Drossman/Kummel **EV 311: Water** **Block 8, 2010**

Types of Reactions, Writing Reactions, BOD and Alkalinity Analysis

In this class, we will be concerned with three types of reactions:

1- *Dissolution/Precipitation:*

solid/liquid: $CaCO_{3(s)} \Leftrightarrow Ca^{2+}{}_{(aq)} + CO_3^{2-}{}_{(aq)}$ K_{sp}

gas/liquid: $CO_{2(g)} \Leftrightarrow CO_{2(aq)}$ K_H

2-Acid/Base: transfer of protons (H^+) or donor/acceptor of electrons

$H_2CO_{3(aq)} + H_2O_{(l)} \Leftrightarrow HCO_3^-{}_{(aq)} + H_3O^+{}_{(aq)}$ K_a

$HCO_3^-{}_{(aq)} + H_2O_{(l)} \Leftrightarrow H_2CO_{3(aq)} + OH^-{}_{(aq)}$ K_b

$H_2O_{(l)} + H_2O_{(l)} \Leftrightarrow H_3O^+{}_{(aq)} + OH^-{}_{(aq)}$ K_w

3- Redox: transfer of electrons

$$CO_{2(g)} + H_2O_{(l)} \Leftrightarrow O_{2(g)} + CH_2O$$

How Do I Write and Classify Acid-Base Reactions?

First, decide if the compound is a salt, acid or a base.

An **acid** is a compound that *donates a proton*. Strong acids ($K_a > 1$) donate protons completely to water. Examples include HCl, HNO_3 and H_2SO_4 (first proton). The conjugate bases of strong acids are neutral ions. Weak acids donate protons, but with $K_a < 1$. What does it mean to have a $K_a < 1$?

Which of the following can act as strong or weak acids? Write the reaction of each acid in water and identify its conjugate base.

NaCl, HF, NH_4NO_3, CH_3COOH, HCO_3^-?

If each of the above is a 1.0 M solution in water, guess the pH.

A **base** is a compound that can *accept a proton*. Strong bases accept a proton from water completely (K_b>1). The primary strong base is OH^-. Thus, compounds that dissociate to provide OH^- completely are strong bases. Such compounds include NaOH and KOH, but $Ca(OH)_2$ and $Mg(OH)_2$, though not as soluble, may be considered strong bases for our purpose.

How will NaCl, KNO_3, $CaCl_2$ and $Mg(NO_3)_2$ affect the pH of water?

A **salt** is a solid compound that results from the reaction between an acid and a base. Some salts are more soluble than others. The value of the K_{sp} provides an idea of how soluble a salt is in water. With any salt, the first step is to dissolve it in water into its constituent ions. Which of the following are salts? Write the reaction for dissolution of each in water.

NaCl, $CaCO_3$, NH_3, CaF_2, KNO_3, H_2CO_3, KNO_3, $Al(OH)_3$, NH_4OH, NH_4Cl, $CaCl_2$, $(NH_4)_2CO_3$, $Mg(NO_3)_2$

The second step is to identify any possible acid-base reactions. For each ion that you wrote above identify those that can act as acids or bases and write the reaction with water. Label each reaction with water as best described by either a K_a or K_b.

Winkler Titration and DO measurements

In the field: add alkaline iodide (NaI and NaOH) and manganous sulfate ($MnSO_4$) to form insoluble brown precipitate manganous hydroxide. What type of reaction is each? Is each balanced? If not, please balance each one.

$$Mn^{2+}_{(aq)} + OH^-_{(aq)} \rightarrow Mn(OH)_{2\,(s)}$$

$$Mn(OH)_{2(s)} + O_{2(g)} \rightarrow Mn(OH)_{3(s)} \text{ (sometimes written as } MnO(OH)_2))$$

In the lab: add sulfamic acid to dissolve the precipitate and form I_2 (golden color)

$$Mn(OH)_{3(s)} + 3\ H^+_{(aq)} \rightarrow Mn^{3+}_{(aq)} + 3H_2O_{(l)}$$

$$Mn^{3+}_{(aq)} + I^-_{(aq)} \rightarrow Mn^{2+}_{(aq)} + I_{2(aq)}$$

Titrate (tri)iodide with known concentration of thiosulfate

$$I_2 + I^- \Leftrightarrow I_3^-$$

$$I_3^- + S_2O_3^{-2} \rightarrow I^- + S_4O_6^{2-}$$

If 8.50 ml of 0.0250 M thiosulfate is required to titrate 200.0 ml of sample, what is the concentration of dissolved oxygen in the original sample?

If 200 ml from a five-day incubation required 4.67 ml of 0.0250 M thiosulfate, what is the BOD of the sample? What assumptions are we making?

Alkalinity Titrations

Assume all carbonate in the water exists as HCO_3^- (we'll discuss this approximation later in the class).

$$HCl_{(aq)} + H_2O_{(aq)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

$$H_3O^+_{(aq)} + HCO_3^-{}_{(aq)} \rightarrow H_2CO_{3(aq)}$$

$$H_2CO_{3(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)}$$

If 100.00 ml of sample is titrated with 10.00 ml of 0.0250 M HCl, what is the concentration of bicarbonate and what is the alkalinity (in ppm)?