CHEMISTRY 30
REVIEW OF ACIDS AND BASES

1. Given the following reactions, write the balanced equation using Bronsted-Lowry acid/base reactions:

a) aqueous solutions of nitrous acid reacts with calcium carbonate

\[ \text{HNO}_2(aq) + \text{CO}_3^{2-}(aq) \rightarrow \text{NO}_2^-(aq) + \text{HCO}_3^-(aq) \]

b) sodium hydrogen sulfite is dissolved in a solution of hydrogen sulfide.

\[ \text{NaSO}_3(aq) + \text{H}_2\text{S}(aq) \rightarrow \text{H}_2\text{SO}_3(aq) + \text{NaS}(aq) \]

c) ammonium sulfate reacts with sodium hydroxide

\[ \text{NH}_4^+(aq) + \text{OH}^-(aq) \rightarrow \text{NH}_3(aq) + \text{H}_2\text{O}(l) \]

d) hydrochloric acid is continually added to silver phosphate solution.

\[ \text{H}_3\text{PO}_4(aq) + \text{Ag}^+(aq) \rightarrow \text{H}_2\text{PO}_4^-(aq) + \text{H}_2\text{O}(l) \]

e) acetic acid reacts with potassium sulfate solution

\[ \text{CH}_3\text{COOH}(aq) + \text{SO}_4^{2-}(aq) \rightarrow \text{H}_2\text{SO}_4(aq) + \text{CH}_3\text{COO}^-(aq) \]

2. Complete the following table:

<table>
<thead>
<tr>
<th>[H\textsubscript{3}O\textsuperscript{+}]</th>
<th>[OH\textsuperscript{-}]</th>
<th>PH</th>
<th>pO</th>
<th>AB/WN</th>
</tr>
</thead>
<tbody>
<tr>
<td>(7.0 \times 10^{-9})</td>
<td>(1.3 \times 10^{-6})</td>
<td>8.13</td>
<td>5.87</td>
<td>B</td>
</tr>
<tr>
<td>(5.05 \times 10^{-10})</td>
<td>(1.98 \times 10^{-3})</td>
<td>9.297</td>
<td>4.703</td>
<td>B</td>
</tr>
<tr>
<td>(3.65 \times 10^{-9})</td>
<td>(9.74 \times 10^{-6})</td>
<td>8.438</td>
<td>5.562</td>
<td>B</td>
</tr>
<tr>
<td>(2.9 \times 10^{-12})</td>
<td>(2.6 \times 10^{-3})</td>
<td>11.3</td>
<td>8.7</td>
<td>B</td>
</tr>
<tr>
<td>(1.5 \times 10^{-3})</td>
<td>(6.7 \times 10^{-12})</td>
<td>2.83</td>
<td>11.17</td>
<td>A</td>
</tr>
</tbody>
</table>
3. A student prepared a solution in which the hydronium ion concentration was $2.45 \times 10^{-3}$. This student should predict that the solution will be:

a) $\text{blue}$ in methyl violet

b) $\text{red}$ in methyl orange

c) $\text{red}$ in phenolphthalein

d) $\text{orange}$ in orange IV

e) $\text{yellow}$ in cresol red

\[ \text{pH} = -\log(2.45 \times 10^{-3}) = 2.611 \]

4. 8.0 moles of hydrogen gas are reacted with 6.0 moles of oxygen in an empty two litre container. At equilibrium, the container has three moles of $\text{H}_2\text{O}$. Calc the $K_{(\text{eq})}$ for this reaction.

\[ 2\text{H}_2(g) + \frac{1}{2}\text{O}_2(g) \rightleftharpoons \text{H}_2\text{O}(g) \]

\[ \frac{[\text{H}_2\text{O}]}{[\text{H}_2]^2[\text{O}_2]^{rac{1}{2}}} = \frac{(1.5)^2}{(2.5)^2(2.25)} = 0.16 \]

5. Suppose you measured the pH of a 0.125 mol/L acidic solution to be 4.67, what would the $K_a$ for this acid be? Is this a strong or weak acid?

\[ K_a = \frac{[\text{H}^+]^2}{[\text{HA}] - [\text{H}^+]} \]

\[ [\text{H}^+] = 10^{-4.67} = 0.000021379 \]

\[ 0.000021379^2 = \frac{(0.000021379)^2}{(0.125) - (0.000021379)} = \frac{3 \times 10^{-9}}{0.000021379} \]

\[ K < 1 \]

\[ \text{Weak Acid} \]
6. Calculate the pH of a 0.410M solution of ammonia.

\[
\text{pH} = 14 - \log(0.002705813) = 2.567702085
\]

b. What is the % ionization for ammonia?

\[
\% \text{ ionization} = \frac{[\text{OH}^-]}{[\text{H}_3\text{O}^+]} \times 100 = \frac{0.002705813}{0.410} \times 100 = 0.66 \%
\]

7. Given the following equation, what effect would the following changes have on the shifting of the equilibrium?

\[
\text{SO}_2(g) + \text{NO}_2(g) \rightleftharpoons \text{NO}(g) + \text{SO}_3(g)
\]

a) addition of \( \text{NO}_2(g) \)  
leaves, favors reactants

b) removal of heat  
Use Hess's law \( \Delta G = -46,826 \text{ J} \)  
right, favors products

c) increase in pressure  
No effect

d) addition of a catalyst  
No effect, speeds up \( \text{rate} \)

e) increase in volume  
No effect

8. A theoretically computed \( K_{eq} \) for the following reaction is 6.00 x 10^{-22}. If 1.0 M solution of glucose were to be formed at equilibrium, what would be the initial concentration of the formaldehyde in the solution?

\[
6\text{HCHO}(aq) \rightleftharpoons C_6\text{H}_{12}\text{O}_6(aq)
\]

\[
6 \left( \frac{1}{C_6\text{H}_{12}\text{O}_6} \right) = \left( \frac{1}{X-6} \right)^6
\]

\[
C_6\text{H}_{12}\text{O}_6 = 0.000159823
\]

\[
X = 6.00
\]
9. Calculate the [H$_3$O$^+$] of a 0.100M H$_2$S$_{(aq)}$ solution.

\[
\text{H}_2\text{S}_{(aq)} + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{H}_3\text{O}^+_{(aq)} + \text{HS}^-_{(aq)}
\]

\[
K_a = \frac{[\text{H}_3\text{O}^+] [\text{HS}^-]}{[\text{H}_2\text{S}]} = \sqrt{8.9 \times 10^{-8} (\text{mol/L})^2}
\]

\[
[H_3O^+] = \sqrt{8.9 \times 10^{-8} (\text{mol/L})^2} = 9.43 \times 10^{-5} \text{ mol/L}
\]

b. What is the $K_b$ for this reaction?

\[
K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{8.9 \times 10^{-8}} = 1.1 \times 10^{-7}
\]

c. What is the pH of the solution?

\[
\text{pH} = -\log (9.43 \times 10^{-5} \text{ mol/L}) = 4.025
\]

10. Given the following equation,

\[
\text{Y}^{(a)} + 2\text{W}^{(a)} \rightleftharpoons 2\text{Z}^{(a)}
\]

If the value of the equilibrium constant is 0.64, what is the concentration of Z if 0.10 moles of Y and 0.50 moles of W are placed in a 12 litre container?

\[
K_c = \frac{[\text{Z}^{(a)}]^2}{[\text{W}^{(a)}]^2}
\]

\[
0.64 = \frac{(2x)^2}{(0.0416 - 2x)^2}
\]

\[
0.0416 - 2x = 2x
\]

\[
0.0416 = 3.6x
\]

\[
x = 0.012 = 0.093
\]

\[
[Z^{(a)}] = 0.019 \text{ mol/L}
\]
11. A 32.9 ml sample of sodium hydroxide is titrated with 25.0 ml of sulfuric acid having a pH of 2.76. What is the pH of the sodium hydroxide solution?

\[
\begin{align*}
\text{Na}^+ + \text{OH}^- + \text{H}_2\text{O} & \rightarrow 2\text{H}_2\text{O} \\
C &= \, ? \\
V &= 0.035L \\
C &= 10^{-2.76} = 0.00017378 \text{ mol/L} \\
V &= 0.029L \\
C &= 10^{-1.0} = 0.0000043445 \text{ mol/L} \\
C &= \frac{N}{V} \\
N &= CV = (0.00017378 \text{ mol/L})(0.00029L) \\
&= 0.000004956 \text{ mol} \\
pOH &= -\log(0.000004956) = 8.7792 \\
pH &= 14 - pOH = 11.221
\end{align*}
\]

12. What is the pH and \([\text{H}_3\text{O}^+]\) of the resulting solution when 45.0 ml of 1.20 mol/L solution of barium hydroxide reacts with 45.0 ml of 1.20 mol/L solution of hydrochloric acid?

\[
\begin{align*}
\text{Ba}^{2+} + \text{Cl}^- + \text{H}_2\text{O} & \rightarrow \text{Ba}^{2+} + \text{H}_2\text{O} \\
\text{OH}^- + \text{H}_2\text{O} & \rightarrow 2\text{H}_2\text{O} \\
C &= 2.40 \text{ mol/L} \\
V &= 0.045L \\
C &= 1.20 \text{ mol/L} \\
N &= CV = (0.000043445 \text{ mol/L})(0.00045L) \\
&= 0.0000196458 \text{ mol} \\
\text{pOH} &= -\log(0.0000196458) = 8.6879 \\
\text{pH} &= 14 - pOH = 13.3121
\end{align*}
\]

13. A 35.0 ml solution of \(\text{H}_3\text{PO}_4\) is titrated with potassium hydroxide with a pH of 13.30 with the following results:

\[
\begin{align*}
\text{K}^+ + \text{OH}^- + \text{H}_2\text{O} & \rightarrow \text{K}^+ \text{OH}^- + \text{H}_2\text{O} \\
\text{initial volume} & \quad 14.5 \text{ ml} \\
\text{final volume} & \quad 39.3 \text{ ml} \\
N &= \frac{24.8 \text{ ml}}{0.035 \text{ L}} = 0.00164941 \text{ mol/L}
\end{align*}
\]

What is the concentration of the phosphoric acid and its pH? Assume all reactions are quantitative!!

\[
\begin{align*}
\text{H}_3\text{PO}_4 (\text{aq}) + \text{OH}^- (\text{aq}) & \rightarrow \text{H}_2\text{PO}_4^- (\text{aq}) + \text{H}_2\text{O} (\text{c}) \\
\text{H}_2\text{PO}_4^- (\text{aq}) + \text{OH}^- (\text{aq}) & \rightarrow \text{HPO}_4^{2-} (\text{aq}) + \text{H}_2\text{O} (\text{c}) \\
\text{HPO}_4^{2-} (\text{aq}) + \text{OH}^- (\text{aq}) & \rightarrow \text{PO}_4^{3-} (\text{aq}) + \text{H}_2\text{O} (\text{c}) \\
\end{align*}
\]

\[
\begin{align*}
V &= 0.035L \\
C &= \, ? \\
\text{UK} & \quad 15 \\
N &= CV = (0.00164941 \text{ mol/L})(0.0498L) \\
&= 0.0000704835 \text{ mol} \\
C &= \frac{N}{V} \\
&= 0.0000494835 \text{ mol/L} \\
\text{pH} &= -\log(0.00164941 \text{ mol/L}) = 3.7792
\end{align*}
\]