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Exam 3

Name:

CM3120

Wednesday 31 March 2021

Rules:

- Closed book, closed notes.
- Two-page 8.5" by 11" study sheet allowed, double sided; you may use a calculator; you may not search the internet or receive help from anyone.
- Please text clarification questions to Dr. Morrison 906-487-9703. I will respond if I am able.
- All work submitted for the exam must be your own.
- Do not discuss the contents of the exam with anyone before midnight Wednesday 31 March 2021.
- ***Please copy the following Honors Pledge onto the first page of your exam submission and sign and date your agreement to it***.

Honor's Pledge:

On my honor, I agree to abide by the rules stated on the exam sheet.

Signature __________________________________

Date _______________________

Exam Instructions:

i. You may work on the exam for up to two hours and 30 minutes (150 minutes).

ii. Please be neat. Only neat answers will be granted partial credit. Please use a dark pencil or pen so that your work is readable once scanned.

iii. Significant figures always count.

iv. Please box your final answers.

v. Submit your work as a single PDF file; put your name on every page. (Genius Scan is a free app that can create a PDF from photos taken by your phone). If you take photos of your work, insert them into Word or Google Docs and create a PDF.

vi. Submit your exam study sheet as a separate PDF file; put your name on the first page (at a minimum)

1. (20 points) Explain the mass-transfer modeling concepts of "source" and "sink." Please limit your answer to four sentences at most.

2. (20 points) Researchers want to measure the diffusion coefficient $\mathcal{D}_{AB}$ of a binary mixture of oxygen (species A) and carbon dioxide (species B). They go to great effort to set up a cell that produces one-dimensional, z-direction, steady diffusion with a zero molar average velocity of the mixture ($\underline{v}^* = 0$, equimolar counter diffusion).
   a. What is the equation for Fick's law of diffusion for this set-up? We have chosen z as the direction of the diffusion. Please be specific and define your variables.
   b. What quantities will the researchers have to measure to be able to calculate the diffusion coefficient from their measurements? Please be clear and complete.

3. (20 points) The partial pressure of water in air ($25.0^oC, 1.00\ atm$, ideal gas) is measured to be $p_A = 2.137\ kPa$. What is the mole fraction of water in the air? Is the humid air saturated? Justify your answer.

4. (20 points) In a binary mixture of ideal gases helium (species A; mole fraction in the region of interest $= 1.1 \times 10^{-2}$) and nitrogen, N_2 (species B), steady one-dimensional diffusion is taking place along the z-axis. In the z-direction, the average speed of all the A molecules is $1.34 \times 10^{-4} m/s$ and the average speed of all the B molecules is $-0.87 \times 10^{-5} m/s$. The temperature of the system is $3.10 \times 10^2 K$ and the pressure is $101.325\ kPa$. Calculate:
   a. The molar average velocity of the mixture
   b. The concentration $c = \frac{moles\ mixture}{volume\ mixture}$ of the mixture

5. (20 points) Benzoic acid is a solid that is soluble in water. When a solid piece of benzoic acid is placed in water it will dissolve very, very slowly. A long cylindrical rod of benzoic acid (radius$= R$) is placed vertically in a large reservoir of quiescent (not moving) water and allowed to slowly dissolve, changing the concentration of the water near the rod. The process comes to steady state but is slow enough that the size of the cylinder does not change much. We desire to calculate the concentration of benzoic acid in the water as a function of position and the steady state vector flux $\underline{N}_A$ of the benzoic acid. Gravity plays no role.
   a. What balance(s) will you perform to address the stated objectives? Justify your answer in a few words.
   b. At the surface of the rod, what is a reasonable boundary condition to use in this problem? What is the calculation domain?
   c. What is the concentration distribution at steady state? For the second boundary condition use the film boundary condition (at a radial position of δ, the mole fraction is equal to known value $x_{A\delta}$). Provide supporting calculations and indicate your assumptions. You may skip the final algebra; provide the two equations that will lead to the integration constants.