KM 211 BASIC PRINCIPLES IN CHEMICAL ENGINEERING
2021 - 2022Fall Semester

Instructors: Doç.Dr.Funda TURGUT BAŞOĞLU
Room No: 519
e-mail: tfunda@gazi.edu.tr

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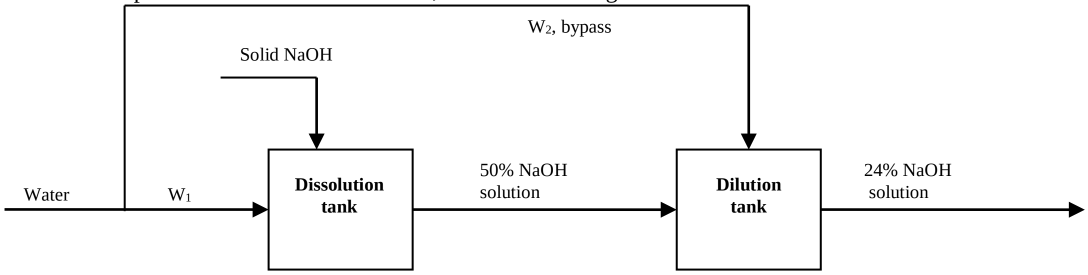
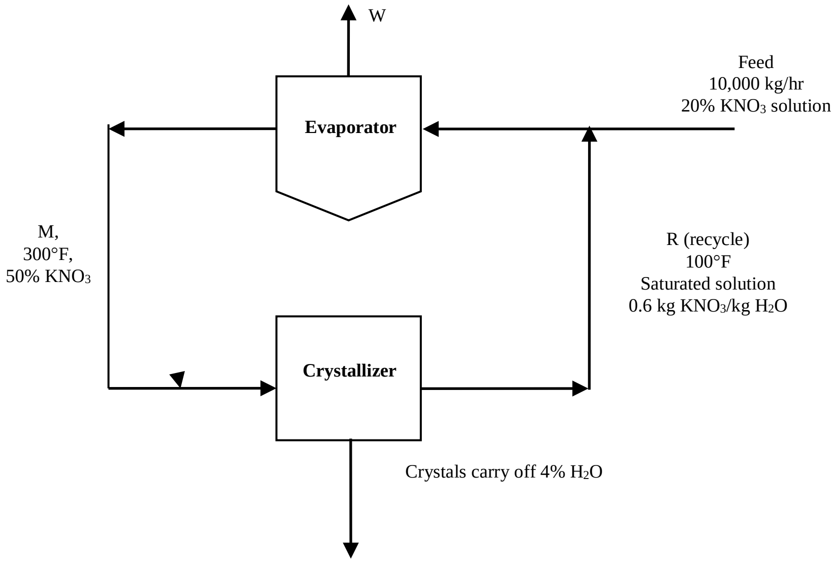
Problem Set2

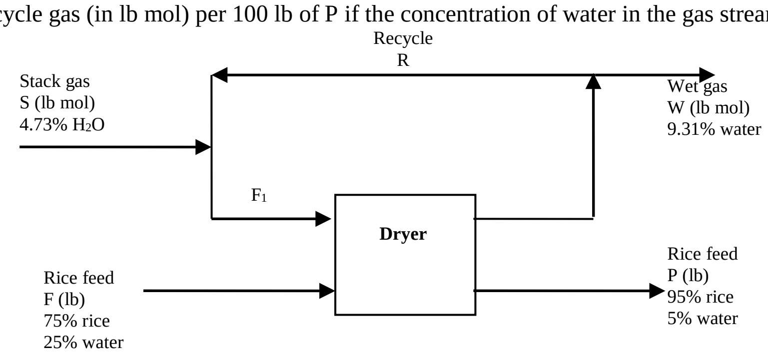
1. In a textile industry, it is desired to make 24% solution (by weight) of caustic soda for a mercerization process. The two-step process is shown in figure below. In a dissolution tank costic soda (solid NaOH) is dissolved to produce 50% solution. After complete dissolution and cooling, the solution is taken to a dilution tank where some more water is added to produce 24% solution. Assuming no evaporation in the dissolution tank, calculate the weight ratio W_1/W_2.



2. Examine the following Figure. What is the quantity of the recycle stream in kg/hr? Crystals contains 4% water.



3. To save energy, stack gas from a furnace is used to dry rice. The flow sheet and known data are shown in Figure. What is the amount of recycle gas (in lb mol) per 100 lb of P if the concentration of water in the gas stream entering the drier is 5.20%?

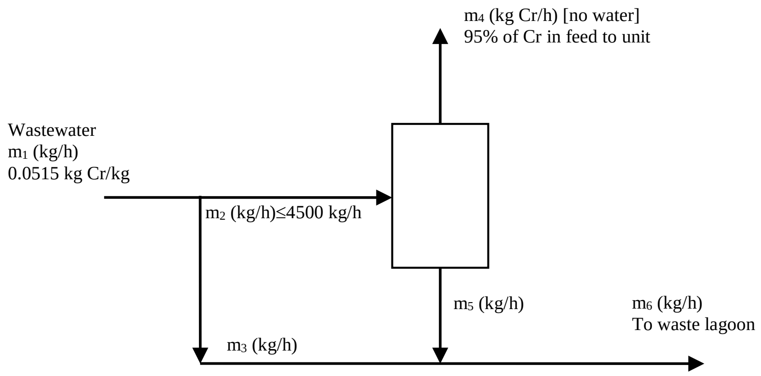


4. A liquid mixture containing 30.0 mol % benzene (B), 25% toluene (T), and the balance xylene (X) is fed to a distillation column. The bottoms products contains 98.0% mole X and no B, and 96.0% of the X in the feed is recovered in this stream. The overhead product is fed to a second column. The overhead product from the second column contains 97.0% of the B in the feed to this column. The composition of this stream is 94.0% mole B and the balance T.

a. Draw and label a flowchart of this process and do the degree-of-freedom analysis to prove that for an assumed basis of calculation, molar flow rates and composition of all process streams can be calculated from the given information. Write in the order the equations you would solve to calculate unknown process variables. In each equation (or pair of simultaneous equations), circle the variable(s) for you would solve. Do not do the calculations.

b. Calculate (i) the percentage of the benzene in the process feed (i.e., the feed to the first column) that emerges in the overhead product from the second column and (ii) the percentage of toluene in the process feed that emerges in the bottom product from the second column.

5. A stream containing 5.15 wt% chronium, Cr, is contained in the wastewater from a metal finishing plant. The wastewater stream is fed to a treatment unit that removes 95% of chronium in the feed and recycles it to the plant. The residual liquid stream leaving the treatment unit is sent to a waste lagoon. The treatment unit has a maximum capacity of 4500 kg wastewater/h. If wastewater leaves the finishing plant at a rate higher than the capacity of the treatment unit, the excess (anything above 4500kg/h) bypasses the unit and combines with the residual liquid leaving the unit, and the combined stream goes to the waste lagoon.



a. Without assuming a basis of calculation, draw and label a flowchart of the process.

b. Wastewater leaves the finishing plant at a rate m1=6000 kg/h. Calculate the flow rate of liquid to the waste lagoon, m6 (kg/h), and the mass fraction of Cr in liquid, x6 versus m1.

c. Calculate the flow rate of liquid to the waste lagoon and the mass fraction of Cr in this liquid for m_1 varying from 1000 kg/h to 10,000 kg/h in 1000 kg/h increments. Generate a plot of x_6 versus m_1. (*Suggestion:* Use a spreadsheet for these calculations.)

d. The company has hired you as a consultant to help them determine whether or not to add capacity to the treatment unit to increase the recovery of chronium. What would you need to know to make this determination.

6. An evaporation-crystallization process of the type desciribed in Figure is used to obtain solid potassium sulfate from an aqueous solution of this salt. The fresh feed to the process contains 19.6 wt% K_2SO_4. The wet filter cake consist of solid K_2SO_4 crystals and 40.0 wt% K_2SO_4 solution, in a ratio 10 kg crystals/kg solution. The filtrate, also a 40.0% solution, is recycled to join the fresh feed. Of the water fed to the evaporator, 45.0% is evaporated. The evaporatoe has a maximum capacity of 175 kg water evaporated/s.

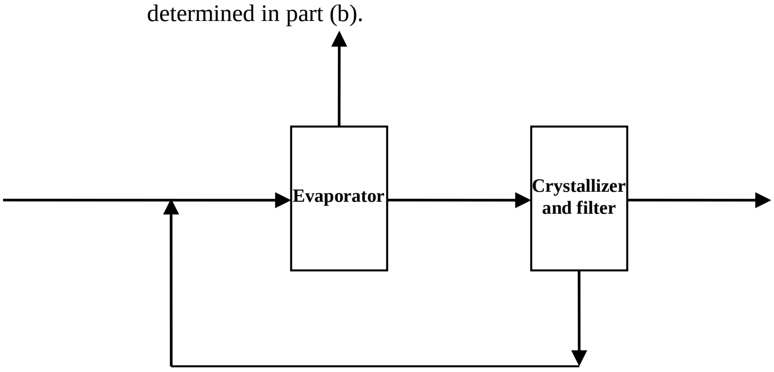
a. Assume the process is operating at maximum capacity. Draw a label a flow chart and do the degree-of-freedom analysis for the overall system. The recycle-fresh feed mixing point, the evaporator, and crystallizer. Then write in a efficent order (minimizing simultaneous equations) the equations you would solve to determine all unknown stream variables. In each equation, circle the varibale for which you would solve, but don't do the calculations.

b. Calculate the maximum production rate of solid K_2SO_4, the rate at which fresh feed must be supplied to achieve this production rate, and the ratio kg recycle/kg fresh feed.

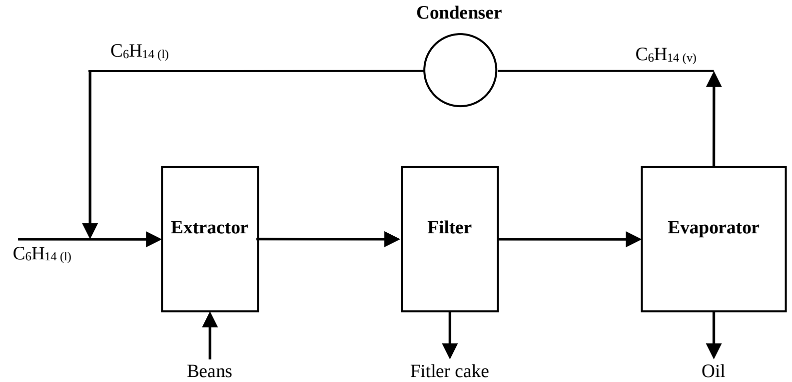
c. Calculate the composition and feed rate of the stream entering the crystallizer if the process is scaled to 75% of its maximum capacity.

d. The wet filter cake is subjected to another operation after leaving the filter. Suggest what it might be. Also, list what you think the principal operating costs for this process might be.

e. Use an equation-solving computer program to solve the equations derived in part (a). Verify that you get the same solution determined in part (b).

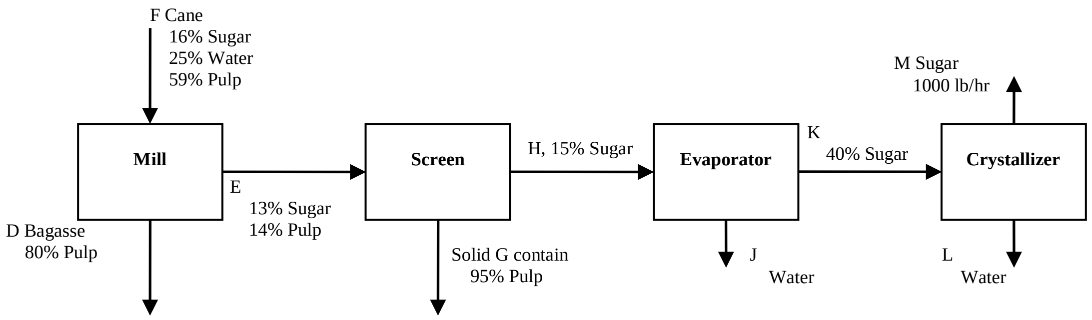


7. In the production of a bean oil, beans containing 13.0 wt% oil and 87.0% solids are ground and fed to a stirred tank (*the extractor*) along with a recycled stream of liquid n-hexane. The feed ratio is 3 kg hexane/kg beans. The ground beans are suspended in the liquid, and essentally all of the oil 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 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.

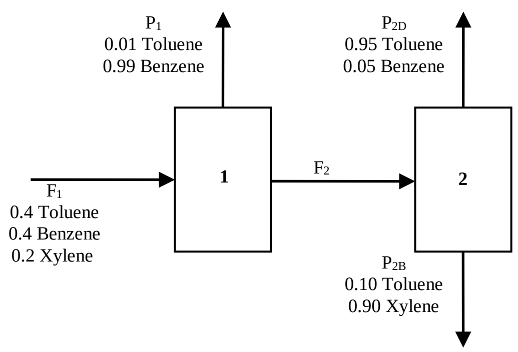


a. Draw and label a flowchart of the process, do the degree-of-freedom analysis, and write in an efficent order the equations you would solve to determine all unknown stream variables, circling the variables for which you would solve.
b. Calculate the yield of bean oil product (kg oil/kg beans fed), the require fresh hexane feed (kg $C_{16}H_{14}$/kg beans fed), and the recycle to fresh feed ratio (kg hexane recycle/kg frresh feed)

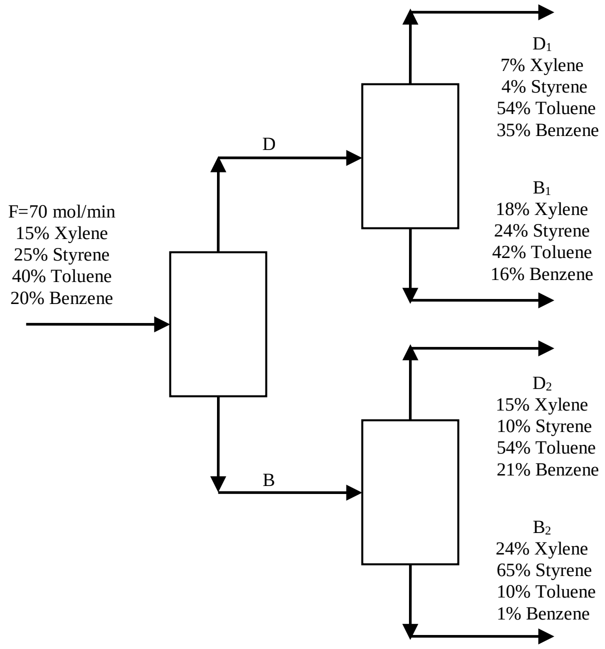
8. Figure shows the process and the known data. You are asked to calculate the compositions of every flow stream, and the fraction of the sugar in the cane that is recovered.



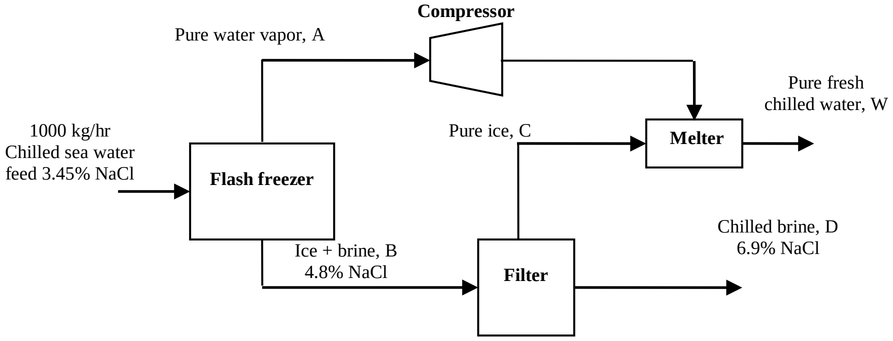
9. A two-stage separations unit is shown in Figure. Given that the input stream F_1 is 1000 lb/hr, calculate the value of F_2 and the composition of F_2.



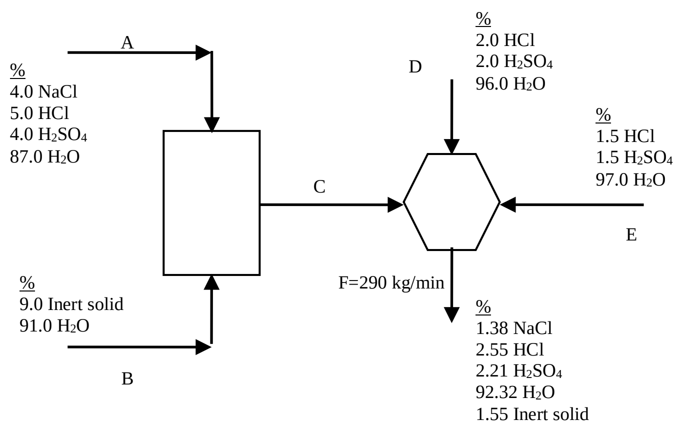
10. Examine Figure provided through the courtsey of Professor Mike Cutlip.
a. Calculate the molar flow rate of D_1, D_2, B_1 and B_2.
b. Reduce the feed flow rate for each one of the compounds by 1% in turn. Calculate the flow rates of D_1, D_2, B_1 and B_2 again. Do you notice something unusual? Explain your results.



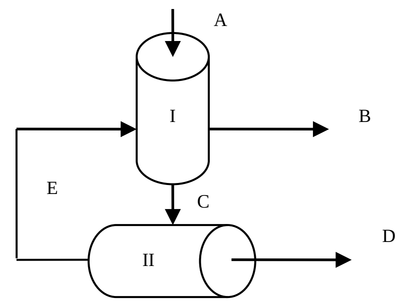
11. Figure shows a schematic for making fresh water from sea water by freezing. The pre-chilled sea water is sprayed into a vacuum at a low pressure. The cooling required to freeze some of the feed sea water comes from evaporation of a fraction of the water entering the chamber. The concentration of the brine stream, B, is 4.8% salt. The pure salt-free water water vapor is compressed and fed to a melter at a higher pressure where the heat of condensation of the vapor is removed through the heat of fusion of the ice which contains no salt. As a result, pure cold water and concentrated brine (6.9%) leave the process as products.
    a. Determine the flow rates of streams W and D if the feed is 1000 kg per hour?
    b. Determine the flow rates of streams C, B and A per hour?



12. Several streams are mixed as shown in Figure . Calculate the flows of each stream in kg/s.



13. In the process shown in the Figure Unit I is a liquid-liquid solvent extractor and Unit II is the solvent recovery system. For the purposes of designing the size of the pipes for stream C and D, the designer obtained from the given data values of C=9,630 lb/hr and D=1,510 lb/hr. Are these values correct? Be sure to show all details of your calculations or explain if you do not use calculations.

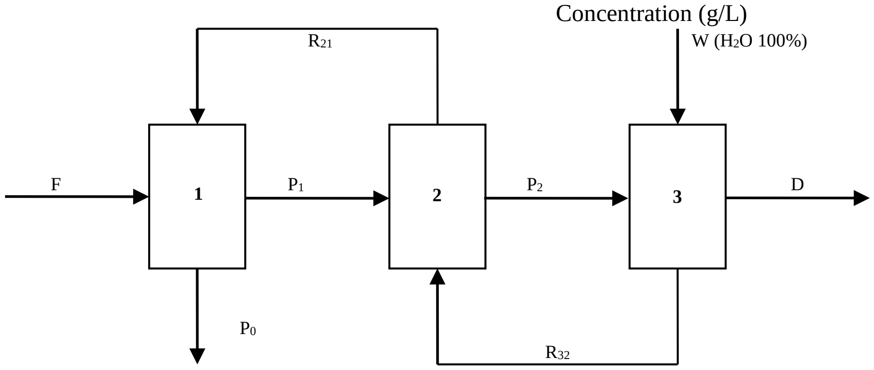


		Composition		
	Flow rate (b/hr)	Butene	Butadiene	Solvent
A	5,000	0.75	0.25	
B			1.00	
C				
D		0.05	0.95	
E	10,000		0.01	0.99

Known Data:

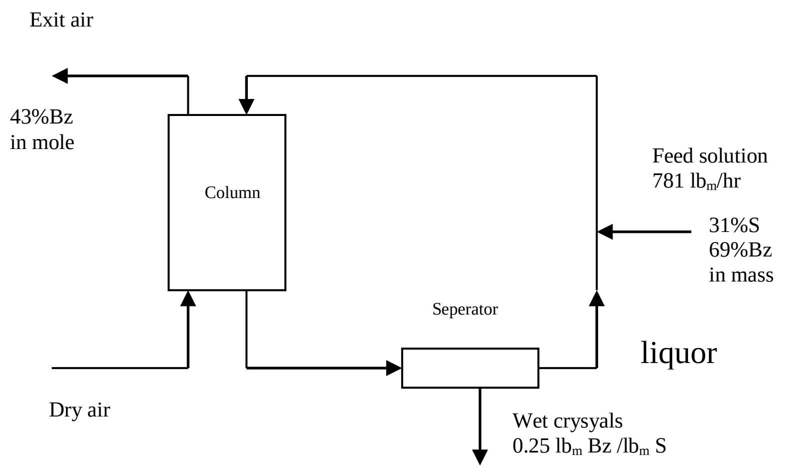
14. A plating plant has a waste stream containing zinc and nickel in quantities in excess of that allowed to be discharged into the sewer. The proposed process to be used as a first step in reducing the concentration of Zn and Ni is shown in Figure. Each stream contains water. The concentrations of several of the streams are listed in the table. What is the flow (in L/hr) of the recycle stream R_{32} if the feed is 1 L/hr?

Concentration (g/L)



Stream	Zn	Ni
F	100	10.0
P_0	190.1	17.02
P_2	3.50	2.19
R_{32}	4.35	2.36
W	0	0
D	0.10	1.00

15. A process is being designed to crystallize a pharmaceutical soax (S) from benzene (Bz) solution. The process is shown below. A solution of S in Bz is fed to the top of a packed column. Dry air is fed to the bottom of the column As the liquid passes down Bz evaporates into the air stream. By the time the liquid leaves the bottom of the column, enough Bz has been removed so that some of the S crystallizes out of solution. Wet crystals of S are then removed in a separator. The liquor from the filter is mixed with the feed solution and sent to the top of the column. Calculations indicate that the mole fraction of Bz in the exit air stream 0.43. Calculate the required feed rate of air in lb-moles. Bz : 78.1



16. 3000 kg/hr of dirty ore (ore+dirt) (1) is charged into a large washer. The amount of dirt on the ore after that process is negligable but water remains on the ore surface (4). Mass flow rate of the cleaned ore is 3100 kg/hr.The second stream from washer is dirty water (3). Assume that the water leaving the washer is saturated with dirt. The solubility of dirt in water is 0.4 kg dirt/kg H_2O. The dirty water is cleaned in a settler. 90 % of the dirt in dirty water is removed in settler. "Dirt" stream (7) contains no water. Stream 8 is then combined with a fresh water. The wet clean ore (4) enters a dryer, in which all of the water is removed (5). The flow rate of clean dry ore (6) is 2900 kg/hr. Use W for water, O for ore,and D for dirt. Composition of the streams will be labelled with the given stream numbers on flow chart. Calculate:

a) the flow rate of fresh water

b) the mass fraction of dirt in the stream (2) that enters the washer.