Exam 1
C&PE 211
Monday October 1, 2012
Closed Book - Closed Notes

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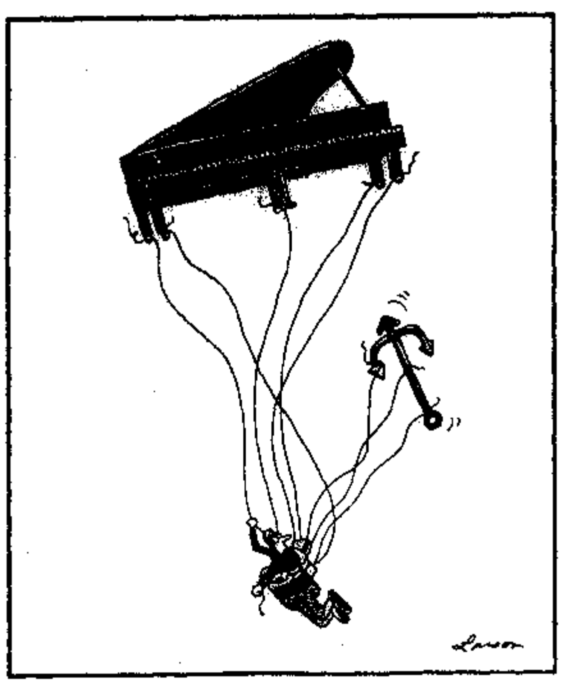
Name:________________________

1. Please do not turn the page until you are instructed to do so.
2. Please write your name in the space provided and put your initials on all of the pages.
3. Please read each question carefully and work those that you know first. Do not spend too much time on one problem. If you get stuck move on to the next question. Partial credit is given so working through a problem as much as you can is to your benefit.
4. Do all of the work on the sheets provided. Write clearly and organized. If I cannot read your writing or follow the solution, no credit will be given.
5. Cheating on this exam will result in a no credit for the exam. Two instances of cheating will result in failure of the course.
6. If a box is provided please put your answers in the box. If a box is not provided, please box your final answers. All work will be checked, but the answer in the box will be considered to be the final answer.

Please remember:
Don't panic! Panicking can cause silly errors.
Good Luck!



Murray didn't feel the first pangs of real panic until he pulled the emergency cord.

1. **(2 points – no partial credit)** Distillation separates components based on what property?

2 boiling point ✓

2. **(3 points each – no partial credit)** Describe why a bypass and purge stream would be used in a chemical process? Your answer can be brief as long as it correctly answers the question.

3 Bypass:
To use a stream later, preserving a smaller volume of the original while also using a portion of the original in a reaction. Useful when actual reactions are inefficient or produce buildup that must be diluted (orange juice concentrate) ✓

3 Purge:
To remove impurities from a recycle stream, reducing buildup

✓

3. **(2 points – no partial credit)** If a gas pump is delivering gasoline (S.G. = 0.739, MW = 100) to your car at 8 gal/min, what is the molar flow rate in (lbmols/hr)?

0 ✗

100 g/mol $\frac{0.739\ g/mL}{1\ g/mL\ H_2O @ 4°C} = 0.739\ g/mL$

lbmols/hr = $\frac{8\ gal}{min} \cdot \frac{1\ m^3}{264.17\ gal} \cdot \frac{1 \cdot 10^6\ cm^3}{1\ m^3} \cdot \frac{1\ mL}{1\ cm^3} \cdot \frac{0.739\ g}{1\ mL} \cdot \frac{1\ mol}{100\ g} \cdot \frac{1\ hr}{60\ min} = 3.73\ \frac{lbmole}{hr}$

4. In a catalytic reactor methane is reacting with oxygen to form H_2 and CO. A second undesired reaction can occur in which methane combusts with oxygen to form CO_2 and water.

   a. **(4 points – no partial credit)** In the box below, write the balanced chemical reaction(s) which can occur in the reactor.

0

$2CH_4 + O_2 \rightarrow 8H_2 + 2CO$ ✗

$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$

   b. **(4 points – no partial credit)** The analysis of the reactor gas shows that the 80% of the methane reacts to form H_2 and a total of 90% of the methane is converted. If the reactor feed contains a 50 moles of methane and 90 moles of oxygen what is the percent excess of oxygen?

4

a. 0% (b) 260% c. 100% d. 125%

$\frac{50 \text{ mol } CH_4}{2} = 25 \text{ mol } O_2 \text{ req}$ % excess $= \frac{\text{fed} - \text{req}}{\text{req}} \cdot 100 = \frac{90-25}{25} \cdot 100 = 260\%$

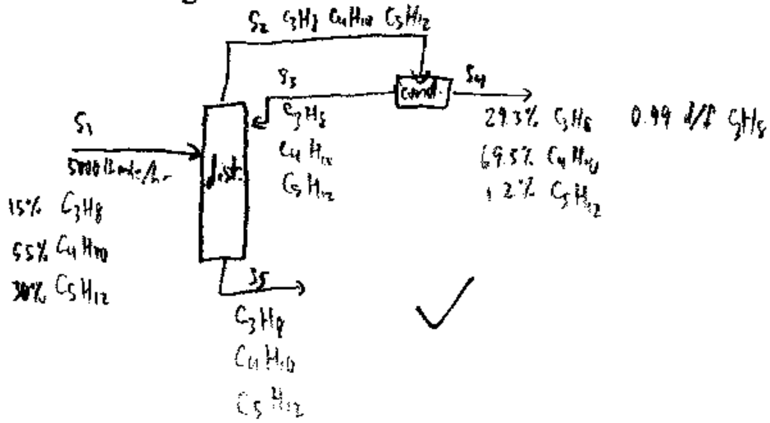
5. **(2 points – No partial credit)** What is the relationship between gauge, atmospheric and absolute pressure? You can use and equation or words to answer the question.

2/

$P_{abs} = P_g + P_{atm}$ ✓

6. **(40 points)** A 5000 lb-mole/hr feed containing 15% propane, 55% butane, and the remainder pentane is fed to a distillation tower. The overhead stream is sent to a total condenser. A portion of the liquid stream out of the condenser is refluxed back to the column with a reflux ratio of 10 to 1. The composition of the distillate is 29.3% propane, 69.5% butane, and 1.2% pentane. The distillate to feed (d/f) ratio of propane is 0.99.

   a. Sketch the process below, label the process flow diagram, set up the initial material balance table, and do a degree of freedom analysis to show that the problem can be solved. You can assume that there is only the bottoms stream coming out of the bottom of the distillation unit.



D.O.F.

poss unkn = (3+1)(5) = 20

kn = 9

unkn = 11

MB = 3·2 = 6

Sum = 2

PS = 3

0

lbmole/hr	1	2	3	4	5		
C_3H_8	$0.15 S_1$	n_{12}	$0.293 S_3$	$0.293 S_4$	n_{15}		
C_4H_{10}	$0.55 S_1$	n_{22}	$0.695 S_3$	$0.695 S_4$	n_{25}		
C_5H_{12}	$0.30 S_1$	n_{32}	$0.012 S_3$	$0.012 S_4$	n_{35}		
Total	S_1	S_2	S_3	S_4	S_5		

b. Write the system of equations that are needed to completely fill in the material balance table. These equations should match the degree of freedom analysis that you did in part a. **You must show any simplifications you make or justify any assumptions.**

P.S.: (1) $5000\ \text{lbmole/hr} = S_1$ ✓

(2) $f_0 S_2 = S_4$ ✗ (-5)

(3) $0.293 S_4 = 0.99(0.15 S_1)$ ✓

MB: Accum = In - Out + Gen - Cons

In = Out ✓

Overall (1) $0.15 S_1 = 0.293 S_4 + n_{15}$ ⟶ $0.15 S_1 = (0.99 \cdot 0.15 S_1) + n_{15} \rightarrow n_{15} = 0.015 S_1$

✓ (2) $0.55 S_1 = 0.695 S_4 + n_{25}$ ⟶ $n_{25} = 0.55 S_1 - 0.695 S_4$

(3) $0.30 S_1 = 0.012 S_4 + n_{35}$ ⟶ $n_{35} = 0.0.30 S_1 - 0.012 S_4$

Condenser

(4) $n_{12} = 0.293 S_3 + 0.293 S_4$

✓ (5) $n_{22} = 0.695 S_3 + 0.695 S_4$

(6) $n_{32} = 0.012 S_3 + 0.012 S_4$

Sum: (1) $S_2 = n_{12} + n_{22} + n_{32}$ ✓

(2) $S_5 = n_{15} + n_{25} + n_{35}$

c. Solve the system of equations you identified in part b to fill in the final material balance table. Take each value out to one decimal place.

lbmole/hr	1	2	3	4	5		
C_3H_8	750.0	816.8	74.3	742.5	7.5		
C_4H_{10}	2750.0	1937.3	176.1	1761.2	988.8		
C_5H_{12}	1500.0	33.4	3.0	30.4	1469.6		
Total	5000.0	2787.5	253.4	2534.1	2465.9		

(-1)

35

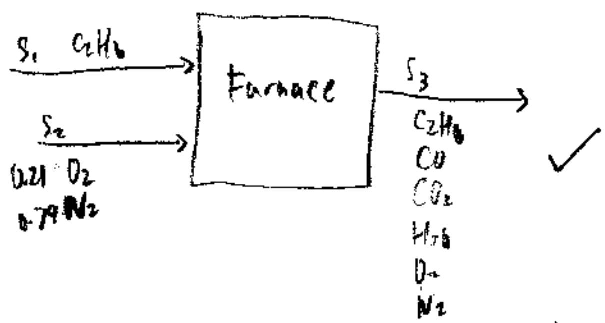
7. **(40 points)** Ethane (C_2H_6) is being burned in a furnace with 50% excess air. The percent conversion of ethane in the furnace is 90%. Of the ethane that is converted, 25% reacts to form CO and the balance reacts to form CO_2.

   a. Write the balanced chemical reaction(s) for this combustion process. .

   $C_2H_6 + \frac{5}{2}O_2 + N_2 \rightarrow 2CO + 3H_2O + N_2$

   $C_2H_6 + \frac{7}{2}O_2 + N_2 \rightarrow 2CO_2 + 3H_2O + N_2$ ✓

   b. Label the process flow diagram and set up the initial material balance table.



mol	1	2	3				
C_2H_6	1 S_1	0	n_{13}				
O_2	0	0.21 S_2	n_{23}				
N_2	0	0.79 S_2	n_{33}				
CO	0	0	n_{43}				
CO_2	0	0	n_{53}				
H_2O	0	0	n_{63}				
Total	S_1	S_2	S_3				

c. Do a degree of freedom analysis to show that the problem can be solved

poss unkn = (6+1)(3) + (2)(1)
= 23
kn = 12
Unkn = 11
MB = 6
Basis = 1
Sum ① 2 ✓ (−1)
PS = 3
0 ✓

d. Write the system of equations that are needed to completely fill in the material balance table. These equations should match the degree of freedom analysis that you did in part c. **You must show any simplifications you make or justify any assumptions.**

Basis: ① $S_1 = 100$ mol ✓

P.S. ② 50 % excess air → $0.50 = \frac{\text{fed} - \text{req}}{\text{req}} \cdot 100 = \frac{S_2 - (S_2 - (n_{23} + n_{33}))}{(S_2 - (n_{23} + n_{33}))} = 0.50$ × (−3)

~~③ 90% conversion C_2H_6 → $0.90 = \frac{\text{reacted}}{\text{fed}} = \frac{\text{fed} - \text{unreacted}}{\text{fed}} = \frac{S_1 - n_{13}}{S_1} = 0.9$~~

~~④ $0.25 n_{13} = n_{43}$~~

~~⑤ $0.75 n_{13} = n_{53}$~~

③ 90% conversion C_2H_6 → $n_{13} = 0.1 S_1$ ✓

④ $(S_1 - n_{13}) \cdot 0.25 = n_{43}$ ✓

MB: Accum = In − Out + Gen − Cons

Out = In + Gen − Cons ✓

C_2H_6 ⑤ $n_{13} = S_1 - \xi_1 - \xi_2$ ✓

O_2 ⑥ $n_{23} = 0.21 S_2 - \frac{5}{2}\xi_1 - \frac{7}{2}\xi_2$ ✓

N_2 ⑦ $n_{33} = 0.79 S_2$ ✓

CO ⑧ $n_{43} = 2\xi_1$ ✓

CO_2 ⑨ $n_{53} = 2\xi_2$ ✓

H_2O ⑩ $n_{63} = 3\xi_1 + 3\xi_2$ ✓

Sum: ~~⑪ $S_2 = 0.21 S_2 + 0.79 S_2$~~ ✓

⑪ $S_3 = n_{13} + n_{23} + n_{33} + n_{43} + n_{53} + n_{63}$

e. Solve the system of equations you identified in part c to fill in the final material balance table. You can round your answers to whole number for the final table.

mol	1	2	3				
C_2H_6	100	0	10				
O_2	0	375.0	105				
N_2	0	918	918				
CO	0	0	45				
CO_2	0	0	135				
H_2O	0	0	270				
Total	100	1293	1483				

(−1)

% excess → 2 C_2H_6 : 5 O_2

50% excess $req = \frac{5}{2} \cdot 100 = 250\ O_2$

$fed = (0.50 \cdot 250) + 250$
$= 375$ mol

$Out = In + Gen - Cons$

$1483 = 100 + 1293 + 6\xi_1 - 3.5\xi_1 + 6\xi_2 - 5.5\xi_2$

$1483 = 1393 + 2.5\xi_1 + 0.5\xi_2$

$1483 = 1393 + 56.25 + 33.75$

$1483 = 1483$ ✓

$n_{13} = 100 - \xi_1 - \xi_2$

$n_{13} = 0.1\xi_1$

$0.1\xi_1 = \xi_1 - \xi_1 - \xi_2$

$10 = 100 - \xi_1 - \xi_2$

$0.9\xi_1 \cdot 0.25 = n_{43}$

$0.9\xi_1 \cdot 0.75 = \frac{n_{53}}{2}$

$n_{43} = 2\xi_1 \rightarrow \xi_1 = 22.5$

$n_{53} = 2\xi_2 \rightarrow \xi_2 = 67.5$

$n_{63} = 3\xi_1 + 3\xi_2$
$= 270$

~~$\frac{100 - n_{13}}{n_{13}} = 0.9$~~

~~$100 - n_{13} = 0.9 n_{13}$~~

~~$100 = 1.9 n_{13}$~~

~~$n_{13} = 52.63 \sim 53$~~