Introduction to Chemical Engineering

Problem Sheet 1 – Week 2 – September 20, 2024

Goal: Understanding Mass Balances

This week's exercise is designed to help you build a solid foundation in the basics of mass balances. We will begin by solving problems involving systems with a single unit. Once you're comfortable, we will move on to more complex tasks involving multi-unit systems.

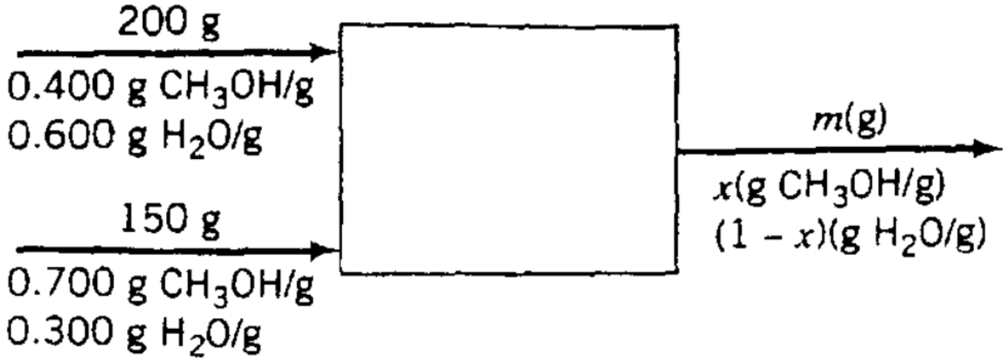
Notes:

1. <u>No Chemical Reactions Yet:</u> At this stage, we are only dealing with systems that do not involve chemical reactions. We'll introduce systems with reactions later in the semester.
2. <u>Guidance for Problem-Solving:</u>
    - If you're finding the material balances challenging, feel free to refer to the detailed methodology provided on the Moodle page. This document outlines the steps for solving mass balances in single-unit processes.
    - While you don't need to strictly follow every step described, using this methodology as a guide is highly recommended, especially when solving material balances for the first time.
    - As you gain experience and work through multiple problems, solving these types of mass balances will gradually become more intuitive.

Remember, the goal is to practice and develop a strong understanding. Don't hesitate to use the resources provided to support your learning!

Problem 1: Warming up with batch mixing process (Material Balance – Single Unit – Non-reactive)

Two methanol-water mixtures are contained in separate flasks. The first mixture contains 40.0 wt% methanol, and the second contains 70.0 wt% methanol. If 200 g of the first mixture is combined with 150 g of the second, what are the mass and composition of the product?



Problem 2: Your first labeled flowchart (Material Balance – Single Unit – Non-reactive)

An experiment on the growth rate of certain organisms requires an environment of humid air enriched in oxygen. **Three input streams** are fed into an evaporation chamber to produce **an output stream** with the desired composition.

A: Liquid water (H_2O), fed at a rate of 20.0 cm^3/min
B: Air (21 mole% O_2, the balance N_2)
C: Pure oxygen (O_2), with a molar flow rate one-fifth of **the molar flow rate** of stream B

The output gas is analyzed and is found to contain 1.5 **mole%** water.

Draw and label a flowchart of the process, and calculate all unknown stream variables.

Hints:

1. Use the **appropriate units** to compute the required material balances, based on the information given in the instructions

2. We consdier that the density of liquid water is given by:

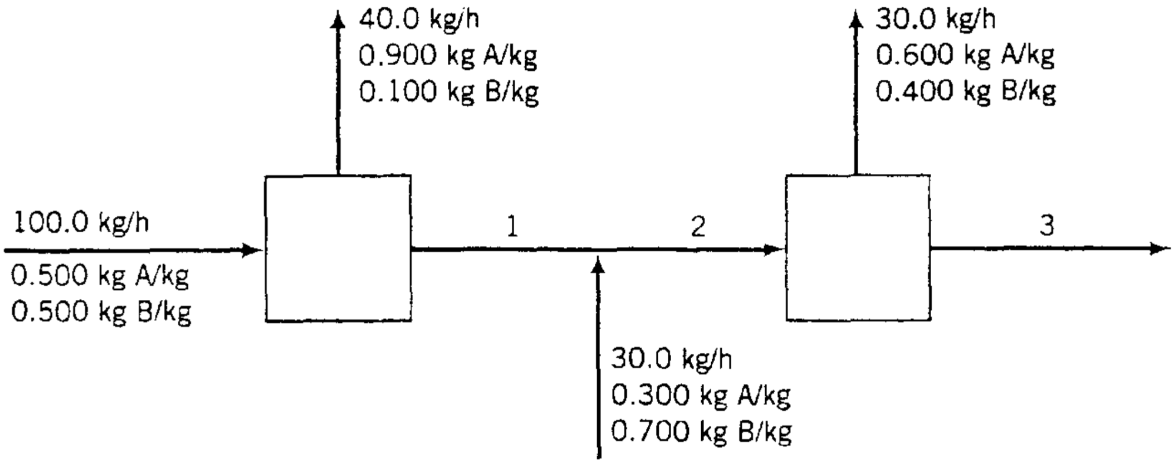
$$\frac{1.00\ g\ H_2O}{cm^3}$$

3. Remember that the molecular weight of water is:

$$\frac{18.02\ g\ H_2O}{mol\ H_2O}$$

Problem 3: One step beyond: Two-unit Process (Material Balance – Multiple Units – Non-reactive)

A labeled flowchart of a continuous steady-state two-unit process is shown below. Each stream contains two components, A and B, in different proportions. Three streams whose flow rates and/or compositions are not known are labeled 1,2, and 3.



Calculate the unknown flow rates and compositions of streams 1,2, and 3.

Problem 4: Here we go again! (Material Balance – Multiple Units – Non-reactive)

A two-stage separations unit is shown. Given that the input stream F1 is 1000 kg/hr, calculate the value of F2 and the composition of F2.

Note that the fractions given in the figure below are **mass fractions.**