

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 .

- Determine the limiting reactant.
- Calculate the percentage by which the other reactant is in excess. (33.3%)
- Calculate the mass feed rate of hydrogen (kg/s) required to produce 4×10^6 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)

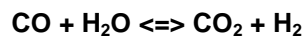
Question 2

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.

- Total molar flow rate (390 kmol/h)
- Mole ratio of hydrogen to acetylene (2 kmol H_2 / C_2H_2)
- Average molecular weight (11.54 kg/kmol)
- Mass flow rate of acetylene (3120 kg/h)

Question 3

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



Is approximately described by the relation

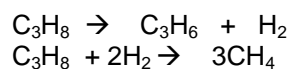
$$\frac{y_{CO_2} y_{H_2}}{y_{CO} y_{H_2O}} = K_e(T) = 0.0247 \exp\left(\frac{4020}{T(K)}\right)$$

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

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

Question 4

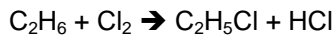
Propane is converted into propene in a tubular reactor. The following reaction takes place.



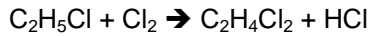
The feed is 100% propane. The fractional conversion of propane is 0.75 and the fractional yield of propene is 0.5. Calculate the selectivity of propene to methane production. (0.667)

Question 5

Ethane is chlorinated in a continuous reactor:



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



Suppose the conversion of ethane is 13%, selectivity is (13.3 moles $\text{C}_2\text{H}_5\text{Cl}$)/(mole $\text{C}_2\text{H}_4\text{Cl}_2$); 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 $\text{C}_2\text{H}_5\text{Cl}$, 719.58 mol C_2H_6 , 115.04 mol HCl , 7.52 mol $\text{C}_2\text{H}_4\text{Cl}_2$, 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: $\text{CH}_3\text{OH} = 0.45\%$, $\text{CO}_2 = 9.03\%$, $\text{CO} = 1.81\%$.

- Draw and label a flowchart and verify that the system has zero degree of freedom
- 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)