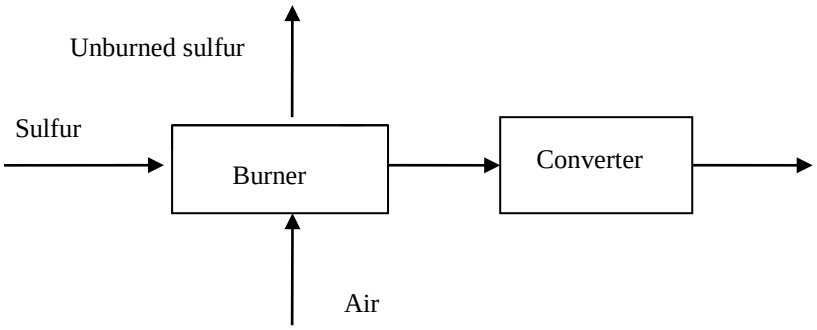
CHE211 BASIC PRINCIPLES IN CHEMICAL ENGINEERING
2021- 2022 Fall Semester

PROBLEM SET 5

1. A simplified process for the production of SO_3 is illustrated in the following figure.Sulfur is burned with 100% excess air in the burner,but for the reaction $S + O_2 \rightarrow SO_2$, only 90% conversion of the sulfur to SO_2 is achieved. In the converter, the conversion of SO_2 to SO_3 is 95% complete. Calculate:
   (a) The lb of air required per 100 lb of sulfur burned
   (b) The concentrations in mole fraction of the components in the exit gas from the burner and the converter.



2.Your company is burning a fuel which consists of nitrogen and CH_4 (methane). The flue gas analysis on dry basis shows 8.0% CO_2, 0.2% CO, 6.0% O_2 and the rest N_2. Calculate:
(a) The analysis of the fuel
(b) The percentage of excess air

3. n-Hexane is burned with excess air. On a dry basis, the product gas contains 0.3% hexane, 7.6% oxygen, 9.1% carbon dioxide, and the balance nitrogen. Calculate the percent excess air and the fractional conversion of hexane.

4. A waste stream from a plant contains 30% CH_4, 10%CO_2, 8%CO, 10% H_2, 2%O_2, 2% H_2S,2%H_2O, 36% N_2. This waste stream is burned in a flare with air. The Orsat analysis of the exit gas shows 0.3%SO_2 along with CO_2, O_2, and N_2. Calculate the percent excess air and the complete Orsat analysis.

5. A syntesis gas analyzing 6.4% CO_2,0.2% O_2,40.0 % CO, and 50.8%H_2 (the balance is N_2),is burned with 30% excess air. What is the composition of the flue gas?

6. Hydrogen - free carbon in the form of coke is burned:
   a) With complete combustion using theoretical air
   b) With complete combustion using 50% excess air
   c) Using 50% excess air but with 10% of the carbon burning to CO only.
   In each case calculate the gas analysis that will be found by testing the flue gases with an Orsat apparatus.

7. A gas containing only CH_4 and N_2 is burned with air yielding a flue gas that has an Orsat analysis of CO_2:8.7%, CO: 1.0%, O_2:3.8%, N_2:86.5% . Calculate the percent excess air used in combustion and the composition of the CH_4 - N_2 mixture.

8. A gas with the following composition is burned with 50% excess air in a furnace .
What is the composition of the flue gas by percent?

CH_4: 60%, C_2H_6. 20% , CO: 5%; O_2: 5%; N_2: 10%

9. Ethanol and the propionic acid are produced from glucose by the following reactions :

Reaction 1: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

Reaction 2: $C_6H_{12}O_6 \rightarrow 2C_2H_3CO_2H + 2H_2O$

In a batch process , a tank is charged with 4000 kg of a 12% glucose / water solution.
After reaction 120 kg of carbon dioxide is produced together with 90 kg of unreacted glucose.
What are the weight percents of ethyl alcohol and propenoic acit remaining in the mixture?

10. A low-grade pyrite containing 32% S is mixed with 10 lb of pure sulfur per 100 lb of pyrites so the mixture will burn readily, forming a burner gas that analyzes (Orsat) 13.4% $SO_2$2.7% O_2, and 83.9% N_2. No sulfur is left in the cinder. Calculate the percentage of the sulfur fired that burned to SO_3. (SO_3 is not detected by the Orsat analysis.)

11. Methane is burned with oxygen to yield carbon dioxide and water. The feed contains 20%CH_4,20%CO_2,, 60%O_2 and a 90% conversion of the limiting reactent is achieved. Calculate the molar composition of the product stream using **(a)** balances on molecular species **(b)** atomic balances.

12. The product gas from a combustion reaction has the following dry-basis molar composition: 80.35 % CO_2, 4.73% CO, 0.033% SO_2, 14.89% O_2. Pure oxygen is fed to the furnace in 10% excess of that required to burn the fuel completely. There is no oxygen in the fuel. Calculate the elemental composition (Mole%of the various elements) of the fuel.

13. A fuel composed of ethane (C_2H_6) and methane (CH_4) in unknown proportions is burned in a furnace with oxygen enriched air (50.0 mole percent O_2) . Your Orsat analysis is : 25% CO_2, , 60% N_2, and 15% O_2. Find:

(a) the composition of the fuel, that is , the mole percent methane in the methane- ethane mixture

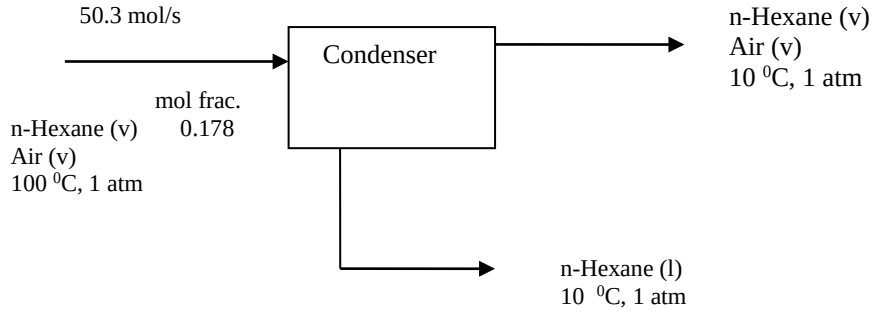
(b) The moles of oxygen enriched air used per mole of fuel

14. A power company operates one of its boilers on natural gas and another on oil. The analysis of the fuels show 96% CH_4 , 2% C_2H_2 and 2% CO_2 for the natural gas and $C_nH_{1.8n}$ for the oil. The flue gases from both groups enter the same stack , and an Orsat analysis of this combined flue gas shows 10.0% CO_2 , 0.63% CO, and 4.55% O_2. What percentage of the total carbon burned comes from the oil?

15. A mixture of 75 mole% propane and 25 mole% hydrogen is burned with 25% excess air. Fractional conversions of 90% of the propane and 85% of the hydrogen are achieved; of the propane that reacts. 95% reacts to form CO_2 and the balance reacts to form CO. The hot combustion product gas passes through a boiler in which heat transferred from the gas converts boiler feed water into steam. Calculate the concentration of CO in the stack gas.

16. A coal analyzing by mass 65.4% C, 5.3%H, 0.6% S, 1.1%N ,18.5% O and 9.1% ash is burned in a combustion chamber. Ash is the non-combustible solid portion of the coal. The flue gas analyzes 13.0 % CO_2, 0.76 % CO , 6.17 % O_2 , 0.87 % H_2 and 79.2 % N_2 by mole. All of the S burns to SO_2 which is included in the CO_2 percentage in the gas analysis (i.e. $CO_2 + SO_2 = 13\%$). S=32 Calculate : a) kg of coal fired per 100 kg mol of dry flue gas as analyzed b) ratio of moles of total combustion gases to moles of dry air supplied c) percent excess air d) partial pressure of water vapor in wet stack gas

17.



A mixture of n-Hexane and Air is fed to a condenser at a rate of 50.3 mol/s at 100 ^{0}C and 1 atm. The mole fraction of hexane in this mixture is 0.178. In the condenser gas mixture is cooled at constant pressure and 60% of the hexane condensed. The exit temperature of both condensed liquid and vapor side is 10 ^{0}C. Calculate;
(a) the molar flow rates of two exit streams (b) the required cooling rate in kW.
Note: When necessary, C_p will be taken as $C_p = a + b\,T$.