HOMEWORK 4

due November 14, 2013

1) A liquid A evaporates at one end of a capillary tube immersed in a large reservoir and the vapour diffuses toward the other end, which is open to a large gas space B that is essentially free of A. Assume that the gas B is insoluble in liquid A and work with the following conditions and properties:

- Total pressure: 760 mmHg
- Vapour pressure of A: 550 mmHg
- Temperature: 25°C
- Capillary length: 10 cm
- Capillary diameter: 1 cm
- Molecular weight of A: 100 g/mol
- Molecular weight of B: 28 g/mol
- Binary diffusion coefficient, $D_{AB}$: 0.25 \text{ cm}^2/\text{s}

a. Find the magnitude of the molar average velocity, $v^*$.
b. What is the rate of evaporation of A (in mol/s)?
c. How much would the error in your answer to the previous question be if you neglected bulk flow in the capillary?
d. Is $v^*$ constant along the capillary axis? Explain your answer.
e. Is $v_z$, the mass average velocity, constant along the capillary axis? Explain your answer.

Clearly state all your assumptions.

2) The first-order heterogeneous reaction $A \rightarrow B$ takes place on spherical catalyst particles of diameter D. The flow around the catalyst particles is such that the concentrations vary in a boundary layer of thickness $\delta$ surrounding the particles. The heterogeneous reaction rate constant is $k^\prime$, such that $N_A^\prime = k^\prime \cdot C_A$, based on the outer area of the spherical catalyst, $4\pi D^2/4$. The binary diffusion coefficient is $D_{AB}$ and the bulk concentration of A is $C_A^{\infty}$. You may neglect the heat of reaction and assume that the process occurs at constant temperature and pressure.

a. Determine the concentration profile, $C_A(r)$ surrounding the catalyst.
b. Determine the molar rate of consumption of A and generation of B.
3) A nanofiltration membrane is used to produce pure water from a dye solution. The membrane is impermeable to the dye and permeable to water. In the process, a constant flux of pure water through the membrane is maintained at 5 kg/m²·h. The mass density of the dye on the feed side of the membrane is 1 g/L. The flow conditions around the membrane are such that the dye concentration varies across a boundary layer of 0.5 mm surrounding the membrane surface. The mass density of the mixture can be assumed to be constant and equal to that of pure water. The binary diffusion coefficient of the dye in water, $D_{AB}$, is $2 \times 10^{-10}$ m²/s.

a. Determine the dye concentration on membrane surface.

b. Plot the dye concentration profile on the membrane surface (i.e. $\rho_A$ vs. $z$).