CHG2317

Introduction to Chemical Process Analysis

Assignment 1: Due on Wednesday Sep 23rd, 2020 before 4:00 pm

Problem 1

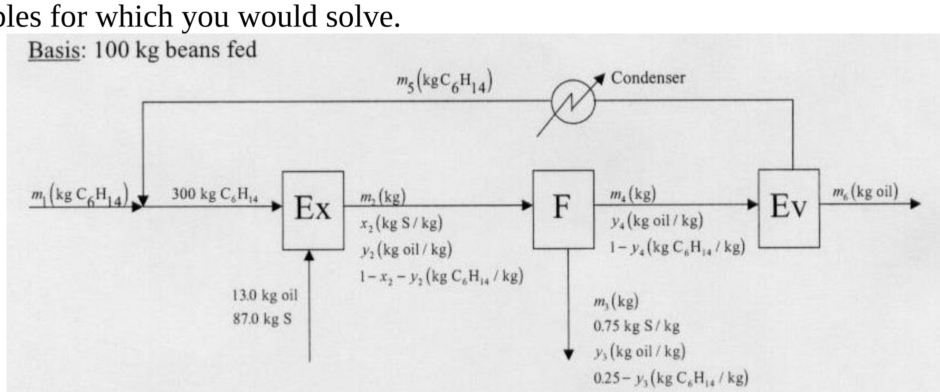
A liquid mixture of benzene and toluene contains 55.0% benzene by mass. The mixture is to be partially evaporated to yield a vapor containing 85.0% benzene and a residual liquid containing 10.6% benzene by mass.

a) Suppose the process is to be carried out continuously and at steady state, with a feed rate of 100.0 kg/h of the 55% mixture. Let m_v (kg/h) and m_L (kg/h) be the mass flow rates of the vapor and liquid product streams, respectively. Draw and label a process flowchart, then write and solve balances on total mass and on benzene to determine the expected values of m_v and m_L. For each balance, state which terms of the general balance equation (accumulation = input + generation - output – consumption) you discarded and why you discarded them.

b) Next, suppose the process is to be carried out in a closed container that initially contains 100.0 kg of the liquid mixture. Let m_v (kg) and m_L (kg) be the masses of the final vapor and liquid phases, respectively. Draw and label a process flowchart, then write and solve integral balances on total mass and on benzene to determine m_v and m_L. For each balance, state which terms of the general balance equation (accumulation = input + generation - output – consumption) you discarded and why you discarded them.

Problem 2

In the production of a bean oil, beans containing 13.0 wt% oil and 87.0% solids are ground and fed to a stirred tank (the extractor) along with a recycled stream of liquid - hexane. The feed ratio is 3 kg hexane/kg beans. The ground beans are suspended in the liquid, and essentially all of the oil in the beans is extracted into the hexane. The extractor effluent passes to a filter. The filter cake contains 75.0 wt% bean solids and the balance bean oil and hexane, the latter two in the same ratio in which they emerge from the extractor. The filter cake is discarded and the liquid filtrate is fed to a heated evaporator in which the hexane is vaporized and the oil remains as a liquid. The oil is stored in drums and shipped. The hexane vapor is subsequently cooled and condensed, and the liquid hexane condensate is recycled to the extractor. The flowchart is given below. Do the degree-of-freedom analysis, and write in an efficient order the equations you would solve to determine all unknown stream variables, circling the variables for which you would solve.



Problem 3

In the Deacon process for the manufacture of chlorine, HCl and O_2 react to form Cl_2 and H_2O. Sufficient air (21 mole% O_2, 79% N_2) is fed to provide 35% excess oxygen and the fractional conversion of HCl is 85%.

a) Calculate the mole fractions of the product stream components, using atomic species balances in your calculation.

b) Again, calculate the mole fractions of the product stream components, only this time use the extent of reaction in the calculation.

Problem 4

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 an undesired side reaction:

$$C_2H_5Cl + Cl_2 \rightarrow C_2H_4Cl_2 + HCl$$

a) Suppose your principal objective is to maximize the selectivity of monochloroethane production relative to dichloroethane production. Would you design the reactor for a high or low conversion of ethane? Explain your answer. (hint: If the reactor contents remained in the reactor long enough for most of the ethane in the feed to be consumed, what would the main product constituent probably be?) What additional processing steps would almost certainly be carried out to make the process economically sound?

b) Take a basis of 100 mol C H Cl produced. Assume that the feed contains only ethane and chlorine and that all of the chlorine is consumed and carry out a degree-of-freedom analysis based on atomic species balances.

c) The reactor is designed to yield a 15% conversion of ethane and a selectivity of 14 mol C_2H_5Cl/mol $C_2H_4Cl_2$, with a negligible amount of chlorine in the product gas. Calculate the feed ratio (mol Cl_2/mol C_2H_6) and the fractional yield of monochloroethane.

Problem 5

Approximately 150 SCFM (standard cubic feet per minute) of nitrogen is required by a process facility. As shown in the diagram below, plans call for supplying the facility from a tank of liquid nitrogen (SG = 0.81) at its normal boiling point (-350°F) and 1 atm. Nitrogen vapor leaves the tank and is compressed and heated to obtain the desired conditions, 150°F and 600 psia.

a) Using the generalized compressibility charts, determine the volumetric flow rate of nitrogen delivered from the heater.

b) What would the required minimum tank size be if deliveries are made to the site no more frequently than every two weeks?