Acid/Base and Solubility Reactions in the Environment

1. Write the two acid/base, one gas solubility, and one solid precipitation chemical equations that control the buffering capacity of most natural waters and
   (a) Show how the four equilibrium relationship equations for $K_{H, CO_2}$, $K_{a1}$, $K_{a2}$, and $K_{sp,CaCO_3}$ are developed from these equations.
   (b) Use these equations to illustrate how rapid photosynthesis will impact pH and calcium carbonate solubility in surface waters, and
   (c) Use these equations to illustrate how an increased carbon dioxide partial pressure due to the biodegradation of leaf litter and soil organic matter may impact pH and calcium carbonate solubility in a groundwater.

2. Calculate $[H_2CO_3^\ast]$, $[HCO_3^-]$, $[CO_3^{2-}]$, and $C_1$ in the epilimnion of a lake (in other words for an open system) with a pH of 6.9. The NOAA measured CO$_2$ levels at Mauna Loa in Dec. 2013 to be 10-3.4.

3. (a) Draw a pCpH diagram for a closed system, such as the hypolimnion of a lake, with a total carbonate concentration of 0.0001 M, and (b) illustrate how your diagram may be used to estimate $[H_2CO_3^\ast]$, $[HCO_3^-]$, and $[CO_3^{2-}]$ at pH=9 in the system represented.

4. Define alkalinity.

5. Will the alkalinity of a water increase, decrease or remain the same if the following compounds are added? Hint consider the equation $TA = 2[CO_3^{2-}] + [HCO_3^-] + [OH^-] - [H^+]$.
   a. Ca(OH)$_2$
   b. KNO$_3$
   c. CaCl$_2$
   d. KHCO$_3$
   e. HNO$_3$

6. What is the difference between carbonate and total alkalinity in terms of species of carbonate present and in terms of how each is determined?

7. Identify the regions of greatest buffering capacity on (a) a pH-pC diagram and (b) a typical alkalinity titration curve.

8. Acid rain falling on a lake is similar to an alkalinity titration. If a lake has a volume of 4,500 m$^3$, a total alkalinity of 1.25 eq/L, and lies in a watershed having a surface area of 50,000 m$^2$ how much acid rain with a pH of 3.5 can fall into the watershed before the buffering capacity of the lake is exceeded? Assume the soils in the watershed have no buffering capacity? Recall: 1000 L = 1 m$^3$ and that the equivalence point (end point) of a titration is when moles acid added = moles base originally present.

9. Read pages 103-128 in your textbook and answer problem 13 on page 130 of your textbook.

10. Read pages 103-128 in your textbook and describe in detail (in a paragraph) an interesting thing you learned from your reading.
11. Read pages 457-463 in your textbook. Summarize in a paragraph how (or why) acid/base reactions are important in the environmental impacts of metal mining.

12. What is solubility and how is solubility related to the solubility product?

13. (a) High \([\text{Al}^{3+}]\) in surface waters is toxic to fish. The Ksp for \(\text{Al(OH)}_3\) is \(1.3 \times 10^{-33}\). Assume the water in two lakes is in equilibrium with \(\text{Al(OH)}_3\) in the underlying soil and rock. The first lake has pH=4.5 and the second lake has pH = 7.5. Calculate \([\text{Al}^{3+}]\) in each lake.

(b) Based on your answers to part A of this question, how may acid rain impact fish populations?

(c) How do your answers to part A of this question illustrate the common ion effect?

14. The Ksp for copper (II) hydroxide \((\text{Cu(OH)}_2)\) is \(2.2 \times 10^{-20}\). A copper plating waste contains \(3.5 \times 10^{-3}\) M copper ion. Will raising the pH of this waste to 7 reduce the copper ion concentration in solution below the secondary maximum contaminant level of 1.3 mg/L?