Conceptual Questions

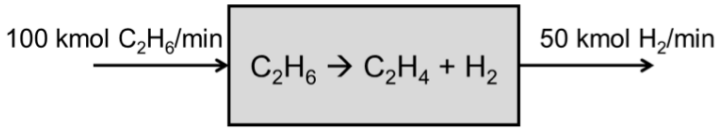
1. (5 points) Consider the reaction 2 $C_2H_4 + O_2 \rightarrow 2\ C_2H_4O$. 100 kmol C_2H_4 and 100 kmol O_2 are fed into a reactor. The reaction proceeds until 60 kmol of O_2 remain. Which of the following is true about the fractional conversion of oxygen (f_{O2})?
   a. $f_{O2} > f_{C2H4}$
   b. $f_{O2} < f_{C2H4}$
   c. 55 mol/s
   d. $f_{O2} = f_{C2H4}$
   e. There's not enough information to determine this

$$f_{O_2} = \frac{n_{O_2}\ \text{reacted}}{n_{O_2}\ \text{fed}} = \frac{100-60}{100} = \frac{40}{100} = 0.4$$

$$f_{C_2H_4} = \frac{C_2H_4\ \text{reacted}}{n_{C_2H_4}\ \text{fed}} = \frac{80}{100} = 0.8$$

40 kmol O_2 reacted, O_2 and C_2H_4 are in a 1:2 ratio (stoich), so 80 kmol C_2H_4 react!

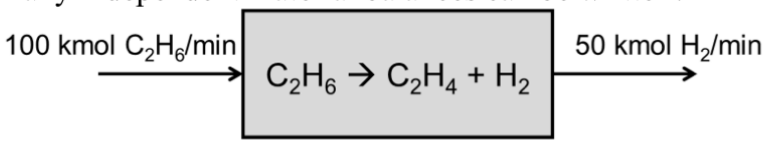
2. (5 points) Are moles conserved in this process?



   a. Yes
   b. No

1 mol → 2 mol

3. (5 points) How many independent material balances can be written?



   a. 1
   b. 2
   c. 3
   d. 4

Out = in + gen/cons

3 species (C_2H_6, C_2H_4, H_2)

4. (5 points) When given volumetric flowrates and volume fractions, you can use them to write a material balance. Select the appropriate response:

   a. Yes for non-reactive and yes reactive systems
   b. Yes for non-reactive systems and no for reactive systems
   c. No for non-reactive systems and yes for reactive systems
   d. No for non-reactive systems and no reactive systems

Volume can change for reactive systems due to chemical rxn

You need Pressure & temperature to use the ideal gas law for mole

Propane Grill Combustion

A) Balanced Chemical Reaction for perfect propane combustion

$$C_3H_8 + 5O_2 \longrightarrow 4H_2O + 3CO_2$$

Labled as: $P + 5O_2 \longrightarrow 4H_2O + 3CO_2$

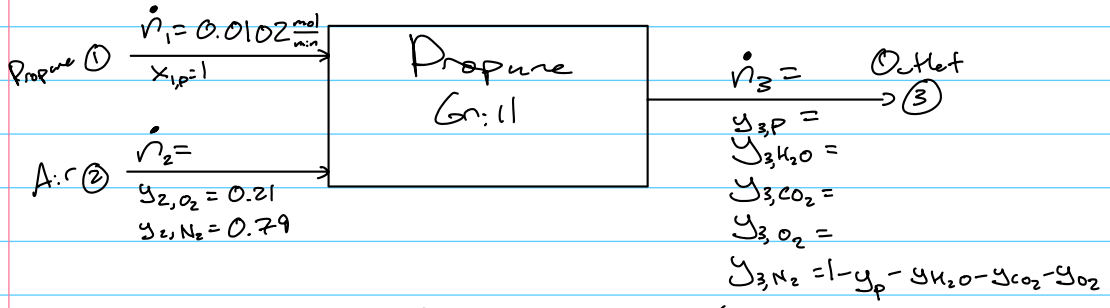
B) Propane Grill Process Flow Diagram

Given: Entrance $P_1 = 103\ mmHg$, $\dot{V}_1 = 14\ \frac{L}{min}$, $T_1 = 2000°C = 2273.15K$; $R = 0.0821\ \frac{L \cdot atm}{mol \cdot K}$

$P_1\ 103\ mmHg \times \frac{1\ atm}{760\ mmHg} = 0.13553\ atm$

Need to convert $\dot{V}$ to $\dot{n}$ to work!

$$P_1\dot{V}_1 = \dot{n}_1 RT_1 \rightarrow \dot{n}_{1,P} = \frac{P_1\dot{V}_1}{RT_1} = \frac{(0.13553\ atm)(14\ \frac{L}{min})}{(0.0821\ \frac{L \cdot atm}{mol \cdot K})(2273.15K)} = 0.0102\ \frac{mol}{min}$$



Want to Know: $\dot{n}_3$ and y_{CO_2} ($\dot{n}_3 y_{CO_2} = \dot{n}_{3,CO_2}$)

Additional EQs $f_P = \frac{mol\ P\ Reacted}{mol\ P\ fed} = \frac{\dot{n}_1 x_{1,P} - \dot{n}_3 y_{3,P}}{\dot{n}_1 x_{1,P}} = \frac{\dot{n}_1 - \dot{n}_3 y_{3,P}}{\dot{n}_1} = 0.90$

C) DoF Analysis

Grill

6 Unknowns ($\dot{n}_2$, $\dot{n}_3$, 4 $y_{3,i}$ in outlet)

- 5 Indep. Mat Balances (bc 5 species: P, O_2, N_2, H_2O, CO_2)
- 1 Additional EQ (f_P)
+1 Indep. Chemical Reaction ($\dot{\xi}$)

1 DoF This cannot be solved !!

If given molar flowrate of air into system we could solve.

D) Molecular Balances

Note: $P + 5O_2 \rightarrow 4H_2O + 3CO_2$

in − out + generation − consumption = accumulation

out = in + gen/consumption

P: $\dot{n}_3 y_{3,P} = \dot{n}_1 x_{1,P} + (-1)\dot{\xi}$ Consumed

O_2: $\dot{n}_3 y_{3,O_2} = \dot{n}_2 y_{2,O_2} + (-5)\dot{\xi}$ "

N_2: $\dot{n}_3 y_{3,N_2} = \dot{n}_2 y_{2,N_2}$ Non-reactive

H_2O: $\dot{n}_3 y_{3,H_2O} = 0 + 4\dot{\xi}$ Generated

CO_2: $\dot{n}_3 y_{3,CO_2} = 0 + 3\dot{\xi}$ "

Cannot write total balance, moles not conserved!

Plan of Attack

Ask for more info!! ☺