CBE 40A: Chemical Processing and Material Balances

HOMEWORK 3

Due: Thurs., 10-21-21

1. Two-Unit Process with Recycle

An aqueous salt solution (salt + water) is fed to a two-unit evaporation-crystallization process. The fresh feed to the overall process contains 12.0 wt% salt. In the evaporator, pure water is removed at 225 kg/s. This is 55.0% of the water entering the evaporator. The concentrated salt stream leaves the evaporator and flows into the crystallizer where temperature is reduced. Two streams exit the crystallizer. One is an aqueous salt stream containing 25.0 wt% salt; this stream is recycled and joins the fresh feed stream entering the evaporator. The other stream leaving the crystallizer is the product stream and contains solid salt crystals and a small amount of 25.0 wt% salt solution (at a ratio of 10.0 kg salt crystals/kg solution).

(a) Draw a flowchart and label all streams. Incorporate all of the information given above. Use S to denote salt and W to denote water.

(b) Do a degree of freedom analysis on the process and show you have enough information to solve for all unknowns.

(c) Calculate the production rate of solid salt crystals, the flowrate of the fresh feed stream, and the recycle ratio: (kg/s recycled)/(kg/s fresh feed)

2. Production of instant coffee

The production of instant coffee is a process involving three units: a percolator and two dryers. Water [W] and ground coffee beans (which contain soluble [S] and insoluble [I] components) are fed to a percolator where the coffee is brewed. The liquid coffee (35.0% soluble components and the balance water) is then fed to a dryer (Dryer 1) where 95.0% of the water is removed and the instant coffee is removed for packaging. The flow rate of the instant coffee product stream is 350. kg/hr. The wet coffee grounds (60.0% insoluble components and the balance liquid coffee) leave the percolator and are fed to a different dryer (Dryer 2) where some of the water is removed and the spent grounds (70.0% insoluble components and the balance water and soluble components) are then disposed of. Note that there are three compounds in this process: water [W], soluble coffee components [S], insoluble coffee components [I].

(a) Draw a detailed flowchart and clearly label <u>all</u> streams and compositions using the information given.

(b) List all unknowns. Determine the maximum number of independent balances that can be written. Then show that the number of degrees of freedom = 1.

(c) If the wet coffee grounds leave the percolator at 1167 kg/hr, calculate the required mass flowrate of coffee beans to the percolator.

3. Mass balance on an intravenous injection (IV) bag

A nurse sets up an IV drip for a patient consisting of normal saline; assume that this is an aqueous solution containing 150mM salt. The saline drip is supplemented with an antibiotic

solution; assume that this is an aqueous solution with 15 mg/mL antibiotic and 100 mM salt. The treatment regimen for this particular patient calls for 4.0 mg of antibiotic to be infused per hour. The saline solution drip is set at 0.75 mL/min. Assume that all solutions have the density of water and that the MW of the salt is 58.5 g/mol.

(a) Draw and label a flowchart for this process.

(b) Perform a DoF analysis.

(c) Determine the drip rate (mL/min) of the antibiotic solution and the mass fraction of salt and antibiotic in the stream that enters the patient.

(d) The drip rate of the saline solution is increased to 1.5 mL/min. What is the required drip rate of the antibiotic solution to maintain the required 4.0 mg per hour dosage?

(e) The prescribed antibiotic dosage is doubled to 8.0 mg per hour. Using the 0.75 mL/min saline solution drip, solve for the required antibiotic solution drip rate.

Helpful clarifications:
– The balance is on the IV bag (two streams in, one stream out)
– The flowrates given are for the saline flowing into the bag and the antibiotic solution flowing into the bag
– The only information given for the stream to the patient is the 4.0 mg antibiotic/h