Name:
SCIPER:

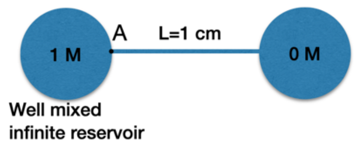
Final Exam
ChE 402: Diffusion and Mass Transfer

- Write your name and SCIPER number clearly on each page of your answer sheet (A4 sheets provided by us).
- Make assumptions if something is not clear. However, you must write down your assumption.

1) You are interested in bubbling O_2 in water, you want to estimate the flux of dissolved O_2 in water. You learned from a chemical engineering database that the diffusion coefficient of O_2 in water is 2.5×10^{-5} cm^2/s. Based on this, what is a reasonable value of the mass transfer coefficient? **(8 points)**

2) Ethylene is separated from ethane using a porous matrix filled with a liquid (like a membrane). When ethylene partial pressure in feed gas is increased, you noticed that the ethylene flux initially increased, however, it then reached a constant value independent of the ethylene partial pressure in the feed. Explain what could be happening? **(4 points)**

3) Calculate velocity of Na^+ ion (1 M in concentration) in position A of the tube shown on the right for the following two questions:



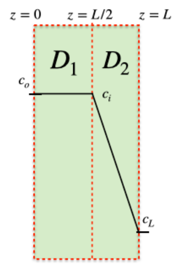
a) Where it experiences a concentration gradient (an infinitely large reservoir containing pure water connected by a small tube at a distance of 1 cm). D of Na^+ is 10^{-5} cm^2/s. **(4 points)**

b) When on top of diffusion gradient in question (a), an electrical potential is applied (such that diffusive flux and drift are in the same direction) such that $F\nabla\psi$ = 24.9 kilojoule/mole/cm/e^-. Assume temperature to be 300 K. **(8 points)**

$$J_i = -u_i RT\left(\nabla c_i + z_i c_i \frac{F\nabla\psi}{RT}\right)$$

4) The diffusion coefficient of a particle in a three-dimensional space is 1 cm^2/s. What will be the diffusion coefficient if the particle is placed in a one-dimensional space. **(4 points)**

5) In the schematic shown on the right-hand side, estimate D_1 and D_2. The measured flux is 10^{-8} $mol/cm^2/s$, L = 2 cm. $C_L = 0$ and $C_o = C_i = 1$ M. Also estimate diffusional velocity at z = 0, and L/2. **(12 points)**



6) An interesting way to study diffusion of oxygen in a water is to introduce oxygen bubbles and monitor their size as a function of time. You carried this experiment by introducing one single bubble of oxygen in a well-mixed infinitely-large water reservoir at 27 ºC. You notice that the bubble radius shrinks from initially 1 cm to 0.9 cm in 100 s.

a) Calculate the mass transfer coefficient of dissolved oxygen in liquid water. **(12 points)**
b) Calculate the flux of oxygen in water at t = 0 s. **(4 points)**
c) Can you predict as to how much the bubble would have shrunk after 200 s? **(4 points)**

You have the following data available:
- Saturation concentration of oxygen in water at 27 ºC is 0.1 mM.
- The experiment is carried at out 1 bar atmospheric pressure.

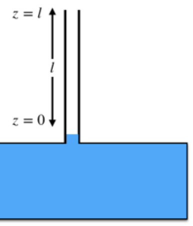
Name:
SCIPER:

7) Consider the following case of capillary evaporation of a water in stagnant air at steady state at 0 ºC and 1 bar. Water vapor diffusion coefficient in air is 10^{-2} cm^2/s. Total concentration corresponds to 1 bar pressure using ideal gas law. l is equal to 10 cm.

a) Will the flux of evaporated water higher or lower at z=0 compared to z = l. Explain in 2-3 sentences **(3 points)**

b) At what z, the velocity of the evaporated water will be highest and why. Explain in 2-3 sentences **(3 points)**

c) What is a good estimate of the flux of the water vapor at z = 0 and z = l. Concentration at z = 0 corresponds to 0.006 bar and z = l is 0.0001 bar **(6 points)**



8) A gas cylinder contains argon at pressure of 1 bar and temperature of 300 K. Under these conditions, mean free path of argon was found to be 400 nm. Boltzmann constant is equal to R/N_A where R is universal gas constant and N_A is the Avagadro number. Molecular weight of Argon is 40 g/mol. Calculate the distance (in Angstrom) over which attractive and repulsive forces between two argon molecules become equal. Hint: see the Lennard-Jones potential term below (V_{LJ} = 0 at this distance). **(8 points)**

$$l = \frac{k_B T/P}{\left(\frac{\pi}{4}\sigma^2\right)} \qquad V_{LJ} = 4\epsilon\left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6}\right]$$

9) As a part of your research, you are extracting a dye from water using an immiscible solvent (dye is more soluble in the solvent). Assume the interface between water and solvent to be at equilibrium with equilibrium constant of 10. Assume steady-state operation. The bulk of both water and solvent are well-mixed with bulk concentration in solvent maintained close to zero (large reservoir of solvent). Bulk concentration of dye in water in 1 M and remains constant. The surface renewable time for dye in water is 3 s, and in the solvent is 5 s. Diffusion coefficient of dye in water is 2.7 x 10^{-5} cm^2/s. Diffusion coefficient of dye in solvent is 1.25 x 10^{-4} cm^2/s.

a) Calculate the flux of dye in water and the organic phases? **(8 points)**

b) What is the interfacial concentration of dye in the water and the organic phases? **(4 points)**

10) Calculate the mass transfer coefficient with homogeneous reaction when interfacial layer thickness is 100 µm, mass transfer coefficient without reaction is 0.01 cm/s. Reaction rate is 10^4 s^{-1}. **(8 points)**