PROBLEM: Questions from text book

3.6 What is concentration of TCE in aqueous phase?

$M_{TCE}^{total} = M_{TCE}^{air} + M_{TCE}^{water}$

$M_{TCE}^{total} = (36\ mL\ water)(100\ ppb) = (36\ mL)(100\ \mu g/L)$

$= (36\ mL)(0.100\ \mu g/mL) = 3.6\ \mu g$

$M_{TCE}^{air} = V^{air} C_{TCE}^{air} = (4\ mL) C_{TCE}^{air}$

$M_{TCE}^{water} = V^{water} C_{TCE}^{water} = (36\ mL) C_{TCE}^{water}$

$\therefore 3.6\ \mu g = (4\ mL) C_{TCE}^{air} + (36\ mL) C_{TCE}^{water}$

1 eqn for 2 unknowns

but $C_{TCE}^{air} = H\ C_{TCE}^{water} = (0.4) C_{TCE}^{water}$

$\therefore 3.6\ \mu g = (4\ mL)(0.4) C_{TCE}^{water} + (36\ mL) C_{TCE}^{water}$

now 1 eqn for 1 unknown

$\Rightarrow C_{TCE}^{water} = 0.0957\ \mu g/mL = \underline{96\ \mu g/L}$

3.12 What concentration of Fe^{3+} is needed to keep PO_4^{3-} below 1 $\frac{mg\ P}{L}$?

Given $Fe^{3+} + PO_4^{3-} \rightleftharpoons FePO_4(s)$, $K = 10^{26.4}$

Notice this is backwards from how we typically write it

I prefer: $FePO_4(s) \rightleftharpoons Fe^{3+} + PO_4^{3-}$, $K_{sp} = 10^{-26.4}$

Thus $\frac{\{Fe^{3+}\}\{PO_4^{3-}\}}{\{FePO_4(s)\}} = [Fe^{3+}][PO_4^{3-}] = K_{sp} = 10^{-26.4}$

What is $[PO_4^{3-}]$?

$1\ \frac{mg\ P}{L} * \frac{1\ g\ P}{1000\ mg\ P} * \frac{1\ mole\ P}{30.97\ g} = 3.23 \times 10^{-5}\ M = 10^{-4.49}\ M$

$\therefore [Fe^{3+}](3.23 \times 10^{-5}) = 10^{-26.4} = 3.98 \times 10^{-27}$

$[Fe^{3+}] = \underline{1.23 \times 10^{-22}\ M}$ ... barely any iron needed at all !!

Notice $1\ \frac{mg\ P}{L} * \frac{94.97\ g\ PO_4^{3-}}{30.97\ g\ P} = \underline{3.1\ mg/L\ as\ PO_4^{3-}}$

PROBLEM: More precipitation-dissolution questions

(a) What is conc. of Mg^{2+} at pH = 11?

$Mg(OH)_2 \rightleftharpoons Mg^{2+} + 2\,OH^-$, $K_{sp} = 6.9\times10^{-12}$ from Table 3.8

$[Mg^{2+}][OH^-]^2 = 6.9\times10^{-12}$

$pH = 11 \Rightarrow [H^+] = 10^{-11}\ M \Rightarrow [OH^-] = 10^{-3}\ M$

$\Rightarrow ([OH^-]^2) = 10^{-6}\ M^2$

$[Mg^{2+}](10^{-6}) = 6.9\times10^{-12}$

$[Mg^{2+}] = 6.9\times10^{-6}\ M = 6.9\times10^{-6}\ \frac{moles}{L}$

$= (6.9\times10^{-6}\ \frac{moles\ Mg^{2+}}{L})(\frac{24.31\ g\ Mg^{2+}}{1\ mole\ Mg^{2+}})(\frac{1000\ mg}{1\ g})$

$[Mg^{2+}] = \underline{0.17\ mg/L}$ at pH = 11

(b) What pH is required to reduce iron conc. to 0.30 mg/L?

$Fe(OH)_3 \rightleftharpoons Fe^{3+} + 3\,OH^-$, $K_{sp} = 6\times10^{-38}$ from Table 3.8

$[Fe^{3+}][OH^-]^3 = 6\times10^{-38}$

$[Fe^{3+}] = 0.30\ \frac{mg\ Fe^{3+}}{L} * \frac{1\ g}{1000\ mg} * \frac{1\ mole\ Fe^{3+}}{55.85\ g\ Fe^{3+}} = 5.37\times10^{-6}\ M$

$(5.37\times10^{-6})[OH^-]^3 = 6\times10^{-38} \Rightarrow [OH^-] = 2.235\times10^{-11}\ M$

Thus $[H^+] = 4.47\times10^{-4}\ M \Rightarrow pH = -\log_{10}(4.47\times10^{-4})$

$\underline{pH = 3.3}$

Must be a very unusual setting if we have to raise the pH to 3.3 !!

Reduction of sulfate by propionate

(a) Balance redox reaction

$SO_4^{2-} \rightarrow HS^-$ .. S goes from +6 to −2

Thus $SO_4^{2-} + 8\,e^- \rightarrow HS^-$

$CH_3CH_2COO^- \rightarrow 3\ HCO_3^-$

Carbon atom C goes from −2 total (for all 3 atoms) to +4 per atom

Thus $CH_3CH_2COO^- \rightarrow 3\ HCO_3^- + 14\,e^-$

Multiply first eqn by 7, second eqn by 4

$7\ SO_4^{2-} + 56\,e^- + 4\ CH_3CH_2COO^- \rightarrow 7\ HS^- + 12\ HCO_3^- + 56\,e^-$

So per mole of propionate we have

$CH_3CH_2COO^- + \frac{7}{4}\ SO_4^{2-} \rightarrow 3\ HCO_3^- + \frac{7}{4}\ HS^-$

This balances C, S, and electrons

Also, check to see that O is balanced

But left side has 5 H, right side has $4\frac{3}{4}$ H

Thus need $\frac{1}{4}$ H on right side

Could add $\frac{1}{4}\ H^+$ on right, or add $\frac{1}{4}\ H_2O$ on right and $\frac{1}{4}\ OH^-$ on left

$$\boxed{CH_3CH_2COO^- + \frac{7}{4}\ SO_4^{2-} + \frac{1}{4}\ OH^- \rightarrow 3\ HCO_3^- + \frac{7}{4}\ HS^- + \frac{1}{4}\ H_2O}$$

(b) How much propionate to reduce 250 mg/L sulfate?

$$\frac{250\ mg\ SO_4^{2-}}{L} * \frac{1\ mmol\ SO_4^{2-}}{96\ mg\ SO_4^{2-}} * \frac{1\ mmol\ CH_3CH_2COO^-}{\frac{7}{4}\ mmol\ SO_4^{2-}} * \frac{73\ mg\ CH_3CH_2COO^-}{1\ mmol\ CH_3CH_2COO^-}$$

$$= \underline{109\ mg/L\ propionate}$$

PROBLEM: CO_2 in the air

(a) Find partial pressure of CO_2 in air

$$\frac{380 \text{ parts } CO_2}{10^6 \text{ parts air}} * 1 \text{ atm} = \underline{3.8 \times 10^{-4} \text{ atm}}$$

$$3.8 \times 10^{-4} \text{ atm} * \frac{101{,}325 \text{ Pa}}{1 \text{ atm}} = \underline{38.5 \text{ Pa}}$$

$$3.8 \times 10^{-4} \text{ atm} * 760 \text{ torr} / 1 \text{ atm} = \underline{0.289 \text{ torr}}$$

(b) Convert to units mg/m^3

$$\frac{n}{V} = \frac{P}{RT} = \frac{38.5 \text{ Pa}}{(8.314 \text{ J/mol·K})(293.15 \text{ K})} = 0.0158 \frac{\text{moles } CO_2}{m^3 \text{ air}}$$

$$0.0158 \frac{\text{moles } CO_2}{m^3 \text{ air}} * \frac{44 \text{ g } CO_2}{1 \text{ mole } CO_2} * \frac{10^3 \text{ mg}}{1 \text{ g}}$$

$$= \underline{695 \text{ mg/m}^3}$$

(c) What is pH of rainwater?

$$CO_2(g) + H_2O \rightleftharpoons H_2CO_3, \quad K_H = 3.91 \times 10^{-2} \text{ M/atm}$$

$$\therefore [H_2CO_3] = K_H \cdot P_{CO_2} = \left(3.91 \times 10^{-2} \frac{M}{\text{atm}}\right)(3.8 \times 10^{-4} \text{ atm})$$

$$[H_2CO_3] = 1.486 \times 10^{-5} \text{ M}$$

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-, \quad K_A = 10^{-6.35} = 4.467 \times 10^{-7}$$

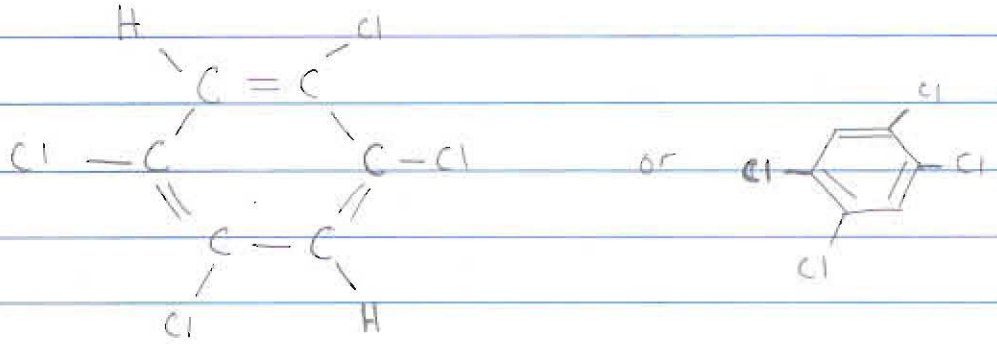
$$\frac{[H^+][HCO_3^-]}{[H_2CO_3]} = 4.467 \times 10^{-7}, \text{ but given } [H^+] = [HCO_3^-] \text{ here}$$

$$\therefore \frac{[H^+]^2}{1.486 \times 10^{-5} \text{ M}} = 4.467 \times 10^{-7} \Rightarrow [H^+] = 2.58 \times 10^{-6}$$

$\underline{pH = 5.6}$, slightly acidic because CO_2 forms H_2CO_3

PROBLEM: Clean-up of tetrachlorobenzene

(a) Chemical structure



(b) Rate constants for data sets

First data set: $\log(C)$ is linear in t

$\Rightarrow$ first-order

$k_1 = 0.099\ \text{min}^{-1}$ (note units!)

See attached graph

Second data set: C is linear in t

$\Rightarrow$ zero-order

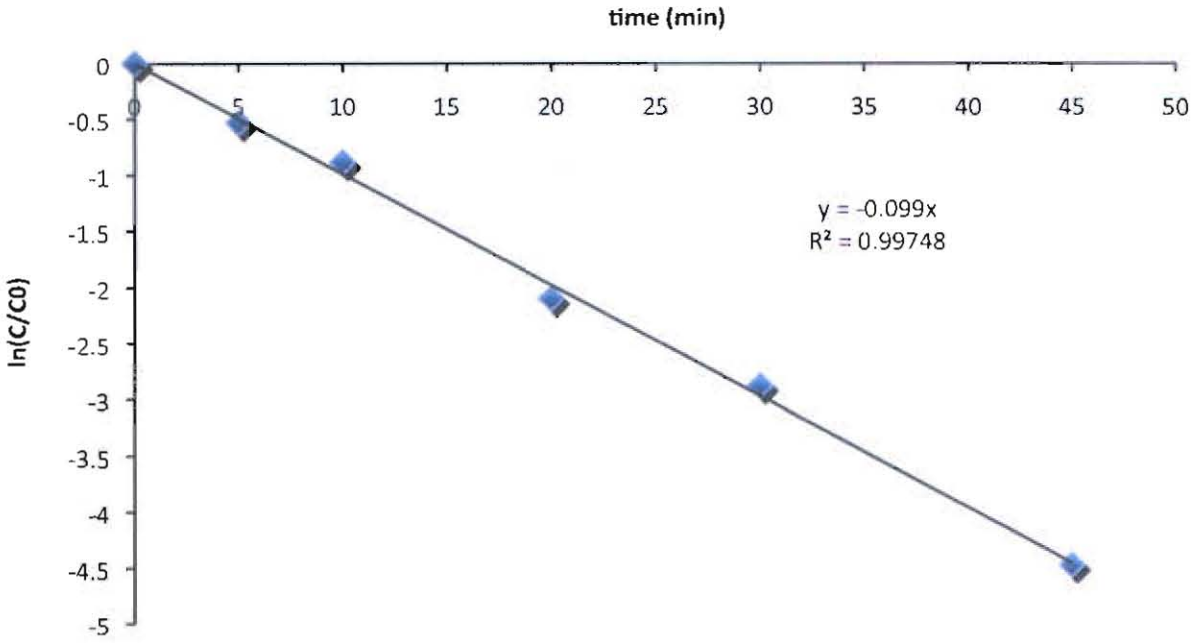
$k_0 = 0.038\ \frac{\text{mg/L}}{\text{min}}$

ENV 4001

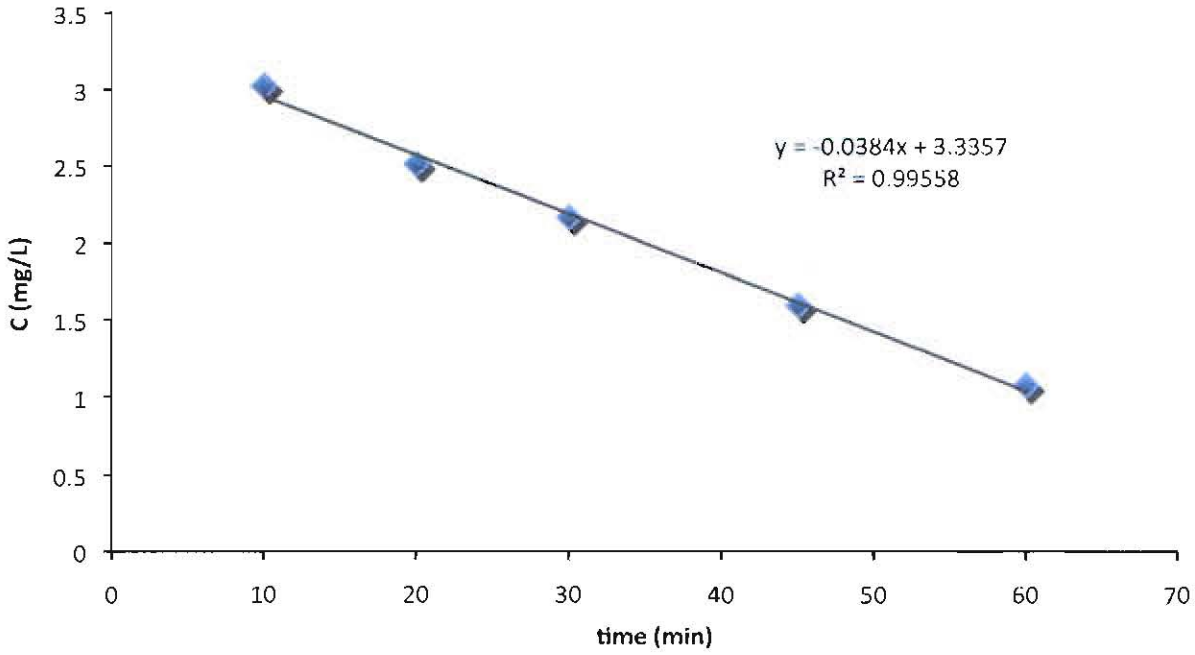
HW #2

Problem #5

Data set #1



ENV 4001
HW #2
Problem #5
Data set 2



PROBLEM: laws administered by the EPA

(a) How many laws does the EPA administer?

It depends a little bit on how you count... for instance, do you count the Superfund Amendments and Reauthorization Act (SARA) as part of CERCLA, or separate? So there is not exactly a "right" answer here. But I would count these:

- Atomic Energy Act
- Clean Air Act
- Clean Water Act
- CERCLA (incl. SARA)
- EPCRA
- Endangered Species Act
- Energy Policy Act
- FFDCA
- FIFRA
- Ocean Dumping Act
- NEPA
- NTTAA
- NWPA
- OSHA
- Oil Pollution Act
- Pollution Prevention Act
- RCRA
- SDWA
- TSCA

19 laws!

(b) Which law is concerned with surface water bodies?

The Federal Water Pollution Control Act was passed pre-1970, then amended in 1972 and 1977. With the 1977 amendments, the law became known as the Clean Water Act. Generally the name "Clean Water Act" refers to the 1972 and 1977 amendments to the original legislation (which was passed before the advent of the EPA).

(c) What is the stated objective of this Act?

"The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."

(d) What three components comprise a Water Quality Standard?

The three components are the designated uses, the water quality criteria, and the antidegradation policy.

The designated uses of a water body indicate what the water ~~should~~ may be used for ... for instance, fishing, swimming, or navigation.

Water quality criteria are description (either numerical or narrative) of how clean the water must be in order to support the designated uses.

The antidegradation policy is a set of rules that should be followed to ensure that the quality of the water does not degrade, especially for high-quality waters that already meet their applicable criteria.