ENV 6002: Physical & Chemical Principles of Environmental Engineering

Fall 2021 | University of South Florida
Homework #1 | Civil & Environmental Engineering
Due Thursday, Sept. 2, 2021 | J.A. Cunningham

(1) (25 pts) On a molar basis, the composition of dry air is approximately 78.03% $N_2$, 20.99% $O_2$, 0.94% Ar, and 0.04% $CO_2$.

(a) Estimate/calculate the molar mass of dry air, in units of g/mol. Report your answer to four significant digits. Hint: use the periodic table.

(b) Estimate/calculate the density of dry air at sea level on a cold day (5 °C) and on a warm day (35 °C). Hint: use the ideal gas law and your answer from part (a). Report your answers in units of $kg/m^3$ and report three significant digits.

(c) For 35 °C, estimate/calculate the concentration of $CO_2$ in units of $mg/m^3$. Hint: use the partial pressure of $CO_2$ along with the ideal gas law.

(d) For 35 °C, estimate/calculate the mass fraction of $CO_2$ in dry air. Hint: use your answers from the parts above.

(2) (10 pts) A dilute aqueous solution of benzene ($C_6H_6$) has a benzene concentration of 15 mg/L. Estimate/calculate the mole fraction of benzene in the solution. Hint: you can make use of the fact that the solution is dilute.

(3) (20 pts) A volume of benzene, $V_{ben}$, is mixed with a volume of toluene, $V_{tol}$. The resultant solution has a benzene concentration of 150 g/L. Estimate/calculate the mole fraction of benzene in the solution.

Hint #1: Benzene and toluene are both liquids. You might have to look up some properties of these liquids.

Hint #2: This solution is not dilute, so you can't make that assumption. However, you can neglect the volume change of mixing. This means that when you mix $V_{ben}$ with $V_{tol}$, the resultant solution has a final volume of $V_{ben} + V_{tol}$. (That might sound obvious, but it actually isn't always true. It is OK here.)

Hint #3: There is more than one way to approach this problem. I found that one simple way is to assume that you have a total solution volume of 1.00 L. Then it is not difficult to figure out how much benzene and how much toluene must be in there – and hence the mole fractions of each.

(4) (20 pts) An aqueous saline solution is 12.0% NaCl by mass and has a density of 1084 g/L.

(a) Estimate/calculate the molar concentration of NaCl in the solution. Report your answer to three significant digits.

(b) Suppose you made the solution by dissolving the appropriate mass of NaCl into 100.0 mL of water. What is the final volume of the solution? Hint: assume that the density of pure water is 998 g/L at the temperature of this problem.

(c) The density of NaCl salt is 2165 g/L. In part (b), what volume of NaCl did you start with? What total volume (volume of water plus volume of NaCl) did you start with? What total volume did you end up with after the NaCl dissolved? What can you conclude about the dissolution of NaCl in water?

(5) (10 pts) The molecular formula for lactose is $C_{12}H_{22}O_{11}$. Suppose we had an aqueous solution of lactose with a concentration of 100 mg/L. Estimate/calculate the concentration of dissolved oxygen (in mg/L) that would be required to completely oxidize the lactose. Hint: you will have to write the stoichiometry for the oxidation of lactose. What are the products when a carbohydrate is oxidized?

(6) (15 pts) Imagine that the soil and groundwater in a nearby area are contaminated with cadmium, a toxic heavy metal. We excavated 1.0 $m^3$ of soil from beneath the water table (which means that the pore spaces of the soil are filled with groundwater). Here is some information about the collected soil sample.

- The mass of the 1.0 $m^3$ sample was 2,120 kg.
- The soil has a porosity of 0.30. That means that, by volume, 30% of the sample is pores, and the other 70% is solid.
- The total mass of cadmium found in the 1.0 $m^3$ sample was 109 g.
- The concentration of cadmium in the aqueous phase (i.e., in the groundwater) is 3.5 mg/L.

Estimate/calculate the concentration of cadmium sorbed to the solid phase of the soil. Report your answer in units of ppm.

(*Note*: I don't actually know if an aqueous concentration of 3.5 mg/L is realistic for cadmium at a contaminated site. I just made it up for this problem. I usually like to use realistic numbers for my made-up problems, but I couldn't find a reliable number for cadmium, so I just made it up. The other numbers in the problem should all be pretty realistic.)