REACTIONS OF DETECTION OF CATIONS OF THE FIRST ANALYTICAL GROUP

Reactions of lithium cations detection:

1. Action of carbonate ammonium. Carbonates of alkaline metals and ammonium form white precipitate:
   
   \[(\text{NH}_4)_2\text{CO}_3 + 2\text{LiCl} \rightarrow \text{Li}_2\text{CO}_3 \downarrow + 2\text{NH}_4\text{Cl}\]

   Lithium carbonate soluble in diluted mineral acids and in acetic acids and does not precipitate in presence of ammonium salts.

2. Action of sodium hydrogenphosphate. \(\text{Na}_2\text{HPO}_4\) in neutral or slightly acidic solution forms white precipitate:

   \[3\text{LiCl} + 2\text{Na}_2\text{HPO}_4 \rightarrow \text{Li}_3\text{PO}_4 \downarrow + \text{NaH}_2\text{PO}_4 + 3\text{NaCl}\]

   Lithium phosphate easily soluble in solutions of acids, insoluble in alcohol and soluble in ammonium salts.

3. Action of sodium hexanitrocobaltate (III). The sodium hexanitrocobaltate (III) in the neutral or acetic solution forms yellow crystalline precipitate similar to potassium salt:

   \[3\text{LiCl} + \text{Na}_3[\text{Co(NO}_2)_6] \rightarrow \text{Li}_3[\text{Co(NO}_2)_6] \downarrow + 3\text{NaCl}\]

4. Action of ammonium fluoride. In presence of \(\text{NH}_4\text{OH}\) ammonium fluoride gives white amorphous precipitate:

   \[\text{LiCl} + \text{NH}_4\text{F} \rightarrow \text{LiF} \downarrow + \text{NH}_4\text{Cl}\]

   It is possible to use this reaction for the separation of lithium ions from ions of potassium and sodium.

5. Action of potassium orthoperiodate of iron(III). \(\text{K}_2[\text{FeIO}_6]\) in neutral or alkali environment at heating forms yellow amorphous sediment \(\text{LiK[FeIO}_6]\):

   \[\text{LiCl} + \text{K}_2[\text{FeIO}_6] \rightarrow \text{LiK[FeIO}_6] \downarrow + \text{KCl}\]

6. Flame test. Salts of lithium paint colourless flame of gas burner in the intensively red colour.

Reactions of potassium cations detection:

1. Action of sodium hidrogentartrate or tartaric acid. The sodium hydrogentartrate or tartaric acid at \(\text{pH 4-5}\) form white crystalline precipitate:

   \[\text{KCl} + \text{NaHC}_4\text{H}_4\text{O}_6 \rightarrow \text{KHC}_4\text{H}_4\text{O}_6 \downarrow + \text{NaCl}\]

   Precipitate potassium hydrogentartrate forms super-saturated solutions. The precipitate dissolves in the hot water, alkalis and acids:

   \[\text{KHC}_4\text{H}_4\text{O}_6 + \text{HCl} \rightarrow \text{H}_2\text{C}_4\text{H}_4\text{O}_6 + \text{KCl}\]

   \[\text{KHC}_4\text{H}_4\text{O}_6 + \text{NaOH} \rightarrow \text{KNaC}_4\text{H}_4\text{O}_6 + \text{H}_2\text{O}\]
**Reaction implementation features:** For acceleration of precipitate formation the reaction make at cooling and rubbing by the glass stick on walls of test tube.
Make reaction with the tartaric acid in presence of sodium acetate.

2. **Action of sodium hexanitrocobaltate (III).** The sodium hexahydrocobaltate(III) at pH 4-5 forms yellow precipitate:

\[
2\text{KCl} + \text{Na}_3[\text{Co(NO}_2\text{)}_6] \rightarrow \text{K}_2\text{Na}[\text{Co(NO}_2\text{)}_6]\downarrow + 2\text{NaCl}
\]

Precipitate is insoluble in acetic acid, dissolves at heating in the strong acids and decomposes by alkalis with formation of the brown precipitate Co(OH)_3:

\[
\text{K}_2\text{Na}[\text{Co(NO}_2\text{)}_6] + 6\text{HCl} \rightarrow 2\text{KCl} + \text{NaCl} + \text{CoCl}_3 + 6\text{HNO}_2
\]

\[
\text{K}_2\text{Na}[\text{Co(NO}_2\text{)}_6] + 3\text{NaOH} \rightarrow \text{Co(OH)}_3\downarrow + 2\text{KNO}_2 + 4\text{NaNO}_2
\]

3. **Action of hydrogen hexachloroplatinate (IV).** Hydrogen hexachloroplatinate in neutral or weak acidic solution forms yellow crystalline precipitate:

\[
\text{KCl} + \text{H}_2[\text{PtCl}_6] \rightarrow \text{K}_2[\text{PtCl}_6]\downarrow + 2\text{HCl}
\]

4. **Action of perchloric acid.** The perchloric acid forms white crystalline precipitate:

\[
\text{KCl} + \text{HClO}_4 \rightarrow \text{KClO}_4\downarrow + \text{HCl}
\]

The potassium perchlorate is partly soluble in water and insoluble in the butyl alcohol.

5. **Action of picric acid.** Picric acid (trinitrophenol) sediments yellow precipitate from concentrated solutions of potassium salts:

\[
\begin{align*}
\text{O}_3\text{N} & \quad \text{OH} & \quad \text{NO}_2 & \quad \text{O}_3\text{N} \\
\text{NO}_2 & \quad & \quad & \quad \text{O}_3\text{N} \\
\text{NO}_2 & \quad + \text{KCl} & \rightarrow & \quad \text{O}_3\text{N} \\
\text{OK} & \quad \text{NO}_2 & \quad \text{NO}_2 & \quad \text{O}_3\text{N} \\
\text{NO}_2 & \quad \quad & \quad & \quad \text{O}_3\text{N} \\
\text{OK} & \quad \quad & \quad & \quad \text{O}_3\text{N} \\
\end{align*}
\]

6. **Action of dipicrylamine.** Dipicrylamine in interaction with potassium-ions substitutes hydrogen of imide-group on potassium ion and forms orange-red precipitate:

\[
\begin{align*}
\text{O}_3\text{N} & \quad \text{O}_3\text{N} & \quad \text{O}_3\text{N} \\
\text{NO}_2 & \quad \text{NO}_2 & \quad \text{NO}_2 \\
\text{O}_3\text{N} & \quad \text{K} & \quad \text{K} \\
\text{O}_3\text{N} & \quad \text{K} & \quad \text{K} \\
\end{align*}
\]

7. **Flame test.** Volatile salts of potassium (KCl) paint flame of gas burner in the pale-violet colour.
Reactions of sodium cations detection:

1. **Action of zinc-uranile-aceaetate.** Zn[(UO$_2$)$_3$(CH$_3$COO)$_8$] in neutral or weak acidic solution gives green-yellow crystalline precipitate, which has brilliant yellow fluorescence:

   \[
   \text{NaCl} + \text{Zn}[(\text{UO}_2)_3(\text{CH}_3\text{COO})_8] + \text{CH}_3\text{COOH} + 9\text{H}_2\text{O} \rightarrow \\
   \rightarrow \text{NaZn}[(\text{UO}_2)_3(\text{CH}_3\text{COO})_9]\cdot9\text{H}_2\text{O} \downarrow + \text{HCl}
   \]

   This reaction can be executed by the drop method. In case of irradiation by the ultraviolet light the green luminescence exists.

2. **Action of potassium hexahydroxystybiate.** K[Sb(OH)$_6$] in neutral environment forms white crystalline precipitate:

   \[
   \text{NaCl} + \text{K}[\text{Sb(OH)}_6] \rightarrow \text{Na}[\text{Sb(OH)}_6] \downarrow + \text{KCl}
   \]

   Na[Sb(OH)$_6$] precipitate is soluble in the hot water and partly in alkalis:

   \[
   \text{Na}[\text{Sb(OH)}_6] + 2\text{NaOH} \rightarrow \text{Na}_3\text{SbO}_4 + 4\text{H}_2\text{O}
   \]

   The acids decompose the K[Sb(OH)$_6$] reagent and formed precipitate Na[Sb(OH)$_6$], creating amorphous precipitate of metha-stybiate acid:

   \[
   \text{Na}[\text{Sb(OH)}_6] + \text{HCl} \rightarrow \text{H}[\text{Sb(OH)}_6] + \text{NaCl}
   \]

   \[
   \text{H}[\text{Sb(OH)}_6] \rightarrow \text{HSbO}_3 \downarrow + 3\text{H}_2\text{O}
   \]

3. **Action of methoxy-phenyl-acetic acid.** Solution of 4-methoxy-phenyl-acetic acid with sodium cations forms white crystalline precipitate:

   \[
   \text{CH}_3\text{O}-\text{CH}_2\text{COOH} + \text{NaCl} \rightarrow \text{CH}_3\text{O}-\text{CH}_2\text{COONa} + \text{HCl}
   \]

4. **Flame test.** The sodium salts paint colourless flame of gas burner in yellow. A test is very sensible to sodium ions.

Reactions of ammonium cations detection:

1. **Action of magnesium oxide and sodium hexanitrocobaltate(III).** Undergo magnesium oxide on solutions containing ammonium-ions forms ammonium. Formed ammonium after intersection with chloride acid and sodium hexanitrocobaltate(III) forms yellow precipitate:

   \[
   2\text{NH}_4\text{Cl} + \text{Na}_3[\text{Co(NO}_2)_6] \rightarrow \downarrow(\text{NH}_4)_2\text{Na[Co(NO}_2)_6] + 2\text{NaCl}
   \]

2. **Action of alkalis.** Alkalis at heating with ammonium salts evolve an ammonia:

   \[
   \text{NH}_4\text{Cl} + \text{NaOH} \rightarrow \text{NH}_3 \uparrow + \text{NaCl} + \text{H}_2\text{O}
   \]

Free ammonia detection methods:
- smell;
- moistened universal indicator paper, placed to opening test tube, from which an ammonia is eluted, becomes green-blue or dark blue;
- «smoke» formation at placing a glass stick moistened by chloride acid;
- moistened mercury indicator paper, placed to opening test tube, from which an ammonia is eluted, colour in black as a result of reaction:

\[
2\text{NH}_3 + \text{Hg}_2(\text{NO}_3)_2 \rightarrow \text{Hg}↓ + \text{NH}_2\text{HgNO}_3↓ + \text{NH}_4\text{NO}_3
\]

2. **Action of the Nessler’s reagent.** The Nessler’s reagent (K₂[HgI₄]) in alkaline environment with ammonium salts forms orange-brown precipitate of the Millon’s base:

\[
\text{NH}_4\text{Cl} + 2\text{K}_2[\text{HgI}_4] + 4\text{KOH} \rightarrow [\begin{array}{c}
\text{H}_2\text{N} \\
\text{Hg} \\
\text{Hg}
\end{array}\text{O}] + \text{KCl} + 7\text{KI} + \text{H}_2\text{O}
\]

Precipitate dissolves in chloride acid and in solutions of alkalis.
REACTIONS OF DETECTION OF CATIONS OF THE SECOND ANALYTICAL GROUP

Reactions of silver cations detection:

1. Action of chloride acid. Chloride acid and water-soluble chlorides form white amorphous precipitate:

\[ \text{AgNO}_3 + \text{HCl} = \downarrow \text{AgCl} + \text{HNO}_3 \]

Silver chloride insoluble in diluted nitrate acid, easily soluble in the ammonia solutions and in ammonium carbonate:

\[ \text{AgCl} + 2\text{NH}_4\text{OH} = [\text{Ag(NH}_3)_2]\text{Cl} + 2\text{H}_2\text{O} \]

Addition of acid or potassium iodide solution to the got ammoniac solution of AgCl or AgI precipitate falls out:

\[
[\text{Ag(NH}_3)_2]\text{Cl} + 2\text{HNO}_3 = \text{AgCl} \downarrow + 2\text{NH}_4\text{NO}_3
\]

\[
[\text{Ag(NH}_3)_2]\text{Cl} + 2\text{KI} = \text{AgI} \downarrow + 2\text{NH}_3 + \text{KCl}
\]

2. Action of iodides. Potassium iodide forms light-yellow precipitate:

\[ \text{AgNO}_3 + \text{KI} = \text{AgI} \downarrow + \text{KNO}_3 \]

Precipitate is practically insoluble in ammonia (unlike AgCl) and diluted nitrate acid, well soluble in solution of potassium cyanide and sodium thiosulphate.

3. Action of hydroxides of alkaline metals and ammonium. The alkalis at first form white precipitate:

\[ \text{AgNO}_3 + \text{NaOH} = \text{AgOH} \downarrow + \text{NaNO}_3 \]

This compound quickly decomposes with formation of the brown precipitate Ag₂O:

\[ 2\text{AgOH} = \text{Ag}_2\text{O} \downarrow + \text{H}_2\text{O} \]

Precipitate is insoluble in the alkali surplus, well soluble in nitrate acid and ammonia solution. The ammonia in case of addition by drops to the neutral solution of silver salt forms the brown precipitate Ag₂O, which easily dissolves in the ammonia surplus:

\[ \text{AgNO}_3 + \text{NH}_4\text{OH} = \text{Ag}_2\text{O} \downarrow + \text{H}_2\text{O} + \text{NH}_4\text{NO}_3 \]

\[ \text{Ag}_2\text{O} + 4\text{NH}_4\text{OH} = 2[\text{Ag(NH}_3)_2]\text{OH} + 3\text{H}_2\text{O} \]

4. Action of hydrogen sulphide. Hydrogen sulphide or ammonia sulphide forms black precipitate:

\[ 2\text{AgNO}_3 + (\text{NH}_4)_2\text{S} = \text{Ag}_2\text{S} \downarrow + 2\text{NH}_4\text{NO}_3 \]

Silver sulphide dissolves in concentrated nitrate acid:

\[ 3\text{Ag}_2\text{S} + 8\text{HNO}_3 = 6\text{AgNO}_3 + 2\text{NO} \uparrow + 3\text{S} + 4\text{H}_2\text{O} \]
5. **Action of chromates.** Salts of chromic acid form orange-red precipitate:

\[
2\text{AgNO}_3 + \text{K}_2\text{CrO}_4 = \text{Ag}_2\text{CrO}_4 \downarrow + 2\text{KNO}_3
\]

6. **Action of dithizone.** Dithizone (diphenylthiocarbazone) with the silver cations forms the complex compound painted in yellow, which is extracted by chloroform and carbon tetrachloride:

\[
\begin{align*}
\text{NH} & \quad \text{N} \\
\text{C} & \quad \text{SH} + \text{AgNO}_3 \\
\text{NH} & \quad \text{N} \\
\text{N} & \quad \text{C} \\
\text{SH} & \quad \text{Ag} + \text{HNO}_3
\end{align*}
\]

7. **Action to formaldehyde.** Formaldehyde easily reduces the silver ion to free metal:

\[
\text{Ag}_2\text{O} + \text{HCOH} = 2\text{Ag} \downarrow + \text{HCOOH}
\]

As a result of reaction in the test tube walls appears the brilliant plaque of free silver, through what this reaction got a name “reaction of silver mirror”.

**Reactions of lead cations detection:**

1. **Action of chloride acid.** Chloride acid and chlorides with lead cations form white precipitate:

\[
\text{Pb(NO}_3)_2 + 2\text{HCl} = \text{PbCl}_2 \downarrow + 2\text{HNO}_3
\]

Precipitate is soluble in the hot water and the HCl surplus.

2. **Action of hydroxides of alkaline metals and ammonium.** Alkalis in the equivalent quantities to the lead form white precipitate:

\[
\text{Pb(NO}_3)_2 + 2\text{NaOH} = \text{Pb(OH)}_2 \downarrow + 2\text{NaNO}_3
\]

Precipitate is soluble in acids and alkali surplus (at pH = 13) forming plumbite Na\textsubscript{2}PbO\textsubscript{2}. Ammonium hydroxide forms white precipitate of base salt insoluble in surplus of reagent:

\[
\text{Pb(NO}_3)_2 + \text{NH}_4\text{OH} = \text{Pb(OH)}\text{NO}_3 \downarrow + \text{NH}_4\text{NO}_3
\]

3. **Action of iodides.** Potassium iodide with the lead salts forms yellow precipitate:

\[
\text{Pb(NO}_3)_2 + 2\text{KI} = \text{PbI}_2 \downarrow + 2\text{HNO}_3
\]

Precipitate is soluble in surplus of reagent, in hot water, and in acetic acid. Precipitate solubility in hot water and acetic acid is used for the additional detection of lead cations, since at cooling of solution the precipitate falls out again as character gold scales.

4. **Action of hydrogen sulphide.** The hydrogen sulphide forms black precipitate:
\[
Pb(NO_3)_2 + H_2S = PbS↓ + 2HNO_3
\]

Lead sulphide does not dissolve in acetic and mineral acids, unless the concentrated nitrate acid:

\[
3PbS + 8HNO_3 = 3Pb(NO_3)_2 + 2NO↑ + 3S + 4H_2O
\]

5. **Action of sulphates.** The water-soluble sulphates with the lead cations form the white precipitate:

\[
Pb(NO_3)_2 + Na_2SO_4 = PbSO_4↓ + 2NaNO_3
\]

6. **Action of chromates.** To potassium chromate forms yellow precipitate:

\[
Pb(NO_3)_2 + K_2CrO_4 = PbCrO_4↓ + 2KNO_3
\]

7. **Action to sodium of rhodizonate.**

\[\text{Diagram of reaction\]}

8. **Action of dithizone.**

\[\text{Diagram of reaction\]}

**Reactions of mercury(I) cations detection:**

1. **Action of chloride acid.** The chloride acid with mercury(I) forms white precipitate:

\[
Hg_2(NO_3)_2 + 2HCl = Hg_2Cl_2↓ + 2HNO_3
\]

The precipitate has luminescence by orange-red colour in the ultraviolet light. Ammonia with mercury(I) chloride forms free mercury, from which the precipitate turns black, and white precipitate of mercury aminochloride (dismutation of univalent mercury on Hg\(^{+2}\) and Hg\(^{0}\)):
\[
\text{Hg}_2\text{Cl}_2 + 2\text{NH}_4\text{OH} = \text{HgNH}_2\text{Cl}↓ + \text{Hg}↓ + \text{NH}_4\text{Cl} + \text{H}_2\text{O}
\]

2. **Action of hydroxides of alkaline metals and ammonium.** Hydroxides of alkaline metals with mercury(I) salt form black precipitate:

\[
\text{Hg}_2(\text{NO}_3)_2 + 2\text{NaOH} = \text{Hg}_2\text{O}↓ + \text{H}_2\text{O} + 2\text{NaNO}_3
\]

Solution of ammonium hydroxide with mercury(I) salt forms a mixture, which consists of black elemental mercury and white mercury aminonitrate:

\[
\text{Hg}_2(\text{NO}_3)_2 + 2\text{NH}_4\text{OH} = \text{Hg}↓ + \text{NH}_2\text{HgNO}_3↓ + \text{NH}_4\text{NO}_3 + \text{H}_2\text{O}
\]

3. **Action of iodides.** Potassium iodide with solutions of mercury(I) salts forms green-grey precipitate:

\[
\text{Hg}_2(\text{NO}_3)_2 + 2\text{KI} = \text{Hg}_2\text{I}_2↓ + 2\text{KNO}_3
\]

Which dissolves in surplus of potassium iodide with colourless complex formation and elemental mercury:

\[
\text{Hg}_2\text{I}_2 + 2\text{KI} = \text{K}_2[\text{HgI}_4] + \text{Hg}↓
\]

4. **Action of hydrogen sulphide.** The hydrogen sulphide forms mixture of elemental mercury and sulphide of bivalent mercury as a result of dismutation of \(\text{Hg}_2\text{S}\) to \(\text{HgS}\) and \(\text{Hg}\):

\[
\text{Hg}_2(\text{NO}_3)_2 + \text{H}_2\text{S} = \text{HgS}↓ + \text{Hg}↓ + 2\text{HNO}_3
\]

Mercury(II) sulphide dissolves in “aqua regia”:

\[
3\text{HgS} + 6\text{HCl} + 2\text{HNO}_3 = 3\text{HgCl}_2 + 3\text{S} + 2\text{NO} + \text{H}_2\text{O}
\]

5. **Action of tin(II) chloride.** The mercury(I) reduces to free metal under action of tin(II):

\[
\text{Hg}_2(\text{NO}_3)_2 + \text{SnCl}_2 = \text{Hg}_2\text{Cl}_2↓ + \text{Sn(NO}_3)_2
\]

\[
\text{Hg}_2\text{Cl}_2 + \text{SnCl}_2 = 2\text{Hg}↓ + \text{SnCl}_4
\]

6. **Reaction on copper plate.** If to drop solution of mercury(I) salt on the copper coin, through 2-3 min coin will be covered by the grey layer of mercury amalgam, which after grinding by the wool piece becomes brilliant:

\[
\text{Hg}_2(\text{NO}_3)_2 + \text{Cu} = 2\text{Hg}↓ + \text{Cu(NO}_3)_2
\]
REACTIONS OF DETECTION OF CATIONS OF THE THIRD ANALYTICAL GROUP

Reactions of calcium cations detection:

1. Action of sulphate acid and soluble in water of sulphates. The sulphate acid and water-soluble sulphates with calcium ions form white crystalline precipitate:

   \[ \text{CaCl}_2 + \text{H}_2\text{SO}_4 = \text{CaSO}_4\downarrow + 2\text{HCl} \]

Saturated solution of ammonium sulphate dissolves precipitate forming a water-soluble complex:

   \[ \text{CaSO}_4 + (\text{NH}_4)_2\text{SO}_4 = (\text{NH}_4)_2[\text{Ca(SO}_4)_2] \]

This reaction uses for separation calcium ions from strontium ions.

2. Action of ammonium oxalate. To the ammonium oxalate with calcium salts forms white crystalline precipitate:

   \[ \text{CaCl}_2 + (\text{NH}_4)_2\text{C}_2\text{O}_4 = \text{CaC}_2\text{O}_4\downarrow + 2\text{NH}_4\text{Cl} \]

Precipitate is insoluble in acetic acid (unlike to oxalates of barium and strontium) and ammonia solution, soluble in solutions of strong acids with oxalic acid formation:

   \[ \text{CaC}_2\text{O}_4 + 2\text{HCl} = \text{CaCl}_2 + \text{H}_2\text{C}_2\text{O}_4 \]


4. Action of potassium hexacyanoferrate(II) (Pharmacopoeia). Potassium hexacyanoferrate(II) at pH > 7 and ammonium chloride presence interacts with calcium ions and forms white crystalline precipitate:

   \[ \text{CaCl}_2 + 2\text{NH}_4\text{Cl} + K_4[\text{Fe(CN)}_6] = \downarrow\text{Ca(NH}_4)_2[\text{Fe(CN)}_6] + 4\text{KCl} \]

5. Action of sodium rhodizonate. Sodium rhodizonate in acidic environment forms violet precipitate with calcium ions:

Reactions of strontium cations:

1. Action of sulphate acid and soluble in water of sulphates. The sulphate acid and water-soluble sulphates with strontium ions form white crystalline precipitate:

   \[ \text{SrCl}_2 + \text{H}_2\text{SO}_4 = \text{SrSO}_4 \downarrow + 2\text{HCl} \]

   The strontium sulphate is possible to convert to carbonate by boiling with saturated solution of sodium or potassium carbonate.

1. Action of ammonium oxalate. Ammonium oxalate with strontium salts forms white crystalline precipitate:

   \[ \text{SrCl}_2 + (\text{NH}_4)_2\text{C}_2\text{O}_4 = \text{SrC}_2\text{O}_4 \downarrow + 2\text{NH}_4\text{Cl} \]

   Precipitate is soluble in the acetic acid and in solutions of strong acids with oxalic acid formation:

   \[ \text{SrC}_2\text{O}_4 + 2\text{CH}_3\text{COOH} = \text{Sr}(\text{CH}_3\text{COO})_2 + \text{H}_2\text{C}_2\text{O}_4 \]

   \[ \text{SrC}_2\text{O}_4 + 2\text{HCl} = \text{SrCl}_2 + \text{H}_2\text{C}_2\text{O}_4 \]

2. Action of gipseous water. The gipseous water (saturated solution CaSO\(_4\) \(\times\) 2H\(_2\)O) with strontium ions forms white crystalline precipitate:

   \[ \text{SrCl}_2 + \text{CaSO}_4 = \text{SrSO}_4 \downarrow + \text{CaCl}_2 \]

   The precipitate appears after heating or at the room temperature after protracted standing.

3. Action of chromates. To potassium chromate with strontium ions forms yellow precipitate:

   \[ \text{SrCl}_2 + \text{K}_2\text{CrO}_4 = \text{SrCrO}_4 \downarrow + 2\text{KCl} \]

   The strontium chromate is soluble in mineral and acetic acids.

1. Action to sodium rhodizonate. Sodium rhodizonate in neutral environment forms brown precipitate with strontium ions:
The red-brown spot forms on filter paper also. This spot disappears after chloride acid addition (precipitate dissolving).

4. **Flame test.** Volatile salts of strontium paint flame of gas burner in the carmine-red colour.

### Reactions of barium cations:

1. **Action of sulphate acid and soluble in water sulphates.** The sulphate acid and sulphates with barium ions form white crystalline precipitate:
   \[
   \text{BaCl}_2 + \text{H}_2\text{SO}_4 = \text{BaSO}_4 \downarrow + 2\text{HCl}
   \]
   Precipitate is insoluble in diluted mineral acids.

2. **Action of potassium dichromate.** Potassium dichromate in presence of sodium acetate with barium ions forms yellow crystalline precipitate:
   \[
   2\text{BaCl}_2 + \text{K}_2\text{Cr}_2\text{O}_7 + \text{H}_2\text{O} + 2\text{CH}_3\text{COONa} = 2\text{BaCrO}_4 \downarrow + 2\text{KCl} + 2\text{CH}_3\text{COOH} + 2\text{NaCl}
   \]
   Precipitate is soluble in mineral acids and insoluble in acetic acid.

3. **Action of sulphate acid and potassium permanganate.** Sulphate acid in saturated solution of potassium permanganate with barium ions forms violet precipitate, which is not discoloured by reducers. The KMnO$_4$ crystals are isomorphic to BaSO$_4$ crystals and wedge to the barium sulphate crystalline grate:
   \[
   \text{BaCl}_2 + \text{H}_2\text{SO}_4 + \text{KMnO}_4 = \text{BaSO}_4 \downarrow + \text{KMnO}_4 + 2\text{HCl}
   \]

4. **Action of sodium rhodizonate.** Sodium rhodizonate with barium salts forms red sediment. On filter paper arises red-brown spot that changes colour in red after chloride acid addition. It is specific reaction on barium ions:

5. **Action of ammonium oxalate.** Ammonium oxalate with barium ions gives white crystalline precipitate:
\[
\text{BaCl}_2 + (\text{NH}_4)_2\text{C}_2\text{O}_4 = \text{BaC}_2\text{O}_4 \downarrow + 2\text{NH}_3\text{Cl}
\]

Precipitate is soluble in boiling acetic acid and in solutions of mineral acids with oxalic acid formation.

6. **Flame test.** Volatile barium salts paint flame of gas burner in the yellow-green colour.
REACTIONS OF THE FOURTH ANALYTICAL GROUP CATIONS DETECTION

Reactions of aluminium cations detection:

1. Action to sodium or potassium hydroxide. Hydroxides of alkaline metals with aluminium ions form white precipitate, soluble in reagent surplus:
   \[
   \begin{align*}
   \text{Al}_2(\text{SO}_4)_3 + 6\text{NaOH} &= \downarrow 2\text{Al(OH)}_3 + 3\text{Na}_2\text{SO}_4 \\
   \text{Al(OH)}_3 + 3\text{NaOH} &= \text{Na}_3[\text{Al(OH)}_6] \\
   \text{Na}_3[\text{Al(OH)}_6] &= \text{NaAlO}_2 + 2\text{H}_2\text{O} + 2\text{NaOH}
   \end{align*}
   \]

2. Action of ammonium hydroxide. The ammonia solution in the neutral environment with aluminium ions forms white amorphous precipitate, insoluble in reagent surplus:
   \[
   \text{Al}_2(\text{SO}_4)_3 + 6\text{NH}_4\text{OH} = \downarrow 2\text{Al(OH)}_3 + 3(\text{NH}_4)_2\text{SO}_4
   \]

3. Hydrolysis of aluminium salts. In presence NH₄Cl at heating aluminate hydrolyses with formation of Al(OH)₃ precipitate:
   \[
   \text{NaAlO}_2 + \text{H}_2\text{O} + \text{NH}_4\text{Cl} = \downarrow \text{Al(OH)}_3 + \text{NH}_3 + \text{NaCl}
   \]

4. Action of cobalt nitrate (Tenard’s blue formation). Cobalt nitrate at ignition with aluminium salts on filter paper forms cobalt aluminate of dark blue colour, which named “Tenard’s blue” (colour of ash):
   \[
   2\text{Al}_2(\text{SO}_4)_3 + 2\text{Co(NO}_3)_2 = 2\text{Co(AlO}_2)_3 + 4\text{NO}_2 + \text{O}_2 + 6\text{SO}_3
   \]

5. Action of 8-oxyquinoline (oxyne). 8-oxyquinoline with aluminium ions at pH 4.5-10 forms the yellow inner-complex compound:

   ![Diagram](image)

6. Action of alizarin. Alizarin red S with aluminium ions alkaline environment, created by NH₄OH, forms bright red precipitate:
   \[
   \text{Al}_2(\text{SO}_4)_3 + 6\text{NH}_4\text{OH} = \downarrow 2\text{Al(OH)}_3 + 3(\text{NH}_4)_2\text{SO}_4
   \]
Reactions of zinc cations detection:

1. Action of sodium or potassium hydroxide. Hydroxides of alkaline metals with zinc ions forms white precipitate soluble in reagent surplus with zincates formation:

   \[
   \text{ZnCl}_2 + 2\text{NaOH} = \text{Zn(OH)}_2 + 2\text{NaCl} \\
   \text{Zn(OH)}_2 + 2\text{NaOH} = \text{Na}_2\text{ZnO}_2 + 2\text{H}_2\text{O}
   \]

2. Action of ammonium hydroxide. Solution of ammonium hydroxide with zinc ions forms white precipitate, which dissolves in the reagent surplus with formation of tetra-ammine complex:

   \[
   \text{ZnCl}_2 + 2\text{NH}_3 + 2\text{H}_2\text{O} = \text{Zn(OH)}_2 + 2\text{NH}_4\text{Cl} \\
   \text{Zn(OH)}_2 + 4\text{NH}_3 = \text{Zn}[(\text{NH}_3)_4](\text{OH})_2
   \]

3. Action of sodium sulphide. Sodium sulphide with zinc ions forms white precipitate insoluble in the acetic acid and soluble in diluted HCl:

   \[
   \text{ZnCl}_2 + \text{Na}_2\text{S} = \text{ZnS} + 2\text{NaCl} \\
   \text{ZnS} + 2\text{HCl} = \text{ZnCl}_2 + \text{H}_2\text{S}
   \]

4. Action of cobalt nitrate (Rinmann’s green formation). Cobalt nitrate at ignition with zinc salts on filter paper forms cobalt zincate of green colour, which named “Rinmann’s green” (colour of ash):

   \[
   \text{Zn(NO}_3)_2 + \text{Co(NO}_3)_2 = \text{CoZnO}_2 + 4\text{NO}_2 + \text{O}_2
   \]

5. Action of ammonium tetrarhodanomercurate. Ammonium tetrarhodanomercurate with zinc salts in weak acidic environment forms white crystalline precipitate:

   \[
   \text{ZnCl}_2 + (\text{NH}_4)_2[\text{Hg(SCN)}_4] = \text{Zn}[\text{Hg(SCN)}_4] + 2\text{NH}_4\text{Cl}
   \]

6. Action of potassium hexacyanoferrate(II). Potassium hexacyanoferrate(II) with zinc salts forms white precipitate:

   \[
   3\text{ZnCl}_2 + 2\text{K}_4[\text{Fe(CN)}_6] = \text{K}_2\text{Zn}_3[\text{Fe(CN)}_6]_2 + 6\text{KCl}
   \]

7. Action of dithizone. Dithizone with zinc ions forms red inner-complex soluble in the organic solvents:
Reactions of chrome(III) cations detection:

1. **Action of sodium or potassium hydroxide.** Hydroxides of alkaline metals with chrome(III) ions form precipitate of green colour, soluble in reagent surplus due to its amphoteric properties:
   \[
   \text{Cr}_2(\text{SO}_4)_3 + 6\text{NaOH} = 2\text{Cr(OH)}_3 + 3\text{Na}_2\text{SO}_4
   \]

2. **Action of ammonium hydroxide.** Solutions of ammonium hydroxide forms precipitate Cr(OH)_3, partly soluble in the reagent surplus with formation of hexamine-chrome(III) hydroxide:
   \[
   \text{Cr(OH)}_3 + 6\text{NH}_4\text{OH} = [\text{Cr(NH}_3)_6]\text{(OH)}_2 + 6\text{H}_2\text{O}
   \]

3. **Action of sodium hydroxide and hydrogen peroxide.** Under H_2O_2 action in alkaline environment the chrome(III) passes to chrome(IV) and forms chromates having yellow colour:
   \[
   2\text{NaCrO}_2 + 3\text{H}_2\text{O}_2 + 2\text{NaOH} = 2\text{Na}_2\text{CrO}_4 + 4\text{H}_2\text{O}
   \]

4. **Action of oxidants.** Under action of oxidants (KMnO_4, Cl_2, (NH_4)_2S_2O_8) in acidic environment are formed dichromates – appears orange colour:
   \[
   \text{Cr}_2(\text{SO}_4)_3 + 3(\text{NH}_4)_2\text{S}_2\text{O}_8 + 4\text{H}_2\text{O} = \text{H}_2\text{Cr}_2\text{O}_7 + 3(\text{NH}_4)_2\text{SO}_4 + 3\text{H}_2\text{SO}_4
   \]

5. **Reaction of perchromate acid formation.** Under action of H_2O_2 on the formed dichromate-ion forms chrome peroxide Cr_2O_5 (or perchromic acid H_2CrO_6):
   \[
   \text{Cr}_2(\text{SO}_4)_3 + 8\text{NaOH} = 2\text{NaCrO}_2 + 3\text{Na}_2\text{SO}_4 + 4\text{H}_2\text{O}
   
   2\text{NaCrO}_2 + 3\text{H}_2\text{O}_2 + 2\text{NaOH} = 2\text{Na}_2\text{CrO}_4 + 4\text{H}_2\text{O}
   
   2\text{Na}_2\text{CrO}_4 + \text{H}_2\text{SO}_4 = \text{Na}_2\text{Cr}_2\text{O}_7 + \text{Na}_2\text{SO}_4 + \text{H}_2\text{O}
   
   \text{H}_2\text{SO}_4 + \text{Na}_2\text{Cr}_2\text{O}_7 + 4\text{H}_2\text{O}_2 = 2\text{H}_2\text{CrO}_6 + \text{Na}_2\text{SO}_4 + 3\text{H}_2\text{O}.
   \]

If to reactionary mixture add a mixture of isoamyl alcohol with diethyl ether and shake up, an overhead layer is painted in the dark blue colour as a result of transition in alcohol-ether layer of chrome peroxide (perchromic acid).
Reactions of tin(II) cations detection:

1. **Action of sodium or potassium hydroxide.** Hydroxides of alkaline metals with tin(II) salts forms white precipitate, soluble in surplus of alkali and acids:

   \[
   \begin{align*}
   SnCl_2 + 2NaOH & = \downarrow Sn(OH)_2 + 2NaCl \\
   Sn(OH)_2 + 2NaOH & = Na_2SnO_2 + 2H_2O \\
   Sn(OH)_2 + 2HCl & = SnCl_2 + 2H_2O
   \end{align*}
   \]

   In case in presence of hydrogen peroxide the sodium stannite across to sodium stannate:

   \[
   Na_2SnO_2 + H_2O_2 = Na_2SnO_3 + H_2O
   \]

2. **Action of ammonium hydroxide.** Ammonium hydroxide with Sn\(^{2+}\) ions forms white precipitate, insoluble in surplus of reagent:

   \[
   SnCl_2 + 2NH_4OH = \downarrow Sn(OH)_2 + 2NH_4Cl
   \]

3. **Action of hydrogen sulphide, solubility of sulphides.** Hydrogen sulphide or ammonium sulphide with solutions of tin(II) salts form dark-brown precipitate:

   \[
   SnCl_2 + H_2S = \downarrow SnS + 2HCl
   \]

   SnS precipitate is insoluble in alkalis and in surplus of sodium sulphide, but easily dissolves in ammonium polysulphide with thio-salts formation:

   \[
   \begin{align*}
   SnS + (NH_4)_2S_2 & = SnS_2 + (NH_4)_2S \\
   SnS_2 + (NH_4)_2S_2 & = (NH_4)_2SnS_3 + S
   \end{align*}
   \]

4. **Action of salts of bismuth(III) and mercury(II) in alkaline environment.** Tin(II) easily enter to oxidation-reducing reaction as reducer. Typical is oxidising-reducing reaction with salts of bismuth(III) and mercury(II) in the alkaline environment. As a result of reactions the precipitations of element mercury and bismuth sediment:

   \[
   \begin{align*}
   SnCl_2 + 4NaOH & = Na_2SnO_3 + 2H_2O + 2NaCl \\
   Na_2SnO_2 + 2HgCl_2 + 2NaOH & = Na_2SnO_3 + \downarrow 2Hg + 4NaCl + H_2O \\
   3Na_2SnO_2 + 2Bi(NO_3)_3 + 6NaOH & = 3Na_2SnO_3 + \downarrow 2Bi + 6NaNO_3 + 3H_2O
   \end{align*}
   \]

Reactions of tin(IV) cations detection:

1. **Action of sodium or potassium, or ammonium hydroxides.** Hydroxides form white precipitate, which has amphoteric properties:

   \[
   H_2[SnCl_6] + 6NaOH = \downarrow H_2[Sn(OH)_6] + 6NaCl
   \]

   Precipitate is soluble in the alkali surplus:

   \[
   H_2[Sn(OH)_6] + 2NaOH = Na_2[Sn(OH)_6] + 2H_2O.
   \]

   In acids the precipitate dissolves with formation of complex salts:
\[ \ce{H_2[Sn(OH)_6] + 6HCl = H_2[SnCl_6] + 6H_2O.} \]

2. **Action of hydrogen sulphide.** With the hydrogen sulphide the tin(IV) salt forms yellow precipitate:

\[ \ce{H_2[SnCl_6] + 2H_2S = \downarrow SnS_2 + 6HCl.} \]

Precipitate is soluble in concentrated chloride acid:

\[ \ce{SnS_2 + 6HCl = H_2[SnCl_6] + 2H_2S.} \]

Unlike \( \ce{Sn^{2+}} \) salts the sulphide of \( \ce{Sn^{4+}} \) is soluble in \( \ce{(NH_4)_2S} \) solution:

\[ \ce{SnS_2 + (NH_4)_2S = (NH_4)_2SnS_3.} \]

3. **Test with metallic iron.** Unlike \( \ce{Sn^{2+}} \), \( \ce{Sn^{4+}} \) does not proceed in ions of bismuth and mercury, however in acidic environment is reduced by iron to \( \ce{Sn^{2+}} \):

\[ \ce{H_2[SnCl_6] + Fe = FeCl_2 + SnCl_2 + 2HCl} \]

4. **Action of cupferron.** Cupferron (ammonium salt of N-nitrozo-phenyl-hydroxyl-amine) with tin(IV) ions forms yellow hardly soluble compound:

Reactions of arsenic(III) cations detection:

1. **Action of sodium hypophosphite.** Sodium hypophosphite in acidic environment reduces compounds of arsenic(III) and arsenic(V) to free arsenic, which forms sediment of brown colour or paints solution in the brown colour:

\[ \ce{NaH_2PO_2 + HCl = NaCl + H_3PO_2} \]
\[ \ce{As_2O_3 + 3H_3PO_2 = \downarrow 2As + H_3PO_3} \]

2. **Action of sodium hydroxide and hydrogen peroxide.** In alkaline environment under action of hydrogen peroxide \( \ce{As^{3+}} \) transforms to \( \ce{As^{5+}} \):

\[ \ce{Na_3AsO_3 + H_2O_2 = Na_3AsO_4 + H_2O} \]
3. **Action of sulphides.** The sulphides in strong acidic environment with arsenic salts form yellow precipitate:

\[
2\text{Na}_3\text{AsO}_3 + 3\text{H}_2\text{S} + 6\text{HCl} = \downarrow\text{As}_2\text{S}_3 + 6\text{NaCl} + 3\text{H}_2\text{O}
\]

Arsenic sulphide is soluble in solutions of sodium hydroxide, sodium sulphide, ammonium polysulphide, and ammonium carbonate and insoluble in concentrated chloride acid:

\[
\begin{align*}
\text{As}_2\text{S}_3 + 6\text{NaOH} &= \text{Na}_3\text{AsS}_3 + \text{Na}_3\text{AsO}_3 + 3\text{H}_2\text{O} \\
\text{As}_2\text{S}_3 + 3\text{Na}_2\text{S} &= 2\text{Na}_3\text{AsS}_3 \\
\text{As}_2\text{S}_3 + 3(\text{NH}_4)_2\text{S}_2 &= 2(\text{NH}_4)_3\text{AsS}_4 + \text{S} \\
\text{As}_2\text{S}_3 + 3(\text{NH}_4)_2\text{CO}_3 &= (\text{NH}_4)_3\text{AsS}_3 + (\text{NH}_4)_3\text{AsO}_3 + 3\text{CO}_2
\end{align*}
\]

4. **Action of silver nitrate.** In neutral or alkaline environment silver nitrate with anion \(\text{AsO}_3^{3–}\) forms yellow precipitate:

\[
\text{Na}_3\text{AsO}_3 + 3\text{AgNO}_3 = \downarrow 3\text{Ag}_3\text{AsO}_3 + 3\text{NaNO}_3
\]

Precipitate is soluble in solutions of nitric and acetic acids, and also in solution of ammonium hydroxide.

5. **Action of iodine solution.** In weak alkali environment under act of free iodine \(\text{AsO}_3^{3–}\) ions transforms in \(\text{AsO}_3^{4–}\), discolouring thus iodine solution:

\[
\text{Na}_3\text{AsO}_3 + \text{I}_2 + 2\text{NaHCO}_3 = \text{Na}_3\text{AsO}_4 + 2\text{NaI} + 2\text{CO}_2 + \text{H}_2\text{O}
\]

6. **The Marsh’s test.** The very small quantities of arsenic (< 0.1 mg) are well detected as arsine \(\text{AsH}_3\), which get after reducing of arsenic:

\[
2\text{Na}_3\text{AsO}_3 + 6\text{Zn} + 9\text{H}_2\text{SO}_4 = \uparrow 2\text{AsH}_3 + 6\text{ZnSO}_4 + 3\text{Na}_2\text{SO}_4 + 6\text{H}_2\text{O}
\]

Formed colourless arsine decomposes at heating with formation of free arsenic:

\[
2\text{AsH}_3 = \downarrow 2\text{As} + 3\text{H}_2
\]

7. **The Gutzeit’s test.** Formed after presented highly reactions arsine forms with silver nitrate yellow complex, which decomposes under action of moisture to metallic silver:

\[
\begin{align*}
\text{AsH}_3 + \text{AgNO}_3 &= [\text{AsAg}_6(\text{NO}_3)_3] + 3\text{HNO}_3 \\
[\text{AsAg}_6(\text{NO}_3)_3] + 3\text{H}_2\text{O} &= \text{H}_3\text{AsO}_3 + \downarrow 6\text{Ag} + 3\text{HNO}_3
\end{align*}
\]

– For the \(\text{AsH}_3\) detection use a paper, saturated by alcoholic solution of \(\text{HgCl}_2\). In this case vapour of arsine form orange or yellow colouring:

\[
\text{AsH}_3 + 3\text{HgCl}_2 = \text{As}(\text{HgCl})_3 + 3\text{HCl}
\]

– It is possible also to detect the \(\text{AsH}_3\) presence in case of his admission through pipe with the crystalline iodine. Thus forms arsenic iodide having red colour:

\[
\text{AsH}_3 + 3\text{I}_2 = \text{AsI}_3 + 3\text{HI}
\]
Reactions of arsenic(V) cations detection:

1. **Action of sodium hypophosphite.** Sodium hypophosphite in acidic environment reduces arsenic(III) and arsenic(V) to free arsenic, which forms sediment of brown colour or paints solution in the brown colour:

   \[
   \text{NaH}_2\text{PO}_2 + \text{HCl} = \text{NaCl} + \text{H}_3\text{PO}_2
   \]

   \[
   \text{As}_2\text{O}_5 + 5\text{H}_2\text{PO}_2 = \downarrow \text{2As} + 5\text{H}_3\text{PO}_3
   \]

2. **Action of sulphides.** Sulphides in strong acidic environment with arsenic salts form yellow precipitate:

   \[
   2\text{Na}_3\text{AsO}_4 + 5\text{H}_2\text{S} + 6\text{HCl} = \downarrow \text{As}_2\text{S}_5 + 6\text{NaCl} + 3\text{H}_2\text{O}
   \]

   The arsenic sulphide is soluble in solutions of sodium of hydroxide, sodium sulphide, ammonium polysulphide, and ammonium carbonate:

   \[
   \begin{align*}
   \text{As}_2\text{S}_5 + 6\text{NaOH} & = \text{Na}_3\text{AsS}_4 + \text{Na}_3\text{AsO}_3\text{S} + 3\text{H}_2\text{O} \\
   \text{As}_2\text{S}_5 + 3\text{Na}_2\text{S} & = 2\text{Na}_3\text{AsS}_3 + 2\text{S} \\
   \text{As}_2\text{S}_5 + 3(\text{NH}_4)_2\text{S}_2 & = 2(\text{NH}_4)_3\text{AsS}_4 + 3\text{S} \\
   \text{As}_2\text{S}_5 + 3(\text{NH}_4)_2\text{CO}_3 & = (\text{NH}_4)_3\text{AsS}_4 + (\text{NH}_4)_3\text{AsO}_3\text{S} + 3\text{CO}_2
   \end{align*}
   \]

3. **Action of silver nitrate.** In the neutral or alkaline environment silver nitrate with anion \(\text{AsO}_4^{3-}\) forms precipitate of chocolate colour:

   \[
   \text{Na}_3\text{AsO}_4 + 3\text{AgNO}_3 = \downarrow 3\text{Ag}_3\text{AsO}_4 + 3\text{NaNO}_3
   \]

   Precipitate is soluble in solutions of nitric and acetic acids, and in solution of ammonium hydroxide.

4. **Action of potassium iodide.** Potassium iodide in acidic environment reduces \(\text{AsO}_4^{3-}\) to \(\text{AsO}_3^{-3}\), the brown colouring of free iodine thus appears:

   \[
   \text{Na}_3\text{AsO}_4 + 2\text{KI} + 2\text{HCl} = \text{Na}_3\text{AsO}_3 + \text{I}_2 + 2\text{KCl} + \text{H}_2\text{O}
   \]

5. **Action of magnesial mixture.** Magnesial mixture with arsenate-ions forms white crystalline precipitate, soluble in chloride acid:

   \[
   \text{Na}_2\text{HAsO}_4 + \text{MgCl}_2 + \text{NH}_4\text{OH} = \downarrow \text{MgNH}_4\text{AsO}_4 + 2\text{NaCl} + \text{H}_2\text{O}
   \]

6. **Action of molybdenum liquid.** In acidic environment ammonium molybdate with arsenate-ions forms yellow precipitate:

   \[
   12(\text{NH}_4)_2\text{MoO}_4 + (\text{NH}_4)_3\text{AsO}_4 + 24\text{HNO}_3 = \downarrow (\text{NH}_4)_3\text{AsO}_4 \cdot 12\text{MoO}_3 + 24\text{NH}_4\text{NO}_3 + 10\text{H}_2\text{O}
   \]

7. **The Marsh’s test.** The very small quantities of arsenic (< 0,1 mg) are well detected as arsenic \(\text{AsH}_3\), which get after reducing of arsenic:

   \[
   2\text{Na}_3\text{AsO}_4 + 8\text{Zn} + 11\text{H}_2\text{SO}_4 = \uparrow 2\text{AsH}_3 + 8\text{ZnSO}_4 + 3\text{Na}_2\text{SO}_4 + 8\text{H}_2\text{O}
   \]

   Formed colourless arsine decomposes at heating with formation of free arsenic:

   \[
   2\text{AsH}_3 = \downarrow 2\text{As} + 3\text{H}_2
   \]

Reactions of arsine detection are presented among reactions of arsenic (III).
Reactions of Detection of the Fifth Analytical Group Cations

Reactions of magnesium cations detection:

1. Action of ammonium and sodium hydroxide. Ammonium and sodium hydroxide with cations to magnesium form white amorphous precipitate, soluble in acids and salts of ammonium:

\[ \text{MgCl}_2 + 2\text{NaOH} = \text{Mg(OH)}_2 \downarrow + 2\text{NaCl} \]

2. Action of sodium monohydrogenphosphate. Sodium hydrogenphosphate in presence of the chloride ammonium and ammonium hydroxide with magnesium salts forms white crystalline precipitate:

\[ \text{MgCl}_2 + \text{Na}_2\text{HPO}_4 + \text{NH}_4\text{OH} = \text{MgNH}_4\text{PO}_4 \downarrow + 2\text{NaCl} + \text{H}_2\text{O} \]

Precipitate is soluble in the strong acids and acetic acid:

\[ \text{MgNH}_4\text{PO}_4 + 3\text{HCl} = \text{H}_3\text{PO}_4 + \text{MgCl}_2 + \text{NH}_4\text{Cl} \]
\[ \text{MgNH}_4\text{PO}_4 + 2\text{CH}_3\text{COOH} = \text{Mg(CH}_3\text{COO)}_2 + \text{NH}_4\text{H}_2\text{PO}_4 \]

3. Action of 8-oxyquinolone (luminescence test). 8-oxyquinoline with magnesium ions to at pH 9-12 forms oxyquinolate fluorescing by the green colour:

\[ \text{OH} \]
\[ \text{N} \]
\[ \text{N} \]
\[ \text{N} \]
\[ \text{Mg(OH)}_2 + 2\text{N} \]
\[ \text{OH} \]
\[ + 2\text{H}_2\text{O} \]

The reaction is performed on filtration paper.

4. Action of magnesone-I and magnesone-II. Magnezone-I (p-nitrobenzenazoresorzinole) and magnesone-II (p-nitrobenzenazonaphthole) in the alkaline environment adsorb on Mg(OH)_2 precipitate, changing thus red-violet colour on dark blue:

\[ \text{O}_2\text{N} \]
\[ \text{N} \]
\[ \text{N} \]
\[ \text{OH} \]
\[ + \text{HO-Mg-OH} \rightarrow \text{O}_2\text{N} \]
\[ \text{N} \]
\[ \text{N} \]
\[ \text{OH} \]
\[ + \text{HO-Mg-OH} \rightarrow \text{O}_2\text{N} \]
\[ \text{N} \]
\[ \text{N} \]
\[ \text{OH} \]
\[ + \text{H}_2\text{O} \]

Magnesone-I
Reactions of iron(II) cations detection:

1. **Action of ammonium hydroxide and sodium hydroxide.** Ammonium hydroxide and sodium hydroxide with the iron(II) ions form amorphous grey-green precipitate, soluble in acids:

   $$FeSO_4 + 2NaOH = Fe(OH)_2 \downarrow + Na_2SO_4$$

   The precipitate quickly oxidises on air, changing colour to red-brown.

2. **Action of ammonium sulphide.** Ammonium sulphide with the iron(II) salts forms black precipitate, soluble in diluted mineral acids:

   $$FeSO_4 + (NH_4)_2S = FeS \downarrow + (NH_4)_2SO_4$$

3. **Action of potassium hexacyanoferrate(III).** Potassium hexacyanoferrate(III) with the iron(II) salts forms dark blue precipitate:

   $$3FeSO_4 + 2K_3[Fe(CN)_6] = Fe_3[Fe(CN)_6]_2 \downarrow + 3K_2SO_4$$

   The precipitate does not dissolve in acids, but decomposes by alkalis. The reaction is specific.

4. **Action of dimethylglyoxime.** Diacethyldioxime in the ammonium environment with the iron(II) ions forms soluble complex halving red colour:

5. **Action of dipyridile.** 2,2-dipyridile or o-phenanthroline in acidic environment with the iron(II) ions forms inner-complex compound halving crimson colour:
6. **Action of oxidants** (KMnO₄, I₂). Oxidants in acidic environment oxidise the iron(II) ion to iron(III) ion:

\[
10\text{FeSO}_4 + 2\text{KMnO}_4 + 8\text{H}_2\text{SO}_4 = 5\text{Fe}_2\text{(SO}_4)_3 + 2\text{MnSO}_4 + \text{K}_2\text{SO}_4 + 8\text{H}_2\text{O} \\
2\text{FeSO}_4 + \text{I}_2 + \text{H}_2\text{SO}_4 = \text{Fe}_2\text{(SO}_4)_3 + 2\text{HI}
\]

Colour of oxidisers – crimson of potassium permanganate or yellow of iodine – disappear.

### Reactions of iron(III) cations detection:

1. **Action of ammonium hydroxide and sodium hydroxide.** Ammonium hydroxide and sodium hydroxide with the iron(III) ions form amorphous red-brown precipitate, soluble in acids and insoluble in alkali surplus:

\[
\text{FeCl}_3 + 3\text{NaOH} = \text{Fe(OH)}_3\downarrow + 3\text{NaCl}
\]

2. **Action of sodium sulphide.** Sodium sulphide with solutions of iron(III) salts forms black precipitate, soluble in mineral acids:

\[
2\text{FeCl}_3 + 3\text{Na}_2\text{S} = \text{Fe}_2\text{S}_3\downarrow + 3\text{NaCl}
\]

3. **Action of potassium hexacyanoferrate(II).** Potassium hexacyanoferrate(II) in slightly acidic environment with the iron(III) salts forms navy precipitate of “Berlin blue”:

\[
4\text{FeCl}_3 + 3\text{K}_4[\text{Fe(CN)}_6] = \text{Fe}_4[\text{Fe(CN)}_6]_3\downarrow + 12\text{KCl}
\]

The precipitate does not dissolve in the mineral acids, but soluble in solution of oxalic acid with the complex formation. The reaction is specific.

5. **Action of thiocyanates.** Potassium or ammonium thiocyanate in slightly acidic environment with the iron(III) salts form the complex halving bloody-red colour:

\[
\text{FeCl}_3 + 3\text{KSCN} = \text{Fe(SCN)}_3 + 3\text{KCl}
\]

6. **Action of sodium acetate.** Sodium acetate with the iron(III) ions at cold forms iron(III) acetate with red-brown colour:

\[
\text{FeCl}_3 + 3\text{CH}_3\text{COONa} = \text{Fe(CH}_3\text{COO)}_3 + 3\text{NaCl}
\]
If to dilute solution by water and to boil, the formed compound hydrolyses with formation of basic salt, which falls as brown precipitate:

\[
\text{Fe(CH}_3\text{COO)}_3 + 2\text{H}_2\text{O} = \text{Fe(OH)}_2(\text{CH}_3\text{COO})\downarrow + 2\text{CH}_3\text{COOH}
\]

7. **Action of potassium iodide.** Potassium iodide reduces the iron(III) ions to the iron(II) ions. As a result of reaction an iodine forms and solution changes colour to brown:

\[
2\text{FeCl}_3 + 2\text{KI} = 2\text{FeCl}_2 + \text{I}_2 + 2\text{KCl}
\]

If to the test-tube add few drops of benzene or chloroform and shake mixture, the iodine will pass to organic solvent and change colour of organic phase on violet.

8. **Action of sulphosalicylic acid.** Sulphosalicylic acid in acidic solutions (pH 1.8 – 2.5) with the iron(III) ions forms stabile complex with red-violet colour:

\[
\text{HO}_2\text{C} - \text{COOH} + \text{FeCl}_3 \rightarrow \text{HO}_2\text{C} - \text{COO}^- + \text{Fe}^{3+} + \text{Cl}^-
\]

At the indicated acidity the reaction is specific for iron(III) ions.

**Reactions of manganese(II) cations detection:**

1. **Action of sodium hydroxide and ammonium hydroxide.** Hydroxides of alkaline metals and ammonium hydroxide precipitate from solutions of manganese(II) salts the white precipitate \(\text{Mn(OH)}_2\), which changes to brown on air as a result of oxidisation by air oxygen to \(\text{MnO(OH)}_2\):

\[
\text{MnSO}_4 + 2\text{NaOH} = \text{Mn(OH)}_2\downarrow + \text{Na}_2\text{SO}_4
\]

\[
2\text{Mn(OH)}_2 + \text{H}_2\text{O} + \text{O}_2 = 2\text{Mn(OH)}_4
\]

\[
\text{Mn(OH)}_4 = \text{MnO(OH)}_2 + \text{H}_2\text{O}
\]

Precipitate is insoluble in alkalis, soluble in acids.

2. **Action of ammonium sulphide.** Ammonium sulphide with manganese(II) cations forms light-brown precipitate:

\[
\text{MnSO}_4 + (\text{NH}_4)_2\text{S} = \text{MnS} \downarrow + (\text{NH}_4)_2\text{SO}_4
\]

Precipitate is soluble in diluted mineral acids.

3. **Action of oxidants.** Oxidants in acidic environment oxidise the manganese(II) cation to \(\text{MnO}_4^-\) anion, which in solutions has the character raspberry (crimcon) colour:

- **ammonium persulphate:**

\[
2\text{MnSO}_4 + 5(\text{NH}_4)_2\text{S}_2\text{O}_8 + 8\text{H}_2\text{O} = 2\text{HMnO}_4 + 5(\text{NH}_4)_2\text{SO}_4 + 7\text{H}_2\text{SO}_4
\]

Cations reactions
A reaction is performed at heating in presence AgNO\textsubscript{3} catalyst.

- **lead dioxide:**
  \[
  2\text{MnSO}_4 + 5\text{PbO}_2 + 6\text{HNO}_3 = 2\text{HMnO}_4 + 2\text{PbSO}_4 + 3\ \text{Pb(NO}_3)_2 + 2\text{H}_2\text{O}
  \]

- **sodium bismuthate:**
  \[
  2\text{Mn(NO}_3)_2 + 5\text{NaBiO}_3 + 16\text{HNO}_3 = 2\text{HMnO}_4 + 5\text{Bi(NO}_3)_3 + 5\text{NaNO}_3 + 7\text{H}_2\text{O}
  \]

**Reactions of bismuth cations detection:**

1. **Action of sodium hydroxide and ammonium hydroxide.** The alkalis form white precipitate of bismuth hydroxide, which dissolves in acids and does not dissolve in alkalis:
   \[
   \text{BiCl}_3 + 3\text{NaOH} = \text{Bi(OH)}_3↓ + 3\text{NaCl}
   \]
   The bismuth hydroxide at boiling transfers to yellow bismuthyl hydroxide Bi(OH).

2. **Action of sodium sulphide.** Sodium sulphide in acidic environment with the bismuth(III) salts gives brown-black precipitate:
   \[
   \text{BiCl}_3 + 3\text{Na}_2\text{S} = \text{Bi}_2\text{S}_3↓ + 6\text{NaCl}
   \]
   Precipitate is insoluble in the diluted acids, except concentrated nitrate acid:
   \[
   \text{Bi}_2\text{S}_3 + 8\text{HNO}_3 = 2\text{Bi(NO}_3)_3 + 2\text{NO}↑ + 3\text{S}↓ + 4\text{H}_2\text{O}
   \]

3. **Action of thiourea and sodium fluoride.** Bismuth ions with thiourea forms various complexes with yellow colour:
   \[
   \text{Bi(NO}_3)_3 + 9\ \text{S}≡\text{C}\ \text{NH}_2 \rightarrow \left[\begin{array}{c}
   \text{Bi} \\
   \text{S}≡\text{C} \\
   \text{NH}_2/9
   \end{array}\right] (\text{NO}_3)_3
   \]

4. **Action of potassium iodide.** Potassium iodide precipitates from solutions of bismuth salts black precipitate BiI\textsubscript{3}, soluble in surplus of reagent with formation of yellow complex:
   \[
   \text{BiCl}_3 + 3\text{KI} = \text{BiI}_3↓ + 3\text{KCl}
   \]
   \[
   \text{BiI}_3 + \text{KI} = \text{K}[\text{BiI}_4]
   \]

5. **Action of sodium stannite.** Reducers (SnCl\textsubscript{2}) reduce ions of bismuth(III) to metallic bismuth, which falls as black precipitate:
   \[
   \text{SnCl}_2 + 4\text{NaOH} = \text{Na}_2\text{SnO}_3 + 2\text{NaCl} + 2\text{H}_2\text{O}
   \]
   \[
   \text{Bi(NO}_3)_3 + 3\text{NaOH} = \text{Bi(OH)}_3↓ + 3\text{NaNO}_3
   \]
   \[
   2\text{Bi(OH)}_3 + 3\text{Na}_2\text{SnO}_2 = 3\text{Na}_2\text{SnO}_3 + 2\text{Bi}↓ + 3\text{H}_2\text{O}
   \]
6. **Hydrolysis of bismuth salts.** In case of dilution of bismuth salts solutions occurs hydrolysis with formation of compounds of bismuth(III) oxide (bismuthyl) BiO⁺ having white colour:

\[
\begin{align*}
\text{BiCl}_3 + 2\text{H}_2\text{O} &= \text{Bi(OH)}_2\text{Cl}↓ + 2\text{HCl} \\
\text{Bi(OH)}_2\text{Cl} &= \text{BiOCl}↓ + \text{H}_2\text{O}
\end{align*}
\]

Precipitate is soluble in mineral acids and insoluble in tartaric acid.

---

**Reactions of antimony(III) [stibium(III)] cations detection:**

1. **Action to sodium hydroxide and ammonium hydroxide.** Alkalis and ammonium hydroxide with salts of antimony(III) form white precipitate:

\[
\text{SbCl}_3 + 3\text{NaOH} = \text{Sb(OH)}_3↓ + 3\text{NaCl}
\]

Fresh precipitate is soluble in alkalis with formation Na[Sb(OH)₃] complex, and also in strong acids with formation of the proper salts.

2. **Action of hydrogen sulphide.** Hydrogen sulphide with salts of antimony(III) in acidic environment forms orange-red precipitate:

\[
2\text{SbCl}_3 + 3\text{Na}_2\text{S} = \text{Sb}_2\text{S}_3↓ + 6\text{NaCl}
\]

Precipitate is soluble at heating in Na₂S surplus with formation of thiosalts and also in solutions of alkalis:

\[
\begin{align*}
\text{Sb}_2\text{S}_3 + 3\text{Na}_2\text{S} &= 2\text{Na}_3\text{SbS}_3 \\
\text{Sb}_2\text{S}_3 + 4\text{NaOH} &= \text{Na}[\text{Sb(OH)}_4] + \text{Na}_3\text{SbS}_3
\end{align*}
\]

3. **Action of metals.** Cations of antimony in acidic environment reduces by metals, which are more active electrochemically – zinc, tin, iron, aluminium; the metallic plate thus turns black:

\[
2\text{SbCl}_3 + 3\text{Zn} = 2\text{Sb}↓ + 3\text{ZnCl}_2
\]

4. **Hydrolysis of antimony (III) salts.** Salts of antimony(III) in slightly acidic solutions hydrolyse forming salts of antimony(III) oxide (antimonyl) SbO⁻ white colour:

\[
\text{SbCl}_3 + \text{H}_2\text{O} = \text{SbOCl}↓ + 2\text{HCl}
\]

5. **Reaction with rhodamine B.** Rhodamine B and other basic triphenylmethane dyes (methyl violet, diamond green) in chloride acid solution with chloride complex of antimony(V) form ionic associate insoluble in water and painted in violet colour:

\[
\text{Rhodamine B} + \text{H[SbCl}_6\text{]} \rightarrow \text{ionic associate}
\]
The complex extracts by benzene and iso-propanole. For transformation of antimony(III) in antimony(V) add concentrated chloride acid and sodium nitrite.

**Reactions of antimony(V) cations detection:**

1. **Action of sodium hydroxide and ammonium hydroxide.** Alkalis and ammonium hydroxide with salts of antimony(V) form white precipitate:

   $$\text{H}[\text{SbCl}_6] + 6\text{NaOH} = \text{SbO(OH)}_3\downarrow + 6\text{NaCl} + 2\text{H}_2\text{O}$$

   Precipitate is soluble in strong acids:

   $$\text{SbO(OH)}_3 + 6\text{HCl} = \text{H}[\text{SbCl}_6] + 4\text{H}_2\text{O}$$

2. **Action of hydrogen sulphide.** Hydrogen sulphide with salts of antimony(V) in acidic environment forms orange-red precipitate:

   $$2\text{H}[\text{SbCl}_6] + 5\text{H}_2\text{S} = \text{Sb}_2\text{S}_5\downarrow + 12\text{HCl}$$

   Precipitate is soluble at heating in Na₂S surplus with formation of thiosalts, and in solutions of alkalis:

   $$\text{Sb}_2\text{S}_5 + 3\text{Na}_2\text{S} = 2\text{Na}_3\text{SbS}_4$$
   $$4\text{Sb}_2\text{S}_5 + 18\text{NaOH} = 3\text{Na}_3[\text{Sb(OH)}_6] + 5\text{Na}_3\text{SbS}_4$$

3. **Action of metals.** Cations of antimony in acidic environment reduce by electrochemically more active metals (zinc, tin, iron, aluminium) to free antimony; the metallic plate thus turns black:

   $$2\text{H}[\text{SbCl}_6] + 5\text{Zn} = 2\text{Sb} + 5\text{ZnCl}_2 + 2\text{HCl}$$

4. **Hydrolysis of antimony(V) salts.** At hydrolysis of salts of antimony(V) forms white precipitate of basic salt of antimony(V), soluble in surplus of chloride acid:

   $$\text{H}[\text{SbCl}_6] + 2\text{H}_2\text{O} = \downarrow\text{SbO}_2\text{Cl} + 5\text{HCl}$$

5. **Reaction with rhodamine B.** Rhodamine B and other basic triphenylmethane dyes (methyl violet, diamond green) in chloride acid solution with chloride complex of antimony(V) form insoluble in water, painted in the violet colour ionic associate:
Cations reactions

\[(C_2H_5)_2N\text{[O}N\text{[N}(C_2H_5)_2\text{Cl}^- + H[SbCl}_6]_2\text{O}

\[(C_2H_5)_2N\text{[O}N\text{[N}(C_2H_5)_2\text{Cl}^- + H[SbCl}_6]_2\text{O}

The complex well extracts by benzene and iso-propanole.
Reactions of the Sixth Analytical Group Cations Detection

Reactions of cadmium cations detection:

1. Action of ammonium hydroxide and sodium hydroxide. Ammonium hydroxide in equivalent quantities and sodium hydroxide with solutions of cadmium salts form white precipitate, insoluble in alkalis, soluble in acids and ammonia solutions with formation of colourless complex of tetraammin-cadmium-ion:

   \[ \text{CdCl}_2 + 2\text{NH}_4\text{OH} = \text{Cd(OH)}_2 \downarrow + 2\text{NH}_4\text{Cl} \]
   \[ \text{Cd(OH)}_2 + 4\text{NH}_3 = [\text{Cd(NH}_3)_4](\text{OH})_2 \]

2. Action of sodium sulphide. Hydrogen sulphide or sulphides of alkaline metals at pH ~ 0,5 with cadmium ions form yellow precipitate, insoluble in solution of sodium sulphide and sodium hydroxide, soluble in concentrated chloride and nitrate acids:

   \[ \text{CdCl}_2 + \text{H}_2\text{S} = \text{CdS} \downarrow + 2\text{HCl} \]
   \[ \text{CdS} + 4\text{HCl} = \text{H}_2[\text{CdCl}_4] + \text{H}_2\text{S} \]
   \[ \text{CdS} + 4\text{HNO}_3 = \text{Cd(NO}_3)_2 + \text{S} \downarrow + 2\text{NO}_2 \uparrow + 2\text{H}_2\text{O} \]
   \[ \text{CdS} + \text{H}_2\text{SO}_4 = \text{CdSO}_4 + \text{H}_2\text{S} \]

3. Action of sodium hydrogen phosphate. Sodium hydrogen phosphate forms white precipitate, soluble in acetic and mineral acids:

   \[ 3\text{Cd(NO}_3)_2 + 4\text{Na}_2\text{HPO}_4 = \text{Cd}_3(\text{PO}_4)_2 \downarrow + 2\text{NaH}_2\text{PO}_4 + 6\text{NaNO}_3 \]

4. Action of ammonium perchlorate. Ammonium perchlorate in ammonium solutions of cadmium salts forms white precipitate:

   \[ \text{Cd(NO}_3)_2 + 2\text{NH}_4\text{ClO}_4 + 4\text{NH}_3 = \text{Cd}[\text{(NH}_3)_4]\text{(ClO}_4)_2 \downarrow + 2\text{NH}_4\text{NO}_3 \]

5. Action of dithizone. Dithizone interacts with cadmium ions in interval pH 6,5-14 with formation of red inner-complex compound, which can be extracted by chloroform or carbon tetrachloride:
Reactions of cobalt(II) cations detection:

1. **Action of ammonium hydroxide.** Ammonium hydroxide precipitates from solutions of cobalt salts dark blue precipitate of basic salt, soluble in the reagent surplus with formation of yellow complex of hexaamminecobalt(II):

$$\text{CoCl}_2 + \text{NH}_3 + \text{H}_2\text{O} = \text{CoOHCl}_\downarrow + \text{NH}_4\text{Cl}$$
$$\text{CoOHCl} + \text{NH}_3 + \text{NH}_4\text{Cl} = \text{Co}[(\text{NH}_3)_6]\text{Cl}_2 + \text{H}_2\text{O}$$

The chloride of hexaamminecobalt(II) under act of air oxygen gradually passes to the chloride of pentaamminecobalt(III) $\text{Co}[(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$ red colour. This reaction passes instantly under act of $\text{H}_2\text{O}_2$.

2. **Action of sodium hydroxide.** The alkalis form with the cobalt(II) ions dark blue precipitate of basic salt $\text{CoOHCl}$:

$$\text{CoCl}_2 + \text{NaOH} = \text{CoOHCl}_\downarrow + \text{NaCl}$$

In case of further addition of alkali and heating the precipitate transforms to cobalt(II) hydroxide rose colour:

$$\text{CoOHCl} + \text{NaOH} = \text{Co(OH)}_2\downarrow + \text{NaCl}$$

On air $\text{Co(OH)}_2$ precipitate gradually change colour to brown, transforming to cobalt(III) hydroxide.

3. **Action of sodium sulphide.** Sulphides form black precipitate, soluble in mineral acids:

$$\text{CoCl}_2 + \text{Na}_2\text{S} = \text{CoS}_\downarrow + 2\text{NaCl}$$

4. **Action of thiocyanates.** Ammonium thiocynate in presence an amyl alcohol with the cobalt salts forms dark-blue complex, which passes to layer of organic solvent:

$$\text{CoCl}_2 + 4\text{NH}_4\text{SCN} = (\text{NH}_4)_2[\text{Co(SCN)}_4] + 2\text{NH}_4\text{Cl}$$

5. **Action of ammonium tetrathiocyanomercurate(II).** Ammonium tetrathiocyanomercurate(II) with the cobalt ions forms blue complex:

$$2(\text{NH}_4)_2[\text{Hg(SCN)}_4] + \text{CoSO}_4 = \text{Co}[\text{Hg(SCN)}_4]_\downarrow + 2(\text{NH}_4)_2\text{SO}_4$$

This reagent in presence of zinc salts forms double salt of cobalt-zinc tetrathiocyanomercurate(II) having navy colour:

$$2(\text{NH}_4)_2[\text{Hg(SCN)}_4] + \text{CoSO}_4 + \text{ZnSO}_4 = \text{Zn}[\text{Hg(SCN)}_4]\cdot\text{Co}[\text{Hg(SCN)}_4]_\downarrow + 2(\text{NH}_4)_2\text{SO}_4$$

6. **Action of $\alpha$-nitroso-$\beta$-napthole.** $\alpha$-nitroso-$\beta$-napthole with the cobalt(III) ions forms red-brown precipitate, soluble in organic solvents – chloroform and benzene. The oxidization of cobalt(II) to cobalt(III) takes place in acidic environment under action of hydrogen peroxide:

\[
\begin{align*}
\text{NO} & \quad \text{OH} \\
\text{N-OH} & \quad \text{O}
\end{align*}
\]
7. Reaction of “Rinmann’s green” formation. After burning a piece of filtration paper, moistened by solution of zinc and cobalt nitrate, get an ash, painted in green colour of cobalt zincate:

\[
\text{Zn(NO}_3\text{)}_2 + \text{Co(NO}_3\text{)}_2 = \text{CoZnO}_2 + 4\text{NO}_2 + \text{O}_2
\]

Reactions of copper(II) cations detection:

1. Action of ammonium hydroxide. At first ammonium hydroxide from solutions of copper(II) salts forms blue-green precipitate of basic salts of copper, which dissolves in the reagent surplus with formation of intensive navy complex:

\[
\text{CuSO}_4 + 2\text{NH}_3\text{OH} = (\text{CuOH})_2\text{SO}_4 \downarrow + (\text{NH}_4)_2\text{SO}_4
\]

\[
(\text{CuOH})_2\text{SO}_4 + (\text{NH}_4)_2\text{SO}_4 + 6\text{NH}_3 = 2[\text{Cu(NH}_3)_4]\text{SO}_4 + 2\text{H}_2\text{O}
\]

In case of acidifying the ammonium complex of copper destroys as a result of exchange of ammonium molecules to \(\text{H}^+\) ions with formation of more stable \(\text{NH}_4^+\) complex. The navy colour of solution thus changes on blue.

2. Action to sodium hydroxide. Hydroxides of alkaline metals with copper(II) ions forms blue precipitate, which in case of heating loses water and transfers to black oxide:

\[
\text{CuSO}_4 + 2\text{NaOH} = \text{Cu(OH)}_2 \downarrow + 2\text{Na}_2\text{SO}_4
\]

\[
\text{Cu(OH)}_2 = \downarrow\text{CuO} + \text{H}_2\text{O}
\]

\(\text{Cu(OH)}_2\) soluble in the ammonia solutions and organic acids (tartaric, citric) with complexes formation. In concentrated solutions of alkalis \(\text{Cu(OH)}_2\) dissolves, forming cuprites \(\text{Na}_2\text{CuO}_2\).

3. Reducing reaction. The reaction of copper(II) ions reducing to elemental copper can be carried out by more active metals (iron, zinc, aluminium):

\[
\text{CuSO}_4 + \text{Zn} = \text{Cu} \downarrow + \text{ZnSO}_4
\]

An acidified by sulphate or chloride acid solution of copper salt places on metallic plate. On the plate appears red spot of free copper.
4. **Action of potassium hexacyanoferrate(II).** Potassium hexacyanoferrate(II) with the copper salts forms red-brown precipitate, insoluble in diluted acids:

\[
2\text{CuSO}_4 + K_4[\text{Fe(CN)}_6] = \text{Cu}_2[\text{Fe(CN)}_6] \downarrow + 2K_2\text{SO}_4
\]

5. **Action of cuprone (α–benzoynoxime).** Cuprone with the copper(II) ions forms insoluble dark-green complex:

6. **Flame test.** Salts of copper(II) paint colourless flame in dark blue or green colour.

**Reactions of nickel cations detection:**

1. **Action of ammonium hydroxide.** Ammonium hydroxide from solutions of nickel(II) salts precipitates green precipitate of basic salt of nickel(II), soluble in surplus of reagent with formation of indigo blue complex:

   \[
   \text{Ni(NO}_3\text{)}_2 + \text{NH}_3 + \text{H}_2\text{O} = \text{NiOHNO}_3 \downarrow + \text{NH}_4\text{NO}_3
   
   \text{NiOHNO}_3 + \text{NH}_4\text{NO}_3 + 5\text{NH}_3 = [\text{Ni}(\text{NH}_3)_5]\text{(NO}_3\text{)}_2 + \text{H}_2\text{O}
   \]

2. **Action of sodium hydroxide.** Alkalis with nickel(II) ions form soluble in acids green precipitate:

   \[
   \text{NiSO}_4 + 2\text{NaOH} = \text{Ni(OH)}_2 \downarrow + \text{Na}_2\text{SO}_4
   \]

3. **Action of sodium monohydrogenphosphate.** Sodium hydrogenphosphate with nickel(II) cations forms green precipitate:

   \[
   3\text{Ni(NO}_3\text{)}_2 + 4\text{Na}_2\text{HPO}_4 = \text{Ni}_3(\text{PO}_4)_2 \downarrow + 2\text{NaH}_2\text{PO}_4 + 6\text{NaNO}_3
   \]

4. **Action of diacetyl dioxime.** Diacetyl dioxime with nickel ions forms inner-complex compound halving red colour:

The reaction performs on filtration paper and uses for fractional method.
Reactions of mercury cations detection:

1. **Action of ammonium hydroxide.** Ammonia solution from water solutions of mercury(II) salts precipitates white precipitate, soluble in the reagent surplus with formation of colourless complex:

   \[
   \text{HgCl}_2 + 2\text{NH}_3 = \text{HgNH}_2\text{Cl}↓ + \text{NH}_4\text{Cl} \\
   \text{HgNH}_2\text{Cl} + \text{NH}_4\text{Cl} + 2\text{NH}_3 = [\text{Hg(NH}_3)_4]\text{Cl}_2
   \]

2. **Action of sodium hydroxide.** Hydroxides of alkaline metals from water solutions of mercury(II) salts precipitate yellow precipitate:

   \[
   \text{HgCl}_2 + 2\text{NaOH} = \text{HgO}↓ + 2\text{NaCl} + \text{H}_2\text{O}
   \]

3. **Action of iodides.** Potassium iodide with mercury(II) cations forms brightly red precipitate, soluble in surplus of reagent with formation of the colourless complex:

   \[
   \text{HgCl}_2 + 2\text{KI} = \text{HgI}_2↓ + 2\text{KCl} \\
   \text{HgI}_2 + 2\text{KI} = K_2[\text{HgI}_4]
   \]

   The reaction goes in weak acidic environment. The reaction with iodides uses for mercury(II) cations detection by drops technique in presence of all another cations: the red spot of HgI₂ forms in the centre of filter paper.

4. **Action of sulphides. Solubility of sulphides.** Sodium sulphide from solutions of mercury(II) salts precipitates brown-black precipitate:

   \[
   \text{HgCl}_2 + \text{Na}_2\text{S} = \text{HgS}↓ + 2\text{NaCl}
   \]

   Precipitate is insoluble in chloride and nitrate acids, but soluble in mixture of this acids (“aqua regia”):

   \[
   3\text{HgS} + 2\text{HNO}_3 + 12\text{HCl} = 3\text{H}_2[\text{HgCl}_4] + 3\text{S}↓ + 2\text{NO}↑ + 4\text{H}_2\text{O}
   \]

5. **Action of reducers.** Reducers (SnCl₂, Cu) proceed mercury(II) cations to mercury(I) cations, and then to the free mercury. In solutions or on filtration paper in case of interaction of mercury salts with tin(II) chloride appears black precipitate of free mercury:

   \[
   \text{HgCl}_2 + \text{SnCl}_2 = \text{Hg}_2\text{Cl}_2↓ + \text{SnCl}_4 \\
   \text{Hg}_2\text{Cl}_2 + \text{SnCl}_2 = 2\text{Hg}↓ + \text{SnCl}_4
   \]

   If on copper plate to place a drop of mercury(II) salt solution, on plate through 4-5 min. will appear black precipitate of free mercury:

   \[
   \text{HgCl}_2 + \text{Cu} = \text{Hg}↓ + \text{CuCl}_2
   \]

   In case of the spot rubbing a brilliant plaque of copper amalgam appears.

6. **Action of diphenylcarbaside.** Diphenylcarbaside with mercury(II) salts in itrate acid environment forms dark blue or violet complex:
Cations reactions