

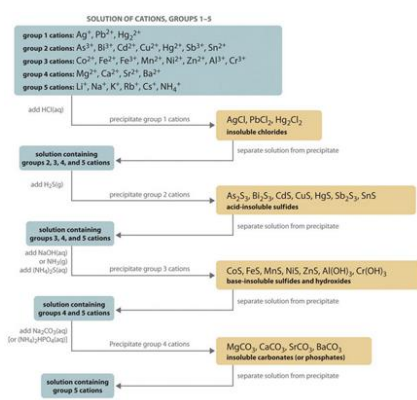
Review Article

Metal Ions of Cations and Anions Separation and Detection Approach

Ayman Y. El-Khateeb

Agricultural Chemistry Department, Faculty of Agriculture, Mansoura University, Mansoura, Egypt

GRAPHICAL ABSTRACT ABSTRACT



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Recent investigation presents exciting, simple and manual procedures to separate and detect different salt radicals of both cations and anions qualitatively and quantitatively. Salt defined as a chemical compound that produces from the reaction of the acid with a base. So, Acid definition, it is a chemical compound that contains reactive hydrogen (meaning that any positive ion or metal can replace all or part of it) reacts with oxides or hydroxides and gives salt and water. Furthermore, the base is defined as a substance that reacts with acids to produce salt and water only. Basic radicals (cations) are often a metal, which is the part of the salt shared by the base or alkali in its formation. Basic radicals carry positive charges when ionized and separated from the original salt in water and are called cations and are attracted to the cathode. Acid radicals (Anions) is the part of the salt that is already in the acid from which it is derived or is the part of the salt that the acid shares. Acid radical carries negative charges when ionized and separated from the original salt in water and are called anions and are attracted to the anode. Descriptive analysis is complete when it verifies the presence of basic and acidic radicals in the material to be examined and often suffices without specifying the truth of the salts formed.

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INTRODUCTION

Classical qualitative inorganic analysis is a method of analytical chemistry that seeks to find the elemental composition of inorganic compounds. It is mainly focused on detecting ions in an aqueous solution, therefore materials in other forms may need to be brought to this state before using

standard methods. The solution is then treated with various reagents to test for reactions characteristic of certain ions, which may cause a color change, precipitation and other visible changes [1].

The qualitative inorganic analysis is that branch or method of analytical chemistry which seeks to

* Corresponding author: **Ayman Y. El-Khateeb**

Tel number: +201066304149, ; Fax: +20502221688

E-mail: aymanco@mans.edu.eg, RCID link: [0000-0003-4014-524X](#).

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establish the elemental composition of inorganic compounds through various reagents[2].

According to their properties, cations are usually classified into six groups. Each group has a common reagent that can be used to separate them from the solution. To obtain meaningful results, the separation must be done in the sequence specified below, as some ions of an earlier group may also react with the reagent of a later group, causing ambiguity as to which ions are present[3]. This happens because cationic analysis is based on the solubility products of the ions. As the cation gains its optimum concentration needed for precipitation it precipitates and hence allowing us to detect it. The division and precise details of separating into groups vary slightly from one source to another; given below is one of the commonly used schemes[4].

The qualitative inorganic analysis is now used only as a pedagogical tool. Modern techniques such as atomic absorption spectroscopy and ICP-MS can quickly detect the presence and concentrations of elements using a very small amount of sample[5].

Reactions of metal ions in solutions and detection methods

1. The basic radicals (Cations) and divided into groups

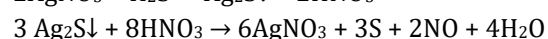
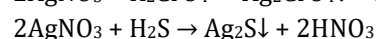
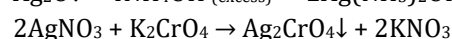
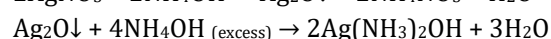
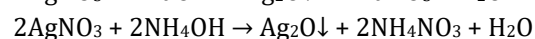
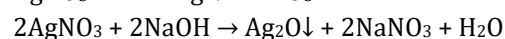
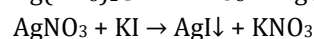
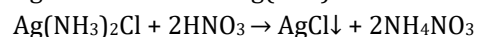
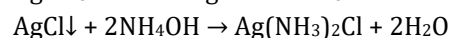
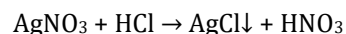
The basic radicals (Cations) in the descriptive analysis are divided into six analytical groups. This division is based on the solubility product (the dissolution of the salts of these metals in water). The solution or solutions used to precipitate any group is called the group reagent. It reacts and precipitate with all the cations present in these metals. Groups in which this detector is divided into two reagents: The modified reagent is added first and acts as a group deposition regulator. Precipitating reagent is added second and contains the precipitated ion of the group's cations[6].

1.1. First Group

The first group of cation radicals contains three cations namely: Silver (Ag^+), Mercurous (Hg_2^{2+}) and Lead (Pb^{2+}).

1.1.1. Silver (Ag^+)

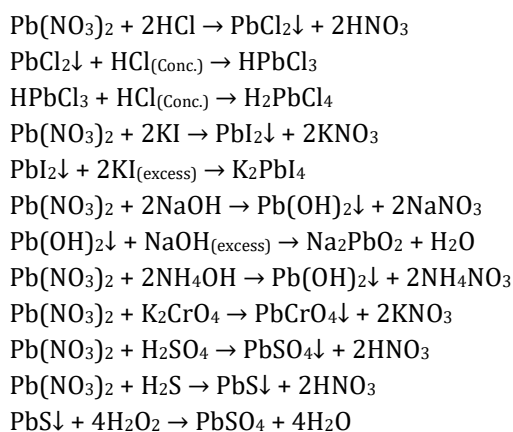
A silver nitrate solution (AgNO_3) reacts with a diluted hydrochloric acid solution (HCl) to produce a white precipitate of silver chloride is darkened in light, the precipitate does not dissolve in dilute acids and dissolves in ammonium hydroxide solution to form the ammonia silver chloride solution. When dilute nitric acid is added to this solution, silver chloride is deposited again. Also, silver nitrate reacts with potassium iodide solution (KI) and a pale-yellow precipitate is formed of silver iodide that does not dissolve in ammonium hydroxide solution but soluble in sodium thiosulfate solution. Additionally, ammonium Hydroxide solution (NH_4OH) produce a white precipitate of silver hydroxide is rapidly transformed into a precipitate of silver oxide, dissolving in excess of the reagent, forming a complex compound of ammonia silver hydroxide. Moreover, an insoluble brown precipitate is formed with a reaction with sodium hydroxide solution (NaOH). Furthermore, potassium chromate solution (K_2CrO_7) produce a red brick precipitate of silver chromate is not soluble in acetic acid but soluble in ammonium hydroxide and nitric acid solution. Finally, hydrogen sulfide (H_2S) by passaging of the gas in the solution, a black precipitate of silver sulfide appears not soluble in water or ammonium hydroxide but soluble in hot dilute nitric acid. The following equations confirm the chemical reactions of the investigated item[7].



1.1.2. Lead (Pb^{2+})

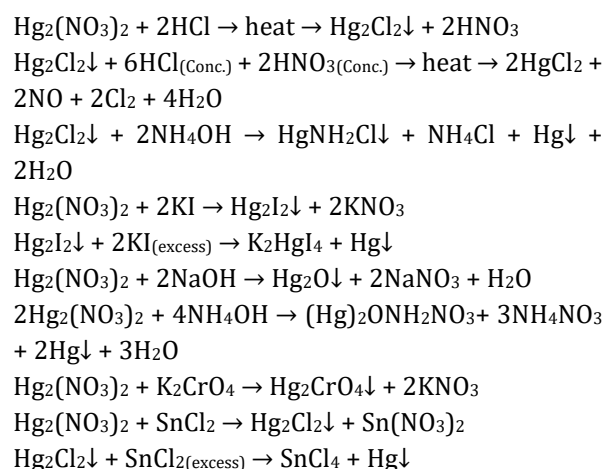
A lead nitrate solution $\text{Pb}(\text{NO}_3)_2$ reacts with a diluted hydrochloric acid solution (HCl) to produce

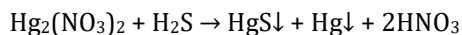
a white precipitate of lead chloride is dissolved in hot water and refrigerated. Lead chloride is separated from the solution again in a crystalline form. The precipitate is dissolved in concentrated HCl acid, forming soluble complexes in water. Also, lead nitrate reacts with potassium iodide solution (KI) and a yellow precipitate of lead iodide dissolves in boiling water, the yellow color disappears and is cooled back in the form of golden yellow crystals. It also dissolves in the excess of the reagent, forming a complex salt of lead potassium iodide dissolved by diluting with water and precipitating lead iodide again. Moreover, sodium hydroxide solution (NaOH) forms a white precipitate of lead hydroxide that dissolves in excess of the reagent forming a sodium lead solution. While a non-soluble white precipitate is formed from the reagent of ammonium hydroxide solution (NH₄OH). Potassium chromate solution (K₂CrO₇) produces a yellow precipitate of lead chromate not soluble in acetic acid or ammonium hydroxide but dissolved in dilute nitric acid and alkaline hydroxide solutions. Likewise, dilute sulfuric acid solution (H₂SO₄) form a white precipitate of lead sulfate is dissolved in concentrated ammonium acetate solution. Finally, hydrogen sulfide (H₂S) as the gas passes through the solution, a black lead of sulfide becomes a white precipitate by treating it with oxidants such as hydrogen peroxide, where sulfide is oxidized to sulfate. Lead sulfide is dissolved in hot dilute nitric acid. The following equations confirm the chemical reactions of the investigated item[7].



1.1.3. Mercurous (Hg₂²⁺)

Mercurous nitrate solution Hg₂(NO₃)₂ reacts with a diluted hydrochloric acid solution (HCl) to produce a white precipitate of mercury chloride is not soluble in hot water or cold dilute acids but soluble in royal water aqua regia (HCl_(Conc.): HNO_{3(Conc.)} 3: 1) with heating where it is converted to mercury chloride. With the addition of ammonium hydroxide solution to the mercury chloride precipitate, a white precipitate of mercury amine chloride is formed. Potassium iodide solution (KI), a green or yellowish-green precipitate is formed from mercury iodide, which dissolves in excess of the reagent, forming a complex compound of mercury-iodide mercury (Nessler reagent) as well as mercury in the form of a fractionated black precipitate (in case of fine fractionation). sodium hydroxide solution (NaOH), the black precipitate is composed of mercury oxide which does not dissolve in excess of the reagent. Ammonium Hydroxide Solution (NH₄OH), a black sludge containing a single mercury fragmentation appears (in case of fine fractionation). Potassium chromate solution (K₂CrO₇), a brown precipitate is formed from mercury chromate that has no amorphous shape and becomes boiling into red crystals with a specific crystal shape. Stannous chloride solution (SnCl₂), a white precipitate that is further converted from the reagent into a gray precipitate containing individual mercury is formed in the case of fine fractionation. Hydrogen sulfide (H₂S), as the gas passes through the solution, a black deposit of mercury sulfide and single mercury appears. The following equations confirm the chemical reactions of the investigated item[7].





The separation of the first group cations in a mixture depends on the following points.

The chlorides of this group do not dissolve in water while the chlorides of the other groups dissolve in water, because the yield of soluble cations of the first group is very low compared to the solubility of the cations of the other groups. The solubility of lead chloride in hot water is cooled again while silver chloride or mercury chloride is not affected. Silver chloride is dissolved in ammonium hydroxide while mercury chloride does not dissolve and the mercury amine chloride is formed[6].

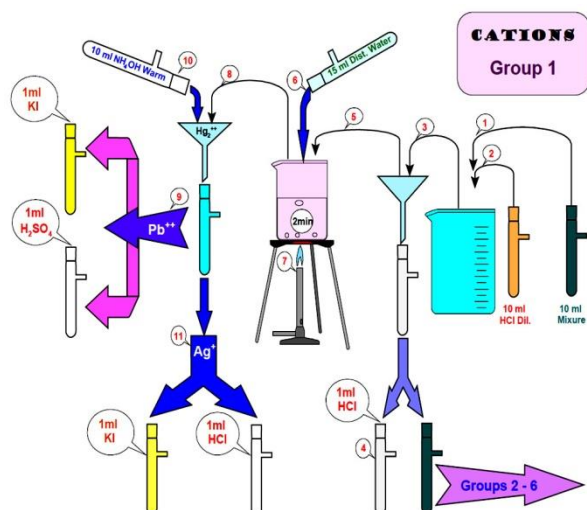


Fig. 1. Schematic diagram of the separation and detection for first group cations mixture.

1.2. Second Group

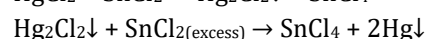
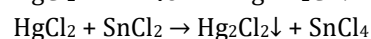
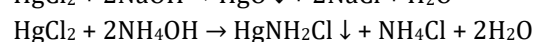
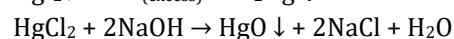
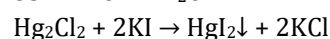
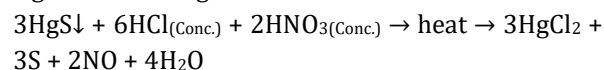
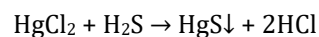
This group is characterized by the fact that the aqueous solutions containing the components of its components are precipitated from the sulfide salts when the hydrogen sulfide gas passes through it in the acidic medium. Dissolves stannous (Sn^{2+} , Sn^{4+}), arsenic (As^{3+} , As^{5+}), antimony (Sb^{3+} , Sb^{5+}) sulfides in the yellow ammonium sulfide solution (NH_4)₂S, unlike the rest of the elements of this group that do not dissolve in the yellow ammonium sulfide solution (NH_4)₂S, and so the cations were divided into two subgroups A and B [6].

Subgroup A: Lead (Pb^{2+}), Mercuric (Hg^{2+}), Copper (Cu^{2+}), Cadmium (Cd^{2+}) and Bismuth (Bi^{3+}).

Subgroup B: Stannous (Sn^{2+} , Sn^{4+}), Arsenic (As^{3+} , As^{5+}) and Antimony (Sb^{3+} , Sb^{5+}).

1.2.1. Mercuric (Hg^{2+}).

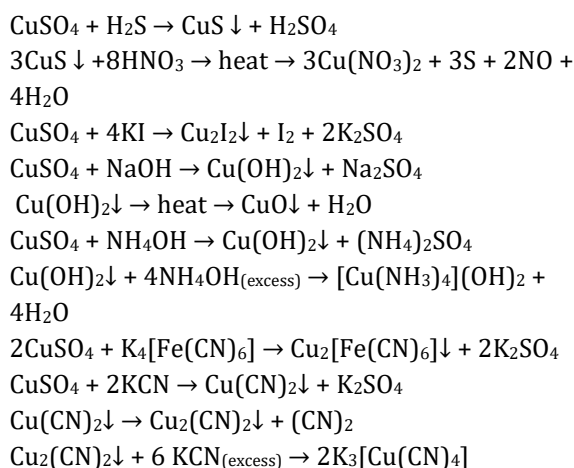
When the hydrogen sulfide (H_2S) gas is passed in the solution, a white precipitate is formed that turns yellow, then brown, and finally turns into the black by increasing the hydrogen sulfide. Potassium iodide solution (KI), a light red precipitate of mercury iodide dissolves, which dissolves in the excess of the reagent, forming a complex compound of mercury potassium iodide or (mercury potassium iodide) (Nessler reagent). Sodium hydroxide (NaOH) solution, a yellow precipitate of mercury oxide is formed by adding an excess of the reagent and the precipitate does not dissolve in the excess of the reagent. Ammonium hydroxide solution (NH_4OH), a white precipitate of mercury amine chloride is formed that does not dissolve in excess of the reagent. Stannous chloride solution (SnCl_2), a white precipitate of mercury chloride is first formed, which is gradually increased from the reagent to a black precipitate of individual mercury in the case of fine fractionation. The following equations confirm the chemical reactions of the investigated item[8].



1.2.2. Copper (Cu^{2+})

A copper sulfate solution is used for the following reactions. When hydrogen sulfide (H_2S) gas is passed through the solution, a black precipitate of copper sulfide is dissolved in hot dilute nitric acid and insoluble in dilute sulfuric acid as well as yellow ammonium sulfide. Potassium iodide solution (KI), a white precipitate of copper iodide appears and the iodine dissolved in the potassium iodide solution is released and the solution is colored brown. Sodium hydroxide (NaOH) solution, a blue precipitate of copper hydroxide does not dissolve in excess of the

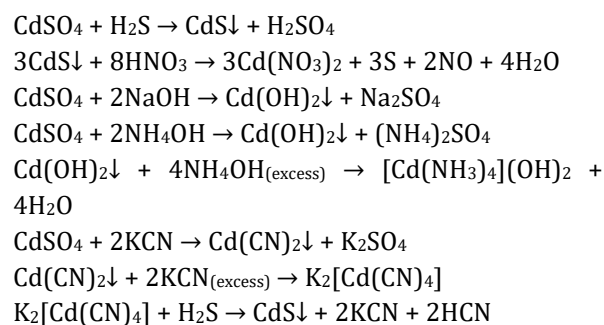
reagent but boils into a black precipitate of copper oxide. Ammonium hydroxide solution (NH₄OH), a pale blue precipitate is formed from a base salt that dissolves in excess of the reagent, forming a dark blue solution of a complex salt containing the copper ion in the form of the ammoniac copper hydroxide. Potassium ferrocyanide K₄[Fe(CN)₆], a reddish-brown precipitate is formed in neutral solution or containing acetic acid. Potassium cyanide solution (KCN), a yellow precipitate is formed of copper cyanide, which dissolves into copper cyanide and cyanogen, then the copper cyanide dissolves in the excess of potassium cyanide and a colorless solution is formed containing a complex copper salt called potassium cyanide copper and when hydrogen sulfide gas passes in this solution does not precipitate copper sulfide. The following equations confirm the chemical reactions of the investigated item [8].



1.2.3. Cadmium (Cd²⁺)

Cadmium sulfate solution is used in the following reactions. When the hydrogen sulfide (H₂S) gas is passed into the solution, a yellow cadmium sulfide precipitate is formed from the solutions acidified with dilute HCl acid. The precipitate is dissolved in hot diluted nitric acid and also dissolved in hot dilute sulfuric acid (other than impurity sulfide) and the precipitate is not dissolved in ammonium sulfide. Sodium hydroxide (NaOH), a white precipitate is composed of cadmium hydroxide that does not dissolve in excess of the reagent. Ammonium hydroxide solution (NH₄OH), a white precipitate of cadmium hydroxide is dissolved in the excess of the

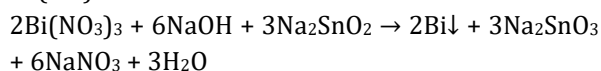
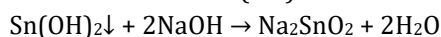
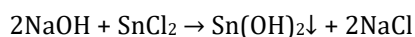
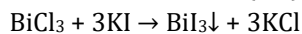
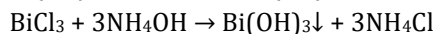
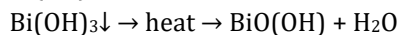
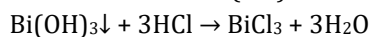
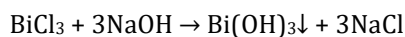
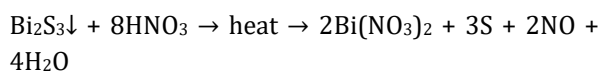
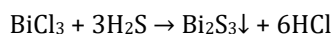
reagent, forming a colorless solution of a complex ammoniac cadmium hydroxide salt. Potassium cyanide solution (KCN), a white precipitate of cadmium cyanide is dissolved in excess of the reagent, forming a colorless solution containing a complex salt called cadmium cyanide potassium. Then, when hydrogen sulfide gas passes in this solution, a yellow precipitate of cadmium sulfide is formed. The following equations confirm the chemical reactions of the investigated item [8].



1.2.4. Bismuth (Bi³⁺)

Bismuth chloride solution is used in the following reactions. When hydrogen sulfide (H₂S) gas is passed into the solution, a brown or black precipitate of bismuth sulfide is formed that does not dissolve in dilute HCl acid and not dissolve in yellow ammonium sulfide but dissolve in hot dilute nitric acid. Sodium hydroxide (NaOH), a white precipitate is composed of bismuth hydroxide that dissolves in acids. The precipitate turns yellow with boiling due to the loss of some water molecules. Ammonium hydroxide solution (NH₄OH), a white precipitate is composed of bismuth hydroxide that does not dissolve in excess of the reagent (as opposed to copper and cadmium hydroxide). Potassium iodide solution (KI), a brown precipitate of bismuth iodide is dissolved in the reagent of the reagent and a complex salt is formed to dissolve this compound by dilution. Sodium stannous solution (Na₂SnO₂), This reagent is prepared in a test tube by adding NaOH solution to the tin chloride solution SnCl₂ until a white precipitate of tin hydroxide is formed and then increasing the sodium hydroxide point by point with shaking until the stannous hydroxide precipitate dissolves into Na₂SnO₂ solution. The Na₂SnO₂ sodium stannous reagent is added to one of the bismuth salts. The following

equations confirm the chemical reactions of the investigated item[8].



The separation of the second group cations in a mixture depends on the following points

The second and fourth groups are precipitated in the form of sulfides, but the solubility of the second group is relatively lower than that of the fourth group sulfides. An acidic medium of hydrochloric acid to prevent the precipitation of fourth group cations with the second group. Mercuric sulfide precipitate is not soluble in dilute nitric acid while cadmium, bismuth, and copper sulfides are dissolved. Bismuth is not soluble in ammonium hydroxide until alkalinity while copper and cadmium are dissolved. Finally, both copper and cadmium are detected separately in the final filtrate[6].

1.3. Third Group

The third group of cation radicals contains four cations namely: Ferrous (Fe^{2+}), Ferric (Fe^{3+}), Aluminum (Al^{3+}) and Chromium (Cr^{3+}).

1.3.1. Ferrous (Fe^{2+})

The following experiments are conducted on a newly prepared ferrous sulfate salt solution FeSO_4 . Ammonium hydroxide solution (NH_4OH), pure ferrous salts are given a white precipitate of ferrous hydroxide, but due to the easy oxidation of ferrous salts by atmospheric air, the precipitate acquires a greenish and then brown color to form ferric oxide, and the precipitate does not dissolve in excess of the reagent but dissolves in acids.

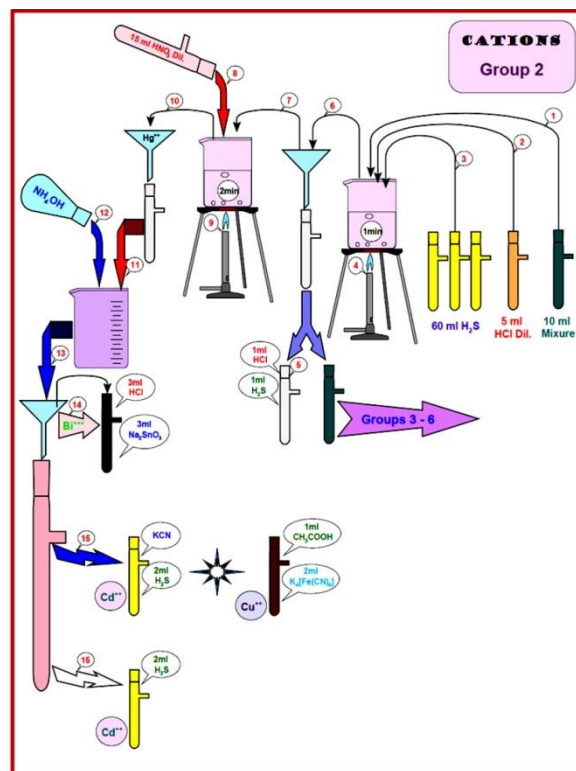
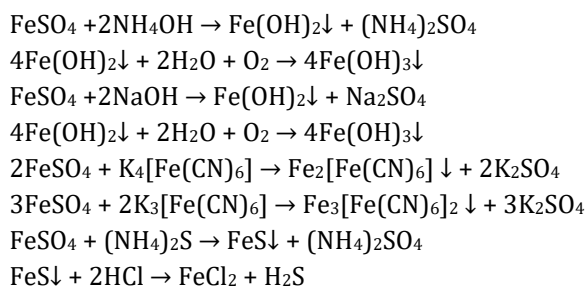


Fig.2. Schematic diagram of the separation and detection for second group cations mixture.

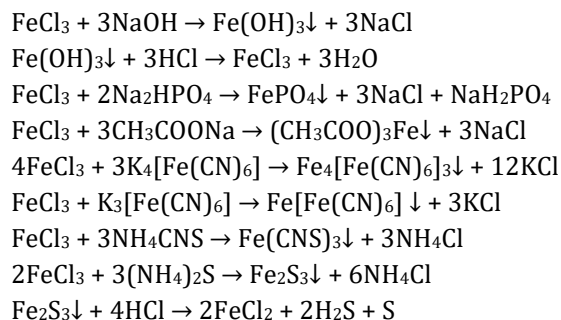
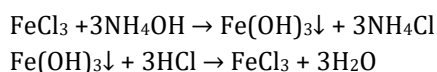
Sodium hydroxide (NaOH), pure ferrous salts give a white precipitate of ferrous hydroxide, but due to the easy oxidation of ferrous salts by atmospheric air, the precipitate acquires a greenish-brown color and then browns to form ferric oxide. The sediment does not dissolve in excess of the reagent but dissolves in acids as in the case of ammonium hydroxide. Ammonium thiocyanate solution (NH_4CNS), there is no change in color with pure ferrous salts, so, this test is used to distinguish ferrous and ferric salts. Potassium ferrocyanide $\text{K}_4[\text{Fe}(\text{CN})_6]$, pure ferrous salts (in the oxygen-free atmosphere) give a white precipitate of ferrous cyanide, but under normal conditions, the precipitate is pale blue due to partial oxidation to ferric ferrous cyanide (Prussia blue). Potassium ferricyanide $\text{K}_3[\text{Fe}(\text{CN})_6]$, a dark blue precipitate of ferrous cyanide (ferrous blue) is made of dilute solutions and this test is used to distinguish between ferrous and ferric salts. Ammonium sulfide solution ($\text{NH}_4)_2\text{S}$, the precipitate consists of ferrous sulfide dissolved in acids with the rise of hydrogen sulfide

gas H₂S. The following equations confirm the chemical reactions of the investigated item [9].



1.3.2. Ferric (Fe³⁺)

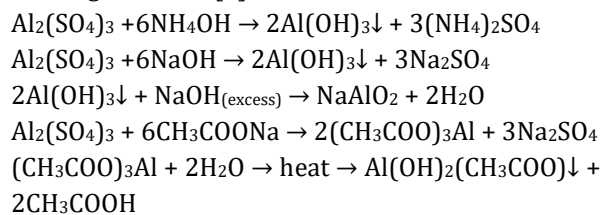
The following experiments are conducted on the ferric chloride salt solution FeCl₃. Ammonium hydroxide solution (NH₄OH), a brown gelatinous precipitate is formed of ferric hydroxide that does not dissolve in excess of the reagent but dissolves in mineral acids. Sodium hydroxide solution (NaOH), a brown gelatinous precipitate is formed of ferric hydroxide that does not dissolve in excess of the reagent but dissolves in mineral acids. Disodium phosphate solution (Na₂HPO₄), a yellowish-white precipitate is formed of ferric phosphate that does not dissolve in acetic acid or ammonium acetate but dissolves in mineral acids. Sodium acetate solution (CH₃COONa), ferric acetate is formed and the solution is colored in brown-red, and when the solution is heated to a boiling point, the basic ferric acetate is deposited in brown. Ammonium thiocyanate solution (NH₄CNS), the solution is colored in bloody red due to the formation of ferric thiocyanate. This test is used to distinguish ferrous and ferric salts. Potassium ferrocyanide K₄[Fe(CN)₆], with neutral and weak acid solutions, a dark blue iron ferric cyanide (Prussia blue) is not dissolved in dilute HCl acid. This test is used to distinguish ferrous and ferric salts. Potassium ferricyanide K₃[Fe(CN)₆], the solution is greenish-brown due to the formation of ferric cyanide ferrous. Ammonium sulfide solution (NH₄)₂S, a black precipitate of ferric sulfide is dissolved in mineral acids forming ferrous chloride and sulfur is separated. The following equations confirm the chemical reactions of the investigated item [9].

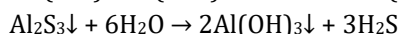
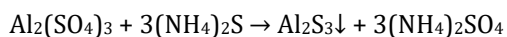
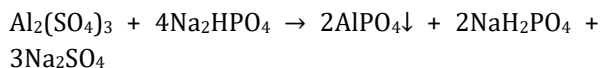


1.3.3. Aluminum (Al³⁺)

Aluminum is a light, soft white stainless steel that easily dissolves in diluted HCl acid and dilute sulfuric acid H₂SO₄. It is somewhat unaffected by the nitric acid HNO₃ as a protective layer of aluminum oxide. Aluminum is trivalent in all its compounds and is an alternating element where the aluminate ion with strong alkali is dissolved in sodium hydroxide to produce sodium aluminate.

The following experiments are carried out on aluminum sulfate solution Al₂(SO₄)₃. Ammonium hydroxide solution (NH₄OH), a white gelatinous precipitate is composed of aluminum hydroxide that dissolves to some extent in the increase of the reagent. Sodium hydroxide solution (NaOH), a white gelatinous precipitate of aluminum hydroxide is dissolved in the reagent, forming sodium aluminate. Sodium acetate solution (CH₃COONa), the precipitate does not consist of cold but with heating and increase of the reagent the precipitate is composed of aluminum acetate. Disodium phosphate solution (Na₂HPO₄), a white gelatinous precipitate is formed of aluminum phosphate which does not dissolve in acetic acid and no ammonium acetate but soluble in both mineral acids and alkali. Ammonium sulfide solution (NH₄)₂S, a white gelatinous precipitate is made of aluminum hydroxide because aluminum sulfide decomposes with water into aluminum hydroxide. The following equations confirm the chemical reactions of the investigated item [9].

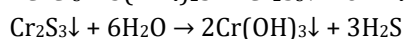
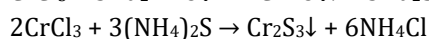
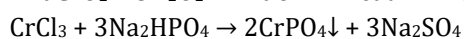
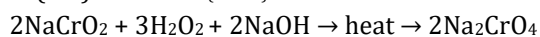
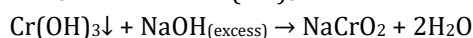
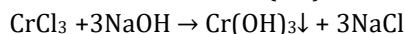
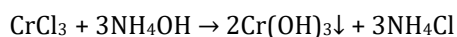




1.3.4. Chromium (Cr^{3+})

Chromium is a shiny gray solid that dissolves in dilute acids such as dilute HCl acid and diluted H_2SO_4 acid which is not affected to some extent by HNO_3 acid as a protective layer of Cr_2O_3 . Chromium may be divalent or trivalent (common valence) or hexavalent.

The following experiments are conducted on the CrCl_3 chloride solution. Ammonium hydroxide solution (NH_4OH), a blue-green precipitate is composed of chromic hydroxide that dissolves in the excess of the reagent to form a violet-tinted solution. Sodium hydroxide solution (NaOH), a green precipitate of chromic hydroxide is dissolved in the reagent to form a green solution as a result of the formation of sodium chromite. The color of the solution is yellow due to the oxidation of sodium chromite to sodium chromate. Disodium phosphate solution (Na_2HPO_4), a green deposit of chromic phosphate does not dissolve in acetic acid or ammonium acetate but dissolves in both mineral acids and alkalis. Ammonium sulfide solution ($(\text{NH}_4)_2\text{S}$), a white gelatinous precipitate is composed of chromic hydroxide because aluminum sulfide decomposes with water into aluminum hydroxide. The following equations confirm the chemical reactions of the investigated item [9].



The separation of the third group cations in a mixture depends on the following points:

Third Group cations are precipitated in the form of hydroxides by adding ammonium hydroxide NH_4OH as a precipitating reagent, but it has also been found that fourth group and magnesium cation of the sixth group may precipitate as hydroxides if

the concentration of hydroxide ions in the solution is not controlled as the solubility of third group hydroxides is relatively lower than of the fourth group and the magnesium of the sixth group. So, the third group cations need a relatively low concentration of hydroxide ions to precipitate. Non-soluble ferric by adding sodium hydroxide and hydrogen peroxide to the third group hydroxide precipitate, while both aluminum and chromium hydroxide dissolve where they are detected directly in the final filtrate [6].

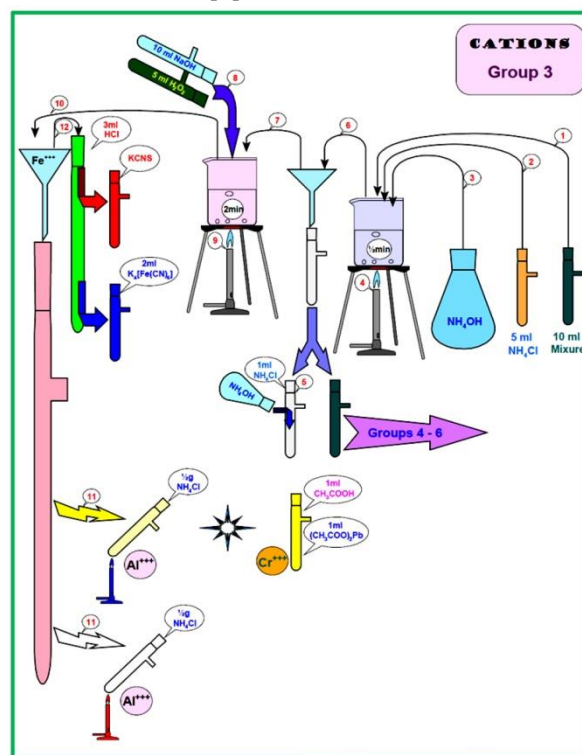


Fig. 3. Schematic diagram of the separation and detection for third group cations mixture.

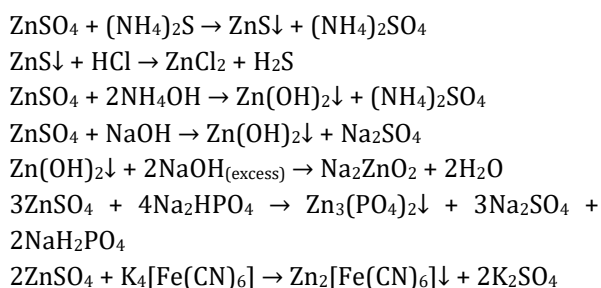
1.4. Fourth Group

The Fourth group of cation radicals contains four cations namely: Zinc (Zn^{2+}), Manganese (Mn^{3+}), Cobalt (Co^{2+}) and Nickel (Ni^{2+}).

1.4.1. Zinc (Zn^{2+})

Zinc is a bluish-white metal that reacts with dilute acids and hydrogen gas rises with both HCl and H_2SO_4 , while nitrogen oxides are given with nitric acid HNO_3 , bivalent zinc in all its compounds, and zinc ion Zn^{2+} is colorless, zinc dissolves in a soluble element. Sodium of the NaOH, is formed sodium zinc Na_2ZnO_2 with hydrogen gas.

The following experiments are carried out on the $ZnSO_4$ salt solution. Ammonium sulfide solution $(NH_4)_2S$, a white precipitate of zinc sulfide is dissolved in mineral acids. Ammonium hydroxide solution (NH_4OH) , a white precipitate of zinc hydroxide is insoluble in excess of the reagent. Sodium hydroxide solution $(NaOH)$, a white gelatinous precipitate of zinc hydroxide is dissolved in the excess of the reagent forming sodium zinc. Disodium phosphate solution (Na_2HPO_4) , a white precipitate of zinc phosphate is dissolved in ammonium hydroxide and dilute acids. Potassium ferrocyanide $K_4[Fe(CN)_6]$, a white precipitate of iron and zinc cyanide is dissolved in excess of the reagent. The following equations confirm the chemical reactions of the investigated item [10].

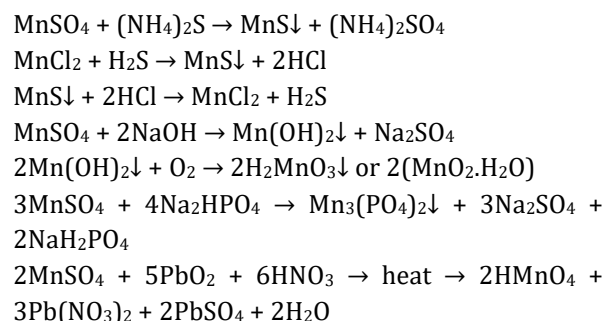


1.4.2. Manganese (Mn^{2+})

Manganese is a gray metal that reacts with dilute acids such as zinc and hydrogen gas with both HCl and H_2SO_4 , while nitrogen oxides are given with nitric acid HNO_3 , manganese may be divalent (manganese ion) Mn^{++} which is a pale purple color in manganese oxide MnO_2 or may be tetravalent as in the ion of permanganate MnO_4 .

The following experiments are carried out on a solution of manganese chloride salt $MnCl_2$ or manganese sulfate $MnSO_4$. Ammonium sulfide solution $(NH_4)_2S$, a pale brown or light brown precipitate of manganese sulfide is dissolved in dilute mineral acids. Ammonium hydroxide solution (NH_4OH) , a mild white precipitate of manganese hydroxide is insoluble in excess of the reagent. Sodium hydroxide solution $(NaOH)$, a white precipitate is composed of manganese hydroxide, which changes color to brown when exposed to atmospheric air for a period of time to form manganese hydroxide to oxidize it by air oxygen. Disodium phosphate solution (Na_2HPO_4) , a pale or

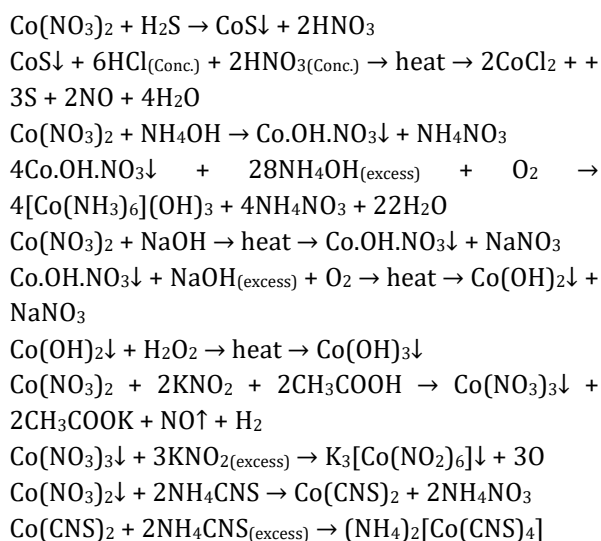
light brown precipitate of manganese phosphate is present. The precipitate is formed only in the presence of an excess of ammonium hydroxide. Lead dioxide PbO_2 with concentrated nitric acid HNO_3 , when the salts of manganese (except manganese chloride) were boiled with a mixture of lead dioxide + concentrated nitric acid, then the solution was allowed to be colored violet as a result of the formation of permanganic acid ($HMnO_4$). Note that this test does not give a positive result in the presence of chlorides because the permanganic acid decomposes in the presence of HCl . The following equations confirm the chemical reactions of the investigated item [10].



1.4.3. Cobalt (Co^{2+})

Water solutions of cobalt salts are pink. Cobalt nitrate solution $Co(NO_3)_2$ is used in the following experiments. Hydrogen sulfide (H_2S), the precipitate is not formed in the acidic medium but in the presence of ammonium chloride and ammonium hydroxide and by the passage of the gas a black precipitate of cobalt sulfide is not dissolved in dilute HCl acid but hot concentrated nitric acid dissolves and also dissolved in royal water and uniquely sulfur. Ammonium hydroxide solution (NH_4OH) , a blue precipitate is composed of a base salt that dissolves in excess of the reagent. A blue solution of ammoniacal cobalt hydroxide is formed and the reaction is in the presence of atmospheric oxygen. Sodium hydroxide solution $(NaOH)$, a blue precipitate consists of a base salt transformed by heating with the increase of the reagent to a pink precipitate of cobalt(II) hydroxide and then boiling in the presence of atmospheric oxygen transformed into a black precipitate of cobalt hydroxide. Potassium nitrite solution (KNO_2), a yellow precipitate of cobalt nitrite is formed when an

excess of potassium nitrite solution is added to a concentrated solution of cobalt salt with acetic acid. Ammonium thiocyanate solution (NH_4CNS), a blue color is formed in the concentrated solution (preferably solid ammonium thiocyanate), which is a complex containing cobalt ion and thiocyanate ion. The color disappears when diluted and when the methyl alcohol is added it is blue because it dissolves it. The following equations confirm the chemical reactions of the investigated item [10].

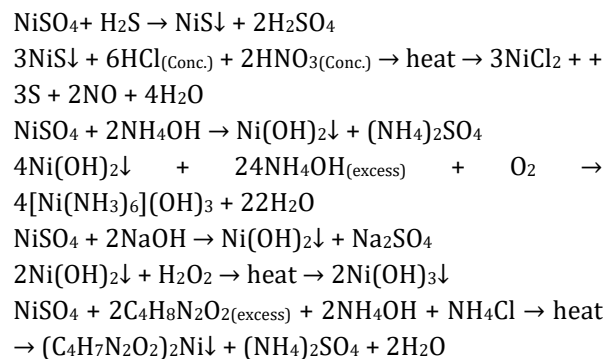


1.4.4. Nickel (Ni^{2+})

Aqueous solutions of nickel salts are green. NiSO_4 is used in the following experiments. Hydrogen sulfide (H_2S), the precipitate is not formed in the acidic medium but in the presence of ammonium chloride and ammonium hydroxide and through the passage of gas or H_2S solution a black precipitate of nickel sulfide is formed not dissolved in dilute HCl acid but dissolved in hot concentrated nitric acid and also dissolved in royal water. Ammonium hydroxide solution (NH_4OH), a green precipitate of nickel hydroxide is dissolved in the reagent and a blue solution of nickel ammonia hydroxide is formed and the reaction is in the presence of atmospheric oxygen.

Sodium hydroxide solution (NaOH), a green precipitate is formed of divalent nickel hydroxide that does not dissolve in excess of the reagent and is oxidized by sodium hypochlorite or H_2O_2 and boiling to trivalent nickel hydroxide which appears as a black precipitate. Dimethylglyoxime ($\text{C}_4\text{H}_8\text{N}_2\text{O}_2$), a

light red precipitate is composed of a complex nickel dimethylglyoxime complex. The following equations confirm the chemical reactions of the investigated item [10].



The separation of the fourth group cations in a mixture depends on the following points:

Soluble zinc and manganese sulfide in diluted HCl acid in the form of a dissolved solution of zinc and manganese chloride while cobalt and nickel sulfide does not dissolve. The addition of NaOH to the solution containing zinc chloride and manganese chloride is a precipitate of zinc hydroxide and manganese hydroxide. Sodium zinc. The solubility of cobalt sulfide and nickel sulfide in sodium hypochlorite NaOCl with boiling then divide the resulting solution into two parts and reveal both cobalt and nickel alone [6].

1.5. Fifth Group

This group contains cations that are deposited as carbonates in the basal medium. The elements of this group are divalent in all their compounds and ions are colorless and oxidized quickly in humid air and therefore must be stored under kerosene or mineral oil to protect them from oxidation by air. The Fifth group of cation radicals contains four cations namely: Barium (Ba^{2+}), Calcium (Ca^{2+}) and Strontium (Sr^{2+}) [11].

1.5.1. Barium (Ba^{2+})

The following experiments are carried out on a solution of barium chloride BaCl_2 . Ammonium carbonate solution $(\text{NH}_4)_2\text{CO}_3$, a white precipitate of barium carbonate is dissolved in acetic acid and in mineral acids.

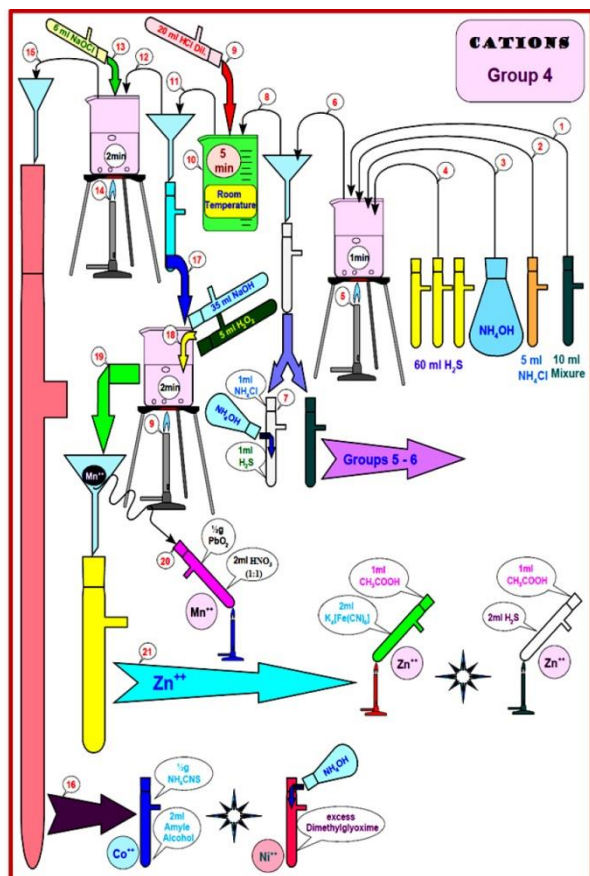
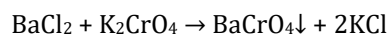
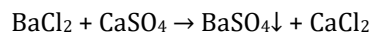
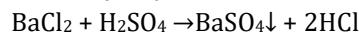
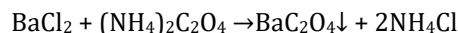
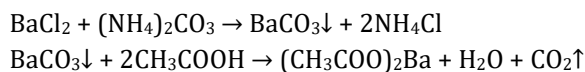


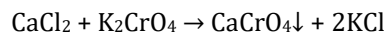
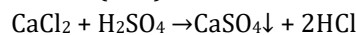
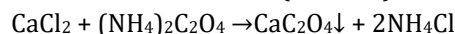
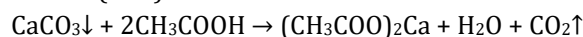
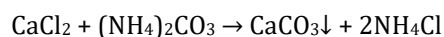
Fig.4. Schematic diagram of the separation and detection for fourth group cations mixture.

Ammonium oxalate solution $(\text{NH}_4)_2\text{C}_2\text{O}_4$, a white precipitate of barium oxalate consists of concentrated solutions dissolved in hot dilute acetic acid (to distinguish between barium and calcium) and in mineral acids. Diluted sulfuric acid (H_2SO_4), a heavy white precipitate of barium sulfate does not dissolve in mineral acids. Saturated calcium sulfate solution (CaSO_4), a white precipitate is immediately composed of barium sulfate and even dilute solutions (to distinguish between barium and strontium). Potassium chromate solution (K_2CrO_4), a yellow precipitate consists of barium chromate that does not dissolve in acetic acid (to distinguish between barium and both calcium and strontium) but is dissolved in concentrated mineral acids such as concentrated HCl . The following equations confirm the chemical reactions of the investigated item[11].



1.5.2. Calcium (Ca^{2+})

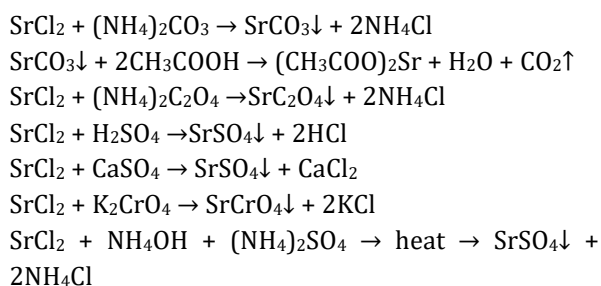
The following experiments are conducted on the CaCl_2 solution. Ammonium carbonate solution $(\text{NH}_4)_2\text{CO}_3$, a white precipitate of calcium carbonate is dissolved in acetic acid and in mineral acids. Ammonium oxalate solution $(\text{NH}_4)_2\text{C}_2\text{O}_4$, a white precipitate of calcium oxalate is formed immediately from concentrated solutions and slowly from dilute solutions. The precipitate does not dissolve in acetic acid but mineral acids. Diluted sulfuric acid (H_2SO_4), a heavy white precipitate of calcium sulfate from concentrated solutions dissolved in concentrated ammonium sulfate solution. Saturated calcium sulfate solution (CaSO_4), no precipitate is formed (to distinguish between calcium and barium and strontium). Potassium chromate solution (K_2CrO_4), A yellow precipitate is formed of calcium chromate that appears only in concentrated solutions to rise if dissolved. The precipitate is dissolved in dilute acetic acid. Potassium ferrocyanide $\text{K}_4[\text{Fe}(\text{CN})_6]$, the white precipitate is composed of ferrous calcium cyanide and potassium; the reaction is more sensitive in the presence of an excessive amount of solid ammonium chloride with heating if necessary. The following reactions confirm the chemical reactions of the investigated item[11].



1.5.3. Strontium (Sr^{2+})

The following experiments are conducted on SrCl_2 . Ammonium carbonate solution $(\text{NH}_4)_2\text{CO}_3$, a white precipitate of strontium carbonate is dissolved in acetic acid and mineral acids except sulfuric acid. Ammonium oxalate solution $(\text{NH}_4)_2\text{C}_2\text{O}_4$, a white precipitate is composed of strontium oxalate that is slightly dissolved in acetic acid but dissolves in mineral acids such as HCl .

Diluted sulfuric acid (H_2SO_4), a white precipitate of strontium sulfate appears not soluble in mineral acids. Saturated calcium sulfate solution (CaSO_4), a white precipitate is composed of strontium sulfate, formed slowly on the cold but precipitated faster by boiling. Potassium chromate solution (K_2CrO_4), a yellow precipitate is composed of strontium chromate that appears only in concentrated solutions for high dissolving time and the precipitate is dissolved in dilute acetic acid. Concentrated ammonium sulfate solution (NH_4) $_2\text{SO}_4$, a white precipitate of strontium sulfate is formed after boiling for 1 minute and then left to cool, where it accumulates at the bottom of the tube after 10-20 minutes. The following equations confirm the chemical reactions of the investigated item [11].



The separation of fifth group cations in a mixture depends on the following points:

Dissolution of fifth group cations carbonate precipitate in diluted acetic acid. The solubility of calcium chromate and strontium chromate in dilute acetic acid is not affected by barium chromate, so when the solution of potassium chromate is added to the solution of barium, calcium and strontium salts, a yellow precipitate of barium chromate is formed only and the solution contains calcium acetate and strontium acetate. Strontium is deposited as a white precursor of strontium sulfate when ammonium hydroxide is added to alkalinity and then ammonium sulfate. Calcium remains in the form of a complex salt solution of calcium and ammonium sulfate $(\text{NH}_4)_2[\text{Ca}(\text{SO}_4)_2]$ [6].

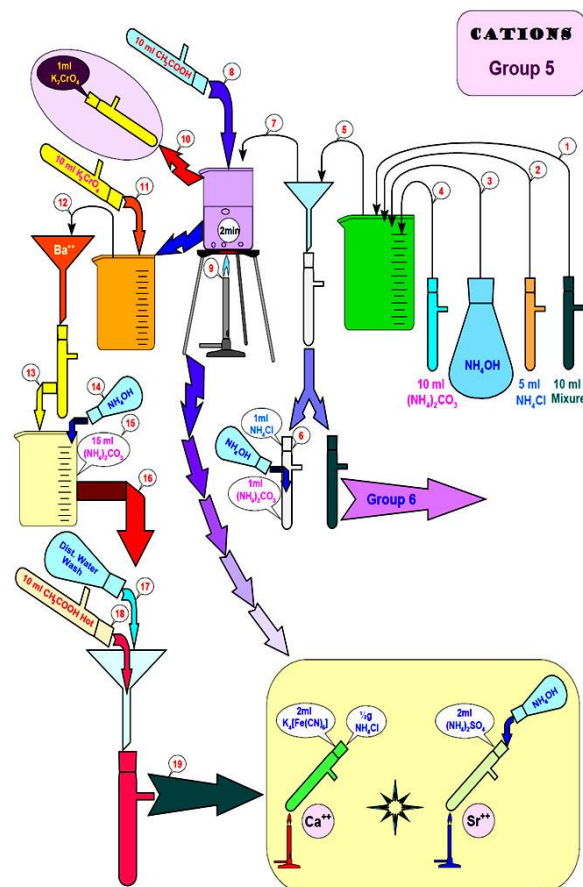


Fig. 5. Schematic diagram of the separation and detection for fifth group cations mixture.

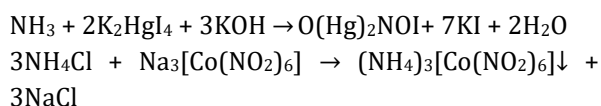
1.6. Sixth Group

This group contains cations that have not precipitated in the previous groups, namely ammonium (NH_4^+), magnesium (Mg^{2+}), sodium (Na^+) and potassium (K^+), and this group does not have a uniform searchlight (essence modified and precipitated substance) as the previous groups but reveals each cation individually. It is noted that the ammonium incision was placed in this group because of its similar interactions with the potassium incision in many respects and that ammonium hydroxide is a weak base, unlike alkali metals. The magnesium fissure is very similar to terrestrial alkali metals, the cations of the fifth group but is placed in the sixth group to facilitate separation and analysis. Magnesium metal is less active than sodium and potassium. It is not easily oxidized in the air and dissolves easily in dilute mineral acids. Sodium and potassium are silver-white minerals, which are very active as they are

easily oxidized in humid air and react strongly with water and acids, giving monovalent ions and hydrogen gas rising. These minerals are known as alkali metals because their hydroxides are strong bases[12].

1.6.1. Ammonium (NH₄⁺)

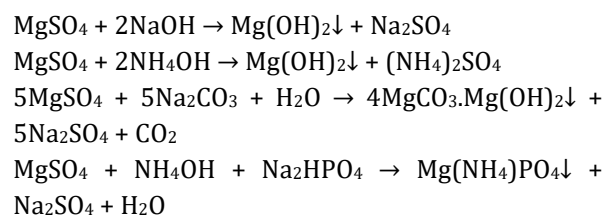
The following experiments are performed on the NH₄Cl ammonium chloride solution. When heating a small amount of solid salt or salt solution with sodium hydroxide solution (NaOH), it is noted that the ammonia gas has a characteristic odor. This gas can be detected in one of the following ways: The distinct smell of ammonia. White clouds of ammonium chloride shall be exposed when a glass leg moistened with HCl acid is exposed. The red sunflower leaf color changes to blue. A filter paper moistened with mercury nitrate solution is black. They are precipitated, brownish or yellowish-brown when exposed to a paper moistened with a Nessler reagent. Nessler reagent (K₂HgI₄), a brownish yellow, the color deposit is formed depending on the concentration of ammonia in the solution. This test can detect the effects of ammonia in drinking water. Sodium cobalt nitrite Na₃[Co(NO₂)₆], a yellow precipitate is formed of ammonium cobalt nitrite as in the case of potassium. Perchloric acid solution, a precipitate other than potassium salts does not appear. The following equations confirm the chemical reactions of the investigated item [12].



1.6.2. Magnesium (Mg²⁺)

The following experiments are carried out on a MgSO₄ solution. Sodium hydroxide solution (NaOH), a white precipitate of magnesium hydroxide is formed not soluble in excess of the reagent but soluble in ammonium chloride solution. Ammonium hydroxide solution (NH₄OH), a white gelatinous precipitate is composed of magnesium hydroxide dissolved in ammonium chloride solution. Sodium carbonate solution (Na₂CO₃), a white precipitate of magnesium carbonate is formed which is dissolved in ammonium chloride solution. Disodium phosphate solution (Na₂HPO₄), a white crystalline

precipitate of magnesium phosphate and ammonium appears in the presence of ammonium chloride and ammonium hydroxide dissolved in acetic acid and dilute mineral acids. The precipitate slowly consists of dilute solutions where this compound tends to form a solution over saturated and overcome this by cooling or shaking or rubbing the inside of the tube with a glass leg or very light heating. The following equations confirm the chemical reactions of the investigated item [13].



1.6.3. Sodium (Na⁺)

The following experiments are carried out on a NaCl solution. Potassium pyroantimonate solution (KH₂SbO₄), a white crystalline precipitate of sodium pyroantimonium dihydrogen is composed of neutral or alkaline solutions. Flame colorization test: The tip of the platinum wire is immersed in a little sodium chloride salt and then cautiously close to the flame at the low-temperature zone. The following equations confirm the chemical reactions of the investigated item [13].



1.6.4. Potassium (K⁺)

The following experiments are carried out on a solution of potassium chloride KCl. Sodium cobalt nitrite Na₃[Co(NO₂)₆] solution (freshly prepared), a yellow precipitate of cobalt nitrite potassium does not dissolve in acetic acid. Perchloric acid solution, a white crystalline precipitate is shown from KClO₄ and the soluble is slightly dissolved in water but almost insoluble in pure alcohol. Carnob test: Prepare (mixed from a drop of diluted bismuth nitrate solution and two or three drops of sodium thiosulfate solution) add the previous solution to KCl, a yellow precipitate formed namely bismuth and potassium thiosulfate K₃[Bi(S₂O₃)₃]. Flame colorization test: The tip of the platinum wire is dipped in a little potassium chloride salt and then

cautiously close to the flame in the low-temperature area gold for sodium. The following equations confirm the chemical reactions of the investigated item[14].

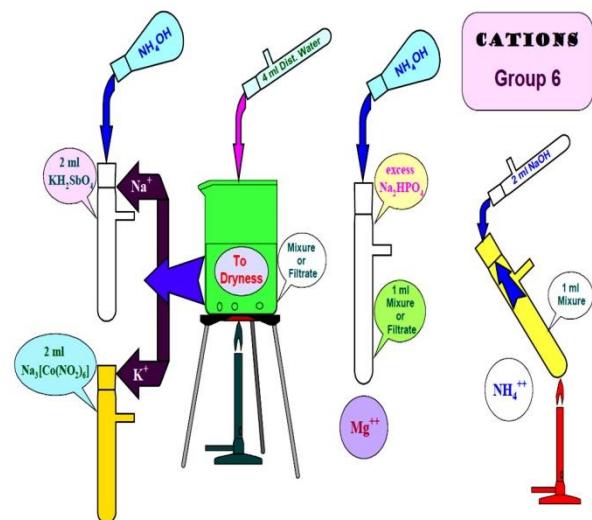
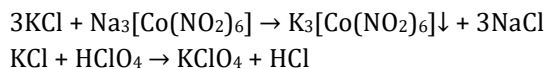


Fig.6. Schematic diagram of the separation and detection for sixth group cations mixture.

2. The acid radicals (Anions) and divided into three groups

Acid radicals (Anions) are divided into three groups according to their sensitivity to dilute and concentrated acids as follows:

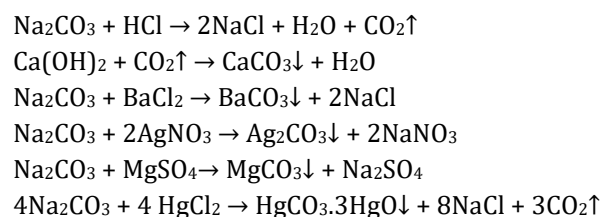
2.1. Diluted Hydrochloric Acid HCl Group

It is the group containing acid fissures that are affected by diluted HCl acid and produce gases characterized by special odors or distinct reactions. This group includes the following anions: Carbonate (CO_3^{2-}), Bicarbonate (HCO_3^-), Sulfite (SO_3^{2-}), Thiosulfate ($\text{S}_2\text{O}_3^{2-}$), Sulfide (S^{2-}), Nitrite (NO_2^-), Cyanide (CN^-), Cyanate (CNO^-) and Chlorate (ClO_3^-).

2.1.1. Carbonate (CO_3^{2-})

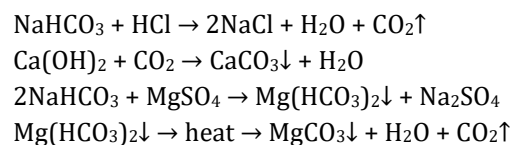
All carbonates do not dissolve in water except sodium carbonate, potassium and ammonium, the following experiments are carried out on Na_2CO_3 . Diluted HCl acid produce effervesce from carbon dioxide, which disturbs lime water. Barium chloride solution (BaCl_2), a white barium carbonate deposit dissolve in dilute HCl acid. Silver nitrate solution

(AgNO_3), a white precipitate of silver carbonate is dissolved in both dilute nitric acid and ammonium hydroxide, and by heating the sediment changes its color to brown to form silver oxide. Magnesium sulfate solution (MgSO_4), a white magnesium carbonate deposit appears cold. Mercuric chloride solution (HgCl_2), cold reddish-brown mercuric carbonate deposits appear. The following equations confirm the chemical reactions of the investigated item[15].



2.1.2. Bicarbonate (HCO_3^{2-})

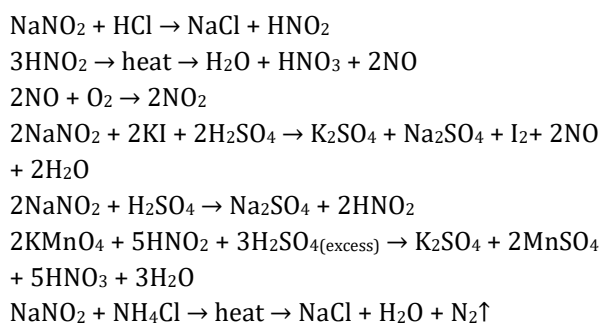
All bicarbonates dissolve in water; the following experiments are performed on NaHCO_3 . Diluted HCl acid produce effervesce from carbon dioxide, which disturbs lime water. Magnesium sulfate solution (MgSO_4), a cold white precipitate does not appear, but the precipitate is formed by boiling as NaHCO_3 is converted to sodium carbonate. Mercuric chloride solution (HgCl_2), a reddish-brown precipitate is not formed as in the case of cold carbonates, but the precipitate appears after heating and is therefore used to distinguish between them. The following equations confirm the chemical reactions of the investigated item[15].



2.1.3. Nitrite (NO_2^-)

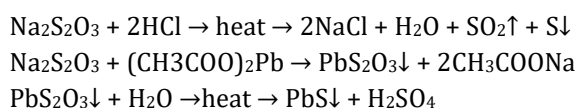
All nitrate salts are dissolved in water except silver nitrite. The following experiments are performed on sodium nitrite NaNO_2 . When Diluted HCl acid is added with caution to the solid sodium nitrite salt a light blue color is formed due to the presence of nitrous acid or anhydride in the solution and brown vapors mount to form nitrogen peroxide with heating. Potassium iodide solution (KI), when sodium nitrite solution is added to the potassium

iodide solution and the mixture is acidified with dilute acetic or sulfuric acid, iodine, which gives a blue color with the starch solution, is separated. Potassium permanganate solution (KMnO_4), when the solution of KMnO_4 acidified with dilute sulfuric acid is reduced and violet is removed by the effect of nitrite salt. Ammonium chloride solution (NH_4Cl), nitrogen gas unrestricted with boiling. The following equations confirm the chemical reactions of the investigated item [15].



2.1.4. Thiosulfate ($\text{S}_2\text{O}_3^{2-}$)

Most of the thiosulfate salts dissolve in water. Silver thiosulfate, lead, and barium are water-soluble. The following experiments are performed on sodium thiosulfate $\text{Na}_2\text{S}_2\text{O}_3$. Diluted HCl acid by heating the solid salt softly, the sulfur dioxide gas with a stifling odor is emitted and at the same time, a yellowish-white sulfur deposit is deposited. Lead acetate solution $(\text{CH}_3\text{COO})_2\text{Pb}$, a white precipitate of lead thiosulfate appears to be boiling into a black precipitate of lead sulfide. The following equations confirm the chemical reactions of the investigated item [15].

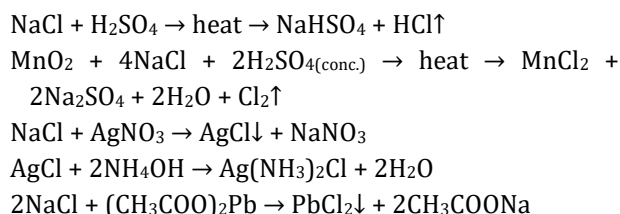


2.2. Concentrated Sulfuric Acid H_2SO_4 Group

It is a group whose effects are not affected by dilute acids but interact with concentrated sulfuric acid and produce distinct gases, include the following anions: Chloride (Cl^-), Bromide (Br^-), Iodide (I^-), Nitrate (NO_3^-) and Thiocyanate (CNS^-) [16].

2.2.1. Chloride (Cl^-)

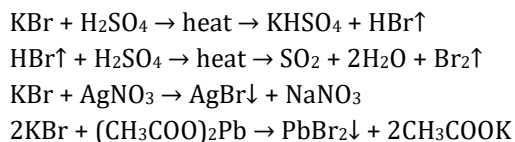
Most chlorides dissolve in water. Silver and mercury chlorides do not dissolve, while lead chloride dissolves in hot water. The following experiments are performed on NaCl. Concentrated sulfuric acid (H_2SO_4) reacts with solid salt and heats hydrogen chloride gas HCl and can be distinguished as follows: Pungent smell, White clouds of NH_4Cl ammonium chloride shall be exposed when a glass stalk moistened with NH_4OH ammonium hydroxide solution, the acidic properties where the blue sunflower leaf browns. Concentrated sulfuric acid in the presence of manganese dioxide ($\text{H}_2\text{SO}_4/\text{MnO}_2$), mix a little manganese dioxide with solid sodium chloride salt and then add 1 ml of concentrated sulfuric acid and then heat the mixture is observed mounting chlorine gas (greenish-yellow), which removes the color of sunflower paper moistened with water. Silver nitrate solution (AgNO_3), a white precipitate of silver chloride is shown that does not dissolve in dilute nitric acid and dissolve in ammonium hydroxide. Lead Acetate Solution $(\text{CH}_3\text{COO})_2\text{Pb}$, a white precipitate is formed of lead chloride that dissolves in hot water and is deposited by cryogenic. The following equations confirm the chemical reactions of the investigated item [17].



2.2.2. Bromide (Br^-)

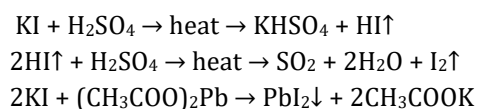
Soluble bromide salts like the soluble chloride salts, the following experiments are performed on KBr potassium bromide. Concentrated sulfuric acid (H_2SO_4) reacts with solid salt and turns the solution in reddish-brown color and by heating brown gases and vapors from both hydrogen bromide and bromine gas. Concentrated sulfuric acid in the presence of manganese dioxide ($\text{H}_2\text{SO}_4/\text{MnO}_2$), a little bit of manganese dioxide is mixed with solid potassium bromide salt, then 1 ml of concentrated sulfuric acid is added and the mixture is heated. Brown vapors from bromine gas are observed only as a result of oxidation of all hydrogen bromide. Silver nitrate solution (AgNO_3), a faded yellow

precipitate of silver bromide is shown that does not dissolve in dilute nitric acid, dissolve in dilute ammonium hydroxide, dissolve in concentrated ammonium hydroxide and dissolve in sodium thiosulfate. Lead acetate solution $(\text{CH}_3\text{COO})_2\text{Pb}$, a white crystalline precipitate of lead bromide is dissolved in boiling water. The following equations confirm the chemical reactions of the investigated item [18].



2.2.3. Iodide (I^-)

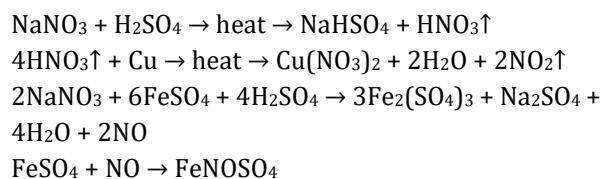
Soluble iodide salts like soluble chloride salts, the following experiments are performed on KI. Concentrated sulfuric acid (H_2SO_4) reacts with solid salt and mounts purple iodine vapors with colorless hydrogen iodide vapors. Silver nitrate solution (AgNO_3), a yellow precipitate of silver iodide appears not soluble in both dilute nitric acid and dissolved in sodium thiosulfate. Lead acetate solution $(\text{CH}_3\text{COO})_2\text{Pb}$, a yellow precipitate of lead iodide is dissolved in hot water, forming a colorless solution. The following equations confirm the chemical reactions of the investigated item [19].



2.2.4. Nitrate (NO_3^-)

All nitrate salts soluble in water except basal mercury nitrate and bismuth nitrate. They dissolve in dilute nitric acid. The following experiments are performed on NaNO_3 . Concentrated sulfuric acid (H_2SO_4), by heating solid nitrate salts with concentrated sulfuric acid, red-brown fumes from nitrogen oxide and nitric acid vapors are visible. Brown Loop Experiment: Add 2-3 milliliters of freshly prepared ferrous sulfate solution to about 1 milliliter of sodium nitrate with a good shaking. Then add 2-3 milliliters of concentrated sulfuric acid on the inner wall of the tube with extreme caution in a diagonal position. Then, position the tube vertically, the brown loop is observed. The following

equations confirm the chemical reactions of the investigated item [20].

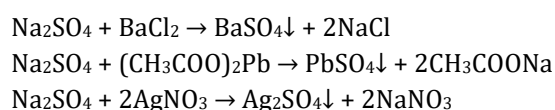


2.3. Special Group

These anions, which are not affected by a particular common reagent and are therefore detected in their interactions, include the following anions: Sulfate (SO_4^{2-}), Phosphate (PO_4^{3-}), Arsenite (AsO_3^{3-}), Arsenate (AsO_4^{3-}) and Borate ($\text{B}_4\text{O}_7^{2-}$).

2.3.1. Sulfate (SO_4^{2-})

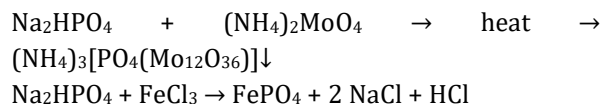
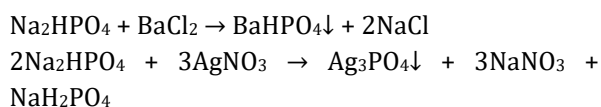
Most of the sulfates dissolve in water except for lead sulfate, barium, calcium, strontium, and mercury. The following experiments are performed on sodium sulfate Na_2SO_4 . Barium chloride solution (BaCl_2), a white precipitate is formed from barium sulfate that does not dissolve in mineral acids such as dilute nitric acid HNO_3 . Lead acetate solution $(\text{CH}_3\text{COO})_2\text{Pb}$, a white precipitate of lead sulfate is dissolved in both ammonium acetate and sodium hydroxide. When silver nitrate solution (AgNO_3) is added to concentrated sulfate solutions, a white precipitate of silver sulfate is formed. The following equations confirm the chemical reactions of the investigated item [21].



2.3.2. Phosphate (PO_4^{3-})

Most of the phosphate salts are very soluble in water except ammonium phosphate and alkali metal phosphate (sodium and potassium) are soluble in water. The following experiments are carried out on Na_2HPO_4 . Barium chloride solution (BaCl_2), a white precipitate of barium phosphate is dissolved in mineral acids such as dilute nitric acid HNO_3 as well as dissolved in acetic acid. When silver nitrate solution (AgNO_3) is added to phosphate solutions, a yellow precipitate of silver phosphate is formed dissolved in ammonium hydroxide and dilute nitric

acid HNO_3 . Ammonium molybdate solution $(\text{NH}_4)_2\text{MoO}_4$, when adding about 4 ml of ammonium molybdate solution to 1 milliliter of disodium sodium phosphate solution and then add 1 ml concentrated nitric acid showing a canary yellow precipitate of ammonium phosphomolybdate after a soft heating. Ferric chloride solution (FeCl_3) , a pale yellow (yellowish white) precipitate of ferric phosphate is dissolved in mineral acids and not dissolved in acetic acid (taking into account the addition of a saturated solution of sodium acetate to get rid of the resulting HCl acid which may cause the dissolution of the ferric phosphate precipitate formed). The following equations confirm the chemical reactions of the investigated item[22].



CONCLUSION

The composition of relatively complex mixtures of metal ions can be determined using qualitative analysis, a procedure for discovering the identity of metal ions present in the mixture (rather than quantitative information about their amounts). The procedure used to separate and identify more than 20 common metal cations from a single solution consists of selectively precipitating only a few kinds of metal ions at a time under given sets of conditions. Consecutive precipitation steps become progressively less selective until almost all of the metal ions are precipitated, as illustrated in Figure (8).

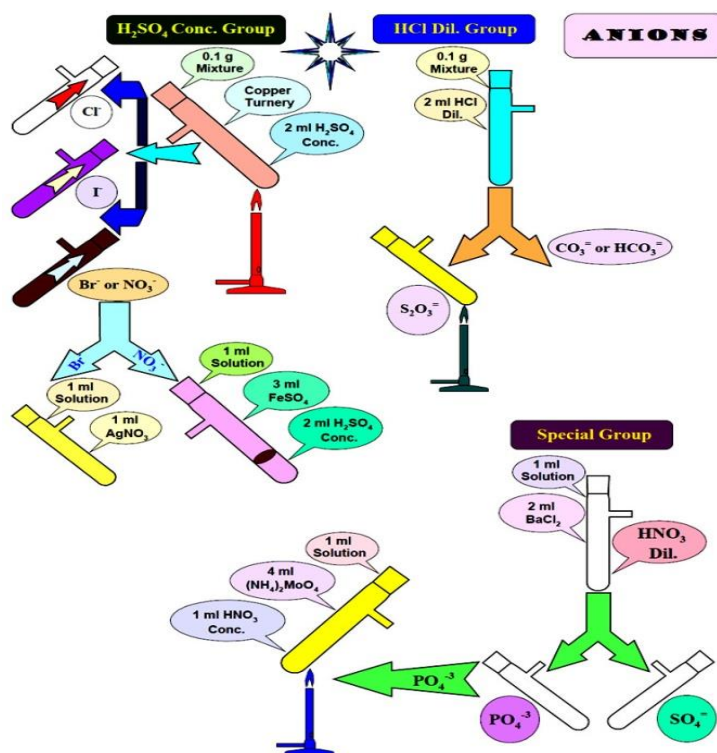


Fig. 7. Schematic diagram of the separation and detection for anions mixture.

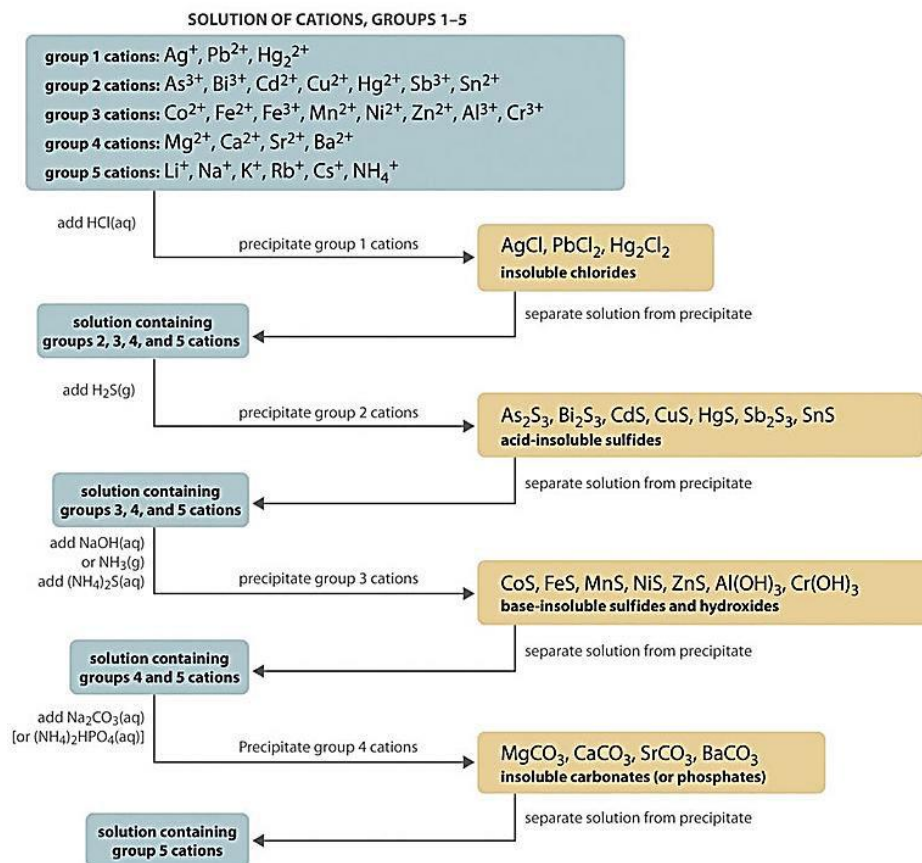


Fig.8. Steps in a Typical Qualitative Analysis Scheme for a Solution That Contains Several Metal Ions.

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