CEE 370	Fall 2019

Homework #2

1. ***How many grams of anhydrous Sodium Sulfate (Na_2SO_4) must be added to a liter of water so that the ionic strength equals 0.01M?***

$$\mu = \tfrac{1}{2}\sum C_i z_i^2$$

1 point

for a solution of sodium sulfate at a molar concentration of "C", we have "C" moles of sulfate (a divalent ion) and "2C" moles of sodium (a monovalent ion). Therefore,

$$\mu = \tfrac{1}{2}\left(2C(1)^2 + C(2)^2\right)$$
$$\mu = 3C$$
$$C = \frac{1}{3}\mu = \frac{1}{3}(0.01) = 3.33x10^{-3}M$$

since the GFW of Na_2SO_4 is (2x23)+32+(4x16)=142

$$C = 3.33x10^{-3}M(142\tfrac{g}{mole}) = 0.473g/L$$

2. ***The pesticide, parathion, undergoes photolytic degradation (destruction by absorption of energy from the sun's rays) in natural waters. This is a first order process with a rate constant of $8x10^{-7}s^{-1}$.***

   a. What is the half-life for parathion based on this degradation process?

1 point

$$t_{1/2} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{0.693}{8x10^{-7}s^{-1}} = 866{,}250s = 14{,}438\min = 241hr = 10d$$

   b. How long will it take for 90% of the parathion to degrade?

$$C = C_o e^{-kt}$$
$$C/C_o = e^{-kt}$$
$$\ln\left(C/C_o\right) = -kt$$

$$t = -\frac{1}{k}\ln\left(C / C_o \right)$$

$$t = -\frac{1}{8x10^{-7} s^{-1}}\ln(0.1) = 2{,}878{,}000s = 47{,}970\min = 800hr = 33.3d = 4.76wks$$

c. How long will it take for 99% of the parathion to degrade?

$$t = -\frac{1}{k}\ln\left(C / C_o \right)$$

$$t = -\frac{1}{8x10^{-7} s^{-1}}\ln(0.01) = 5{,}756{,}000s = 95{,}940\min = 1{,}600hr = 66.6d = 9.52wks$$

3. ***Hypochlorous acid (HOCl) reacts with phenol (C_6H_5OH) to produce a wide range of products including highly offensive chlorophenols. The rate of this reaction is second order, overall (first order in each reactant). The rate constant is $2x10^3$ $M^{-1}s^{-1}$. In this problem you have 1.2 ppb of phenol in water, and to this you add 0.1 mM hypochlorous acid.***

    a. How long will it take to destroy 50% of the phenol?

1 point

First, calculate molar phenol concentration.

$$Molarity = \frac{grams/L}{GFW}$$

$$GFW = (6x12) + (6x1) + 16 = 94$$

$$Molarity = \frac{1.2x10^{-6} g/L}{94} = 1.27x10^{-8} M = 0.0000128mM$$

Although this is a <u>second order kinetic</u> problem, one of the reactants (hypochlorous acid) is present at a very large molar excess (e.g., 0.1 mM vs 0.0000128mM). Therefore, this reactant will not become depleted as the reaction proceeds, and the overall reaction takes on the form of <u>pseudo-first order kinetics</u>.

So the following equation will hold:

$$C = C_o e^{-k't}$$

Where:

$$k' = k[HOCl] = 2x10^3 M^{-1}s^{-1}(10^{-4} M) = 2x10^{-1} s^{-1}$$

and now we can simply used the re-arranged form of the first order kinetic equation as developed in question #2 above.

$$t = -\frac{1}{k'}\ln\left(C / C_o \right)$$

$$t=-\frac{1}{2x10^{-1}s^{-1}}\ln(0.5)=3.47s$$

b. How long will it take to destroy 99.99% of the phenol?

And using the same equation again:

$$t=-\frac{1}{k'}\ln\left(C/C_o\right)$$

$$t=-\frac{1}{2x10^{-1}s^{-1}}\ln(0.0001)=46.1s$$

4. Calculate the ThOD of the following wastewaters

a. 45 mg/L of methanol

The balanced stoichiometric equation is:

$$\underbrace{CH_3OH}_{32}+\underbrace{1\tfrac{1}{2}O_2}_{48}\rightarrow 1CO_2+2H_2O$$

The ThOD is then:

$$ThOD=45\frac{mg-CH_3OH}{L}\times\left(\frac{48mg-O_2}{32mg-CH_3OH}\right)$$

2 points

$$ThOD=67.5\frac{mg-O_2}{L}$$

b. 10 mg/L of glucose

The balanced stoichiometric equation is:

$$\underbrace{C_6H_{12}O_6}_{180}+\underbrace{6O_2}_{192}\rightarrow 6CO_2+6H_2O$$

The ThOD is then:

$$ThOD=10\frac{mg-C_6H_{12}O_6}{L}\times\left(\frac{192mg-O_2}{180mg-C_6H_{12}O_6}\right)$$

$$ThOD=10.7\frac{mg-O_2}{L}$$

c. 45 mg/L of methanol with 10 mg/L glucose

The ThOD of the two components are calculated in parts a and b. The answer is the sum of the two, or:

$$ThOD = 67.5\frac{mg-O_2}{L} + 10.7\frac{mg-O_2}{L}$$

$$\boxed{ThOD = 78.2\frac{mg-O_2}{L}}$$

d. 10^{-4} M acetic acid

First, the mass-based concentration is:

$$C_{HAc} = 10^{-4}\frac{mol-HAc}{L} \times \left(\frac{60g-HAc}{mol-HAc}\right) \times \left(\frac{1000mg}{g}\right) = 6\frac{mg-HAc}{L}$$

The balanced stoichiometric equation is:

$$\underbrace{CH_3COOH}_{60} + \underbrace{2O_2}_{64} \rightarrow 2CO_2 + 2H_2O$$

The ThOD is then:

$$ThOD = 6\frac{mg-CH_3COOH}{L} \times \left(\frac{64mg-O_2}{60mg-CH_3COOH}\right)$$

$$\boxed{ThOD = 6.4\frac{mg-O_2}{L}}$$

e. 5 mg/L of trichloroethane

The balanced stoichiometric equation is:

$$\underbrace{Cl_3CCH_3}_{133.5} + \underbrace{2O_2}_{64} \rightarrow 2CO_2 + 3HCl$$

The ThOD is then:

$$ThOD = 5\frac{mg-CCl_3CCH_3}{L} \times \left(\frac{64mg-O_2}{133.5mg-CCl_3CCH_3}\right)$$

$$\boxed{ThOD = 2.4\frac{mg-O_2}{L}}$$

Don't forget to check that all elements are balanced as well as the charge

5. Nitrogen occurs at a variety of oxidation states in water environments. Balance the following oxidation-reduction reaction which is important in wastewater treatment:

$NH_3 + O_2 \rightarrow NO_3^- + H_2O$

1 point

Show all steps.

Oxidation: $3H_2O + \overset{-III}{N}H_3 \rightarrow \overset{+V}{N}O_3^- + 9H^+ + 8e^-$

Reduction: $\overset{0}{O}_2 + 4H^+ + 4e^- \rightarrow 2H_2\overset{-II}{O}$

Multiply the reduction reaction by 2x and adding the two we get:

$$NH_3 + 2O_2 \rightarrow NO_3^- + H^+ + H_2O$$