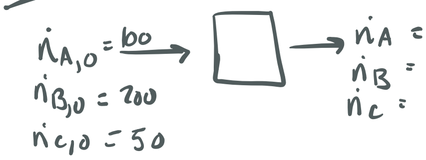
Problem 1

$2A + B \rightarrow C \qquad \xi_1$

PFD



Material Balance

A: $\dot{n}_A = \dot{n}_{A0} - \underbrace{2\xi_1}_{\text{consumption}} =$

consumption → $2\xi_1 = 5$ so $\xi_1 = 2.5$

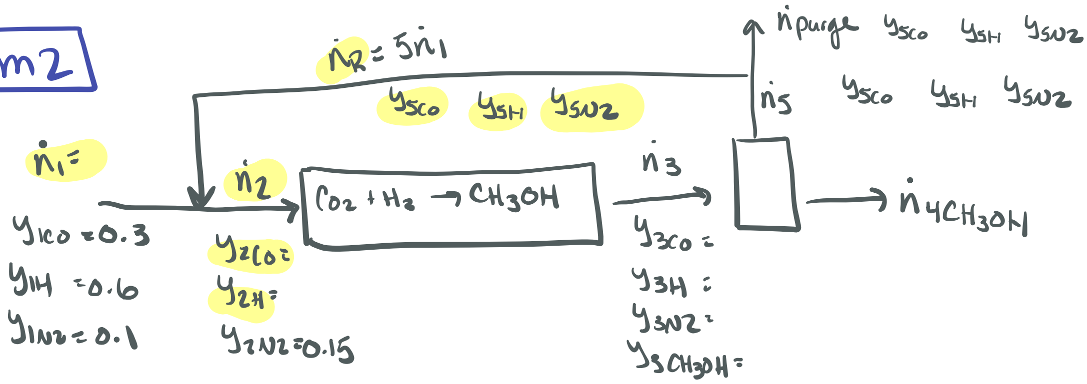
C: $\dot{n}_C = \dot{n}_{C0} + 2\xi_1$

$\dot{n}_C = 50 + 2(2.5)$

$\dot{n}_C = 55$ mol/s

$\boxed{\text{c. 55 mol/s}}$

Problem 2



DOF - Mixing

8 unknowns ($\dot{n}_1$ y_{5CO} y_{5H} y_{5N2} $\dot{n}_2$ y_{2H} y_{2CO} $\dot{n}_R$)
- 3 mat. balances
- 3 add. equations ($\dot{n}_R = 5\dot{n}_1$, $\Sigma y_{2i} = 1$, $\Sigma y_{5i} = 1$)

2 DOF

DOF - Reactor

8 unknowns ($\dot{n}_2$ y_{2CO} y_{2H} $\dot{n}_3$ y_{3CO} y_{3H} y_{3N2} y_{3CH_3OH})
- 4 mat. balances (N_2, CO, H, CH_3OH)
+ 1 chemical rxns ξ_1
- 2 ($\Sigma y_{2i} = 1$, $\Sigma y_{3i} = 1$)

3 DOF

DOF - Condenser

10 unknowns ($\dot{n}_3$ y_{3CO} y_{3H} y_{3N2} y_{3MeOH} $\dot{n}_{4CH_3OH}$, $\dot{n}_5$ y_{5CO} y_{5H} y_{5N2})
- 4 mat balances
- 2 add. equations ($\Sigma y_{3i} = 1$, $\Sigma y_{5i} = 1$)

4 DOF

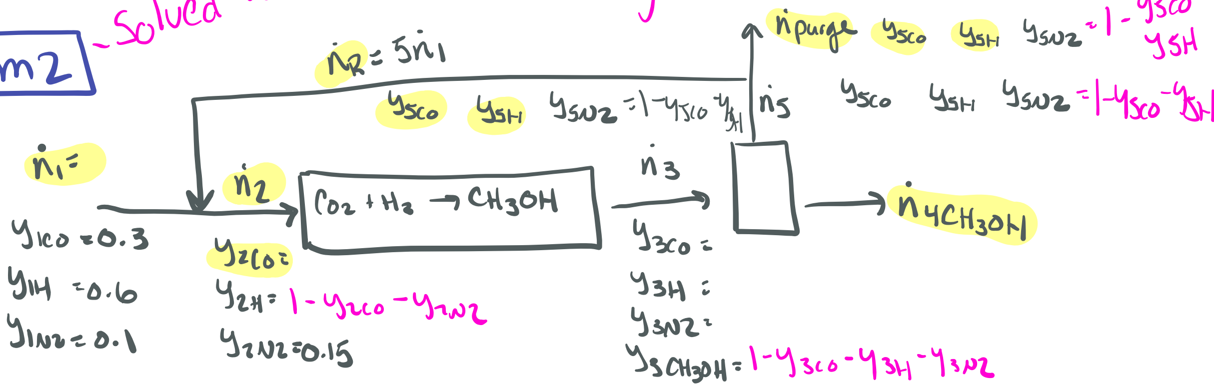
DOF - overall

6 unknowns ($\dot{n}_1$ $\dot{n}_{4CH_3OH}$ $\dot{n}_{purge}$ y_{5CO} y_{5H} y_{5N2})
- 4 mat. balances
+ 1 chemical rxn
- 1 additional eqs. $\Sigma y_{5i} = 1$

2 DOF

$\boxed{\text{e. None of the above}}$

Problem 2 - Solved with different labeling scheme



DOF - Mixing

6 unknowns ($\dot{n}_1$ $\dot{n}_2$ $\dot{n}_R$ y_{2CO}, y_{5CO}, y_{5H})
- 3 mat. balances
- 1 add. equations ($\dot{n}_R = 5\dot{n}_1$)

2 DOF

DOF - Reactor

6 unknowns ($\dot{n}_2$ y_{2CO} $\dot{n}_3$ y_{3CO} y_{3H} y_{3N_2})
- 4 mat. balances (N_2, CO, H, CH_3OH)
+ 1 chemical rxns (ξ)
- 0 add. equations

3 DOF

DOF - Condenser

8 unknowns ($\dot{n}_3$ y_{3CO} y_{3H} y_{3N_2} $\dot{n}_{4CH_3OH}$, $\dot{n}_5$ y_{5CO} y_{5H})
- 4 mat balances

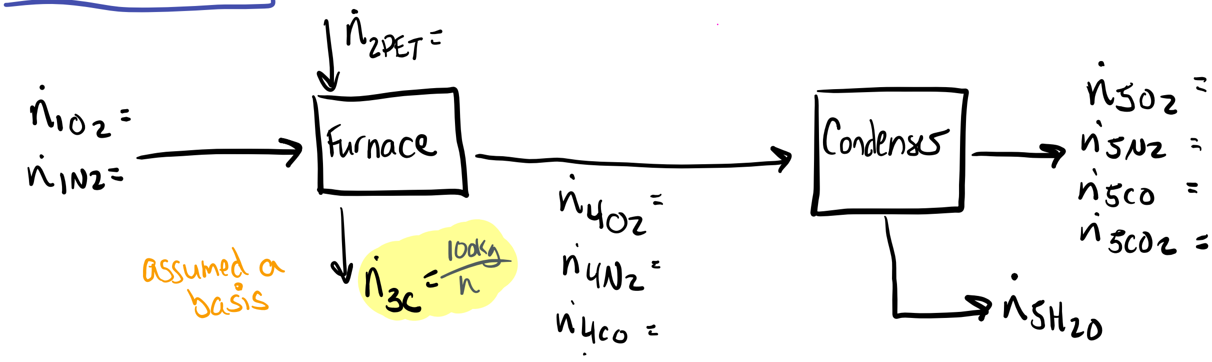
4 DOF

DOF - overall

5 unknowns ($\dot{n}_1$ $\dot{n}_{purge}$ y_{5CO} y_{5H} $\dot{n}_{4CH_3OH}$)
- 4 mat. balances
+ 1 chemical rxn
- 0 add. equations

2 DOF

Problem 3



1) $PET + 9O_2 \rightarrow 9CO_2 + 4H_2O + C$
2) $PET + 4O_2 \rightarrow 8\,CO + 4H_2O + 2C$

What is the fractional conversion of O_2?

Want to Know: $f_{O_2} = \dfrac{\dot{n}_{1O_2} - \dot{n}_{4O_2}}{\dot{n}_{1O_2}}$

or anything related to the composition of air

Additional Equations

(*) $\dfrac{\dot{n}_{1O_2}}{\dot{n}_{2PET}} = \dfrac{3}{1}$

(**) $\dfrac{\dot{n}_{1O_2}}{\dot{n}_{1O_2} + \dot{n}_{1N_2}} = 0.23$

(***) $\alpha_{CO/CO_2} = 4 = \dfrac{\dot{n}_{4CO}}{\dot{n}_{4CO_2}}$

DOF - Furnace

8 unknowns [$\dot{n}_{1O_2}$ $\dot{n}_{1N_2}$ $\dot{n}_{2PET}$ $\dot{n}_{4CO_2}$ $\dot{n}_{4O_2}$ $\dot{n}_{4N_2}$ $\dot{n}_{4CO}$ $\dot{n}_{4H_2O}$]

$\dot{n}_{3C}$ is known because I assumed a basis

+ 2 chemical reactions (ξ_1, ξ_2)
− 7 ind. material balances
− 3 additional equations ((*) (**) (***))

0 DOF

optional

DOF - Condenser

10 unknowns (all $\dot{n}_{4i}$ and $\dot{n}_{5i}$)
+ 0 chemical rxns
− 5 ind. mat balances
− 0 add. equations

5 DOF

$\dot{n}_{3C}$ is known because I assumed a basis

DOF - overall

8 unknowns (all $\dot{n}_{1i}$, $\dot{n}_{2i}$, $\dot{n}_{5i}$)
+ 2 chemical rxns (ξ_1, ξ_2)
− 7 ind. mat balances
− 1 add equations ((*))

1 DOF

How to solve: Can solve furnace then f_{O_2}

b) Material balances on furnace

$$\text{in} - \text{out} + \text{gen} - \text{cons} = \cancel{\text{accumulation}}\ 0$$

continuous
steady state

O₂: $\dot{n}_{4O_2} = \dot{n}_{1O_2} - 9\xi_1 - 4\xi_2$

PET: $0 = \dot{n}_{2PET} - \xi_1 - \xi_2$

CO: $\dot{n}_{4CO} = 8\xi_1$

CO₂: $\dot{n}_{4CO_2} = 9\xi_1$

H₂O: $\dot{n}_{4H_2O} = 4\xi_1 + 4\xi_2$

C: $\dot{n}_{3C} = \xi_1 + 2\xi_2$

N₂: $\dot{n}_{4N_2} = \dot{n}_{1N_2}$

no chemical rxn, so in=out

(*) $\frac{\dot{n}_{1O_2}}{\dot{n}_{2PET}} = \frac{3}{1}$

(**) $\frac{\dot{n}_{1O_2}}{\dot{n}_{1O_2} + \dot{n}_{1N_2}} = 0.23$

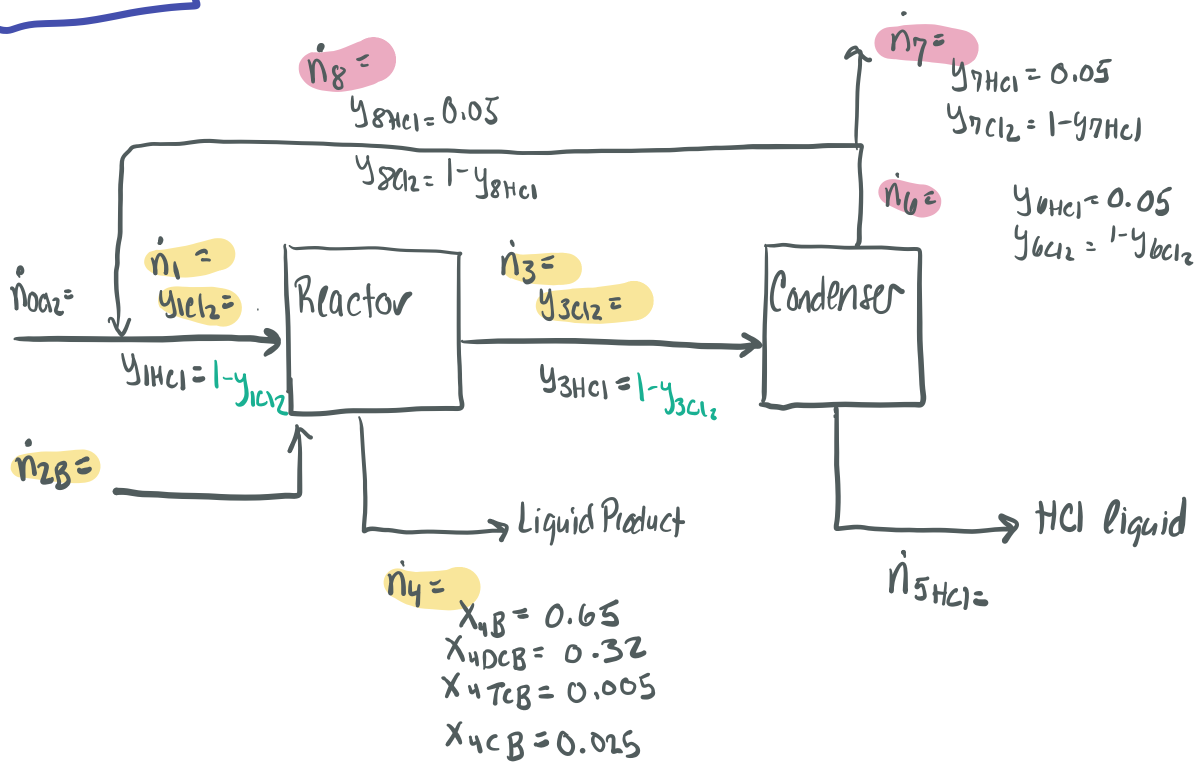
(***) $\alpha_{CO/CO_2} = 4 = \frac{\dot{n}_{4CO}}{\dot{n}_{4CO_2}}$

= known (from assuming a basis)

How to solve

1. Plug CO and CO₂ balances into (***), calculate ξ_1
2. Use ξ_1 in CO balance to calc. $\dot{n}_{4CO}$
3. Use ξ_1 in CO₂ balance to calc $\dot{n}_{4CO_2}$
4. Use ξ_1 in C balance to calc ξ_2
5. Use PET balance to calc $\dot{n}_{2PET}$
6. Use (*) to calculate $\dot{n}_{1O_2}$
7. Use $\dot{n}_{1O_2}$ to calc $\dot{n}_{4O_2}$
8. Finally, $\boxed{f_{O_2} = \frac{\dot{n}_{1O_2} - \dot{n}_{4O_2}}{\dot{n}_{1O_2}}}$

Problem 4



Additional Information:

1) $B + Cl_2 \rightarrow CB + HCl$
2) $CB + Cl_2 \rightarrow DCB + HCl$
3) $DCB + Cl_2 \rightarrow TCB + HCl$

Want to Know

$$f_{B,single} = \frac{\dot{n}_{2B} - \dot{n}_4 x_{4B}}{\dot{n}_{2B}}$$

$$f_{B,overall} = \frac{\dot{n}_{2B} - \dot{n}_4 x_{4B}}{\dot{n}_{2B}}$$

$$\alpha_{CB|DCB} = \frac{\dot{n}_4 x_{3CB}}{\dot{n}_4 x_{3DCB}}$$

DoF - Reactor

6 unknowns ($\dot{n}_{2B}$, $\dot{n}_1$, y_{1Cl_2} $\dot{n}_3$ y_{3Cl_2} $\dot{n}_4$)
- 6 material balances
+ 3 chemical reactions
- 0 additional equations

3 DoF   Can assume a basis to reduce to   DoF

DOF - Splitting Point

3 unknowns ($\dot{n}_6$ $\dot{n}_7$ $\dot{n}_8$)
- 1 material balance
- 0 additional equations

2 DOF

Cl_2 Material balance - Reactor

$$Cl_2: \quad \dot{n}_3 y_{3Cl_2} = \dot{n}_1 y_{1Cl_2} - \xi_{1single} - \xi_{2single} - \xi_{3single}$$

Cl_2 Material balances - Overall

$$Cl_2: \quad \dot{n}_7 y_{7Cl_2} = \dot{n}_{0Cl_2} - \xi_{1overall} - \xi_{2overall} - \xi_{3,overall}$$