Midterm Practice Problems

1. (90 points) The water-gas shift reaction can be written as $CO + H_2O \leftrightarrow CO_2 + H_2$. In a continuous, steady-state reactor 1 mol CO and 2 mol H_2O are fed to the system. The equilibrium constant, K at 100°C for the reaction is equal to 1. The reactor effluent is fed to a condenser that operates at equilibrium conditions and atmospheric pressure. The mol fraction of water in the vapor stream exiting the condenser is 0.2. What is the composition of the stream leaving the reactor? What is the operating temperature of the condenser? What is the flowrate of liquid water leaving the condenser?

    a. (20 points) Draw and fully label a process flow diagram. Assign variables to all relevant unknowns.

    b. (5 points) Write mathematical expressions or variables to describe the quantities for which you will solve. Utilize the variables from your process flow diagram.

    c. (10 points) Translate all additional information from the problem statement into mathematical expressions. Utilize the variables from your process flow diagram.

    d. (30 points) Perform a degree of freedom analysis on ALL SUBSYTEMS (REACTOR, CONDENSER, OVERALL). Clearly identify the variables and equations associated with the analysis.

    e. (25 points) Based on your DOF analysis, list the equations you would use to solve the problem and explain your problem solving process.

2. (90 points) Chlorobenzene is a chemical precursor for many pharmaceutical products and commodity chemicals such as dry-cleaning agents, rubbers and dyes. It is produced by bubbling chlorine gas through liquid benzene in the presence of a catalyst. In an undesired side reaction, dichlorobenzene is produced from the reaction of chlorine and benzene.

   In a continuous steady state process, the feed to the chlorination reactor consist a 1:1 (mol/mol) ratio of chlorine to benzene. The selectivity for chlorobenzene to dicholorbenzene is 10 and all chlorine reacts in the reactor. The reactor effluent is fed to a distillation column which operates at 150^{o}C and equilibrium conditions. The liquid leaving the distillation column contains pure dichlorobenzene. The vapor phase mol fraction of dichlorobenzene is 0.8.

   What is the volumetric flowrate of the liquid dichlorobenzene stream? What is the operating pressure of the distillation column? What is the volumetric flowrate of the chlorine feed if it enters at P=1atm and T=100^{o}C?

   a. (20 points) Draw and fully label a process flow diagram. Assign variables to all relevant unknowns.

   b. (5 points) Write mathematical expressions or variables to describe the quantities for which you will solve. Utilize the variables from your process flow diagram.

   c. (10 points) Translate all additional information from the problem statement into mathematical expressions. Utilize the variables from your process flow diagram.

   d. (30 points) Perform a degree of freedom analysis on ALL SUBSYTEMS (REACTOR, DISTILLATION, OVERALL). Clearly identify the variables and equations associated with the analysis.

   e. (25 points) Based on your DOF analysis, list the equations you would use to solve the problem and explain your problem solving process. **Do not solve them**.