Principles of Chemical Processes I (SKKK 1113)

Assignment 03

Multiple-Unit Process with/without recycle and bypass

Instruction : Write down the basis of calculation and assumptions (if any) clearly. Box the final answer(s).

1. In a process producing jam (C1), 1000 kg of crushed fruit (CF) containing 14 wt% soluble solids (SS) and the balance water (W) is mixed in a mixer with 1220 kg of sugar and 2.5 kg of pectin. The resultant mixture is then evaporated in a kettle to produce a jam containing 6.7 wt% soluble solids.

    a. Draw and completely label the process flow diagram of the process
    b. Perform the degree of freedom analysis
    c. Calculate the mass (kg) and the mass composition (wt%) of the jam produced. Also calculate the kg water evaporated. *(2089.6 kg jam produced, 6.7 wt% soluble solids, 58.4 wt% sugar, 0.12 wt% pectin, 34.78 wt% water, 132.9 kg water evaporated)*

2. A 100 kg/hr liquid mixture containing 50 wt% methanol and 50 wt% ethanol undergoes a process involving two unit operations and is separated into two product streams that each contains 90 wt% of one of the components (referred to as the "methanol-rich" and "ethanol-rich" products) and a third waste stream of unknown composition. In the first unit, the mixture is separated into the above methanol-rich phase that is collected and another stream that has twice the mass flow rate of the methanol-rich phase. This second stream enters a second separation unit that produces the ethanol-rich product and another stream of unknown composition with twice the mass flowrate of the ethanol-rich stream.

    a. Draw and completely label the above process.
    b. Determine the mass flow rates of the methanol-rich product *(33.3 kg/h)*, the ethanol-rich product *(22.2 kg/h)*, the waste product stream *(44.5 kg/h)* and the stream flowing between the two separation units *(66.7 kg/h)*.
    c. Determine the compositions of the waste stream *(0.6 kg EtOH/kg & 0.4 kg MeOH/kg)* and the stream flowing between the two separation units *(0.3 kg MeOH/kg & 0.7 kg EtOH/kg)*

3. A liquid mixture containing 30 mole% benzene (B), 25% toluene (T), and 45% Xylene (X) is fed at a rate of 1275 kmol/h to a distillation unit consisting of two columns. The bottoms product (B1) from the first column is to contain 99 mole% X and no B, and 98% of the X in the feed is to be recovered in this stream. The overhead product (P1) from the first column is fed to a second column. The overhead product (P2) from the second column contains 99

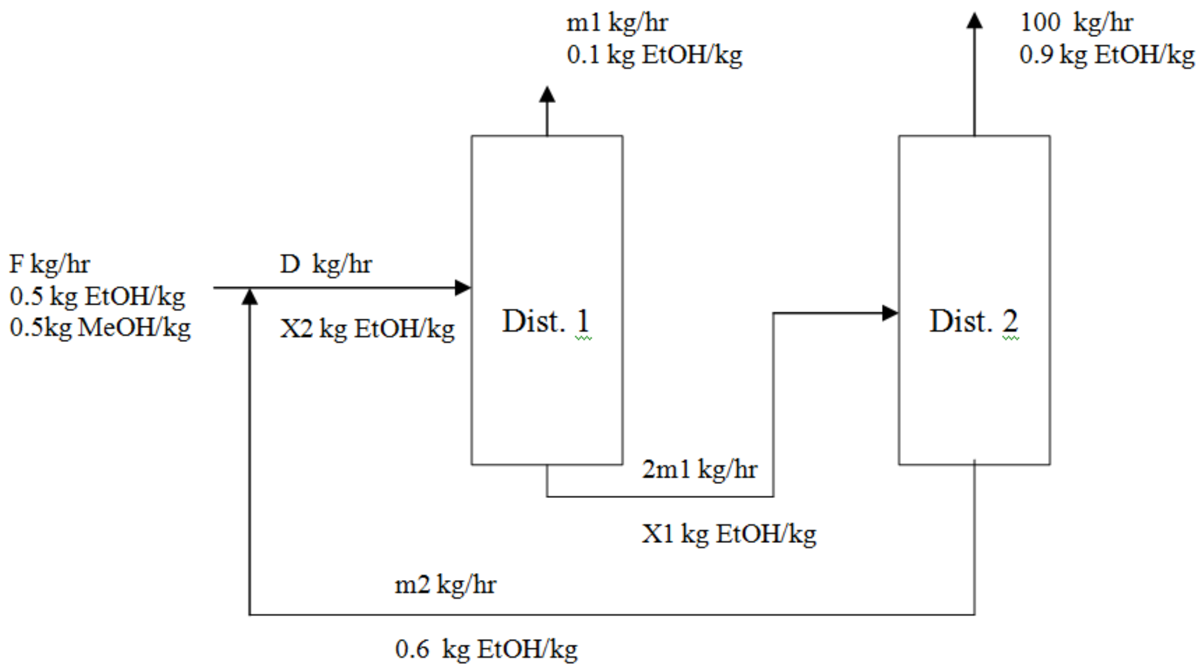
mole% B and no X. The benzene recovered in this stream represents 96% of the B in the feed to this column.

a. Draw and completely label the above process.
b. Perform the degree of freedom analysis
c. Calculate the molar flow rates (kmol/h) and component mole fractions in each product stream from both columns. *(P1=707, B1=568, P2=371, bottom product of second column, B2=337)(mol fraction of overhead product leaving distillation 1; B=0.541, X=0.0162, T=0.4428. Mol fraction of bottom product leaving distillation 2; B=0.0455, X=0.0341, T=0.9204)*

4. Natural gas dehydration is a process of removing water present in natural gas stream. Dehydration of natural gas necessary to prevent the formation of gas hydrates, which can plug valves and other components of a gas pipeline. A simple natural gas dehydration system can be described as follows; Wet natural gas stream containing 1.5 mole% water is fed to the bottom section of an absorption column at a rate of 11289.35 lb-mole/day, flows upwards and is contacted with a recycled liquid solvent (triethylene glycol, TEG (molecular weight= 150.2) containing 1.36 mole% water fed from the top section of the column. The dried natural gas leaving the top section of the absorption column contains 0.2 Ib-mole % water. The water-rich TEG solvent leaves the bottom section of the column and is fed to a distillation column to remove water. The top stream of the distillation column contains only water and the bottom stream containing regenerated liquid solvent is recycled back to the absorption column. For efficient dehydration process, it is found that 37 Ibm of TEG is required for every 1.0 Ibm of water removed from the wet natural gas.

a. Draw and completely label the above process.
b. Perform the degree of freedom analysis.
c. Calculate the amount of water leaving the overhead of the distillation column. *(147.1 Ib-mole/day).*
d. Calculate the amount of TEG required (in lbmoles/day). *(652.2 Ib-mole/day)*

5. Referring to the following process flow diagram/chart



   a. Draw and completely label the above process.
   b. Perform the degree of freedom analysis
   c. calculate the values of F, D, m1, X1 and X2. *(200 kg/hr, 300 kg/hr, 100 kg/hr, 0.75 kg EtOH/kg, 0.533 kg EtOH/kg)*

6. 100 kmol/min of gas stream containing 45 wt % ethane (C_2H_6) and 55 wt% methane (CH_4) is fed to a distillation column, where it is separated into an overhead product containing 90 mol % methane and a bottom product containing 98 mol % ethane. However, a customer wants to purchase a product contains 97 mol % methane. To produce this, the overhead product from the first column is fed to a second column. The overhead from the second column is the desired product and contains 98 % of the methane in the feed to this column, while the bottoms product from the second column is recycled to mix with the fresh gas stream before feeding back to the first column.

   a. Draw and label the flowchart from the description of this process.
   b. What is the purpose of recycle stream in this process?
   c. What is the separating agent used in this process?

Calculate:

   a. The flowrates of the final product in kg/min. *(1136.8 kg/min)*

b. The flowrates (kmol/min) and the molar composition of the recycle stream. *(6.91 kmol/min, 80 mol% ethane, 20 mol% methane)*
c. The flowrates (kmol/min) and the molar composition of the fresh gas stream. *(93.1 kmol/min, 27.4 mol% ethane, 72.6 mol% methane)*

7. A waste water stream containing 5.0 wt % chromium(Cr) from a metal finishing plant is fed to a treatment unit. The treatment unit recovers 95 % of the chromium in the unit feed and let all water pass through it. The recovered chromium (with no water) is then recycled back to the plant. The residual liquid stream containing water and unrecovered chromium leaves the treatment unit and is then sent to a waste lagoon. The treatment unit has a maximum capacity of 4500 kg wastewater/h. If the wastewater leaving the finishing plant is higher than the maximum capacity, the excess of the wastewater will bypass the treatment unit and combines with the residual liquid leaving the unit, and the combined stream goes to the waste lagoon. Based on 6000 kg/h of waste water from the metal finishing, calculate

   a. the flow rate of the combined liquid stream to the waste lagoon. *(5786. 25 kg/h)*
   b. the mass fraction of chromium in the combined liquid stream to the waste lagoon. *(0.0149 kg Cr/kg)*
   c. the flow rate of the residual liquid (kg/h) leaving the treatment unit. *(4286.25 kg/h)*
   d. the mass fraction of chromium in the residual liquid (kg/h) leaving the treatment unit. *(0.002625 kg Cr/kg)*