CHE 211 BASIC PRINCIPLES IN CHEMICAL ENGINEERING
2021- 2022 Fall Semester
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Problem Set I

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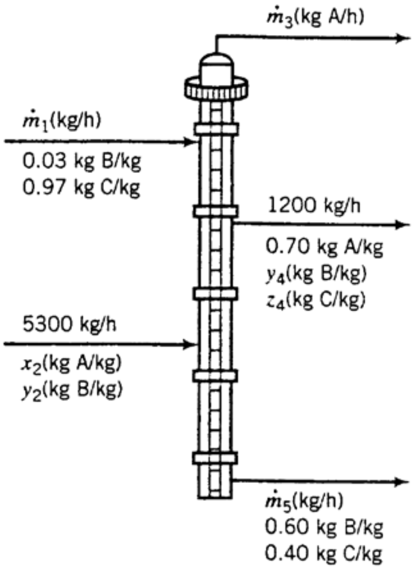
1. Felder , 3 rd ed., 4.6

A *distillation column* is a process unit in which a feed mixture is separated by multiple partial vaporizations and condensations to form two or more product streams. The overhead product stream is rich in the most *volatile* components of the feed mixture (the ones that vaporize most readily), and the bottom product stream is rich in the least volatile components.

The following flowchart shows a distillation column with two feed streams and three product streams:



(a) How many independent material balances may be written for this system?

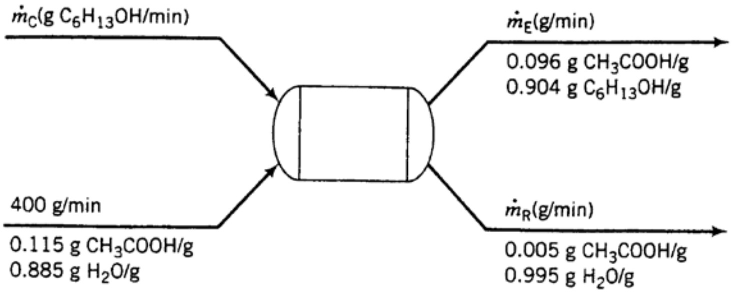
(b) How many of the unknown flow rates and/or mole fractions must be specified before the others may be calculated? (See Example 4.3-4. Also, remember what you know about the component mole fractions of a mixture—for example, the relationship between x_2 and y_2.) Briefly explain your answer.

(c) Suppose values are given for $\dot{m}_1$ and x_2. Give a series of equations, each involving only a single unknown, for the remaining variables. Circle the variable for which you would solve. (Once a variable has been calculated in one of these equations, it may appear in subsequent equations without being counted as an unknown.)

2. Felder , 3 rd ed., 4.7

Liquid extraction is an operation used to separate the components of a liquid mixture of two or more species. In the simplest case, the mixture contains two components: a solute (A) and a liquid solvent (B). The mixture is contacted in an agitated vessel with a second liquid solvent (C) that has two key properties: A dissolves in it, and B is immiscible or nearly immiscible with it. (For example, B may be water, C a hydrocarbon oil, and A a species that dissolves in both water and oil.) Some of the A transfers from B to C, and then the B-rich phase (the raffinate) and the C-rich phase (the extract) separate from each other in a settling tank. If the raffinate is then contacted with fresh C in another stage, more A will be transferred from it. This process can be repeated until essentially all of the A has been extracted from the B.

Shown below is a flowchart of a process in which acetic acid (A) is extracted from a mixture of acetic acid and water (B) into 1-hexanol (C), a liquid immiscible with water.



(a) What is the maximum number of independent material balances that can be written for this process?

(b) Calculate $\dot{m}_C$, $\dot{m}_E$, and $\dot{m}_R$, using the given mixture feed rate as a basis and writing balances in an order such that you never have an equation that involves more than one unknown variable.

(c) Calculate the difference between the amount of acetic acid in the feed mixture and that in the 0.5% mixture, and show that it equals the amount that leaves in the 9.6% mixture.

(d) Acetic acid is relatively difficult to separate completely from water by distillation (see Problem 4.6) and relatively easy to separate from hexanol by distillation. Sketch a flowchart of a two-unit process that might be used to recover nearly pure acetic acid from an acetic acid–water mixture.

3. Felder , 3 rd ed., 4.10

Three hundred gallons of a mixture containing 75.0 wt% ethanol (ethyl alcohol) and 25% water (mixture specific gravity = 0.877) and a quantity of a 40.0 wt% ethanol–60% water mixture (SG = 0.952) are blended to produce a mixture containing 60.0 wt% ethanol. The object of this problem is to determine V_{40}, the required volume of the 40% mixture.

(a) Draw and label a flowchart of the mixing process and do the degree-of-freedom analysis.

(b) Calculate V_{40}.

4. Felder , 3 rd ed. 4.12

One thousand kilograms per hour of a mixture containing equal parts by mass of methanol and water is distilled. Product streams leave the top and the bottom of the distillation column. The flow rate of the bottom stream is measured and found to be 673 kg/h, and the overhead stream is analyzed and found to contain 96.0 wt% methanol.

(a) Draw and label a flowchart of the process and do the degree-of-freedom analysis.

(b) Calculate the mass and mole fractions of methanol and the molar flow rates of methanol and water in the bottom product stream.

(c) Suppose the bottom product stream is analyzed and the mole fraction of methanol is found to be significantly higher than the value calculated in part (b). List as many possible reasons for the discrepancy as you can think of. Include in your list possible violations of assumptions made in part (b).

5. A manufacturer of briquets has a contract to make briquets for barbecuing that are guaranteed to not contain over 10% moisture or 10% ash. The basic material they use has the analysis: moisture 12.4%, volatile material 16.6%,carbon 57.5%, and ash 13.5%. To meet the specifications (at their limits) they plan to mix with the base material a certain amount of petroleum coke that has the analysis: volatile material 8.2%, carbon 88.7%, and moisture 3.1%. How much petroleum coke must be added per 100 lb of the base material?

6. If 100 g of Na_2SO_4 is dissolved in 200 g of H_2O and the solution is cooled until 100 g of $Na_2SO_4 \cdot 10H_2O$ crystallizes out, find

a. The composition of the remaining solution (mother liquor).
b. The grams of crystals recovered per 100 g of initial solution.

7. The crude oil is fed to a washing unit and in this unit it is mixed with fresh water fed to the washing unit. Crude oil contains salt and oil. There are two exit streams from washing unit. The first stream is the oil stream. The oil stream contains 5% salt but not water. The second stream is "spent wash water" stream. This stream contains 15% salt and the balance water. The mass ratio of crude oil to fresh water used is 4:1. All compositions are given on mass basis.

a) Draw and label a flowchart to this process
b) Do the degree of freedom analysis. Prove that for an assumed basis of calculation, flow rate and compositions of all process streams can be calculated from the given information.
c) Calculate flow rate and compositions of all process streams for 100 kg of oil stream taken as product.

8. Ammonia is a gas for which reliable analytical methods are available to determine its concentration in other gases. To measure flow in a natural gas pipeline, pure ammonia gas is injected into the pipeline at a constant rate of 72.3 kg/min for 12 min. Five miles downstream from the injection point, the steady-state ammonia concentration is found to be 0.382 weight percent. The gas upstream from the point of ammonia injection contains no measurable ammonia. How many kilograms of natural gas are flowing through the pipelines per hour?

9. Sludge is wet solids that result from the processing in municipal sewage systems. The sludge has to be dried before it can be composted or otherwise handled. If a sludge containing 70% water and 30% solids is passed through drier and the resulting product contains 25% water, how much water is evaporated per ton of sludge sent to the drier?

10. A stream of 5 wt % oleic acid (A) in cottonseed oil (O) enters an extraction unit at a rate of 100 kg/hr. A seperate stream of propane (P) also enters the same unit. Propane is able to dissolve oleic acid but can not mix with the cottonseed oil. Two streams exit the unit: One stream contains propane and 90% of the oleic acid that enters the process. The concentration of oleic acid in this stream is 6.15 wt%. The second stream contains all of the cotton seed oil along with the remaining oleic acid.

(a) Draw and label the flow chart.. Perform a degree of freedom analysis.
(b) Determine the unknown flow rates.

11.A tank holds 1000 kg of a saturated solution of Na_2CO_3 at 30 °C. You want to crystallize from this solution 531 kg of $Na_2CO_3 . 10\ H_2O$ without any accompanying water. To what temperature must the solution be cooled? Molecular weights : Na_2CO_3 :106, H_2O: 18 The solubility data are given in the following table.

Temperature(° C)	0	10	20	30
Solubility,g Na_2CO_3/100gH_2O	7	12.5	21.5	38.8

12. A gas mixture containing CH_4, C_2H_6 and N_2 has to be prepared with the use of following three gas streams. (1) N_2-CH_4 mixture (80 % N_2 and 20 % CH_4), (2) A gas mixture of 90 % N_2 and 10 % C_2H_6 and (3) Pure nitrogen. Mole ratio of CH_4 to C_2H_6 will be 1.5:1.0 in the final prepared mixture.

a) Draw a flowchart and label the unknown variables.
b) Do degrees of freedom analysis. For the calculation of flow rates and compositions of all process streams how many additional data are required ?

13. 100 kg/h of a solution of soda ash (Na_2CO_3) in water, (30% Na_2CO_3) is cooled slowly to 20 ^{0}C. The crystals formed are decahydrate, $Na_2CO_3.10\ H_2O$. The solubility of the Na_2CO_3 at 20 ^{0}C is 21.5 kg of Na_2CO_3 per 100 kg of water. During cooling %3 of water in the soda ash solution is lost by evaporation. Na_2CO_3:106 , $Na_2CO_3.10\ H_2O$: 286

(a) Draw the flow chart of the process , do the degrees of freedom analysis.
(b) Calculate the weight of the cystals formed .