Problem Set 2

CENG 340–Introduction to Environmental Engineering
Instructor: Deborah Sills

September 9, 2013

Due Date

Wednesday 18 September, in class.

Learning Goals

1. Calculate chemical concentrations in units of mass/mass, mass/volume, mole/volume, mole/mole, volume/volume, ppm_v, ppm_m, and partial pressure.
2. Describe and quantify physical characteristics of water (e.g., turbidity and solids concentrations).
3. Write balanced chemical reactions and use these to calculate chemical transformations of one compound to another.
4. Apply equilibrium relationships to calculate chemical concentrations of pollutants in air and water.
5. Apply kinetic equations to determine reaction times.

Questions

1. **6 points** (Modified from *Environmental Engineering*, by MacKenzie and Cornwell)
   In 2001,the U.S. Environmental Protection Agency mandated a new standard MCL for arsenic in drinking water. The standard is now 10 parts per billion (ppb_m).
   a) What is the MCL of arsenic in units of mg/L, μg/L, mmoles/L, , and nmole/L.
   b) Why is arsenic considered a human health hazard? (hint: read Ch. 10.1–10.3)
   c) In what parts of the world has arsenic been detected in drinking water?(hint: read Ch. 10.1–10.3)
2. **3 points** Explain the word turbidity in words that the mayor of Lewisburg (or mayor of any community) could understand?

3. **16 points** (Adapted from *Environmental Engineering*, by B. Ray)
An aqueous suspension is formed by combining the materials shown in the following table.

Table 1: Composition of aqueous suspension

Compound	Concentration (mg/L)	Dissolves	Volatalizes or burns at 550 ^{0}C
Sodium chloride	45	Yes	No
Calcium sulfate	30	Yes	No
Clay	100	No	No
Copper chloride	10	Yes	No
Acetic acid	20	Yes	Yes
Coffee grounds	25	No	Yes

(a) Determine the total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), volatile suspended solids (VSS), and fixed dissolved solids (FDS) of the suspension.

(b) Explain why inorganic compounds such as $MgCO_3$, that are unstable when exposed to heat (e.g., 550 ^{0}C), can introduce an error in the measurement of volatile solids.

4. **16 points** Researchers who study microbial degradation of vinyl chloride (VC) use small sealed glass bottles to keep VC from partitioning into the room air during experiments. Once, while I was working in a lab, a new Masters students walked up to me to show me that her sealed bottle was open (true story). Before the seal broke the bottle contained 3 mg of vinyl chloride in 60 mL of water.

Assume the volume of air in the lab equaled 100 m^3 and that there was no ventilation (luckily that was not true), the temperature and pressure in the lab were 25 ^{0}C and 1 atm, respectively. In addition the log of the dimensionless Henry's Law Constant equals 0.04 ($\log K_H = 0.04$).

a) Compare the equilibrium concentration of VC in the air to the 3-h air quality standard of $[\mathrm{VC}]_{std} = 10$ ppm$_v$.
b) What should the new Masters student have done, when she noticed the seal on the bottle that contained VC was open?

5. **16 points** Open raceway ponds used to cultivate algae for biofuel production include carbonation systems that bubble CO_2 into the ponds. Carbonation systems are needed, because the concentration of dissolved CO_2 in surface water is not high enough to sustain rapid growth of algae. And rapid growth of algae is critical for commercializing this technology. The first step in designing carbonation systems is to calculate the equilibrium concentration of aqueous CO_2.

a) Calculate the concentration of of dissolved CO_2 (in units of moles/L and mg/L) in surface water equilibrated with the atmosphere at 20 ^{0}C. The Henry's law constant for CO_2 at 20 ^{0}C is 29.4 $\frac{\mathrm{L} \times \mathrm{atm}}{\mathrm{mole}}$.

b) *Related Carbonate Chemistry* Henry's law dictates that as the concentration of atmospheric CO_2 increases, so does the concentration of aqueous CO_2 in surface water. How does increased $[CO_2]_{(aq)}$ affect pH?

6. **15 points** A tanker truck carrying ethanol has a crash and spills 500 lbs of ethanol into a river adjacent to the road. The good news is that if enough oxygen is available, all of the ethanol will be biodegraded by native aerobic microbes in the river. The unbalanced chemical reaction is:

$$\mathrm{C_2H_5OH} + O_2 \rightarrow CO_2 + H_2O$$

If all of the ethanol in the river is biodegraded,

a) How many kg of oxygen are needed?

b) How many kg of CO_2 are produced?

c) How many cubic meters of CO_2 are produced at 1 atm and 30 ^{0}C?

7. **16 points** Acid-Base Chemistry

a) What is the pH of of a 100 mL solution with 10 mg/L of sulfuric acid (H_2SO_4)?

b) What is the normality of the sulfuric acid solution (note that 1 normal (N) equals 1 eq/L)?

c) What volume of a bicarbonate (HCO_3^-) solution with a concentration of 90 mg/L of alkalinity as CaCO3 would you need to neutralize the sulfuric acid solution?

8. **12 points** (From Mihelcic and Zimmerman) A first-order reaction that results in the destruction of a pollutant has a rate constant of 0.1 /day.

a) How many days will it take for 90 percent of the chemical to be destroyed?

b) How long will it take for 99 percent of the chemical to be destroyed?

c) How long will it take for 99.9 percent of the chemical to be destroyed?