ChE 212 Chemical Process Calculations University of Rhode Island
Professor Greenfield Fall 2008

Homework 7, due October 16, 2008

1. (a) Felder and Rousseau, problem 3.40 (manometers), but with the following changes: the sealed-end manometer reads 795 mm Hg and the open-end manometer reads 30 mm Hg.

   (b) Felder and Rousseau, problem 3.43 (manometers), except that the unknown fluid and flow conditions have changed! Now the sealed-end manometer (connected to the atmosphere) reports 6.98 m (for an absolute pressure P of 756 mm Hg), and the manometer attached to the pipe shows a difference of 24 cm.

2. Felder and Rousseau, problem 4.56 (reactions)

3. Felder and Rousseau, problem 4.74 (combustion)

4. *Problem from the BioENGR Educational Materials Bank*, `http://www.engr.sjsu.edu/~bioemb/index.php`

   The process of taking corn flour to ethanol in a single reaction step is state-of-the-art for biethanol production, using a cocktail of enzymes produced by Genencor (Danisco). The microorganism is brewer's yeast, *S. cerevisiae*. Flour is converted first to chains of glucose (oligosacharides) which are broken down to glucose and can be consumed by the yeast. The production of yeast and ethanol is broken into two separate chemical reactions, producing ethanol and more yeast (approximated as $C_8H_xO_3N$) under anaerobic conditions as

   $$\begin{array}{rcll} C_6H_{12}O_6 & \rightarrow & 2\,C_2H_5OH + 2\,CO_2 & (1) \\ a\,C_6H_{12}O_6 + b\text{NH}_4\text{OH} & \rightarrow & c\,C_8H_xO_3N + d\text{CO}_2 + e\text{H}_2\text{O} & (2) \end{array}$$

   A new enzyme cocktail is available from Genencor* that can degrade ground corn granules (flour) into glucose at ambient temperature. For each kg of corn flour consumed, 0.64 kg of glucose is reacted. (For simplicity we will assume all sugar in the reaction is glucose.) The remaining corn residue is sold together with the dried biomass produced in the fermentation process as "Dry Distiller Grain Solids" (DDGS). Some of the glucose is converted to biomass according to the second reaction. The conversion of glucose is 100%, and 0.51 g of CO_2 are produced per 1 g of glucose consumed.

   A new ethanol production plant is to be built based on the above process data. The process inputs include 570 million kg/year of corn flour that is mixed with 946 million kg/year of H_2O plus adequate nitrogen source and yeast inoculum. Neglect water and ethanol losses in the offgas. Assume there is no loss of ethanol in the purification steps.

   a.) For a 50 million gal/year ethanol production facility, calculate the molar yield of biomass on glucose (moles biomass per mole glucose) and the mass yield of ethanol on corn (mass ethanol per mass corn).

   b.) What is the ratio of glucose consumed by the first reaction to glucose consumed by the second reaction? How much water is produced by the second reaction?

   c.) What is the final concentration of ethanol in the liquid-phase reaction product that emerges from the process?

   Hint: It turns out that using extent of reaction (ξ) to solve for material balances in the presence of reactions **requires** that you know **all** of the reactions, so you can write a variable ξ_i for each reaction. If the reaction mechanism is complicated, as in this problem, then you may choose (and sometimes *must choose*) to use atomic balances instead. Another way to say this is that atomic balances work very well for cases when you can't easily write a balanced reaction, as in the second reaction in this problem.