Homework Set 3

Due: Thursday, September 8 (sections 001, 003, and 004)/Friday, September 9 (section 002)

This assignment is to be completed individually. The number in parentheses next to each problem shows how many points the problem is worth in the overall assignment. Please show all work and use correct significant figures to receive full credit. Be sure to follow the problem formatting instructions to avoid unnecessary deductions. If you use an equation-solving tool (calculator, APEx, Solver, MATLAB), write out the equation(s) and note the tool that you used; otherwise, show all hand calculations used to solve any equations.

For this and subsequent assignments, you may need to use APEx, an equation solving tool that is linked to the FR&B physical property appendices, on your personal computer. Please go ahead and install it:

a. Go to http://bcs.wiley.com/he-bcs/Books?action=resource&bcsId=9692&itemId=0470616296&resourceId=38769
b. Review the APEx documentation related to installation (1st link) before installing (I suggest you save this on your computer since it will be a handy reference in the future). Watch the brief "Installation Screencast" (2nd link) and then download the APEx Excel Add-In (3rd link).
c. Download the Excel Tutorial Workbook (4th link), which has helpful suggestions on solving typical problems in each chapter.

1. (**6 pts**) If you are a chemical engineering major, visit http://www.che.ncsu.edu/academics/concentrations.html and look at the different concentrations. Write a brief description of which concentration (or the "standard" CHE curriculum) is most appealing to you and why. Also identify a required course that is specific to this concentration/curriculum and why you are interested in taking this course. If you are not a chemical engineering major, identify a career path related to your major that strongly interests you. Identify one specialty course in your curriculum that may help prepare you for this area.

2. (**12 pts**) Draw and label the given streams and derive expressions for the indicated quantities in terms of labeled variables. The solution of Part (a) is given as an illustration – you do not need to include it in your response.

(a) A continuous stream contains 40.0 mole% benzene and the balance toluene. Write expressions for the molar and mass flow rates of benzene, $\dot{n}_B$ (mol C_6H_6/s) and $\dot{m}_B$ (kg C_6H_6/s), in terms of the total molar flow rate of the stream, $\dot{n}$ (mol/s).

Solution

$$\xrightarrow[\begin{array}{l}0.400 \text{ mol } C_6H_6/\text{mol}\\ 0.600 \text{ mol } C_7H_8/\text{mol}\end{array}]{\dot{n}(\text{mol/s})}$$

$$\dot{n}_B = \boxed{0.400\dot{n} \text{ (mol } C_6H_6/\text{s)}}$$

$$\dot{m}_B = \frac{0.400\dot{n} \text{ (mol } C_6H_6) \quad | \quad 78.1 \text{ g } C_6H_6}{\text{mol}} = \boxed{31.2\dot{n}(\text{g } C_6H_6/\text{s})}$$

(b) The feed to a batch process contains equimolar quantities of nitrogen and methane. Write an expression for the kilograms of nitrogen in terms of the total moles *n* (mol) of this mixture.

(c) A stream containing ethane, propane, and butane has a mass flow rate of 100.0 g/s. Write an expression for the molar flow rate of ethane, $\dot{n}_E$ (lb-mole C_2H_6/h), in terms of the mass fraction of this species, x_E.

(d) A continuous stream of humid air contains water vapor and dry air, the latter containing approximately 21 mole% O_2 and 79% N_2. Write expressions for the molar flow rate of O_2 and for the mole fractions of H_2O and O_2 in the gas in terms of $\dot{n}_1$ (lb-mole H2O/s) and $\dot{n}_2$ (lb-mole dry air/s).

(e) The product from a batch reactor contains NO, NO_2, and N_2O_4. The mole fraction of NO is 0.400. Write an expression for the gram-moles (mols) of N_2O_4 in terms of *n* (mol mixture) and y_{NO2} (mol NO_2/mol).

3. (**18 pts**) A liquid mixture of acetone and water contains 35 mole% acetone. The mixture is to be partially evaporated to produce a vapor that is 75 mole% acetone and leave a residual liquid that is 18.7 mole% acetone.

   (a) Suppose the process is to be carried out continuously and at steady state with a feed rate of 10.0 kmol/h. Let $\dot{n}_v$ and $\dot{n}_l$ be the flow rates of the vapor and liquid product streams, respectively. Draw and label a process flowchart, then write and solve balances on total moles and on acetone to determine the values of $\dot{n}_v$ and $\dot{n}_l$. For each balance, state which terms in the general balance equation (*accumulation = input + generation - output – consumption*) can be discarded and why. (See Example 4.2-2.)

   (b) Now suppose the process is to be carried out in a closed container that initially contains 10.0 kmol of the liquid mixture. Let n_v and n_l be the moles of final vapor and liquid phases, respectively. Draw and label a process flowchart, then write and solve integral balances on total moles and on acetone. For each balance, state which terms of the general balance equation can be discarded and why.

   (c) Returning to the continuous process, suppose the vaporization unit is built and started and the product stream flow rates and compositions are measured. The measured acetone content of the vapor stream is 75 mole% acetone, and the product stream flow rates have the values calculated in Part (a). However, the liquid product stream is found to contain 22.3 mole% acetone. It is possible that there is an error in the measured composition of the liquid stream, but give at least five other reasons for the discrepancy. [Think about assumptions made in obtaining the solution of Part (a).]

4. (**18 pts**) 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. (**16 pts**) Certain vegetables and fruits contain plant pigments called *carotenoids* that are metabolized in the body to produce Vitamin A. Lack of Vitamin A causes an estimated 250,000 to 500,000 children worldwide to become blind every year. An approach to reducing blindness and other childhood health problems resulting from this deficiency is to use **genetic engineering** of rice—a food staple in developing countries and economically disadvantaged regions of the world—so that rice becomes a dietary source of Vitamin A. For example, a strain known as **Golden Rice** has been genetically engineered so that it can produce and store carotenoids such as β-carotene (which helps give carrots and squash their yellow-orange color). One type of Golden Rice contains approximately 30 micrograms of carotenoids (81% β-carotene, 16% α-carotene, and 3% β-cryptoxanthin) per gram of uncooked rice. A study has reported that when a person eats Golden

Rice, their body metabolizes 1 microgram of Vitamin A for every 3.8 micrograms of β-carotene they consume.

(a) It is recommended that children between 1 and 3 years of age should get 300 micrograms of Vitamin A per day. Considering only the metabolism of β-carotene given above, how many grams of Golden Rice would a child have to eat in order to obtain this much Vitamin A? Does this seem like a reasonable amount of rice to eat in one day, if one cup of cooked rice is approximately 175 g?

(b) α-carotene and β-cryptoxanthin can also be converted into Vitamin A, but when compared to β-carotene, it takes twice as much of each of these compounds to produce one unit of Vitamin A. Considering all of the carotenoids in Golden Rice as potential sources of Vitamin A, how many grams of Golden Rice would a three-year-old child have to eat in order to obtain the recommended daily amount of Vitamin A?

(30 pts) The remainder of the assignment (3 problems) will be completed online using WileyPLUS. *You do not have to turn in any paperwork with this portion of the assignment.* Use the link for your class on the Moodle site, and then you can access the Assignment within WileyPLUS. The due date for the WileyPLUS completion is the same as for the homework assignment – the beginning of your class period. Note that the WileyPLUS assignment cannot be submitted late.

Challenge Problem: F&RB 4.33