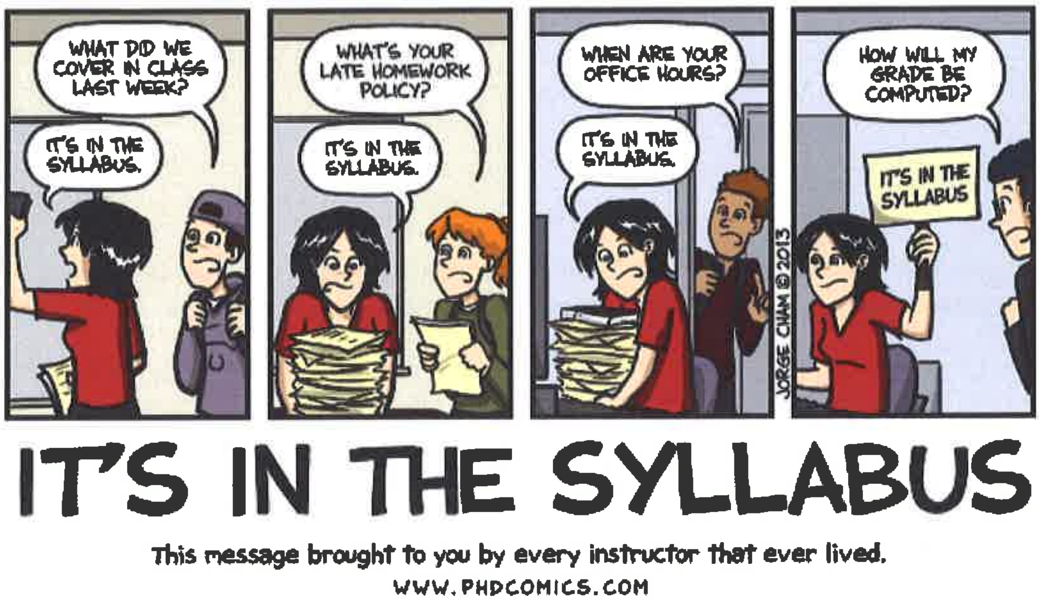
Midterm 1

CEEG 340–Introduction to Environmental Engineering
Instructor: Deborah Sills
September 14, 2018



Name: KEY

1. ________ (10 Points)
2. ________ (25 Points)
3. ________ (50 Points) Three independent sub-questions
4. ________ (15 Points)

TOTAL ________ (100 Points)

Instructions: You may use calculators to solve numerical problems, as well as one single-sided equation sheet, which you should submit with your exam. Molecular Weights: C: 12 g/mole, O: 16 g/mole, H: 1 g/mole, N: 14 g/mole. In addition, a periodic table with molecular weights is included as the last page of the exam. **Please show all work; clearly label your solutions; and indicate units as appropriate.** Advise: If you get stuck on a problem, move onto the next one and come back. SHOW All OF YOUR WORK!!!

1. Short Answer Questions:

   (a) *(3 pts)* List the three pillars of sustainability.

   ENVIRONMENTAL
   ECONOMIC
   SOCIAL

   (b) *(5 pts)* List one major environmental regulation, the governmental body that enacted this regulation, and the governmental agency that enforces the regulation.

   CLEAN WATER ACT
   ENACTED BY CONGRESS
   ENFORCED BY EPA

(c) *(2 pts)* List one environmental application for which alkalinity is important.

ANAEROBIC DIGESTION

ACID RAIN

(d) *(Extra Credit: 2 pts)*: Name the hurricane hitting the Carolinas.

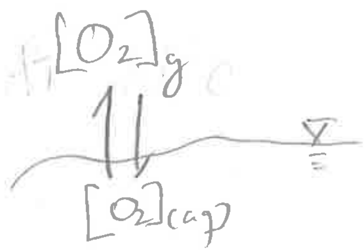
FLORENCE

2. *(25 pts)* Temperature & Dissolved Oxygen

At at 10 °C, Henry's law constant for oxygen (O_2), $K_H = 1.7\times10^{-3}\ \frac{\text{mole}}{\text{L}\times\text{atm}}$. At 20 °C, $K_H = 1.3\times10^{-3}\ \frac{\text{mole}}{\text{L}\times\text{atm}}$. The concentration of oxygen in air is 210,000 ppm_v.

A stream that is popular with fisher-men and women is in equilibrium with the air.

Calculate the difference between the concentration of dissolved oxygen (in units of mg/L) when the temperuature is 10 °C and the concentration of dissolved oxygen (in units of mg/L) when the temperature is 20 °C?



$$[O_2](g) \underset{}{\overset{K_H}{\rightleftharpoons}} [O_2](aq)$$

$$K_H = \frac{[O_2](aq)}{[O_2]_g} = \frac{[O_2](aq)}{P_{O_2}}$$ 5 pts

$[O_2]_g = 210{,}000\ ppm_v$; $ppm_v = \frac{V_i}{V_{TOT}} \times 10^6$

$$\frac{V_{O_2}}{V_{TOT}} = \frac{210{,}000}{10^6} = 0.21$$

$$\frac{P_{O_2}}{P_{TOT}} = \frac{V_{O_2}}{V_{TOT}} = 0.21 \text{ (5 pts)} ; \quad P_{TOT} = 1\ ATM$$

$$\Downarrow\ P_{O_2} = 0.21\ ATM$$

AT 10 °C

$$K_H = \frac{[O_2](aq)}{P_{O_2}} = 1.7\times10^{-3}\ \frac{mole}{L\cdot atm}$$ 5 pts

$$[O_2](aq) = K_H \times P_{O_2} = 1.7\times10^{-3}\ \frac{mole}{L\cdot atm} \times 0.21\ atm = 3.57\times10^{-4}\ \frac{mole}{L}$$

$$[O_2](aq) = 3.57\times10^{-4}\ \frac{mole}{L} \times \frac{32\ g}{mole} \times \frac{1000\ mg}{g} = 11.4\ mg/L$$

Extra Workspace

AT 20°C – SAME PROCEDURE AS FOR 10°C

$$[O_2]_{(aq)} = 1.3\times10^{-3}\ \frac{mole}{L\cdot atm} \times 0.21 = 2.73\times10^{-4}\ \frac{mole}{L}$$

5 pts

$$[O_2]_{(aq)} = 2.73\times10^{-4}\ \frac{mole}{L} \times 32\ \frac{g}{mole} \times \frac{1000\ mg}{g} = 8.7\ mg/L$$

$$\Delta[O_2]_{(aq)} = [O_2]^{10°C}_{(aq)} - [O_2]^{20°C}_{(aq)} = 2.7\ mg/L$$

5 pts

$$\boxed{\Delta[O_2]_{(aq)} = 2.7\ mg/L}$$

3. An industrial wastewater contains 300 $\frac{\text{mg-N}}{\text{L}}$ of total ammonia ($[NH_4^+] + [NH_3]$). Ammonium, $[NH_4^+]$, is a weak acid. Ammonium, $[NH_4^+]$, and ammonia, $[NH_3]$, are in equilibrium with each other based on the following chemical equation.

$$[NH_4^+] \overset{K_a}{\rightleftharpoons} [NH_3] + [H^+]$$

where $K_a = 10^{-9.2}$, or $pK_a = 9.2$.

(a) *(15 pts)* What is the concentration of total ammonia in units of mole/L.

$$[NH_4] + [NH_3] = 300 \frac{mg-N}{L} \times \frac{1 \text{ mole-N}}{14 \text{ g-N}} \times \frac{1 g}{1000 mg} = 0.02 \frac{mole}{L}$$

$$\text{TOT. AMMON. CONC.} = 0.02 \frac{mole}{L}$$

(b) *(20 pts)* An environmental engineer is designing a process to recover ammonium, $[NH_4^+]$, from this wastewater to produce fertilizer. As a first step in recovering ammonium, the environmental engineer will alter the pH such that 80 percent of the *total* ammonia is in the form of ammonium. **At what pH will 80 percent of the total ammonia, $[NH_4^+] + [NH_3]$, be in the form of ammonium, $[NH_4^+]$?**

$$\frac{[NH_4]}{[NH_3] + [NH_4^+]} = 0.8 \Rightarrow [NH_3] = \frac{0.2}{0.8} [NH_4]$$

$$K_a = \frac{[NH_3][H^+]}{[NH_4^+]} \Rightarrow [H^+] = K_a \frac{[NH_4^+]}{[NH_3^+]}$$

$$[H^+] = K_a \frac{[NH_4^+]}{\frac{0.2}{0.8}[NH_4^+]} = 10^{-9.2} \times \frac{0.8}{0.2} = 2.52 \times 10^{-9}$$

Problem 2 cont.

$$pH = -\log[H^+] = -\log[2.52\times10^{-9}]$$

$$\boxed{pH = 8.6}$$

(c) *(15 pts)* In addition to total ammonia, the water contains 200 mg/L of $[HCO_3^-]$, and 60 mg/L of $[CO_3^{2-}]$. Using the pH you calculated in Part (b), calculate the alkalinity of this water in units of "mg/L as $CaCO_3$". **If you are unsure of your pH calculation in Part (b), assume pH=9.**

$$\underset{eq/L}{[ALK]} = \underset{mole/L}{[HCO_3^-]} + 2\underset{mole/L}{[CO_3^{2-}]} + \underset{mole/L}{[OH^-]} - \underset{mole/L}{[H^+]}$$

FOR $pH = 8.6$

$$[HCO_3^-] = 200\frac{mg}{L} \times \frac{1\ mole}{61\ g} = 3.3\times10^{-3}\ \frac{mole}{L}$$

$$[CO_3^{2-}] = 60\frac{mg}{L} \times \frac{1\ mole}{60\ g} = 10^{-3}\ \frac{mole}{L}$$

$$[H^+] = 10^{-8.6}$$

$$[OH^-] = 10^{-5.4}$$

$$ALK = 3.3\times10^{-3} + 2\times10^{-3} + 10^{-5.4} - 10^{-8.6} = 5.3\times10^{-3}\ eq/L$$

4. *(15 pts)* An engineer is studying bioremediation of methylcyclohexanemethanol (MCHM). The microbe she is studying can break down 70 percent of the MCHM in five days. What is the first-order rate coefficient for this reaction.

$$C = C(0)e^{-kt}$$

$$0.3C(0) = C(0)e^{-k \times 5}$$

$$\ln 0.3 = -5\,\text{day}\,k$$

$$k = -\frac{\ln 0.3}{5}$$

$$\boxed{k = 0.2\ \text{day}^{-1}}$$

⑤ CONT.

$$[ALK] = 5.3\times10^{-5}\ \frac{eq}{L} \times 50\ \frac{g}{eq} \times 1000\ \frac{mg}{g} = 265\ mg/L$$

$$\boxed{[ALK] = 265\ mg/L\ \text{as}\ CaCO_3}$$

FOR pH = 9

$$\boxed{ALK = 265\ \frac{mg}{L}\ \text{as}\ CaCO_3}$$