

## Separation and Identification of Group B Cations (Bi<sup>3+</sup>, Fe<sup>3+</sup>, Mn<sup>2+</sup>, Cr<sup>3+</sup> and Al<sup>3+</sup>)

### Objectives

- To understand the chemical reactions involved in the separation and identification of the Group B cations.
- To complete a flow diagram summarizing the qualitative analysis scheme for the Group B ions.
- To successfully identify the Group B cation(s) in an unknown.

### Background Chemistry and Discussion

To separate the Group B cations from Groups C and D, ammonia solution is added to the supernatant left after precipitation and removal of the Group A cations. Addition of ammonia to this supernatant results in the formation of a buffer solution. The pH of the buffer solution is adjusted to between 9 and 10 and, under these conditions, the Group B cations precipitate as hydroxides while Groups C and D remain in solution. The hydroxides of Group B have characteristic colors that may be useful in their identification. As part of your analysis, you will test known samples to determine the colors of the Group B hydroxide precipitates. Unfortunately, the color of the precipitate alone cannot always clearly identify the ions present in an unknown since light colored precipitates may be masked by darker ones. Further analysis is usually needed.

Before analyzing the Group B precipitate, any lead(II) ion that did not precipitate during the Group A analysis is removed from the Group B precipitate by addition of sulfuric acid. The Group B hydroxides will dissolve and then stay in solution upon addition of H<sub>2</sub>SO<sub>4</sub> while lead(II) hydroxide dissolves and then reprecipitates as insoluble PbSO<sub>4</sub>. The Group B1 (Bi<sup>3+</sup>, Fe<sup>3+</sup>, Mn<sup>2+</sup>) and B2 (Cr<sup>3+</sup>, Al<sup>3+</sup>) cations are then separated from each other by adding NaOH to make a strongly alkaline solution followed by the addition of H<sub>2</sub>O<sub>2</sub>. The hydroxides of aluminum and chromium (III) are amphoteric and will dissolve in excess strong base, forming the complex ions Al(OH)<sub>4</sub><sup>-</sup> and Cr(OH)<sub>4</sub><sup>-</sup>. Hydrogen peroxide acts as an oxidizing agent in alkaline solutions, resulting in the conversion of the green colored Cr(OH)<sub>4</sub><sup>-</sup> ion to yellow CrO<sub>4</sub><sup>2-</sup>. The Group B1 cations are insoluble in strongly alkaline solution containing H<sub>2</sub>O<sub>2</sub>: the Bi<sup>3+</sup> and Fe<sup>3+</sup> ions form insoluble hydroxides while Mn<sup>2+</sup> is oxidized to Mn<sup>4+</sup> by the H<sub>2</sub>O<sub>2</sub> yielding insoluble MnO<sub>2</sub>. Thus, after making the solution strongly basic with NaOH and adding H<sub>2</sub>O<sub>2</sub> the B1 cations are present as precipitates while the B2 cations are in solution. The two subgroups are then separated by centrifuging and decanting.

The precipitate containing the Group B1 cations is heated to destroy excess H<sub>2</sub>O<sub>2</sub> that could interfere with later tests and then dissolved in hot hydrochloric acid. The ions present in solution are Bi<sup>3+</sup>, FeCl<sub>4</sub><sup>-</sup> and Mn<sup>4+</sup>. (Iron (III) forms a complex ion with chloride ions in solution.) The confirmation test for the Group B1 cations can be performed without further separation; an aliquot of this acidic solution will be used for each individual test.

The supernatant remaining after addition of NaOH and H<sub>2</sub>O<sub>2</sub> contains the Group B2 cations. The ions present in solution are chromate (CrO<sub>4</sub><sup>2-</sup>) and tetrahydroxoaluminate, Al(OH)<sub>4</sub><sup>-</sup>. The solution is heated to destroy excess peroxide. The confirmation test for the Group B2 cations can be performed without further separation; an aliquot of this basic solution will be used for each individual test.

#### Group B1 Confirmation Tests:

**Identification of Mn<sup>2+</sup>:** The test for manganese involves an oxidation reduction reaction where Mn<sup>2+</sup> reacts with bismuthate ion (BiO<sub>3</sub><sup>-</sup>). The bismuthate ion is reduced to Bi<sup>3+</sup> accompanied by the oxidation of Mn<sup>2+</sup> to form the purple permanganate ion, MnO<sub>4</sub><sup>-</sup>. This test requires the manganese ion to be in its +2 oxidation state; the +4 oxidation state cannot be oxidized by BiO<sub>3</sub><sup>-</sup>. Recall that in separating the Group B1 and B2 cations from each other, the Mn<sup>2+</sup> ion was oxidized to Mn<sup>4+</sup> in a side reaction. Thus, to test for Mn<sup>2+</sup>, the Mn<sup>4+</sup> must first be reduced back to Mn<sup>2+</sup>. This is accomplished by adding H<sub>2</sub>O<sub>2</sub> in acidic solution. (In acidic solution H<sub>2</sub>O<sub>2</sub> is a reducing agent.) This is followed by the addition of sodium bismuthate. **The appearance of a purple supernatant confirms the presence of Mn<sup>2+</sup>.** Bubbles may also be observed since the bismuthate will also react with any left over H<sub>2</sub>O<sub>2</sub> producing a gas.

**Identification of Fe<sup>3+</sup>:** To test for Fe<sup>3+</sup>, potassium thiocyanate (KSCN) is added. Upon addition of SCN<sup>-</sup> to a test solution containing Fe<sup>3+</sup>, the red-brown colored FeSCN<sup>2+</sup> complex ion readily forms. **The immediate formation of a reddish-brown solution confirms the presence of Fe<sup>3+</sup>.**

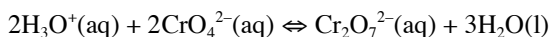
**Identification of Bi<sup>3+</sup>:** The test for the presence of Bi<sup>3+</sup> involves reducing Bi<sup>3+</sup> to elemental Bi<sup>0</sup> with Sn<sup>2+</sup> in basic

solution. The test solution is made basic by adding NaOH. This will cause  $\text{Bi}^{3+}$  to precipitate as  $\text{Bi}(\text{OH})_3$ . A small quantity of solid  $\text{SnCl}_2$  is then added. In NaOH solution, the  $\text{Sn}^{2+}$  ion is present as  $\text{Sn}(\text{OH})_3^-$ . Reaction between  $\text{Bi}(\text{OH})_3(\text{s})$  and  $\text{Sn}(\text{OH})_3^-(\text{aq})$  will yield  $\text{Sn}(\text{OH})_6^{2-}(\text{aq})$  and black colored  $\text{Bi}^0(\text{s})$ . **The immediate appearance of a black precipitate of elemental bismuth confirms the presence of  $\text{Bi}^{3+}$ .**

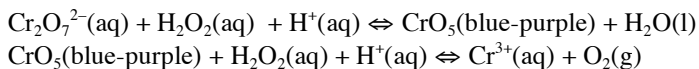
### Group B2 Confirmation Tests:

**Identification of  $\text{Al}^{3+}$ :** The test for aluminum ion involves the adsorption of the red dye aluminon (aurin tricarboxylic acid) by aluminum hydroxide as the  $\text{Al}(\text{OH})_3$  precipitates. To the basic solution containing the B2 cations, hydrochloric acid is added slowly until the solution is acidic. Watch closely while adding the HCl for a fine, flocculent precipitate to form and then redissolve. If you see this precipitate, what is it and why does it redissolve? To the acidic solution, aluminon dye is added. The dye will color the solution red. Ammonia is then added until the solution is basic. Aluminum ion, if present, will precipitate as aluminum hydroxide. The dye will be adsorbed onto the precipitate as it forms. Since the solution is red, any precipitate that forms must be centrifuged to determine its color. **A cherry red precipitate found after centrifuging confirms the presence of  $\text{Al}^{3+}$ .**

**Identification of  $\text{Cr}^{3+}$ :** The test for chromium (III) ion involves the reduction of dichromate by hydrogen peroxide in acidic solution. In aqueous solution, an equilibrium is established between chromate ion ( $\text{CrO}_4^{2-}$ ) and dichromate ion ( $\text{Cr}_2\text{O}_7^{2-}$ ):



In acidic solution, this equilibrium is shifted right, increasing the concentration of dichromate ion. First, hydrogen peroxide is added to the basic test solution containing the B2 cations. Then  $\text{HCl}(\text{aq})$  is added slowly. The peroxide then reacts with  $\text{Cr}_2\text{O}_7^{2-}$  in solution, producing dark blue-purple colored peroxychromate ( $\text{CrO}_5$ ). In  $\text{CrO}_5$  the chromium is in its +6 oxidation state and the oxygens are present as one oxide,  $\text{O}^{2-}$ , and two peroxide,  $\text{O}_2^{2-}$ , ligands. The  $\text{CrO}_5$  is unstable, decomposing quickly to  $\text{Cr}^{3+}$ . The **unbalanced net-ionic** chemical equations for the reactions involved are:



**You must watch carefully for the sudden appearance of a blue-purple color that will fade rapidly, confirming the presence of  $\text{Cr}^{3+}$  in your original sample solution.**

### Reagents Available

6-M $\text{NH}_3$	Solid $\text{NaBiO}_3$
6-M $\text{HCl}$	Solid $\text{SnCl}_2$
6-M $\text{NaOH}$	0.1 M $\text{KSCN}$
3M $\text{H}_2\text{SO}_4$	Aluminon
Dilute, Known Solutions of $\text{Bi}^{3+}$ , $\text{Fe}^{3+}$ , $\text{Mn}^{2+}$ , $\text{Cr}^{3+}$ and $\text{Al}^{3+}$	3% $\text{H}_2\text{O}_2$

### Safety and Waste Disposal

Some of Group B cations and reagents used are toxic. The  $\text{HCl}$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{NH}_3$  and  $\text{NaOH}$  are irritants. Avoid contact and wash immediately if any is spilled or splashed on you. Wear eye protection at all times.

As you perform the experiment, collect all waste solutions in a waste beaker. This mixture should then be discarded in the appropriate waste container. **DO NOT POUR ANY OF THE SOLUTIONS DOWN THE DRAIN.**

### Unknowns and Knowns

Separate known samples containing  $\text{Bi}^{3+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Cr}^{3+}$  and  $\text{Al}^{3+}$  are provided for your use. Testing known samples is helpful in this analysis since doing so will allow you to observe what a positive test looks like. It is usually convenient to test a known sample simultaneously with your unknown. To test a known sample, you can either prepare a known mixture of the Group B cations or the known Group B cation solutions can be tested separately. In the case of a known mixture, steps in the procedure that are required for separation of the cations must be followed before the confirmation tests can be conducted. If a known is prepared that contains only one of the cations, then the confirmation test can be conducted directly

on the known. To prepare a known sample for testing, add 2 to 3 drops of the solution(s) containing the cation(s) you wish to test to about 0.5 mL of water. **Note that the experimental conditions such as pH, oxidation state, etc. for the known test must be the same as that for the unknown.**

## Outline of Procedure: Use a flow diagram in your notebook to record all observations for each step in the procedure.

Chemistry and Relevant Background Information:	Experimental Procedure:
<p><b>Testing Known Cations:</b> We will begin our Group B analysis by testing known samples to observe the colors of some precipitates and solutions formed by the Group B cations. These observations will assist you in identifying the cations present in your sample. You can perform these tests on the knowns with a partner if you choose.</p> <p><b>In the space below, write the net ionic chemical equation for the reaction corresponding to the formation of the complex ion formed when excess <math>\text{Cl}^-</math>(aq) is added to a solution containing <math>\text{Fe}^{3+}</math>(aq) ions.</b></p>	<p><b>Carefully record all of your observations, such as colors of precipitates and solutions, for each of the following steps:</b></p> <p><b>1.</b> Start by preparing separate known solutions of each Group B cation. Prepare these by adding 2 to 3 drops of each known solution to about 0.5 mL of water in separate test tubes.</p> <p>(a) Add a few drops of 6 M hydrochloric acid to each test solution. (<b>Note, iron(III) ions are complexed with 4 chloride ions when HCl is added.</b>)</p> <p>(b) To each solution, add 6 M <math>\text{NH}_3</math> until the pH is 9-10. <b>STIR</b> thoroughly before testing the pH. Centrifuge and decant, discarding the supernatant.</p> <p>(c) To the test tube containing the <math>\text{Mn}(\text{OH})_2(\text{s})</math> add 6 M HCl dropwise until the precipitate dissolves. If the resulting solution is dark brown, add water to dilute until it is a light amber/brown color. Then add several VERY small portions of solid <math>\text{NaBiO}_3</math>, carefully observing the color of the resulting supernatant as you add the <math>\text{NaBiO}_3</math>.</p> <p>(d) To the test tube containing the <math>\text{Fe}(\text{OH})_3(\text{s})</math> add 6 M HCl dropwise until the precipitate dissolves. Then add several drops of 0.1 M KSCN.</p> <p>(e) To the test tube containing the <math>\text{Bi}(\text{OH})_3(\text{s})</math> add 6 M HCl dropwise until the precipitate dissolves. Then add 6 M NaOH until the solution is basic (pH about 9) followed by a small quantity of solid <math>\text{SnCl}_2</math>.</p> <p>(f) To the test tube containing <math>\text{Al}(\text{OH})_3(\text{s})</math> add 6M NaOH dropwise until the solid dissolves, then add 6M HCl dropwise until the solution tests acidic, watching and noting any observations as you add the HCl. Then add several drops of aluminum followed by 6M <math>\text{NH}_3</math> until the solution tests basic. Centrifuge.</p> <p>(g) To the test tube containing <math>\text{Cr}(\text{OH})_3(\text{s})</math> add 6M NaOH dropwise until the solid dissolves. The solution should appear light green, dilute with water if it is too dark. Then add 3% <math>\text{H}_2\text{O}_2</math> dropwise until the solution changes color from green to yellow. Next, slowly drip in 6 M HCl until the solution is acidic, carefully observing the solution as the HCl is added.</p>
<b>Analysis of Unknown Solution:</b>	<b>1.</b>

Chemistry and Relevant Background Information:	Experimental Procedure:
<p><b>1. Precipitation of Group B cations:</b> The Group B cations are the only cations in our qualitative analysis scheme that form insoluble hydroxides upon the addition of 6M ammonia. Addition of 6M NH<sub>3</sub> separates the Group B cations from Groups C &amp; D.</p> <p><b>The reaction for Bi<sup>3+</sup> is.:</b> Bi<sup>3+</sup>(aq) + 3H<sub>2</sub>O(l) + 3NH<sub>3</sub>(aq) ⇌ Bi(OH)<sub>3</sub>(s) + 3NH<sub>4</sub><sup>+</sup>(aq)</p> <p>The reactions for the other ions are similar to this, however for Fe<sup>3+</sup> we need to recall that it is present in the HCl(aq) solution as a complex ion.</p> <p><b>In the space below, write the balanced net ionic chemical equation, including phase labels, for the precipitation of the FeCl<sub>4</sub><sup>-</sup> when NH<sub>3</sub>(aq) is added.</b></p>	<p><b>Experimental Procedure:</b></p> <p>(a) Using your group B-D supernatant from the group A separation, add 6 M NH<sub>3</sub> until the pH is 9-10. <b>STIR</b> thoroughly before testing the pH. Centrifuge for 2 minutes. Retain the supernatant and label as group C &amp; D. <b>DO NOT FORGET TO LABEL THIS TEST TUBE!</b></p> <p>(b) Wash the precipitate twice with 10 drops of 6 M NH<sub>3</sub>, discarding the washes. Then wash the precipitate twice with 10 drops deionized water, discarding the washes.</p>
<p><b>2. Removal of Any Contaminating Lead Cations:</b> The solubility of PbCl<sub>2</sub> is relatively high and some lead may not precipitate as PbCl<sub>2</sub> during the group A analysis. If Pb<sup>2+</sup> is present in your unknown, your Group B-D supernatant may contain some residual Pb<sup>2+</sup> that will precipitate with your Group B cations upon addition of the NH<sub>3</sub>(aq). In this case, it is necessary to remove the Pb<sup>2+</sup> contaminant. This is accomplished by adding sulfuric acid; the Group B hydroxides will dissolve while any Pb<sup>2+</sup> ion will form insoluble PbSO<sub>4</sub>.</p> <p><b>In the space below, write the balanced net ionic chemical equation, including phase labels, for the dissolving of Cr(OH)<sub>3</sub> using sulfuric acid.</b></p> <p><b>In the space below, write the balanced net ionic chemical equation, including phase labels, for the precipitation of Pb<sup>2+</sup>(aq) ions using sulfuric acid.</b></p>	<p><b>2. If your unknown was found to contain Pb<sup>2+</sup> continue with this step</b>, otherwise proceed to the next step. Add 3 M sulfuric acid until the pH is acidic (pH 3 to 4) to dissolve the precipitate. <b>STIR</b> thoroughly before testing the pH. Heat the mixture in a boiling water bath for a few minutes. Any remaining white precipitate is probably PbSO<sub>4</sub>(s). Centrifuge and discard the precipitate. Proceed to the next step with your supernatant.</p>
<p><b>3. Separation of the Group B1 and B2 Cations:</b> The group B cations will be subdivided into two groups: (1) the B1 cations of Bi<sup>3+</sup>, Mn<sup>2+</sup> and Fe<sup>3+</sup>, and (2) the group B2 cations of Cr<sup>3+</sup> and Al<sup>3+</sup>. Upon addition of NaOH and H<sub>2</sub>O<sub>2</sub>, the group B2 cations are left in solution while the group B1 cations are present as precipitates. The chemistry is as follows: The addition of 6 M NaOH dissolves the aluminum hydroxide precipitate into the soluble complex ion tetrahydroxoaluminate(III), Al(OH)<sub>4</sub><sup>-</sup>. <b>In the space below, write the balanced net ionic chemical equation, including phase labels, for the reaction that occurs when excess NaOH(aq) is added to a solution containing Al(OH)<sub>3</sub>(s).</b></p>	<p><b>3.</b></p> <p>(a) Add enough drops of 6 M NaOH to either your precipitate or supernatant to bring the pH to at LEAST 10. <b>STIR</b> thoroughly before testing the pH. Add 4 drops 3% H<sub>2</sub>O<sub>2</sub>, stir, then allow the mixture to sit for 2 minutes.</p> <p>(b) Centrifuge then decant the supernatant into a clean test tube and LABEL as GROUP B2. Heat the supernatant for 10 minutes in a boiling water bath to destroy any excess peroxide.</p> <p>(c) Add 2 mL of deionized water to the precipitate from 3(b), stir, and heat for 10 minutes in a boiling water bath to</p>



Chemistry and Relevant Background Information:	Experimental Procedure:
<p>Sodium bismuthate is then added to test for the presence of <math>\text{Mn}^{2+}</math>. The bismuthate is added in small portions, as the effervescence may be vigorous if any peroxide is still present, until no further reaction occurs. The bismuthate ion oxidizes <math>\text{Mn}^{2+}</math> to the purple colored <math>\text{MnO}_4^-</math> ion. The unbalanced net ionic equation for this reaction is:</p> $\text{Mn}^{2+}(\text{aq}) + \text{H}^+(\text{aq}) + \text{BiO}_3^-(\text{aq}) \rightleftharpoons \text{MnO}_4^-(\text{aq}) + \text{Bi}^{3+}(\text{aq})$ <p><b>Balance this equation and write it in the space below:</b></p>	
<p><b>6. Identification of Iron(III) Ion:</b> To test for the presence of <math>\text{Fe}^{3+}</math>, potassium thiocyanate is added. The <math>\text{Fe}^{3+}</math> ion reacts with <math>\text{SCN}^-</math> forming a reddish brown, soluble complex ion:</p> $\text{Fe}^{3+}(\text{aq}) + \text{SCN}^-(\text{aq}) \rightleftharpoons \text{FeSCN}^{2+}(\text{aq})$	<p><b>6.</b> Measure 4 drops of the B1 solution from step 4 into a test tube. Add 3 drops of 0.1 M KSCN.</p>
<p><b>7. Identification of Bismuth Ion:</b> To test for the presence of <math>\text{Bi}^{3+}</math>, the solution is made basic by adding NaOH. This precipitates <math>\text{Bi}^{3+}</math> as <math>\text{Bi}(\text{OH})_3</math>. <math>\text{SnCl}_2</math> is then added. This causes <math>\text{Bi}(\text{OH})_3</math> to be reduced to elemental <math>\text{Bi}^0</math>, a black solid. The unbalanced net ionic chemical equation for this reaction is:</p> $\text{Bi}(\text{OH})_3(\text{s}) + \text{Sn}(\text{OH})_3^-(\text{aq}) + \text{OH}^-(\text{aq}) \rightleftharpoons \text{Bi}^0(\text{s}) + \text{Sn}(\text{OH})_6^{2-}(\text{aq})$ <p><b>Balance this net ionic equation and write it in the space below:</b></p>	<p><b>7.</b> Measure 4 drops of the B1 solution from step 4 into a test tube. Add 6 M NaOH until the solution is basic (pH about 9). Then add a small quantity of solid <math>\text{SnCl}_2</math>.</p>
<p><b>8. Identification of Aluminum Ion:</b> To test for <math>\text{Al}^{3+}</math>, a portion of the B2 supernatant is first acidified to destroy the <math>\text{Al}(\text{OH})_4^-</math> complex ion.</p> <p><b>Write the balance net ionic chemical equation for this reaction in the space below:</b></p> <p>Aluminon dye is then added followed by <math>\text{NH}_3</math> to precipitate aluminum hydroxide. While forming, the dye is adsorbed onto the precipitate turning it cherry red.</p>	<p><b>8.</b></p> <p>(a) Measure 4 drops of the Group B2 supernatant solution from step 3(b) into a test tube. Add 6 M HCl, dropwise, until the solution is acidic. Carefully observe the solution as the HCl is added.</p> <p>(b) Add 3 drops of aluminon, and then add 6 N <math>\text{NH}_3</math> until the solution tests basic. Centrifuge.</p>

Chemistry and Relevant Background Information:	Experimental Procedure:
<p><b>9. Identification of Chromium(III) Ion:</b> To test for <math>\text{Cr}^{3+}</math>, a portion of the B2 supernatant is made acidic and treated with <math>\text{H}_2\text{O}_2</math>. Dichromate ion in the test solution is converted to the dark blue-purple <math>\text{CrO}_5</math> that fades quickly as it decomposes to <math>\text{Cr}^{3+}</math>. The unbalanced net ionic chemical equations for these reactions are:</p> $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + \text{H}_2\text{O}_2 + \text{H}^+(\text{aq}) \rightleftharpoons \text{CrO}_5(\text{dark-purple}) + \text{H}_2\text{O}(\text{l})$ $\text{CrO}_5(\text{dark-purple}) + \text{H}_2\text{O}_2(\text{aq}) + \text{H}^+(\text{aq}) \rightleftharpoons \text{Cr}^{3+}(\text{aq}) + \text{O}_2(\text{g})$ <p><b>Balance these net ionic equations and write them in the space below:</b> <b>Balancing hints:</b> The first one of these reactions is not a redox reaction; to balance this reaction it is helpful to remember that <math>\text{CrO}_5</math> contains two peroxide ions (<math>\text{O}_2^{2-}</math>) from the hydrogen peroxide and one oxide ion. The second reaction is a redox reaction and can be balanced using the half-reaction method.</p>	<p><b>9.</b> Measure 4 drops of the Group B2 supernatant solution from step 3(b) into a test tube. Add 2 drops of 3% <math>\text{H}_2\text{O}_2</math> followed by 6 M HCl until the solution tests acidic to pH paper. Observe closely as you add the HCl.</p>

**Prelab Exercise:**

Name: \_\_\_\_\_

1. Explain why the  $\text{Pb}^{2+}$  ion, a Group A ion, may also be found in the Group B precipitate after the  $\text{NH}_3$  is added.
  
2. Two of the Group B cations form insoluble hydroxides when  $\text{NH}_3$  is added that will dissolve when excess  $\text{NaOH}$  is added. Which two cations are they?
  
3. A Group B unknown is treated according to the procedure for the B analysis. For each step below, answer the questions asked.
  - a) Addition of  $\text{NaOH}$  and  $\text{H}_2\text{O}_2$  to the Group B hydroxide precipitate, yields a precipitate and a yellow supernatant.
    - i) What cation(s) MAY be present in the precipitate?
    - ii) What cations MAY be present in the supernatant?
    - iii) What does the yellow color strongly suggest is present?
  - b) The precipitate from step (a) is dissolved by adding 6 M  $\text{HCl}$ . A clear, colorless solution results. This solution is tested as follows:
    - i) A few drops of 3%  $\text{H}_2\text{O}_2$  are added to four drops of this solution followed by addition of solid  $\text{NaBiO}_3$ . A purple supernatant results. What can you conclude?
    - ii) 6 M  $\text{NaOH}$  is added to four drops of this solution until it is basic. This is followed by addition of solid  $\text{SnCl}_2$ . A black precipitate is observed. What can you conclude?
    - iii) A few drops of 0.1 M  $\text{KSCN}$  are added to four drops of this solution. A clear, yellow solution results. What can you conclude?
  - c) To four drops of the supernatant from step (a) 6 M  $\text{HCl}$  is added until the solution is acidic. Then aluminum is added, followed by 6 M  $\text{NH}_3$  until the solution is basic. A clear, red solution results. What can you conclude?
  - d) To four drops of the supernatant from step (a) 3%  $\text{H}_2\text{O}_2$  is added followed by 6 M  $\text{HCl}$  until the solution is acidic. A dark blue-purple solution that quickly fades is observed. What can you conclude?

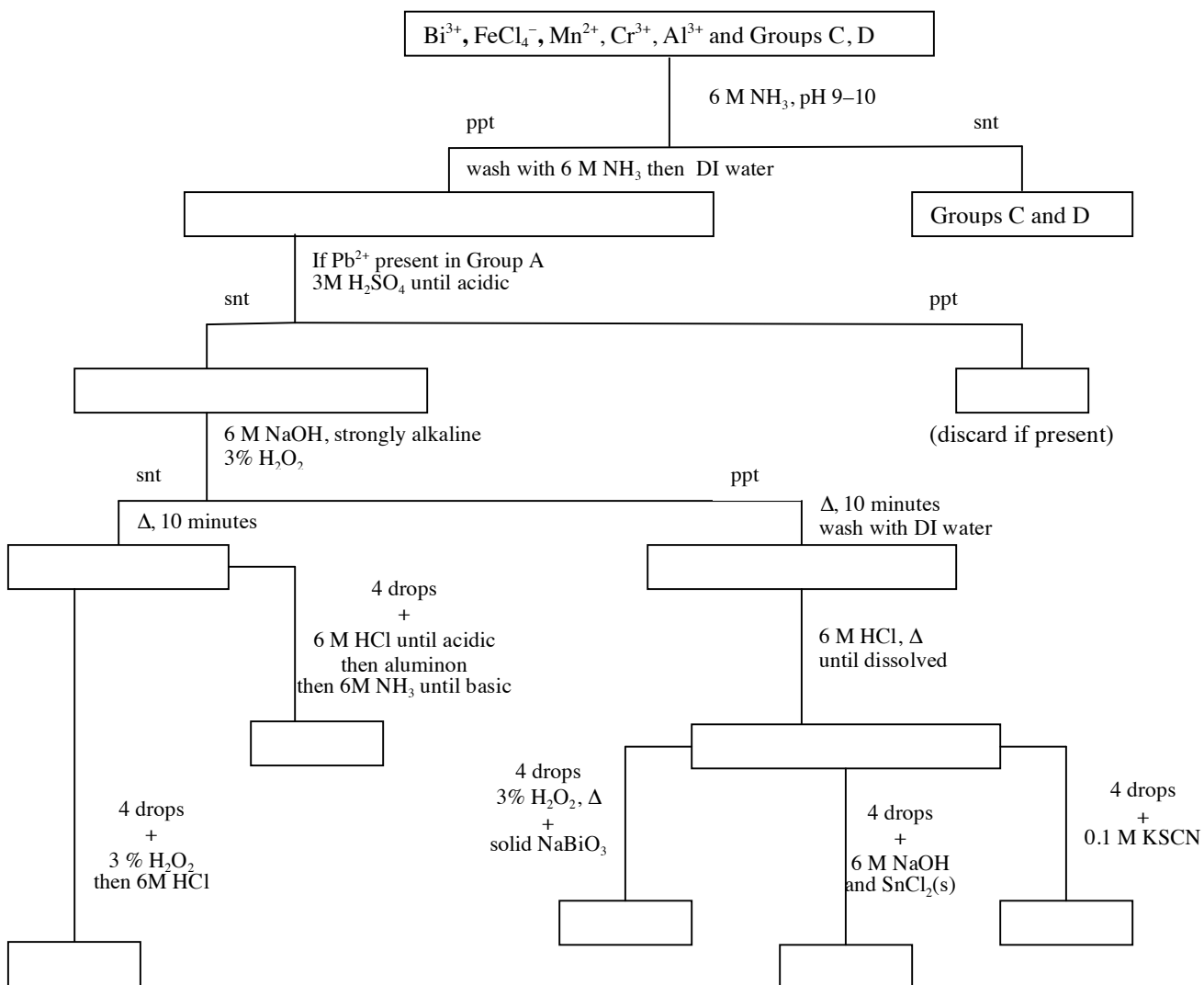


4. Complete the flow diagram below for Group B analysis. For each step, indicate the chemical form of each Group B cation that is present at the given step (for example  $\text{FeCl}_4^-$ ,  $\text{Al}(\text{OH})_3$ ,  $\text{CrO}_4^{2-}$ , etc.). Add colors of solutions and precipitates where known.

snt = supernatant

ppt = precipitate

$\Delta$  = heat



**Follow-up Questions:**

Name: \_\_\_\_\_

**For numerical problems, you must show all work for credit!**

- When ammonia solution is added to the supernatant left after removal of the Group A cations, a buffer solution results.
  - What is the identity of the conjugate acid-base pair that makes up this buffer?
  - What is the pH of this buffer solution when the weak acid concentration is equal to the conjugate base concentration?
- What problem could arise in the Group B analysis if the step where  $\text{H}_2\text{O}_2$  is added to the acidic Group B1 sample before testing for  $\text{Mn}^{2+}$  is skipped on accident?
- Why can't the same portion of the test solution used to test for  $\text{Mn}^{2+}$  be used to test for  $\text{Bi}^{3+}$ ?
- If the Group B hydroxide precipitate dissolves completely upon addition of the NaOH and  $\text{H}_2\text{O}_2$ , what can you conclude?
- Draw a flow diagram for an identification of the cations in an unknown that contains only  $\text{Ag}^+$ ,  $\text{Fe}^{3+}$ , and  $\text{Mn}^{2+}$  ions. Use as few steps/tests as possible.
- Describe a simple, one step test that would allow you to distinguish between the following:
  - $\text{Bi}(\text{OH})_3$  and  $\text{Al}(\text{OH})_3$
  - $\text{Pb}^{2+}(\text{aq})$  and  $\text{Fe}^{3+}(\text{aq})$