

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?**

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

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,

$$\mu = \frac{1}{2} (2C(1)^2 + C(2)^2)$$

$$\mu = 3C$$

$$C = \frac{1}{3} \mu = \frac{1}{3} (0.01) = 3.33 \times 10^{-3} M$$

since the GFW of Na_2SO_4 is $(2 \times 23) + 32 + (4 \times 16) = 142$

$$C = 3.33 \times 10^{-3} M (142 \frac{\text{g}}{\text{mole}}) = 0.473 \text{ g / L}$$

1
point

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 $8 \times 10^{-7} \text{ s}^{-1}$.**

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

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

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

1
point

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

$$C = C_o e^{-kt}$$

$$C/C_o = e^{-kt}$$

$$\ln\left(\frac{C}{C_o}\right) = -kt$$

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

$$t = -\frac{1}{8 \times 10^{-7} \text{ s}^{-1}} \ln(0.1) = 2,878,000 \text{ s} = 47,970 \text{ min} = 800 \text{ hr} = 33.3 \text{ d} = 4.76 \text{ wks}$$

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

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

$$t = -\frac{1}{8 \times 10^{-7} \text{ s}^{-1}} \ln(0.01) = 5,756,000 \text{ s} = 95,940 \text{ min} = 1,600 \text{ hr} = 66.6 \text{ d} = 9.52 \text{ wks}$$

3. Hypochlorous acid (HOCl) reacts with phenol (C₆H₅OH) 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 2x10³ M⁻¹s⁻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?

First, calculate molar phenol concentration.

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

$$\text{GFW} = (6 \times 12) + (6 \times 1) + 16 = 94$$

$$\text{Molarity} = \frac{1.2 \times 10^{-6} \text{ g/L}}{94} = 1.27 \times 10^{-8} \text{ M} = 0.0000128 \text{ mM}$$

Although this is a second order kinetic 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 pseudo-first order kinetics.

So the following equation will hold:

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

Where:

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

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

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

1 point

$$t = -\frac{1}{2 \times 10^{-1} \text{ s}^{-1}} \ln(0.5) = 3.47 \text{ s}$$

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

And using the same equation again:

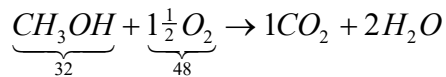
$$t = -\frac{1}{k'} \ln\left(\frac{C}{C_o}\right)$$

$$t = -\frac{1}{2 \times 10^{-1} \text{ s}^{-1}} \ln(0.0001) = 46.1 \text{ s}$$

4. Calculate the ThOD of the following wastewaters

a. 45 mg/L of methanol

The balanced stoichiometric equation is:



The ThOD is then:

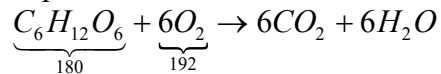
$$ThOD = 45 \frac{\text{mg} - CH_3OH}{L} \times \left(\frac{48 \text{mg} - O_2}{32 \text{mg} - CH_3OH} \right)$$

2 points

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

b. 10 mg/L of glucose

The balanced stoichiometric equation is:



The ThOD is then:

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

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

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:

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

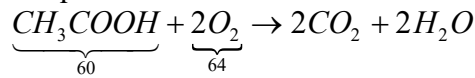
$$ThOD = 78.2 \frac{mg - O_2}{L}$$

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:



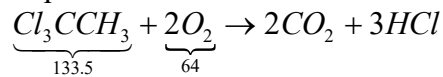
The ThOD is then:

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

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

e. 5 mg/L of trichloroethane

The balanced stoichiometric equation is:



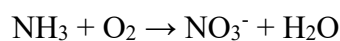
The ThOD is then:

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

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

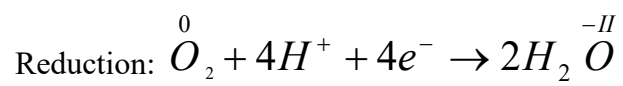
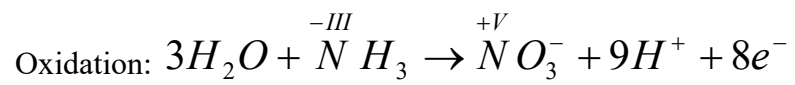
Don't forget to check that all elements are balanced as well as the charge

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



Show all steps.

1 point



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

