ChEn 3603 Homework 5

Problem 1 (10 pts)

Let's revisit the beaker problem from homework 4. Note that there are a few key functional dependencies on temperature:

- The molar concentration in the vapor will change (via ideal gas law).
- The vapor pressure of benzene will change (Antoine's equation can help you here)
- The diffusivity will change. Diffusivities of gases can be predicted by the Chapman-Enskog expression:

  $$D_{AB} = \frac{A T^{3/2} \sqrt{1/M_A + 1/M_B}}{p \sigma_{AB}^2 \Omega}$$

  where most of these are constants. Ω is a "collision integral" that we will assume to be constant for our purposes here. Since you already have the diffusivity at one temperature from homework 4, you can use this to obtain D_{AB} at other values of T. Use T in K.

1. (4 pts) Plot D_{AB}, c and p_A^s (saturation pressure of benzene) as functions of temperature for $T = [10, 80]$ $^\circ C$.
2. (6 pts) Using the more rigorous estimate for the time to empty the beaker (where N_A varies with space), generate a plot with four lines for t_{dry} as a function of temperature for $T = [10, 80]$ $^\circ C$:
   (a) Accounting for variation of D_{AB}, p_A^{sat}, and c.
   (b) Accounting for varition of D_{AB} and c assuming p_A^{sat} is constant at 40 C.
   (c) Accounting for varition of p_A^{sat} and c assuming D_{AB} is constant at 40 C.
   (d) Accounting for varition of p_A^{sat} and D_{AB} assuming c is constant at 40 C.

Comment on your findings.

Note that you can use your results from homework 4 as a starting point, including:

- Antoine equation code & constants
- Equation for t_{dry}
- Value for D_{AB} at the temperature considered in homework 4.

Problem 2 (6 pts)

SHR 3.33 (4^{th} ed.):

> Water is used to remove CO_2 from air by absorption in a column packed with Pall rings described in Chapter 6. At a region of the column where the partial pressure of CO_2 at the interface is 150 psia and the concentration in the bulk liquid is negligible, the absorption rate is 0.017 $^{\text{lbmol}}/_{\text{h-ft}^2}$. The CO_2 diffusivity in water is 2.0×10^{-5} $^{\text{cm}^2}/_{\text{s}}$. Henry's law for CO_2 is $p = Hx$, where $H = 9,000$ psia.
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> Calculate:
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> (a) liquid-phase mass-transfer coefficient and film thickness;
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> (b) contact time for the penetration theory; and
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> (c) average eddy residence time and the probability distribution for the surface-renewal theory.

For part (c), just calculate s - the surface renewal rate.

Problem 3 (8 pts)

SHR 3.34 (4^{th} ed.):

> Determine an average diffusivity of H_2S in water, using penetration theory, from the data below for absorption of H_2S into a laminar jet of water at 20°C. Jet diameter=1 cm, jet length=7 cm, and solubility of H_2S in water is 100 $^{\text{mol}}/_{\text{m}^3}$. Assume the contact time is the time of exposure of the jet.

Jet Flow Rate, $^{\text{cm}^3}/_{\text{s}}$	Rate of Absorption, $^{\text{mol}}/_{\text{s}} \times 10^6$
0.143	1.5
0.568	3.0
1.278	4.25
2.372	6.15
3.571	7.20
5.142	8.75