CHME420
Spring 2014
Final Exam
6/12/2014
6/19/2014 10:15 AM

Name (Print): ____________________

This exam contains 6 sides (including this cover side) and 5 problems. Check to see if any pages are missing. Enter all requested information on the top of this page. Put your initials on on every page you submit in case the pages become separated.

The exam is open book, notes, and homeworks.

You are required to show your work on each problem on this exam. The following rules apply:

- **Organize your work** in a reasonably neat and coherent way in the spaces provided. Work scattered all over the page without a clear order will receive very little credit. Make sure to begin each problem in its own page. Do not write on the back side of pages. Do not attempt to save the planet by writing on every mm of every page.
- **Mysterious or unsupported answers will not receive full credit**. A correct answer unsupported by calculations or explanation will receive no credit; an incorrect answer supported by substantially correct calculations and explanations might receive partial credit. A correct answer accompanied randomly by an incorrect one will undergo a deduction.
- The exam should be completed individually. Absolutely no discussion with your classmates is allowed.
- You are allowed to ask questions during the exam. If something is not clear, please ask.

Do not write in the table to the right.

Problem	Points	Score
1	20	
2	20	
3	20	
4	20	
5	20	
Total:	100	

1. (20 points) An ideal gas A diffuses (D_{AB}) to a planar, catalytic surface where it reacts to form B. The system is at steady state and at constant temperature and pressure. The general form of the reaction at the surface is:

$$\mathrm{A} \longrightarrow \mathrm{mB}$$

   And the general reaction rate:

$$k_n'' c_A^n$$

   (a) (5 points) Based on a stagnant film model, draw a picture of this situation clearly specifying your frame of references and any other important parameters. I should be able to understand the math in your answers to Parts b-d from your schematic.

   (b) (5 points) Given a stagnant film model and your drawing for Part a, write the boundary conditions for this system.

   (c) (5 points) Obtain the relevant differential equations to solve, including an expression for N_A in the appropriate direction.

   (d) (5 points) Solve the equations from Part c to obtain an algebraic expresion for either C_A or x_A. You do not need to solve for the inegration constants.

2. (20 points) Prof. Turgman's mother in law has a serious question involving mass transport. She wants to estimate the rate of evaporation of alcohol from a bottle of wine that was left open. You will model wine as a binary mixture of 80.0% mole/mole water and the balance ethanol. The wine is in a cylinder with inside diameter of 1.50 cm. The liquid level is 5.00 cm away from the end of the cylinder and assumed constant for short times. At the open end of the bottle the concentration of ethanol and water can be considered negligible. The whole system is at constant temperature of 298 K and constant pressure of 1 atm. The following data is available:

Diffusivity (ethanol in air)	1.32×10^{-5} m²/s
Diffusivity (water in air)	2.57×10^{-6} m²/s
Vapor pressure of ethanol	58.7 mm Hg
Vapor pressure of water	23.7 mm Hg
Density of Ethanol	785 kg/m³
Density of Water	997 kg/m³

(a) (5 points) What are the mole fraction of water and ethanol at the air side of the wine/air interface?

(b) (10 points) Estimate the evaporation rate of both water and ethanol assuming that the system is pseudo-binary, that is, that the diffusion of ethanol has no convective effects on the diffusion of water and *vice versa*. State any additional assumptions clearly since *there are many possible ways to make this estimate with various sets of assumptions.*

(c) (5 points) Given the estimated evaporation rate, how long would it take to evaporate 1.4 moles of ethanol (the estimated number of moles in a 750 mL bottle of wine)?

3. (20 points) A droplet of a solvent S with a solute A is suspended in a well stirred region of gas. The solute A is volatile and diffuses to the well stirred gas. The concentration of A at the surface (r=R) of the solvent droplet is given by its saturation concentration C_{AS}.

   (a) (10 points) Obtain the concentration profile and flux of A assuming a stagnant film model around the solvent droplet.

   (b) (10 points) The flux for Part (a) is given by:

   $$N_A = \frac{D_A C_{AS}}{R}\left(\frac{1+\frac{\delta}{R}}{\frac{\delta}{R}}\right)$$

   Obtain the expression for the Sherwood number.

4. (20 points) In solid tumors, O_2 is often consumed in a reaction that is nearly independent of the oxygen concentration (C_{O_2}). This means that the homogeneous reaction inside the tumor is essentially zero order (rate constant k_0''').

   (a) (10 points) Obtain the steady state concentration profile of oxygen in a spherical tumor of radius R. The concentration at the surface of the tumor is C_R.

   (b) (10 points) For large enough tumors and high reaction rates, a central core within the tumor will stop receiving O_2, leading to cell death. At what combination of the parameters will this occur?

   (c) (5 points (bonus)) Find an expression for the core radius R_C.

5. (20 points) Analyze the CSTR depicted in Figure 1 by using the macroscopic mass balance for species A. The volume of the CSTR is V and is initially full with a solution of A with mass density ρ_{A0}. The incoming solution has a flow rate of w and a mass density of ρ_{Ai}. A first order reaction consumes A in the reactor (kinetic rate constant $k_1^{'''}$).

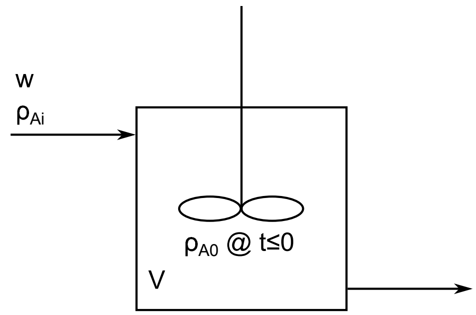

Figure 1: Simple continuously stirred tank reactor.

(a) (10 points) What is the mass density (ρ_A) as a function of time?

(b) (5 points) If $\rho_{A0} = \rho_{Ai}$, what is the outlet ρ_A as a function of time?

(c) (5 points) Given your answer in Part (b), what is the mass density of A leaving the tank as time approaches infinity.