Assignment 4
Mass Balance on Reactive Process

Note : BOX your answers.

Question 1

Acetylene (C_2H_2) is hydrogenated to form ethane (C_2H_6). The feed to the reactor contains 1.5 mol H_2/mol C_2H_2.

a. Determine the limiting reactant.
b. Calculate the percentage by which the other reactant is in excess. (*33.3%*)
c. Calculate the mass feed rate of hydrogen (kg/s) required to produce 4 x 10^6 metric tons of ethane per year, assuming the reaction goes to completion and that the process operates for 24 hours a day and 300 days a year. (*20.6 kg H_2/s)*

Question 2

Ethane is fed to a dehydrogenation reactor at a rate of 150 kmol/h. The reaction products are acetylene and hydrogen. A fractional conversion of 80% is achieved. Calculate the following properties of the final product gas.

a. Total molar flow rate *(390 kmol/h)*
b. Mole ratio of hydrogen to acetylene *(2 kmol H2/C2H2)*
c. Average molecular weight *(11.54 kg/kmol)*
d. Mass flow rate of acetylene *(3120 kg/h)*

Question 3

At low to moderate pressures, the equilibrium state of the water gas shift reaction

$CO + H_2O <=> CO_2 + H_2$

Is approximately described by the relation

$$\frac{y_{CO_2} y_{H_2}}{y_{CO} y_{H_2O}} = K_e(T) = 0.0247 \exp\left(\frac{4020}{T(K)}\right)$$

The feed to a continuous shift reactor contains 30 mol% CO, 10 mol% CO2, 40 mol % water, and the balance an inert gas. The reaction proceeds to equilibrium

a. Calculate the gram-moles of hydrogen produced per mol of water fed if the reaction is carried out at 850^{o}C *(0.0521 mol H_2 produced / mol H_2O fed)*
b. Calculate the temperature (°Celcius) at which the reaction should be run to achieve a fractional CO conversion of 75% (*469 °C)*

Question 4

Propane is converted into propene in a tubular reactor. The following reaction takes place.

$C_3H_8 \rightarrow C_3H_6 + H_2$
$C_3H_8 + 2H_2 \rightarrow 3CH_4$

The feed is 100% propane. The fractional conversion of propane is 0.75 and the fractional yield of propene is 0.5. Calculate the selectivity of propene to methane production. *(0.667)*

Question 5

Ethane is chlorinated in a continuous reactor:

$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$

Some of the product monochloroethane is further chlorinated in and undesired side reaction:

$C_2H_5Cl + Cl_2 \rightarrow C_2H_4Cl_2 + HCl$

Suppose the conversion of ethane is 13%, selectivity is (13.3 moles C_2H_5Cl)/(mole $C_2H_4Cl_2$); and the product contains a negligible amount of chlorine. Calculate the moles of all species present in the product stream per 100 moles of monochloroethane produced. (*100 mol C_2H_5Cl, 719.58 mol C_2H_6, 115.04 mol HCl, 7.52 mol $C_2H_4Cl_2$*
827.1 mol C_2H_6, 115.04 mol Cl_2)

Mass Balance on Reactive Process (Combustion)

Question 1
A natural gas contains 92 mole% methane, 5% ethane and 3% propane. If 100 kmol/h of this fuel is to be burned completely with 25% excess oxygen, what is the required air feed rate? Calculate the molar composition of the combustion products. *(1288 kmol/h air;0.0796, 0.1513, 0.0388, 0.7302)*

Question 2
Liquid methanol is fed to a space heater at a rate of 12.0 liters/h and is burned with excess air. The product gas is analyzed and the following dry-basis mole percentages are determined: CH_3OH = 0.45% CO_2 = 9.03% CO = 1.81%.

a. Draw and label a flowchart and verify that the system has zero degree of freedom
b. Calculate the fractional conversion of methanol, the percentage excess air fed, and the mol fraction of water (mol/h) in the product gas. *(0.96; 29.1%; 0.178 mol H_2O/mol)*

Question 3
A mixture of propane and butane is burned with excess air. The combustion products contain the following composition on a dry basis: 9.7 mole % CO_2, 0.5 % CO, 5.9% O_2 and the balance N_2. What is the mass percent (i.e. wt%) of propane and butane? *(18 wt% C_3H_8, 82% C_4H_{10})*

Question 4
In a motor vehicle engine test, 20 kg of C_3H_8 is burned with 400 kg of air to produce 44 kg of CO_2 and 12 kg of CO. What was the percent of excess air? *(28 mol%)*

Question 5
Ethane is initially mixed with oxygen to obtain a gas containing 80% C_2H_6 and 20% O_2 that is then burned in an engine with 200% excess air. Eighty percent of the ethane goes to CO_2, 10% goes to CO and 10% remains unburned. Calculate the composition of the exhaust gas on a wet basis. (0.*20% C_2H_6, 14.41% O_2, 76.05% N_2, 3.32% CO_2, 0.41% CO, 5.60% H_2O)*