The principles that are employed in the identification of cations can also be applied to the analysis of anions. The qualitative detection of anions in a sample depends on the distinctive solubility properties of particular salts of the ions and specific chemical reactions that are (ideally) unique to a particular ion. In this experiment, we will explore ways to detect the presence of $\text{CO}_3^{2-}$, $\text{SO}_4^{2-}$, $\text{PO}_4^{3-}$, $\text{Cl}^-$, and $\Gamma^-$. You will be testing both known and unknown solutions.

**Procedure**

1. **Test for the Sulfate Ion**
   
   To 1 mL of the test solution, add 6 M HNO$_3$ drop by drop until the solution is acidic. Then add 1 mL of 0.1 M BaCl$_2$ solution in order to produce a white precipitate of BaSO$_4$.

   \[
   \text{SO}_4^{2-}(aq) + \text{Ba}^{+2}(aq) \rightarrow \text{BaSO}_4(s) \tag{1}
   \]

2. **Test for the Carbonate Ion**
   
   To 1 mL of a new test solution, add 20 drops of 6 M HNO$_3$. Verify it is acidic. Place the tube in a warm water bath, gently heat, and observe to see if any gas bubbles form. This gas formation is a strong indication of the presence of $\text{CO}_3^{2-}$.

   \[
   \text{CO}_3^{2-}(aq) + 2\text{H}^+(aq) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(l) \tag{2a}
   \]

3. **Test for the Chloride Ion**
   
   To 1 mL of a new test solution, add a couple drops of 6 M HNO$_3$ as needed to make the solution slightly acidic. Add 10 drops of 0.1 M AgNO$_3$. No precipitate proves the absence of Cl$^-$, Br$^-$, or $\Gamma^-$. Centrifuge the mixture. Test the clear filtrate with 1 drop of 0.1 M AgNO$_3$ for complete precipitation. If necessary, centrifuge again. Discard the filtrate. To this precipitate, add 1 mL of D.I. water, 2 drops of 6 M NH$_3$, and 6 drops of 0.1 M AgNO$_3$. The proportions are important, since we want to dissolve ONLY AgCl.

   \[
   \text{AgCl}(s) + 2\text{NH}_3(aq) \rightarrow \text{Ag(NH}_3)_2^+(aq) + \text{Cl}^-(aq) \tag{3a}
   \]
   
   Shake the mixture well and centrifuge. Transfer the clear solution to a clean test tube, and acidify once again with 6 M HNO$_3$. A white precipitate of AgCl confirms the presence of Cl$^-$. 

   \[
   \text{Ag(NH}_3)_2^+(aq) + \text{Cl}^-(aq) + 2\text{H}^+ \rightarrow \text{AgCl}(s) + 2\text{NH}_4^+(aq) \tag{3b}
   \]
4. Test for the Iodide Ion

Acidify a 2 mL sample of a new test solution by adding 6 M HCl. Add 1 mL of 0.1 M FeCl$_3$ to oxidize any I$^-$ to I$_2$. Add 1 mL of hexane and agitate the mixture. A purple color of I$_2$ in the hexane layer indicates I$^-$ was present in the original sample.

\[2I^-(aq) + 2Fe^{+3}(aq) \rightarrow I_2(aq) + 2Fe^{+2}(aq) \quad (4)\]

5. Test for the Phosphate Ion

(A) If no I$^-$ was present, mix about 2 drops of 0.5 M (NH$_4$)$_6$Mo$_7$O$_{24}$ reagent with 5 drops of 6 M HNO$_3$ to 1 mL of a new test solution.

(B) If I$^-$ was present, add 5 drops of 6 M HNO$_3$ to 1 mL of a new test solution and boil the test tube for 5 min to remove the iodide. Then add 2 drops of the ammonium molybdate reagent to the test solution.

A yellow precipitate of ammonium phosphomolybdate, (NH$_4$)$_3$PO$_4$ · 12MoO$_3$, appearing at once or after the mixture has been warmed a few minutes to 40 ºC indicates the presence of PO$_4^{3-}$.

\[21NH_4^+(aq) + 12[Mo_7O_{24}^{6-}](aq) + 7H_3PO_4(aq) + 51H^+(aq) \rightarrow 7(NH_4)_3PO_4 \cdot 12MoO_3(aq) + 36 H_2O(l) \quad (5)\]

Record your observations for your known and unknown solutions below. Determine the identity of your unknown.

Observations:

UNKNOWN______ IONS PRESENT______________________________
Discussion Question

1. Construct separate flow charts for the identification of the various five anions in a known sample. Refer to Experiment #10 for guidelines on preparing your flow charts.
Advance Study Assignment: Anion Analysis

1. A solution may contain Cl\(^-\), CO\(_3\)^{2-}, PO\(_4\)^{3-}, and/or SO\(_4\)^{2-}. No effect is observed upon addition of 6 M HNO\(_3\); this resulting mixture will be referred to as solution 1. No effect is observed on addition of 0.1 M AgNO\(_3\) to solution 1. A white precipitate is reported on addition of 1 M BaCl\(_2\) to solution 1. Finally, a yellow precipitate is observed on addition of 0.5 M (NH\(_4\))\(_6\)Mo\(_7\)O\(_24\) to solution 1. Which of the ions are present, which are absent, and which remain undetermined? State your reasoning below. **NOTE:** simply listing ions below without the appropriate reasoning will NOT earn you any credit!

Present _________________________

Absent _________________________

In doubt _________________________