Qualitative Analysis of Group I and Group II Ions

Introduction

Qualitative analysis in chemistry focuses on identifying the presence of specific ions in a mixture. In classical inorganic analysis, cations are divided into groups based on their precipitation properties with specific reagents.

This lecture will cover the **Group I (chlorides)** and **Group II (sulfides)** ions, their chemical characteristics, and the procedures for their detection.

Group I: The Chloride Group

Definition

Group I cations form **insoluble chlorides** when treated with dilute hydrochloric acid (HCl). The cations in this group include:

1) **Silver (Ag^+)**
2) **Mercurous (Hg_2^{2+})**
3) **Lead (Pb^{2+})**

Group II: The Sulfide Group

Group II cations form **insoluble sulfides** when treated with hydrogen sulfide (H_2S) in an acidic medium. The cations in this group include:

Copper (Cu^{2+})

Cadmium (Cd^{2+})

Mercuric (Hg^{2+})

Bismuth (Bi^{3+})

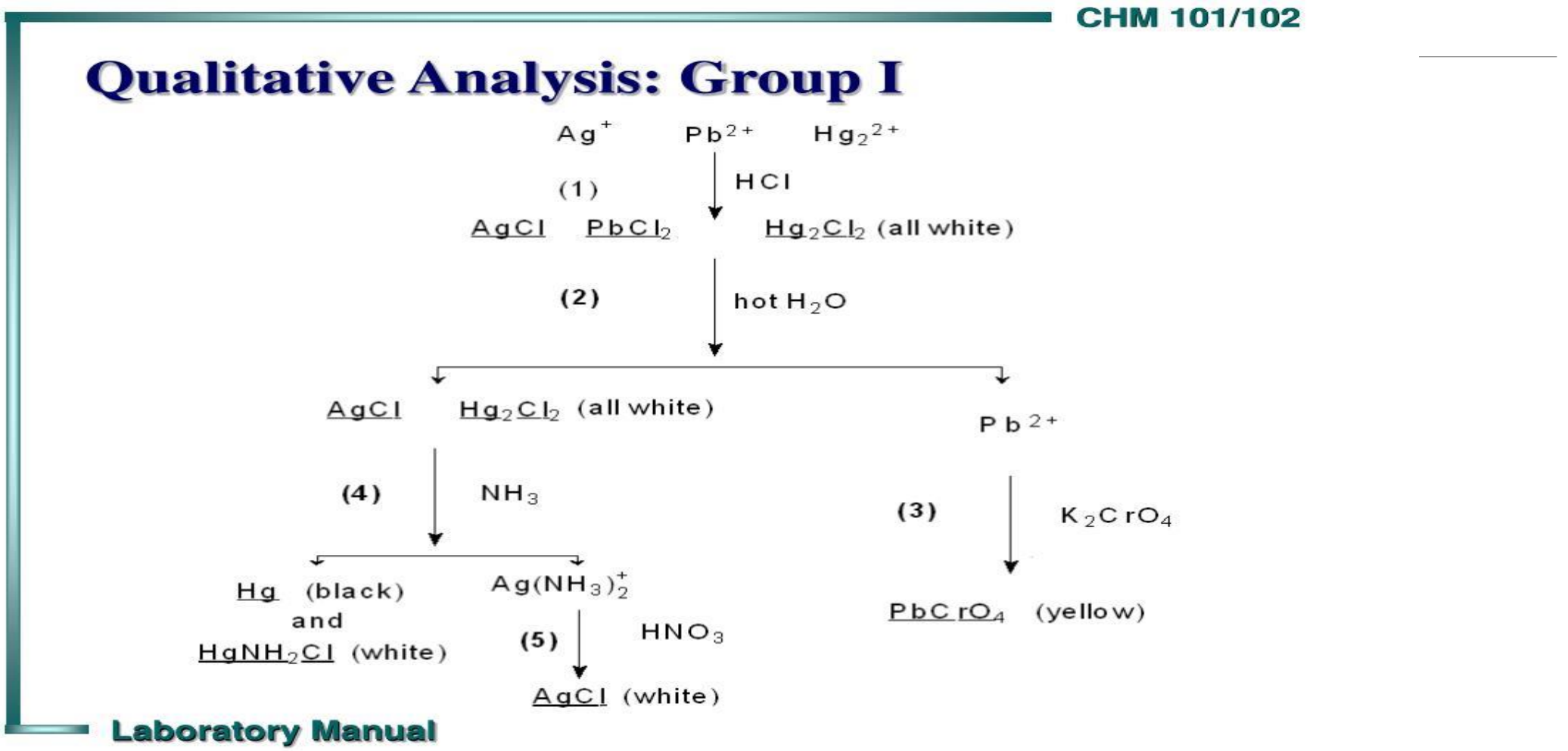
Arsenic (As^{3+} and As^{5+})

Properties

1. Precipitation: These ions form chlorides that are insoluble in water.
2. Reagents Used:

- Dilute HCl: To precipitate chlorides.
- Ammonia (NH_4OH): For selective dissolution and identification

Chemical Reactions



Theoretical Background:

1. Cations included in this group:

- Silver (Ag^+)
- Lead (Pb^{2+})
- Mercurous (Hg_2^{2+})

2. Group Reagent:

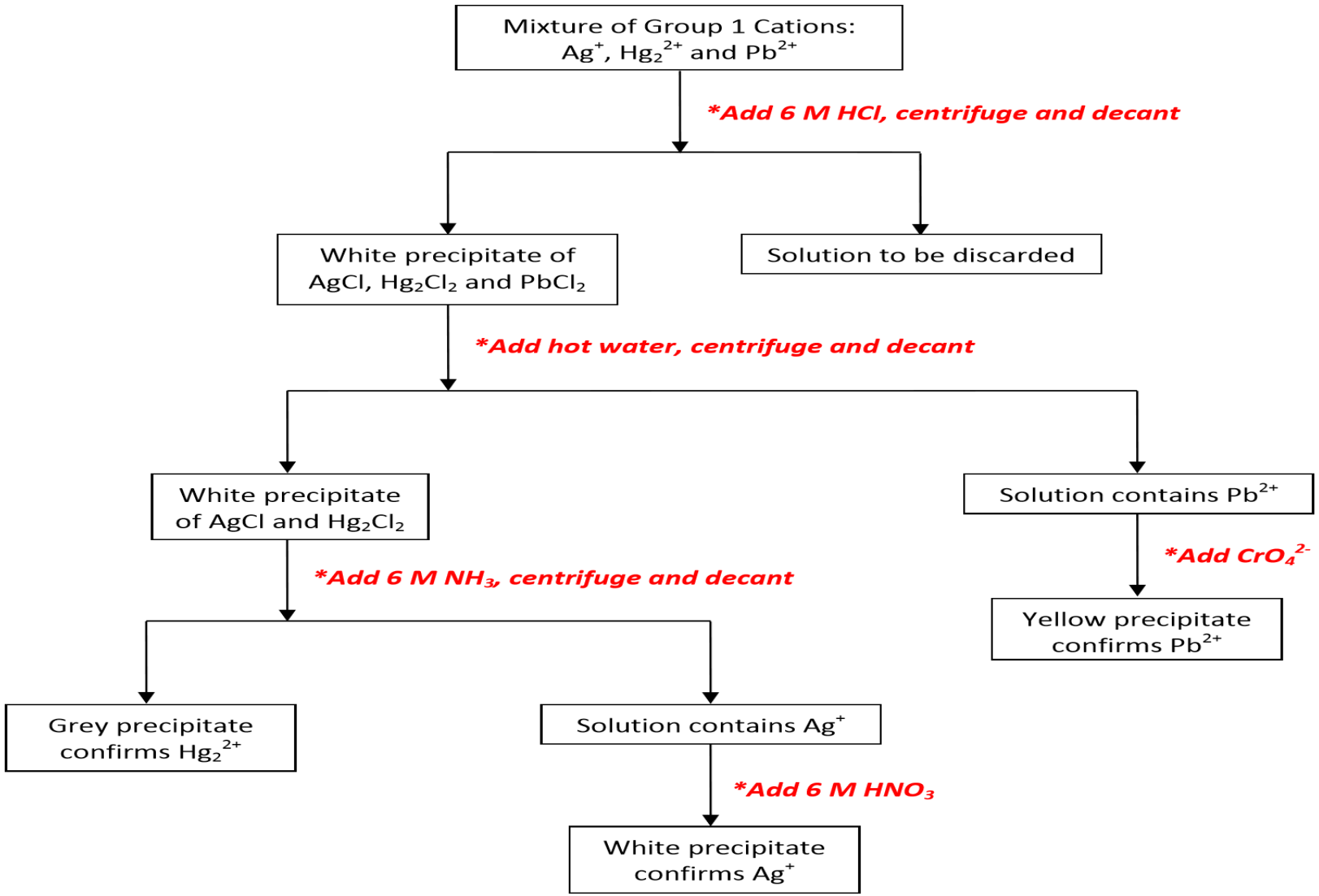
- Diluted hydrochloric acid (HCl)

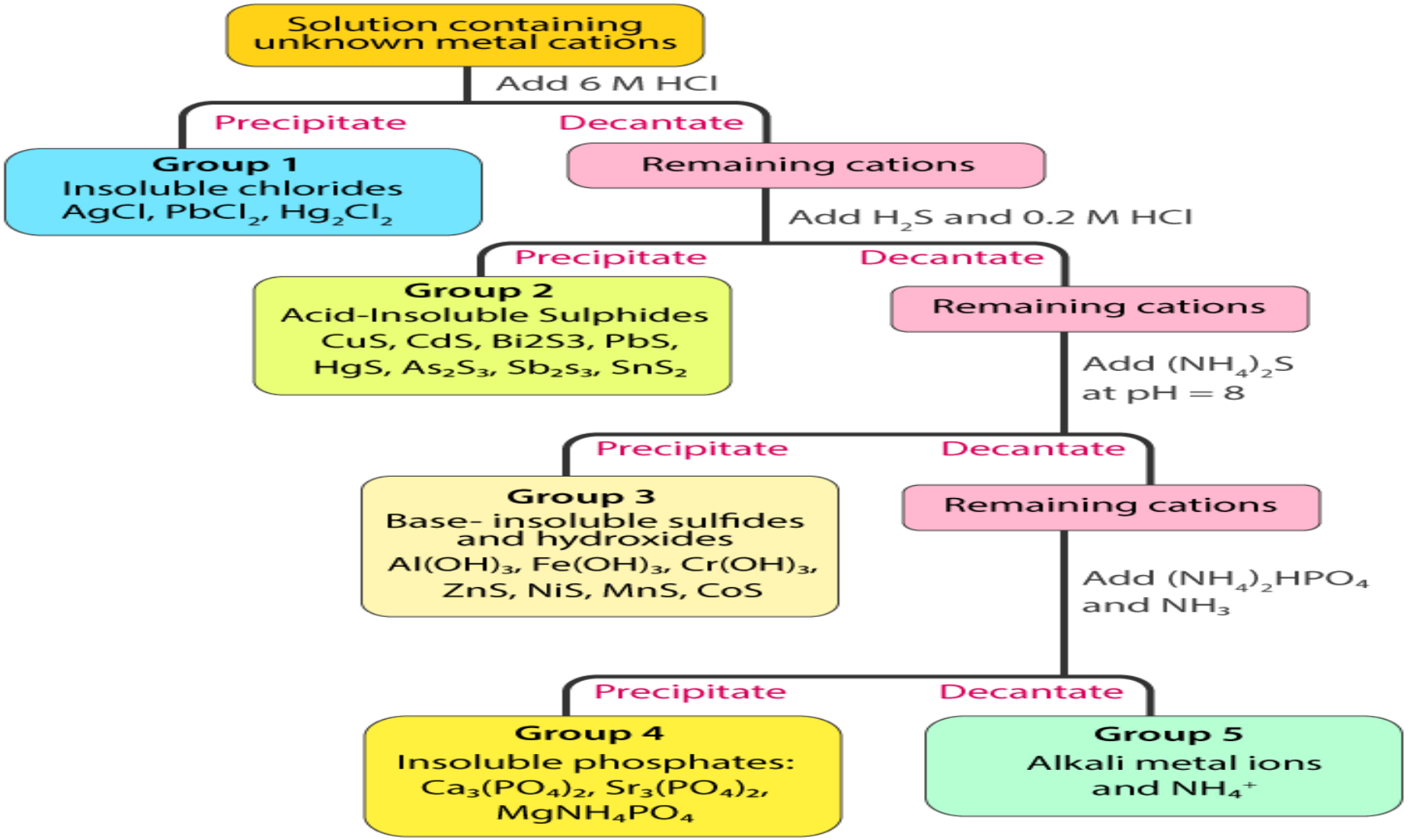
3. Precipitate Form:

- Silver chloride (AgCl): white precipitate
- Lead chloride ($PbCl_2$): white precipitate
- Mercurous chloride (Hg_2Cl_2): white precipitate

4. Chlorides' Characteristics:

- They are all insoluble in water, except for lead chloride, which dissolves in hot water.


Mixture of Group 1 Cations: Ag^+, Hg_2^{2+} and Pb^{2+}
*Add 6 M HCl, centrifuge and decant
White precipitate of AgCl, Hg_2Cl_2 and $PbCl_2$
Solution to be discarded
*Add hot water, centrifuge and decant
White precipitate of AgCl and Hg_2Cl_2
Solution contains Pb^{2+}
*Add CrO_4^{2-}
Yellow precipitate confirms Pb^{2+}
*Add 6 M NH_3, centrifuge and decant
Grey precipitate confirms Hg_2^{2+}
Solution contains Ag^+
*Add 6 M HNO_3
White precipitate confirms Ag^+


Solution containing unknown metal cations
Add 6 M HCl
Precipitate
Decantate
Group 1
Insoluble chlorides
AgCl, PbCl2, Hg2Cl2
Remaining cations
Add H2S and 0.2 M HCl
Precipitate
Decantate
Group 2
Acid-Insoluble Sulphides
CuS, CdS, Bi2S3, PbS,
HgS, As2S3, Sb2S3, SnS2
Remaining cations
Add (NH4)2S
at pH = 8
Precipitate
Decantate
Group 3
Base- insoluble sulfides
and hydroxides
Al(OH)3, Fe(OH)3, Cr(OH)3,
ZnS, NiS, MnS, CoS
Remaining cations
Add (NH4)2HPO4
and NH3
Precipitate
Decantate
Group 4
Insoluble phosphates:
Ca3(PO4)2, Sr3(PO4)2,
MgNH4PO4
Group 5
Alkali metal ions
and NH4+

Comparison of Group I and Group II

Reagents:

- Group I: Precipitated by dilute HCl (chlorides).
- Group II: Precipitated by H_2S in acidic conditions (sulfides).

Solubility:

- Group I chlorides are more soluble than Group II sulfides.

Colors:

- Group I: Mostly white precipitates.
- Group II: Colored sulfides (e.g., black, yellow, brown).

Practical Application

Required Materials

1. Test tubes
2. pipettes
3. water bath
4. HCl
5. H_2S
6. NH_4OH

Analysis Procedure

1. **Addition of Dilute HCl**:
   - Add HCl to the sample. If a white precipitate forms, Group I ions may be present.
2. **Separation of Precipitates**:
   - Heat the precipitate in hot water.
   - If it dissolves, PbCl2PbCl_2 is confirmed.
3. **Testing with NH_4OH**:

   Add ammonia to the remaining precipitate:

   - ❑ AgClAgCl: Dissolves, forming a colorless solution.
   - ❑ Hg2Cl2Hg_2Cl_2: Forms a gray precipitate (Hg and $HgNH_2Cl$).

Conclusion

Qualitative analysis of Group I and Group II ions is an essential skill in inorganic chemistry. It requires careful observation of reactions, solubility, and colors. By following systematic procedures, chemists can accurately identify these ions in mixtures.

Group I Cations

Group I typically includes Ag^{+}, Pb^{2+}, and Hg_2^{2+}. These ions form insoluble chlorides, making it easy to separate them at the initial stage.

Procedure:

1.Add HCl: When HCl is added to the solution, AgCl, $PbCl_2$, and Hg_2Cl_2 precipitate out.

2.Confirmatory Tests:

1. **For Silver (Ag^{+})**: Dissolve the precipitate in NH_4OH; silver chloride forms a complex ion [Ag(NH3)2Cl][$Ag(NH_3)_2Cl$], which dissolves.
2. **For Lead (Pb^{2+})**: Add K_2CrO_4; a yellow precipitate of $PbCrO_4$ confirms lead.
3. **For Mercury (I)**: React with NH_4OH; a black precipitate of $Hg(NH_2)Cl$ + Hg forms.

Group II Cations

Group II is subdivided into Group IIA (As^{3+}, Sb^{3+}, Sn^{2+}) and Group IIB (Cu^{2+}, Cd^{2+}, Bi^{3+}, Hg^{2+}). These ions form sulfides that are insoluble in dilute acid but soluble in alkalies.

Procedure**:**

Add H_2S in HCl: Precipitates the Group II cations as their sulfides.

Confirmatory Tests:

- **For Copper (II) (Cu^{2+})**: Dissolve the precipitate in NaOH; add NH_4OH drops until the solution is basic. A deep blue solution indicates Cu^{2+}.
- **For Cadmium (II) (Cd^{2+})**: React sulfide precipitate with yellow ammonium sulfide; a yellow precipitate of CdS confirms cadmium.
- **For Bismuth (III) (Bi^{3+})**: Dissolve in dilute HCl, add NaOH; a white precipitate of $Bi(OH)_3$ forms.
- **For Mercury (II) (Hg^{2+})**: Mix with NaOH; a black precipitate of HgO confirms mercury.