Assignement - 2.

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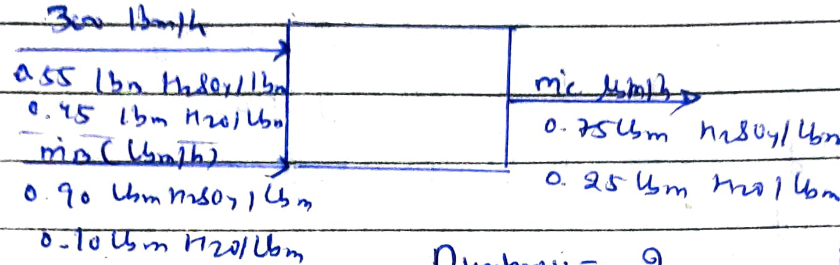
(3) 4.21

a)



$n_{unknown} = 2$,
$n_{indep. eq} = 2$, so $\boxed{n_{df} = 0}$ Solvable

$300 + \dot m_B = \dot m_c$ — (1)

H_2SO_4 balance:- $0.55(300) + 0.90(\dot m_B) = 0.75 \dot m_c$ — (2)

Solving (1) & (2)

$\dot m_B = 400$ lbm/h, $\dot m_c = 700$ lbm/h

b) Slopes will be equal.

for A $\quad \dfrac{\dot m_A - 150}{R_A - 25} = \dfrac{500 - 150}{70 - 25} \Rightarrow \dot m_A = 7.78 R_A - 44.2$

for B $\quad \dfrac{\dot m_B - 200}{R_B - 20} = \dfrac{800 - 200}{60 - 20} \Rightarrow \dot m_B = 15 R_B - 100$

$\dfrac{\ln x - \ln 20}{R_x - 4} = \dfrac{\ln 100 - \ln 20}{10 - 4}$, $\ln x = 0.2682 R_x + 1.923$

$x = 6.841 e^{0.2682 R_x}$

$m_A = 300$, $R_A = \dfrac{300 + 44.2}{7.78} = 44.3$

$m_B = 400$, $R_B = \dfrac{400 + 100}{15} = 33.3$

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$x = 55\%$, $R_x = \frac{1}{0.268} \ln(55/6.347) = 7.78$

© H_2SO_4 balance: $0.01 \dot{m}_A + 0.90 \dot{m}_B = 0.75 \dot{m}_C = 0.75(\dot{m}_A + \dot{m}_B)$

Since $(\dot{m}_C = \dot{m}_A + \dot{m}_B)$

$$\dot{m}_B = \frac{(0.75 - 0.01x)\dot{m}_A}{0.15}$$

$$15.0 R_B - 100 = \frac{[0.75 - 0.01(6.41 e^{0.2682 R_x})](7.78 R_A - 44.4)}{0.15}$$

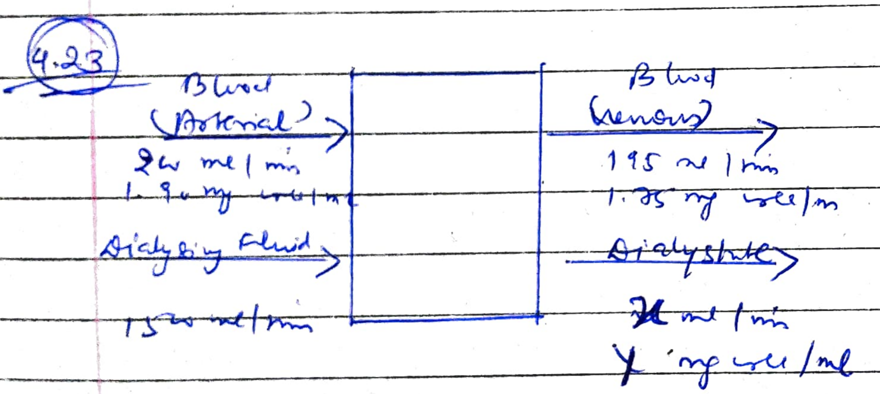
$R_B = (2.59 - 0.236 e^{0.2682 R_x}) R_A + 1.35 e^{0.2682 R_x} - 8.13$

$R_A = 44.3$

$R_x = 7.78$

$R_B = (2.59 - 0.236 e^{0.2682(7.78)})44.3 + 1.35 e^{0.2682(7.78)} - 8.13 = 33.3$

4.23



a) Rate of the removal of water $= 200 - 195 = 5$ ml/min

Urea removal rate $= 1.9(200) - 1.75(195) = 38.8$ mg urea/min

b) $x = 1500 + 5 = 1505$ ml/min

$$y = \frac{38.8 \text{ mg urea/min}}{1505 \text{ ml/min}} = 0.0258 \text{ mg urea/ml}$$

c) $$\frac{(2.7 - 1.1)\text{ mg removed}}{\text{ml}} \left| \frac{1 \text{ ml}}{38.8 \text{ mg removed}} \right| \frac{10^3 \text{ ml}}{1 \text{L}} \left| 5.0 \text{ L} \right.$$

$= 206$ min $(3.4$ h$)$

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4.28 No. of Balances

Overall - 3

for mixing point - 3

for unit 1 - 2

for unit 2 - 3

Overall mass balance => $\dot{m}_3$

Mass balance - Unit 1 => $\dot{m}_1$

A- balance in Unit 1 → x_4

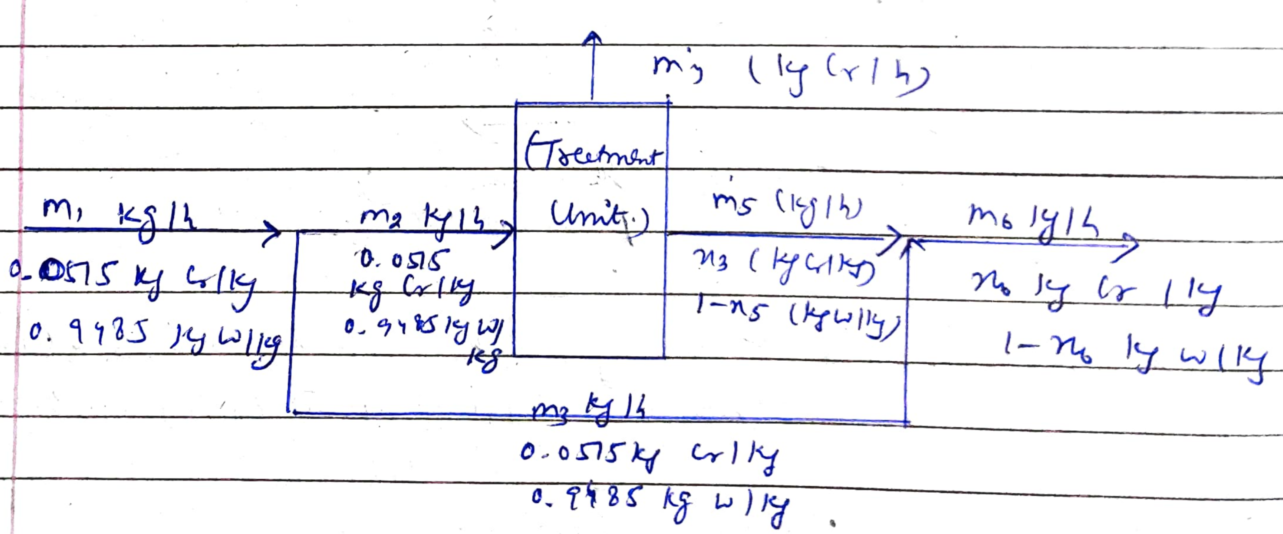
mass balance - mixing point, $\dot{m}_2$

A - balance - mixing point → x_2

C - balance - mixing point → y_2

4.32

a)



b)

$m_1 = 6000$ kg/h, $m_2 = 4500$ kg/h

$m_3 = 6000 - 4500 = 1500$ kg/h

95% Cr is removed => $\dot{m}_4 = 0.95(0.0515)(4500)$

$= 220.2$ kg Cr/h

$\dot{m}_5 = 4500 - 220.2 = 4279.8$ kg/h

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Balacing Cr on Treatment Unit

$4779.8x_5 + 220.2 = 0.0575(4500)$

$x_5 = 0.0027076$ kg Cr/kg

$m_6 = 1500 + 4279.8 = 5779.8$ kg/h

Cr balance: $x_6 = \frac{0.0575(1500) + 0.0002707(4279.8)}{5779.8}$

$= 0.0154$ kg Cr/kg

d) Things that I need to know are -

1. Revenue from recovered Chromium
2. Chromimum emissions limit in the sea
3. Installation of Equipment
4. Maintenance
5. Additional Costs.

4.40 a) $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

5 lb-mole O_2 → 4 lb-mole NO formed.

$\frac{5}{4} =$ 1.25 mole O_2 reacts / lb-mole NO formed

b) ~~(n_{O_2}) theoretical~~ $= \frac{100 \text{ kmol } NH_3}{h} \Big| \frac{5 \text{ kmol } O_2}{4 \text{ kmol } NH_3} = 125$ kmol O_2

40% excess O_2 ⇒ $(n_{O_2})_{feed} = 1.40(125 \text{ kmol } O_2)$

$= 175$ kmol O_2

c) $500 \text{ (kg } NH_3) \times \frac{1 \text{ (kmol } NH_3)}{17 \text{ (kg } NH_3)} = 2.94$ kmol NH_3

$100 \text{ (kg } O_2) \times \frac{1 \text{ (kmol } O_2)}{32 \text{ (kg } O_2)} = 3.125$ kmol O_2

$\left(\frac{n_{O_2}}{n_{NH_3}}\right)_{input} = \frac{3.125}{2.94} = 1.06$, $\left(\frac{n_{O_2}}{n_{NH_3}}\right)_{output} = \frac{5}{4} = 1.25$

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1.06   21.25

thus O_2 is limiting reagent!

NH_3 required = 3.125 kmol O_2 | $\frac{4 \text{ kmol } NH_3}{5 \text{ kmol } O_2}$ = 2.5 kmol NH_3

% excess $NH_3 = \frac{2.94 - 2.50}{2.50} \times 100 =$ 17.6% excess NH_3

extent of rxn, $n_{O_2} = (n_{O_2})_0 - \nu_{O_2}\xi \Rightarrow 0 = 3.125 - (.5)\xi$

ξ = 0.625 kmol = 625 mol

Mass of NO :. 3.125 kmol O_2 | $\frac{4 \text{ kmol NO}}{5 \text{ kmol } O_2}$ | $\frac{30 \text{ kg NO}}{1 \text{ kmol NO}}$

= 75 kg NO

4.48

a) $A + B \rightleftharpoons C + D$

$n_A = n_{A_0} - \xi$ $n_C = n_{C_0} + \xi$

$n_B = n_{B_0} - \xi$ $n_D = n_{D_0} + \xi$

thus

$y_A = \frac{(n_{A_0} - \xi)}{n_T}$, $y_B = \frac{(n_{B_0} - \xi)}{n_T}$, $y_C = \frac{(n_{C_0} + \xi)}{n_T}$

$y_D = \frac{(n_{D_0} + \xi)}{n_T}$

at eq. $\frac{y_C y_D}{y_A y_B} = 4.87$.

$(n_{C_0} + \xi)(n_{D_0} + \xi) = 4.87(n_{A_0} - \xi)(n_{B_0} - \xi) = 3.87$

$3.87\xi^2 - (n_{C_0} n_{D_0} - 4.87 n_{A_0} n_{B_0}) - (n_{C_0} + n_{D_0}$

$+ 4.87(n_{A_0} + n_{B_0}))\xi$

$\boxed{a\xi^2 + b\xi + c = 0}$ form

$\xi = \frac{1}{2a}(-b \pm \sqrt{b^2 - 4ac})$

$a = 3.87$, $b = -(n_{C_0} + n_{D_0} + 4.87(n_{A_0} + n_{B_0}))$

$c = -(n_{C_0} n_{D_0} - 4.87 n_{A_0} n_{B_0})$

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b) 1 mol A ~~feed~~ fed.

$n_{A0} = 1, \quad n_{B0} = 1, \quad n_{C0} = n_{D0} = n_{I0} = 0$

$a = 3.87, \quad b = -9.74, \quad c = 4.87$

$$\xi = \frac{1}{2(3.87)}\left(9.74 \pm \sqrt{(9.74)^2 - 4(3.87)(4.87)}\right)$$

$$\Rightarrow \xi = \underline{0.688}$$

fractional conversion

$$x_A = x_B = \frac{n_{A0} - n_A}{n_{A0}} = \frac{\xi}{n_{A0}} = \underline{0.688}$$

c) $n_{B0} = 80, \quad n_{C0} = n_{D0} = n_{I0} = 0$

$n_{C0} = 0$

$n_C = 70 = n_{C0} + \xi$

$\underline{70 = \xi}$

$n_A = n_{A0} - \xi_e = n_{A0} - 70 \text{ mol}$

$n_B = n_{B0} - \xi = 80 - 70 = 10 \text{ mol}$

$n_C = n_{C0} + \xi_e = 70 \text{ mol}$

$n_D = n_{D0} + \xi_e = 70 \text{ mol}$

$$4.87 = \frac{y_C y_D}{y_A y_B} = \frac{n_C n_D}{n_A n_B} \Rightarrow \frac{(70)(70)}{(n_{A0} - 70)(10)} = 4.87$$

$n_{A0} = 170.6$ mol methanol fed

Product gases

$n_A = 170.6 - 70 = 100.6$ mol

$n_B = 10$ mol

$n_C = 70$ mol

$n_D = 70$ mol

total $= 250.6$ mol.

$y_A = 0.401$ mol CH_3OH/mol

$y_B = 0.040$ mol CH_3COOH/mol

$y_C = 0.279$ mol CH_3COOCH_3/mol

$y_D = 0.279$ mol H_2O/mol

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c) ① Cost of reactants
② Market price of product
③ Selling price
④ Rate of the reaction

4.5)

ⓐ $C_2H_4 + H_2O \rightarrow C_2H_5OH$

$2\, C_2H_5OH \rightarrow (C_2H_5)_2O + H_2O$

n_1 mol C_2H_4 → [ ] → 100 mol
n_2 mol $H_2O(v)$ → 0.433 mol C_2H_4/mol
n_3 (mol I) → 0.4476 mol $H_2O(v)$/mol
0.025 mol C_2H_5OH/mol
0.093 mol I/mol
0.0017 mol $(C_2H_5)_2O$/mol

3 unknowns
- 2 independent atomic balances
- 1 I balance

$n_{df} = 0$

① O balance : $n_2 = 100\,(0.025 + 0.0017 + 0.4476)$

② H balance : $4n_1 + 2n_2 = 100\,((2 \times 0.433) + (4 \times 0.0017) + (2 \times 0.025))$

③ C balance : ~~$4n_1 + 2n_2 = 100$~~

$2n_1 = 100\,((2 \cdot 0.433) + (2 \times 0.025) + (4 \times 0.0017))$

ⓑ solving we get $n_3 = 9.3$
$n_1 = 46.08$
$n_2 = 47.4$

Reactor feed has 47.8% C_2H_6, 46.1 % H_2O and 9.1 % I

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% conversion of C_2H_4 = $\frac{76.08 - 73.2}{46.08} \times 100 = 6\%$

If C_2H_4 was converted 100%, and second rxn didn't take place

$(n_{C_2H_5OH})_{max} = 46.08$ mol

fractional yield for C_2H_5OH: $n_{C_2H_5OH} / (n_{C_2H_5OH})_{max}$

$= \left(\frac{2.5}{46.08}\right) \times 0.037$

Selectivity of C_2H_5OH to C_2H_5O

$\frac{2.5 \text{ mol } C_2H_5OH}{0.14 \text{ mol } (C_2H_5)_2O} = 17.9$ C_2H_5OH / mol $(C_2H_5)_2O$.

(c) Keep the conversion low to prevent C_2H_5OH from being in reactor long enough and form $(C_2H_5)_2O$ in large amount.

Separate and recycle C_2H_4!