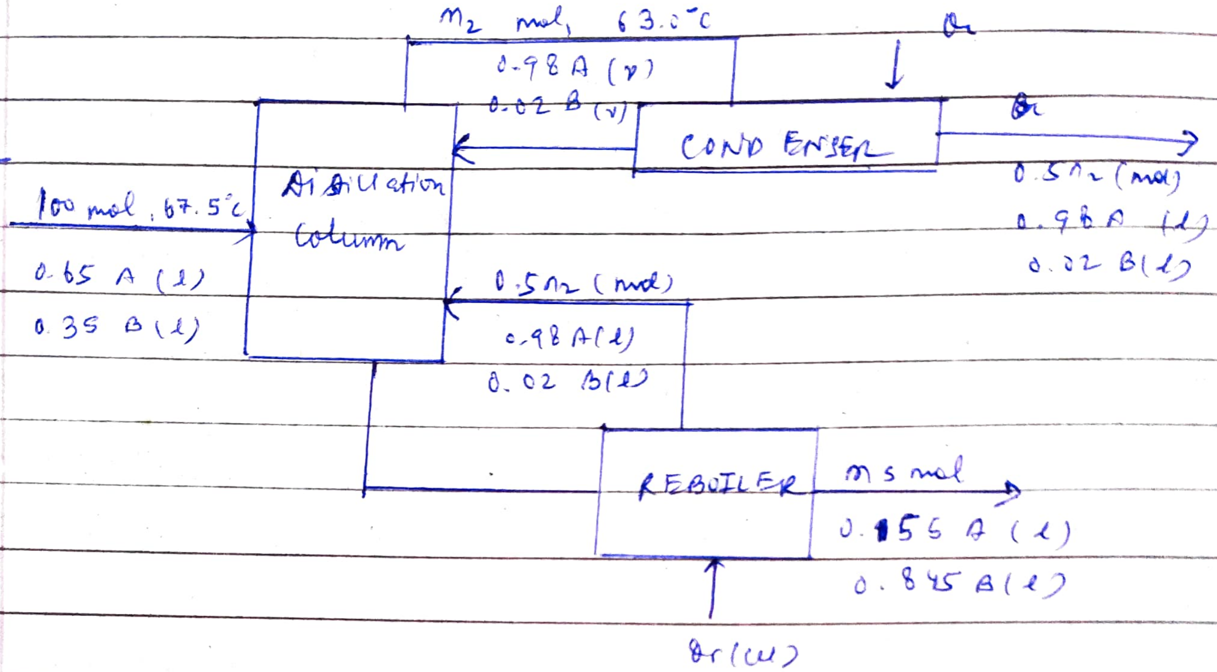
ASSIGNMENT- 5

7.42



(a) By overall balance on the system

Balancing moles : $100 = 0.5\, n_2 + m_5$ — ①

$0.65 \times 100 = 0.155\, m_5 + 0.5 n_2 \times 0.98$ — ②

from ① & ②

$m_2 = 120$ mol & $m_5 = 40$ mol

Overhead product flow rate :-

$0.5\,(120)\,0.98 = 58.8$ (mol A)

$0.5\,(120)\,0.02 = 1.2$ (mol B)

Bottom product flow rate

$0.155\,(40) = 6.2$ moles A

$0.845\,(40) = 33.8$ mol B

Doing the overall energy balance :-

$$Q = \Delta H = \sum_{out} n_i \hat{H}_i - \sum_{in} n_i \hat{H}_i$$

$$Q = 58.8\,(0) + 1.2\,(0) + 6.2\,(1385) + 33.8\,(1312)$$
$$- 65\,(354) - 35\,(335)$$

$$Q = 1.82 \times 10^4 \text{ cal}$$

b) Condenser

$2(58.8) = 117.6$ moles A

$2(1.2) = 2.4$ moles B

Energy balance - $Q_c = \Delta H$

$Q_c = 117.6(0 - 7322) + 2.4(0 - 6807)$

$= -8.77 \times 10^5$ cal.

$Q_r = Q - Q_c = 1.62 \times 10^4 - (-8.77 \times 10^5)$

$Q_r = 8.95 \times 10^5$ cal.

8.5 H_2O (v, 100°C, 1 atm) & H_2O (v, 350°C, 100 bar).

a) $\hat{H} = 2926$ kJ/kg $- 2676$ kJ/kg (from steam tables)

$\hat{H} = 250$ kJ/kg

b) $$\hat{H} = \int_{100}^{350} [(0.03346 + 0.6886 \times 10^{-5} T) + (0.7604 \times 10^{-8} T^2) - 3.593 \times 10^{-12} T^3)] \, dT$$

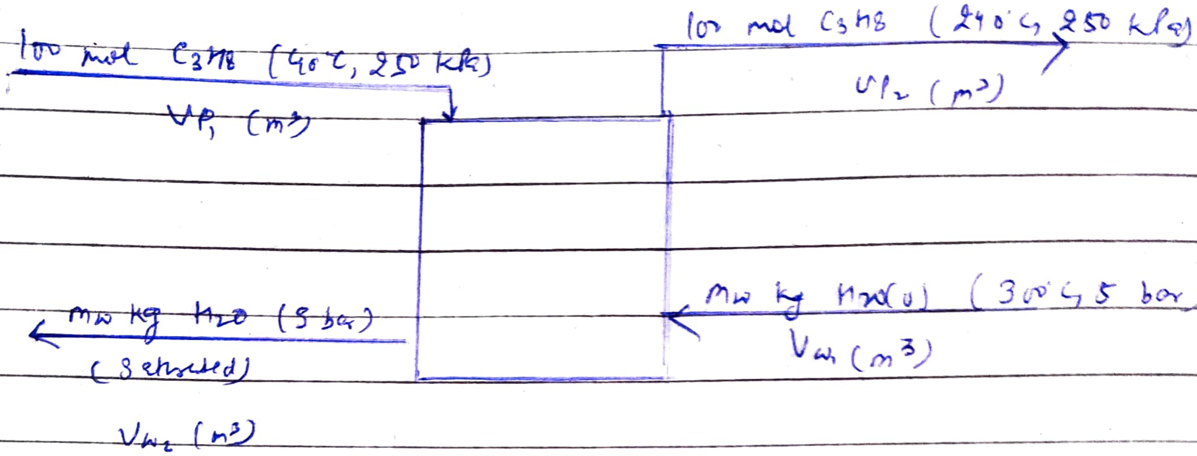
$\hat{H} = 8.845$ kJ/mol

$\Rightarrow 491.4$ kJ/kg (from table B2)

The difference between the values calculated in a and b is $\Delta\hat{H}$ for H_2O when it transforms from H_2O (v, 350°C, 1 atm) to H_2O (v, 350°C, 100 bar)

8.24

a)



b) C_3H_8 : $H_{in} = 0$ kJ/mol

$$\hat{H}_{out} = \int_{40}^{240} C_p\,dT = 19.36 \text{ kJ/mol}$$

H_2O : $\hat{H}_{in} = 3065$ kJ/kg (from table B7)

$\hat{H}_{out} = 640.1$ kJ/kg (form table B6)

c) $\Delta\hat{H}_{C_3H_8} = 19.36$ kJ/mol

$\Delta\hat{H}_w = (640.1 - 3065)$ kJ/kg $= -2425$ kJ/kg

$Q = \Delta H = 100\,\Delta\hat{H}_{C_3H_8} + m_w\,\Delta\hat{H}_w = 0 \Rightarrow m_w = 0.798$ kg

V_{steam} @ 5 bar & 300°C $= 0.522$ m^3/kg (B7)

$$\hat{V}_{C_3H_8}\,(40°C, 250\text{ kPa}) = \frac{0.008314\ m^3\ \text{kPa/mol.K}}{250\text{ kPa}}\ \Big|\ 313\text{K}$$

$\hat{V}_{C_3H_8}$ @ 40°C, 250 kPa $= 0.0104$ m^3/mol C_3H_8

$$\frac{0.798\text{ kg steam}}{100\text{ mol } C_3H_8}\ \Big|\ \frac{0.522\ m^3\text{ steam}}{1\text{ kg steam}}\ \Big|\ \frac{1\text{ mol } C_3H_8}{0.0104\ m^3\ C_3H_8} = 0.4\ m^3\text{ steam}/m^3\ C_3H_8$$

d) $\dot{Q} = m_w \Delta \hat{H}_w = \dfrac{0.798 \text{ kg steam}}{100 \text{ mol } C_3H_8} \Bigg| \dfrac{2425 \text{ kJ}}{\text{kg steam}} \Bigg| \dfrac{1 \text{ mol } C_3H_8}{0.0104 \text{ m}^3 \, C_3H_8}$

$$\dot{Q} = 1860 \; \frac{\text{kJ}}{\text{m}^3 \, C_3H_8 \text{ fed}}$$

e) As a result of decreased heat transfer there will be a lower outlet temperature for propane and a higher outlet temperature for steam

8-35

a) $\dot{m} = 175$ kg / min

$\Delta \hat{H}_v = 56.9$ kJ / mol

M.W. = 62.07 g / mol

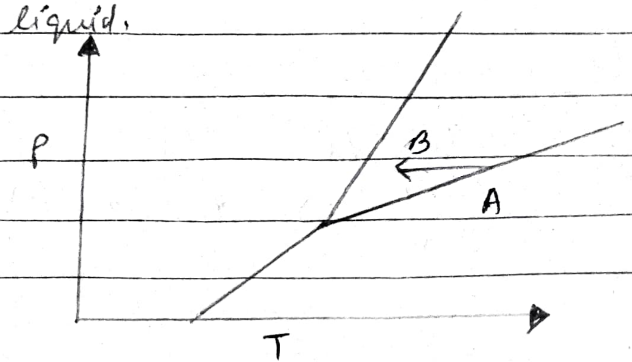
$\dot{Q} = \Delta H = \dfrac{175 \text{ kg}}{\text{min}} \Bigg| \dfrac{10^3 \text{ g}}{\text{kg}} \Bigg| \dfrac{56.9 \text{ kJ}}{\text{mol}} \Bigg| \dfrac{1 \text{ mol}}{62.07 \text{ g}} \Bigg| \dfrac{1 \text{ min}}{60 \text{ s}} = 2670 \text{ kW}$

$\dot{Q} = 2670$ kW

b) If heat were transferred at a lower rate than that calculated in part (a) then the product stream will be a mixture of vapor and liquid.

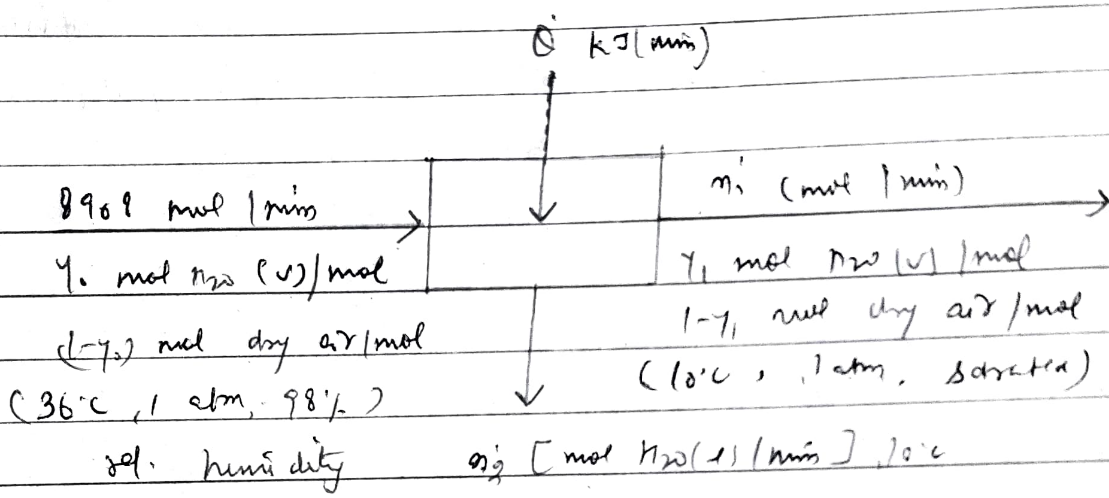
c) If heat were transfered at a higher rate than that calculated in part (a) then the product stream will be a supercooled liquid.

Phase diagram:-



8.47

$$\frac{226\ m^3}{min} \left| \frac{273\ K}{309\ K} \right| \frac{10^3\ mol}{22.415\ m^3\ (STP)} = 8908\ \text{mol air (humid) / min}$$



a) DOF analysis

5 unknowns − (2 material balances + 1 energy balance + 1 rel. humidity + 1 saturation @ outlet)

DOF = 0

b) Air @ inlet

$y_0 P = 0.98\ p_w^*\ (36°C)$ (from table B3), $P = 760$ mm Hg

$y_0 = 0.0575$ mol H_2O (v) / mol $p_w^* = 44.58$ mm Hg

Air @ outlet

$y_1 = p^*(10°C) / P$

$= \frac{9.209}{760} \Rightarrow y_1 = 0.0121$ mol H_2O (v) / mol

Air balance

$(1-0.0575)(8908 \text{ mol/min}) = (1-0.0121)\dot{n}_1 \Rightarrow \dot{n}_1 = 8499$ mol/min

H_2O balance

$0.0575(8908) = 0.0121(8499) + \dot{n}_2$

$\dot{n}_2 = 409$ mol $H_2O(l)$ / min

Energy balance

$$Q = \Delta H = \sum_{out} \dot{n}_i \hat{H}_i - \sum_{in} \dot{n}_i \hat{H}_i$$

$= -2.5 \times 10^4$ kJ	60 min	9.486×10^{-4} Btu	1 ton
min	1 h	0.001 kJ	-12×10^3 Btu/h

$Q = 119$ tons

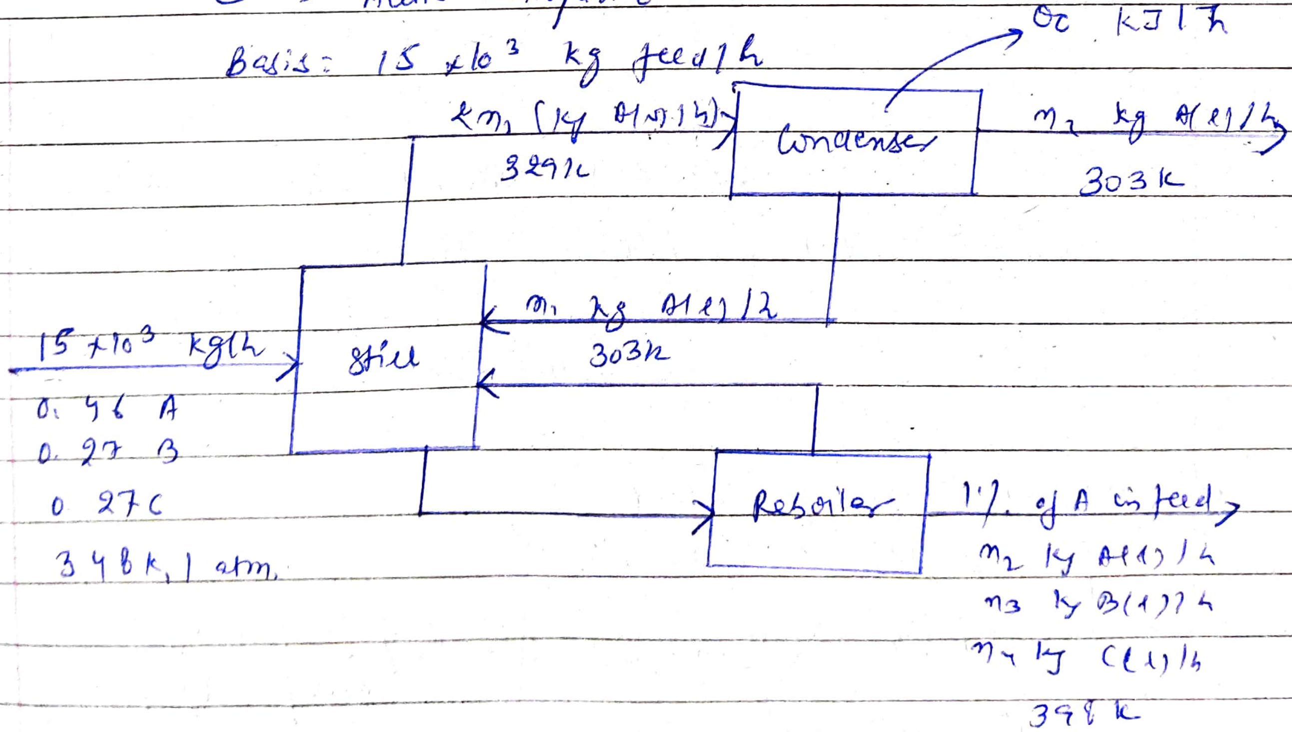
8.57 Let,

A → Acetone

B → Acetic Acid

C → Acetic anhydride

Basis: 15×10^3 kg feed/h



a) $\dot{m}_2 = 10^{-2} \times 0.46 \times 15 \times 10^3 = 69$ kg A/h

Acetic acid balance :- $\dot{m}_3 = 0.27\,(15 \times 10^3) = 4050$ kg B/h

Acetic anhydride balance :- $\dot{m}_4 = 0.27\,(15 \times 10^3) = 4050$ kg/h

Acetone balance :- $(0.46)(15 \times 10^3) = m_1 + 69$

$m_1 = 6831$ kg/h

Bottom product :- $(69 + 4050 + 4050)$ kg/h

$= 8169$ kg/h

0.8% acetone

49.6% acetic acid

49.6% acetic anhydride

b) By energy balance on ~~condenser~~ condenser

$C_3H_6O\ (v,\ 329\,K) \rightarrow C_3H_6O\ (l,\ 329\,K) \rightarrow C_3H_6O\ (l,\ 303\,K)$

$$\Delta\hat{H} = -\Delta\hat{H}_v\,(329\,K) + \int_{329}^{303} C_p\, dT \qquad (C_p = 2.3)$$

$= -520.6 + 2.3\,(-26) = -580.4$ kJ/kg

$$\dot{Q}_c = \Delta H = \dot{m}\,\Delta\hat{H} = \frac{(2 \times 6831)\ \text{kg}}{\text{h}} \left| \frac{-580.4\ \text{kJ}}{\text{kg}} \right.$$

$= -7.93 \times 10^6$ kJ/h

c) Overall Energy Balance

for acetic anhydride :-

$$C_p = [(4 \times 12) + (6 \times 18) + (3 \times 25)]\ \frac{\text{J}}{\text{mol}} \left| \frac{10^3\ \text{mol}}{\text{kg}} \right| \frac{1\ \text{mol}}{102\ \text{g}} \left| \frac{1\ \text{kJ}}{10^3\ \text{J}} \right.$$

$\hat{H}\,(T) = C_p\,(T - 348)$

$\dot{Q} = \Delta \dot{H} = \dot{Q}_c + \dot{Q}_r$

$\sum_{out} \dot{n}_i \hat{H}_i - \cancel{\sum_{in} \dot{n}_i \hat{H}_i}^{0} \Rightarrow \dot{Q}_r = -\dot{Q}_c + \sum_{out} \dot{n}_i \hat{H}_i$

$= (7.93 \times 10^6 + 2 \times 10^5)$

$\dot{Q}_r = 8.13 \times 10^6 \text{ kJ/h}$

d) H_2O (saturated) @ 11 bar

from table 8.6

$\Delta \hat{H}_v = 1999 \text{ kJ/kg}$

$\dot{Q}_r = \dot{n}_{H_2O} \Delta \hat{H}_v$

$\dot{n}_{H_2O} = \dfrac{8.13 \times 10^6 \text{ kJ/h}}{1999 \text{ kJ/kg}} = 4070 \text{ kg steam/h}$