1. (4 pts) The hydrogen oxalate ion (HC$_2$H$_4$^-) is amphoteric.
   a) Write a balanced chemical equation showing how it acts as an acid with water and another equation showing how it acts as a base with water.
   \[
   \text{HC}_2\text{H}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{C}_2\text{H}_4\text{O}_4^- \quad \text{as an acid}
   \]
   \[
   \text{HC}_2\text{H}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{C}_2\text{H}_4 + \text{OH}^- \quad \text{as a base}
   \]
   b) What is the conjugate acid of HC$_2$H$_4$^-? What is its conjugate base?
   \[
   \text{C}_2\text{H}_4\text{O}_4^- \]

2. (4 pts) Calculate the pH and pOH for each of the following strong acid or base solutions:
   a) 0.0575 M HNO$_3$
      \[\text{pH} = 1.24 \quad \text{pOH} = 12.76\]
   b) a solution formed by mixing 10.0 mL of 0.300 M HBr with 40.0 mL of 0.100 M HCl.
      \[
      (0.010 \text{ mL})(0.300) + (40.0 \text{ mL})(0.100) = 7.06 \text{ mol H}^+/\text{L} \rightarrow \text{pH} = 0.85 \quad \text{pOH} = 13.15
      \]
   c) a solution labeled 0.200 M NaOH
      \[\text{pOH} = 0.699, \quad \text{pH} = 14.00 - \text{pOH} = 13.30\]
   d) a solution labeled 0.400 M Ca(OH)$_2$
      \[
      \Rightarrow \text{pOH} = 0.800, \quad \text{pH} = 13.90
      \]

3. (4 pts) Boric acid, B(OH)$_3$, or H$_3$BO$_3$, is used as a mild antiseptic. What is the pH of a 0.050 M aqueous solution of boric acid (K$_a$ = 5.9 x 10$^{-10}$)?
   \[
   \text{B(OH)}_3(\text{aq}) + 3\text{H}_2\text{O(l)} \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{B(OH)}_4^-(\text{aq})
   \]
   \[\text{K}_a = 5.9 \times 10^{-10} = \frac{x^2}{0.050 - x} \Rightarrow x = 5.43 \times 10^{-6} \Rightarrow \text{pH} = 5.27\]

4. (8 pts) Hydrogen sulfide (H$_2$S) is a diprotic acid. Its acid dissociation constants are K$_{a1}$ = 9.5 x 10$^{-8}$ and K$_{a2}$ = 1.00 x 10$^{-19}$. If 0.0100 mol of hydrogen sulfide is dissolved and diluted to 1.000 liter of solution, calculate the equilibrium concentrations of all species present. Be careful of approximations, state each clearly and check each.
   \[
   \text{H}_2\text{S} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{HS}^-
   \]
   (1) 0.0100
   \[\text{K}_{a1} = 9.5 \times 10^{-8} = \frac{x^2}{(0.0100 - x)(0.0100)} \Rightarrow x = 3.10 \times 10^{-5} \quad \text{mM}
   \]
   \[\text{K}_{a2} = 1.00 \times 10^{-19} = \frac{(3.1 \times 10^{-5})(x)}{(3.1 \times 10^{-5} - x)}
   \]
   \[x = \frac{x - 1.00 \times 10^{-19}}{3.1 \times 10^{-5} - x} \Rightarrow x = 3.1 \times 10^{-5} \quad \text{mM}
   \]
   \[\text{[H}_2\text{S}] = 0.0100 \text{ M}
   \]
1. (4 pts) The bicarbonate ion, $\text{HCO}_3^-$, is amphoteric.  
   a) Write a balanced chemical equation showing how it acts as an acid with water and another equation showing how it acts as a base with water.  
   \[
   \text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CO}_3^{2-} \quad (\text{acid}) \\
   \text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^- \quad (\text{base})
   \]
   b) What is the conjugate acid of $\text{HCO}_3^-$? What is its conjugate base?  
   \[
   \text{H}_2\text{CO}_3 \\
   \text{CO}_3^{2-}
   \]

2. (4 pts) Calculate the pH and pOH for each of the following strong acid or base solutions:  
   a) 0.0757 M $\text{HNO}_3$  
   \[
   \text{pH} = 1.12, \quad \text{pOH} = 12.88
   \]
   b) a solution formed by mixing 15.0 mL of 0.300 M HBr with 35.0 mL of 0.100 M HCl.  
   \[
   (15.0\text{ mL})(0.300\text{ M}) + (35.0\text{ mL})(0.100\text{ M}) = (45.5 + 3.5\text{ mL})\text{ H}^+ \Rightarrow \text{[H}] = \frac{2\text{.00}\text{ mmol}}{50.0\text{ mL}} = 0.04
   \]
   c) a solution labeled 0.125 M NaOH  
   \[
   \text{pOH} = 0.90, \quad \text{pH} = 13.1
   \]
   d) a solution labeled 0.250 M $\text{Ba(OH)}_2$  
   \[
   \Rightarrow \text{[OH]} = 0.500\text{ M}, \quad \text{pOH} = 0.30, \quad \text{pH} = 13.70
   \]

3. (4 pts) Calculate the pH and pOH for a solution of $1.15 \times 10^{-2}$ M solution of hypobromite ion, $\text{BrO}^-$, which acts as a base with water and has $K_b = 4.0 \times 10^{-6}$.  
   \[
   \text{pOH} = 3.67, \quad \text{pH} = 10.33
   \]

4. (8 pts) Carbonic acid, $\text{H}_2\text{CO}_3$, has two dissociation constants: $K_{a1} = 4.3 \times 10^{-7}$ and $K_{a2} = 5.6 \times 10^{-11}$. If 0.0100 mol of carbonic acid is dissolved and diluted to 2.000 liter of solution, calculate the concentrations of all species present. Be careful of approximations, state each clearly, and check each.  
   \[
   \text{H}_2\text{CO}_3 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CO}_3^{2-}  \\
   \text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CO}_3^{2-}
   \]
   \[
   0.005000 \text{ M} \times x \times x \\
   K_{a1} = 4.3 \times 10^{-7} = \frac{x^2}{(5.00 \times 10^{-3} - x)} = \frac{x^2}{(5.00 \times 10^{-3})}  \\
   x = 2.14 \times 10^{-4} = 4.63 \times 10^{-5} \text{ M} \quad \text{assumption OK}
   \]
   \[
   4.63 \times 10^{-5} \times x \times x \\
   K_{a2} = 5.6 \times 10^{-11} = \frac{4.63 \times 10^{-5} + x}{(4.63 \times 10^{-5})} \times x  \\
   x = 5.6 \times 10^{-11} \quad \text{assumption OK}
   \]
   \[
   x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}
   \]