CE 111: Environmental Engineering MIDTERM EXAM #1 27 September 2017

1. Environmental engineering concepts (4 points; 1 each)

Provide a brief, accurate response to each of the following problems or questions.

(a) A sample of water has a volume of 2 liters and contains xylene (C_8H_{10}, MW = 106.2 g/mol) at a level of 10 ppb. What is the *mass concentration* of xylene in this water sample?

(b) A cloud droplet in the unpolluted atmosphere has pH = 5.6. Why isn't the pH equal to 7?

(c) Sulfur is an important minor species in coal. Assume that coal is burned with sufficient air for complete combustion. What is the most likely chemical form for S in the exhaust?

(d) In an editorial published in *Environmental Science & Technology* (November 5, 2013), the editor (J Schnoor) wrote "it is astonishing that the pH of the entire surface ocean has changed from about 8.2 to 8.08 in only 50 years or so." What chemical compound has so acidified the ocean on a global scale over the past half century?

2. Carbon tetrachloride partitioning in air and water (4 points; 2 each)

Consider this situation. A closed vessel contains V_w = 10 L of liquid water and V_a = 20 L = 0.02 m^3 of air. An experiment is conducted in which M = 0.20 moles of carbon tetrachloride (CCl_4, MW = 153.8 g/mol), also known as CT, are added to the vessel. At equilibrium, it is determined that the vessel contains M_a = 0.096 moles of gaseous CT and M_w = 0.051 moles of aqueous CT. The temperature is T = 293 K.

(a) What is the water solubility of CT, in units of mg/L?

(b) What is the Henry's law constant for CT, in units of M/atm?

3. Balancing redox: Nitrification (4 points)

"Nitrification is the biological oxidation of ammonia or ammonium to nitrite followed by the oxidation of the nitrite into nitrate. The transformation of ammonia to nitrite is usually the rate limiting step of nitrification. Nitrification is an important step in the nitrogen cycle in soil." (Source: Wikipedia article on "nitrification"; accessed 24 September 2017). Let's focus on the first step of nitrification, in which ammonia (NH_3) is converted to nitrite (NO_2^-) by oxygen (O_2). Assume that the reaction occurs in water.

(a) What is the oxidation state of N in ammonia (NH_3)? (1 point)

(b) What is the oxidation state of N in the nitrite ion (NO_2^-)? (1 point)

(c) Write a stoichiometrically balanced reaction for this process. (2 points)

4. Octane combustion (4 points; 2 each)

Gasoline is a mixture of different organic molecules, mainly hydrocarbons. It can be reasonable to represent gasoline as octane (C_8H_{18}, MW = 114 g/mol). Let's do so for the following exercises. Please assume that combustion is complete and that the air-fuel mixture is stoichiometric. [*Hint 1*: As usual, represent air as a two-component mixture, O_2 + 3.78 N_2, MW = 29 g/mol. *Hint 2*: You may find it helpful to write a balanced stoichiometric combustion reaction.]

(a) How many grams of CO_2 are generated for each gram of octane burned?

(b) What is the air-to-fuel mass ratio for this combustion process?

5. Sorbing toluene (4 points)

Consider a sealed vessel that contains 1 L of pure water plus 1 g of toluene (C_7H_8, MW = 92 g/mol). The water solubility of toluene is 535 mg/L. This solution is to be treated so as to reduce the equilibrium toluene concentration in the water to 50 mg/L. The treatment entails the addition of granular activated carbon (GAC). The isotherm that describes the equilibrium sorption of toluene in water on GAC is $q = 100\ C^{0.45}$, where q represents the mg of sorbed toluene per g of GAC and C represents the aqueous concentration of toluene in mg/L. What mass of GAC must be added to the vessel to meet the treatment objective?