CHEM 132  
Problem Set Ch.15  
Key Begins on Page 3. 

1. For each of the following, identify the acids and bases involved in both the forward and reverse directions

   a) \( \text{HOBr} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OBr}^- \)

   b) \( \text{HSO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{SO}_4^{2-} \)

   c) \( \text{HS}^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{S} + \text{OH}^- \)

   d) \( \text{C}_6\text{H}_5\text{NH}_3^+ + \text{OH}^- \rightleftharpoons \text{C}_6\text{H}_5\text{NH}_2 + \text{H}_2\text{O} \)

2. Use table 15.2 in your text to determine whether the species on the left or those on the right are favored by the reaction.

   a) \( \text{NH}_4^+ + \text{CO}_3^{2-} \rightleftharpoons \text{NH}_3 + \text{HCO}_3^- \)

   b) \( \text{HCO}_3^- + \text{H}_2\text{S} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{HS}^- \)

   c) \( \text{CN}^- + \text{H}_2\text{O} \rightleftharpoons \text{HCN} + \text{OH}^- \)

   d) \( \text{CN}^- + \text{H}_2\text{CO}_3 \rightleftharpoons \text{HCN} + \text{HCO}_3^- \)

3. Calculate the \([\text{H}^+]\) and \([\text{OH}^-]\) for each of the following solutions.

\[
\begin{array}{ccc}
\text{[H}^+\text{]} & \text{[OH}^-\text{]} \\
\hline
\text{a) 0.0060 M HCl} & \text{[H}^+\text{]} & \text{[OH}^-\text{]} \\
\text{b) 0.082 M NaOH} & \text{[H}^+\text{]} & \text{[OH}^-\text{]} \\
\text{c) 4.2 \times 10^{-3} M HNO}_3 & \text{[H}^+\text{]} & \text{[OH}^-\text{]} \\
\end{array}
\]

4. The following are solution concentrations. State whether each is acidic, neutral or basic.

   a) \( 2 \times 10^{-4} \text{ M OH}^- \)

   b) \( 2 \times 10^{-6} \text{ M H}^+ \)

   c) \( 6 \times 10^{-10} \text{ M OH}^- \)

   d) \( 6 \times 10^{-10} \text{ M H}^+ \)
5. Obtain the pH corresponding to the following concentrations.

   a) $1.0 \times 10^{-4}$ M $\text{H}^+$ ________  
   b) $2.91 \times 10^{-11}$ M $\text{H}^+$ ________  
   c) $2.3 \times 10^{-5}$ M $\text{OH}^-$ ________  
   d) $3.2 \times 10^{-10}$ M $\text{OH}^-$ ________

6. A sample of wine was found to have a pH of 3.85. Calculate the $[\text{H}^+]$ and $[\text{OH}^-]$.

   $[\text{OH}^-] = $ ________________  
   $[\text{H}^+] = $ ________________

7. List the following compounds in order of increasing acidity. Explain your reasoning.

   HBrO$_2$, HClO$_2$, HBrO

8. Predict whether each of the following aqueous solutions is acidic, basic, or neutral.

   a) KCl ________________  
   b) NaNO$_2$ ________________  
   c) NH$_4$NO$_3$ ________________  
   d) NaI ________________

9. A 1.00 L aqueous solution contains 6.78 g of Barium hydroxide, Ba(OH)$_2$. What was the pH of the solution at 25°C?

   pH = ________________

10. A 2.500-g sample of a mixture of sodium chloride and sodium carbonate is dissolved in 25.00 mL of 0.798 M HCl. Some acid remains after the treatment of the sample.

   a) Write a net ionic equation for the complete reaction of sodium carbonate with hydrochloric acid.

   b) If 28.7 mL of 0.108 M NaOH were required to titrate the excess hydrochloric acid, how many moles of sodium carbonate were present in the original sample?
1. For each of the following, identify the acids and bases involved in both the forward and reverse directions.

   a) \[ \text{HOBr} + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{O}^+ + \text{OBr}^- \]  
   b) \[ \text{HSO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{O}^- + \text{SO}_4^{2-} \]  
   c) \[ \text{HS}^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{S} + \text{OH}^- \]  
   d) \[ \text{CH}_3\text{NH}_3^+ + \text{OH}^- \rightleftharpoons \text{CH}_3\text{NH}_2 + \text{H}_2\text{O} \]

2. Use Table 15.2 in your text to determine whether the species on the left or those on the right are favored by the reaction.

   a) \[ \text{NH}_4^+ + \text{CO}_3^{2-} \rightleftharpoons \text{NH}_3 + \text{HCO}_3^- \]  
   \[ \text{SINCE} \text{NH}_4^+ > \text{HCO}_3^- \]

   b) \[ \text{HCO}_3^- + \text{HS}^- \rightleftharpoons \text{H}_2\text{CO}_3 + \text{H}_2\text{S} \]  
   \[ \text{SINCE} \text{H}_2\text{CO}_3 > \text{H}_2\text{S} \]

   c) \[ \text{CN}^- + \text{H}_2\text{O} \rightleftharpoons \text{HCN} + \text{OH}^- \]  
   \[ \text{SINCE} \text{HCN} > \text{H}_2\text{O} \]

   d) \[ \text{CN}^- + \text{H}_2\text{CO}_3 \rightleftharpoons \text{HCN} + \text{HCO}_3^- \]  
   \[ \text{SINCE} \text{H}_2\text{CO}_3 > \text{HCN} \]

3. Calculate the [H\(^+\)] and [OH\(^-\)] for each of the following solutions.

<table>
<thead>
<tr>
<th>[H(^+)]</th>
<th>[OH(^-)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) 0.0060 M HCl</td>
<td>0.006</td>
</tr>
<tr>
<td>b) 0.082 M NaOH</td>
<td>1.22 \times 10^{-3}</td>
</tr>
<tr>
<td>c) 4.2 \times 10^{-3} M HNO(_3)</td>
<td>0.0042</td>
</tr>
</tbody>
</table>

4. The following are solution concentrations. State whether each is acidic, neutral or basic.

   a) \(2 \times 10^{-4} \text{ M OH}^-\) \(pH = 10.3\) \(\text{BASIC}\)  
   b) \(2 \times 10^{-8} \text{ M H}^+\) \(pH = 5.7\) \(\text{ACIDIC}\)  
   c) \(6 \times 10^{-10} \text{ M OH}^-\) \(pK = 4.8\) \(\text{ACIDIC}\)  
   d) \(6 \times 10^{-10} \text{ M H}^+\) \(pK = 9.2\) \(\text{BASIC}\)
5. Obtain the pH corresponding to the following concentrations.

\[ \text{pH} = -\log [\text{H}^+] = -\log \left( \frac{\text{concentration of } \text{H}^+}{\text{concentration of } \text{OH}^-} \right) \]

a) \( 1.0 \times 10^{-4} \text{ M H}^+ \) \( 4 \)

b) \( 2.91 \times 10^{-11} \text{ M H}^+ \) \( 10.5 \)

c) \( 2.3 \times 10^{-5} \text{ M OH}^- \) \( 9.4 \)

d) \( 3.2 \times 10^{-9} \text{ M OH}^- \) \( 4.5 \)

6. A sample of wine was found to have a pH of 3.85. Calculate the \([\text{H}^+]\) and \([\text{OH}^-]\).

\[ \text{pH} = 3.85 \]

\[ [\text{H}^+] = 10^{-3.85} = 1.41 \times 10^{-4} \]

\[ [\text{OH}^-] = \frac{\text{ Kw }}{[\text{H}^+]} = \frac{1.0 \times 10^{-14}}{1.41 \times 10^{-4}} = 7.1 \times 10^{-11} \]

\[ [\text{H}^+] = 1.41 \times 10^{-4} \]

7. List the following compounds in order of increasing acidity. Explain your reasoning.

HBrO \( \rightarrow \) HClO \( \rightarrow \) HBrO

\( \text{HBrO} < \text{HBrO}_2 < \text{HClO}_2 \)

8. Predict whether each of the following aqueous solutions is acidic, basic, or neutral.

a) KCl  

b) NaNO\textsubscript{2}  
c) NH\textsubscript{3}NO\textsubscript{3}  
d) NaI  

\( \text{will be colored in CH}_3 \text{I}_2 \)

9. A 1.00 L aqueous solution contains 6.78 g of Barium hydroxide, \( \text{Ba(OH)}_2 \). What was the pH of the solution at 25°C?

\[ 0.783 \text{ mL } \text{Ba(OH)}_2 \left( \frac{1 \text{ mol } \text{Ba(OH)}_2}{171.38 \text{ g}} \right) \left( \frac{2 \text{ mol } \text{OH}^-}{1 \text{ mol } \text{Ba(OH)}_2} \right) = 0.0792 \text{ mol OH}^- \]

\[ [\text{OH}^-] = 0.0792 \times \frac{1.0 \times 10^{-14}}{1.0 \text{ L}} = 1.2 \times 10^{-13} \]

\[ \text{pH} = 12.9 \]

10. A 2.500-g sample of a mixture of sodium chloride and sodium carbonate is dissolved in 25.00 mL of 0.798 M HCl. Some acid remains after the treatment of the sample.

a) Write a net ionic equation for the complete reaction of sodium carbonate with hydrochloric acid.

\[ \text{CO}_3^{2-} + 2 \text{H}^+ \rightarrow \text{H}_2\text{CO}_3 \]

b) If 28.7 mL of 0.105 M NaOH were required to titrate the excess hydrochloric acid, how many moles of sodium carbonate were present in the original sample?

\[ \text{Total HCl used} = (0.025) \times (0.798 \text{ mol}) = 0.01995 \text{ mol HCl total.} \]

\[ \text{Excess HCl} = \text{moles HCl used} - (0.02876 \times 0.01081) = 0.00310 \text{ mol HCl left over.} \]

\[ \text{Subtract 0.00310 mol HCl from} \text{Na}_2\text{CO}_3 \text{ present.} \]