{\partial X_A} \right) = X_W H_A - \cancel{X_W H_W} + \cancel{4X_A X_W} - 4X_W^2$$

$$\bar{H}_A = (X_A + \cancel{X_W}) H_A - 4X_W^2$$

$\xrightarrow{=1}$

so, $\bar{H}_A = H_A - 4X_W^2$

Thus,

$$\begin{aligned} \bar{H}_A - H_A &= -4X_W^2 \\ &= -4(0.8)^2 \end{aligned}$$

$$\bar{H}_A - H_A = -2.56 \text{ kJ/mol}$$