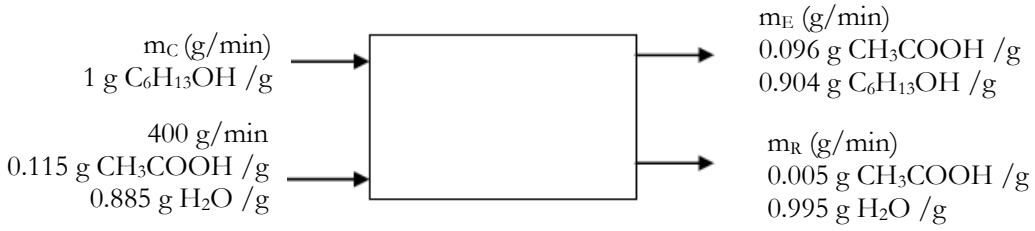
Principle of Chemical Process 1 (SKKK1113)
Assignment 02 – Single unit

1. A liquid mixture contains 60 wt% ethanol, 5 wt% of a dissolved solute and the balance water. A stream of this mixture is fed to a continuous distillation column operating at steady state. Product streams emerge at the top and bottom of the column and equal mass flowrates. The top stream contains 90 wt% ethanol and no solute.
   a. Perform the degree of freedom analysis to prove that the problem can be solved.
   b. Calculate (i) the mass fraction of the solute in the bottom stream and (ii) the fraction of the ethanol in the feed that leaves in the bottom product stream (i.e., kg ethanol in bottom/kg ethanol in feed) *(Ans: 0.1 kg S/kg; 0.25 kg E in bottom stream/kg E in feed)*

2. Two aqueous sulphuric acid solutions containing 20 wt% H_2SO_4 (SG = 1.139) and 60 wt% H_2SO_4 (SG=1.498) are mixed to form a 4.00 molar solution (SG=1.213).
   a. Perform the degree of freedom analysis to prove that the problem can be solved.
   b. Taking 100 kg of the 20 wt% feed solution as a basis, calculate the feed ratio (liters 20 wt% solution/liters 60 wt% solution)
   c. What feed rate of the 60 wt% solution (L/h) would be required to produce 1250 kg/h of the product? (*Ans: 2.96 L 20% soln/L 60% soln; 257 L/hr)*

3. A mixture of propane and air containing 4.00 mole% C_3H_8 is to be diluted with a stream of pure air (dilution air) prior to entering a furnace. If propane flows at a rate of 150 mol C_3H_8 /s in the original fuel-air mixture, what is the minimum molar flow rate of the dilution air if the diluted fuel-air mixture should not contain more than 2.05 mole% C_3H_8. Draw and label a flowchart of the fuel gas-dilution air mixing unit and perform the degree of freedom analysis to prove that the problem can be solved. (*Ans: 36000 mol/s*)

4. The following flowchart shows a process in which acetic acid (CH_3COOH) is extracted from a mixture of acetic acid (CH_3COOH) and water (H_2O) into 1-hexanol ($C_6H_{13}OH$), a liquid immiscible with water :



   a. What is the maximum number of independent material balances that can be written for this process
   b. Perform the degree of freedom analysis to prove that there is sufficient information to solve this problem
   c. Calculate m_c, m_E, and m_R *(Ans: 3; 417 g/min, 461 g/min, 356 g/min)*

5. 100 kg/hr of air that is contaminated with trichloroethylene (TCE), HC_2Cl_3 , is fed to an absorption column. The TCE makes up 10 mole% of the inlet air-TCE mixture stream when it enters the column, and is 0.01 mole % in the outlet air stream. If water is being used as the liquid that absorbs the TCE, how much water (liters) would you need per hour if the solubility of TCE in water is 1100 mg/L and you reach the solubility limit before the water stream leaves the column? Assume that you were using pure water in your inlet to the absorption column and that no water evaporates into the air and that no air dissolves into the water. Perform the degree of freedom analysis to prove that the information given is sufficient.(Note: the molecular weight of air is 29 g/mol.) *(Ans: 30,260 L water / hr)*

6. Glucoamylase is an enzyme that aids in the conversion of starch to glucose. Experiments show that 1.5 μmol of glucoamylase in a 4 wt% starch solution results in a production rate of glucose of 1.0 μmol/(mL)(min). Determine the production rate of glucose for this system in the units of lb-mol/(ft^3)(day). (note : μ = micro) (*Ans: 0.0899 lb-mol/(ft^3.day)*)

7. 100 kg Skim milk is prepared by the removal of some of the fat from Whole milk. Only fat was removed to make the Skim milk and that there are no losses in processing. The Skim milk contains 90.5% water, 3.5% protein, 5.1% carbohydrate, 0.1% fat and 0.8% ash. If the Whole milk contained 4.5% fat:
   a. Perform the degree of freedom analysis to prove that the information given is sufficient.
   b. Calculate the mass (kg) of fat in the whole milk.
   c. Calculate the composition (in percent) of the whole milk. (*Ans: 4.71 kg Fat; 86.51 wt% H2O, 3.35 wt% Protein, 4.88 wt% carb, 0.76 wt% ash, 4.5 wt% Fat*)

8. 35,000 kg of whole milk containing 4 wt % fat is to be separated in a 6-hour period into two streams, which is skim milk with 0.45 wt % fat and cream with 45 wt % fat. By using continuous centrifuge to accomplish this separation:
   a. Perform the degree of freedom analysis to prove that the information given is sufficient.
   b. Calculate the flow rate (kg/hr) of Skim Milk stream
   c. Calculate the ratio of Cream stream to Skim Milk stream (*Ans: 5368.18 kg/h; 0.0866 kg/hr Cream/kg/h Skim*)

9. A manufacturer of briquettes (a block of compressed coal dust used for fuel) has a contract to make briquettes for barbecuing that are guarantee to not contain over 10 wt% moisture. 100 kg of basic material are used having the following analysis; moisture 12.4 wt%, volatile material 16.6 wt%, carbon 57.5 wt% and ash 13.5 wt%. To meet the specifications (at their limits) they plan to mix the base material with a certain amount of petroleum coke that has the analysis; volatile material 8.2 wt%, carbon 88.7 wt% and moisture 3.1 wt%. On the basis of 100 kg of the base material
   a. Perform the degree of freedom analysis to prove that the information given is sufficient.
   b. How much (kg) petroleum coke is required?
   c. Determine of mass percent (wt%) of the components (ash, volatile material and carbon) of briquette.
   (*Ans: 34.78 kg; 10.0 wt% ash, 14.4 wt% volatile material, 65.6 wt% carbon*)