

Study Methodology of Analytical Group II Cations

Chanturia Mineda

PhD, Associate Professor, Doctor of Chemistry, Faculty of Natural Science, Mathematics, Technology and Pharmacy, Sokhumi State University

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ABSTRACT

The article analyzes properties, significance and application of metal cations of the II analytical group Ag^+ , Pb^{2+} , $[\text{Hg}_2]^{2+}$, formed on the basis of many years of experience in teaching chemistry. Principles with the following stages: base-acid classification of II analytical group cations: General characterization of cations of analytical group II with base-acid classification → Chemical bases of toxic action of their representative heavy metals - **integration with ecology** → Their importance and use in medicine - **integration with medicine, solving the tasks of the teaching process of human life safety** → Private reactions of identification - **solving the tasks of the teaching process of chemistry** → Control task: the course of analysis of II analytical group of cations in the course of systematic analysis → drawing up the results of private reactions and mixture analysis of II analytical group according to the given schemes → Laboratory work assessment system → Synthesis of information - multi-component analysis of the studied material.

INTRODUCTION

Teaching the course “Analytical Chemistry” focuses on mastering modern and classical chemical analysis methods. It also addresses theoretical problems, develops new techniques for component identification and quantification, and improves existing methods to determine chemical composition.

The concept of teaching analytical chemistry has been elaborated and thoroughly defined, the base and foundation of which is the lecture theoretical material. The theory formulates laws using scientific concepts, terms, and hypotheses. At the lectures, The course introduces students to the essence of the course, its purpose, tasks, main content, final result, and simple and acceptable ways to achieve them.

Relevance of the topic:

In the literature, various ion detection, identification-classification systems are known: sulphide, base-acid, phosphate-ammonia, etc. The sulphide method of analysis is classical. Its theory and practice are well studied and worked out, although toxic hydrogen sulfide is used in its work. At Sukhumi State University, preference was given to the environmentally safe base-acid method of classification of cations and anions, which greatly contributes to the formation of the student's logical, analytical thinking, which is the strongest tool for physical, moral and spiritual perception of the world.

The base-acid system of cation analysis divides metal cations into six groups. This classification depends on their reactions with hydrochloric acid, sulfuric acid, alkalis, and ammonia solutions. [1]

The positive side of the system is as follows: basic properties of elements are used in the basic-acid system of analysis: their dependence on acids and alkalis, amphotericity of hydroxides and the ability to form complexes of elements. The batch reagent needs to satisfy these requirements:

1. Precipitation of cations should be practically quantitative (the concentration of cations in the solution after precipitation should not exceed 10^{-6} g-ion/l);
2. The resulting precipitate should be easily dissolved in acids for further analysis;

3. The excess amount of reagent added should not interfere with the identification of ions remaining in solution.

The paper discusses the main principles of analysis, properties, importance and use of metal cations of the II analytical group Ag^+ , Pb^{2+} , $[\text{Hg}_2]^{2+}$, formed on the basis of many years of experience in teaching chemistry, as follows in stages:

Table #1

I	General characterization of cations of analytical group II with base-acid classification.
II	Chemical bases of the toxic effect of heavy metals representative of analytical group II - [Evaluation of the importance of elements in human life and production from the point of view of their use (Chemistry, Natural Sciences.4,12,13)]. Integration with ecology.
III	Their importance and use in medicine. Integration with medicine, solving the tasks of the process of teaching the safety of human life.
IV	Identification of private reactions. Solving problems in the process of teaching chemistry.
V	Control task: the course of the analysis of cations of the II analytical group - the formation of research skills.
VI	Decoration of private reactions and mixture analysis results of the II analytical group according to the given schemes.
VII	Evaluation system for laboratory work
VIII	Synthesis of information - multi-component analysis of the study material.

Stage I: General Characterization of II Analytical Group Cations

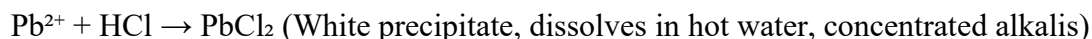
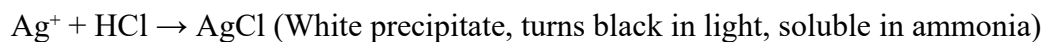
Analytical classification of ions differs from d.i. The distribution of chemical elements in groups in Mendeleev's periodic system is based on certain regularities related to the solubility of some compounds, the acid-base properties of oxides and hydroxides of elements, the dependence of metal cations on hydrochloric acid, sulfuric acid, and alkalis and is represented by 6 analytical groups of cations and 3 anions.

Ag^+ , Pb^{2+} and $[\text{Hg}_2]^{2+}$ belong to II analytical group of cations with acid-base system. Silver and mercuric chlorides are insoluble in water. Lead chloride, however, dissolves slightly in cold water and more readily in hot water. Ag^+ , Pb^{2+} and $[\text{Hg}_2]^{2+}$ are colorless in aqueous solutions. In addition to chlorides, iodides, bromides, sulfides, carbonates, phosphates, chromates and oxalates are insoluble in water from their salts, sulfates are slightly soluble. Discussion of this issue helps students to remove, separate and identify sediments of different composition using a systematic method in the process of performing the control task.

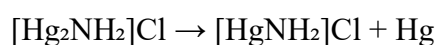
Silver has an s^1 electron on the outer valence layer, after giving it up it turns into a single charge cation, its properties are very different from the properties of cations of analytical group I, which is explained by the formation of the $\text{Ag } 4d^{10}$ electronic configuration. The Pb^{2+} cation has a charge two units lower than the group number. This is explained by the effective detection of the inert pair $5s^2$, which is expressed by the resistance of the s^2 electron pair on the outer layer to participate in the formation of a covalent bond. Mercury is hardly oxidized to $[\text{Hg}_2]^{2+}$ ion, since it contains a $6s^2$ electron pair, which is weakly screened by the $4f$ –sublevel and because of this is strongly bound by the charge of the nucleus. Cations of analytical group II with hardly polarizable anions CH_3COO^- , F^- , ClO^- and others form water-soluble salts. (Evaluation indicators - the student should be able to: [Characterization of the properties of elements, including metals/non-metals and their important compounds based on the location of elements in the periodic system (Chemistry, Natural Sciences 1,4,6,7,8,9,11,12,13), (Chemistry, Natural Sciences 2 ,6,7,8, 9,11)] explanation of the properties of substances based on the electronic structure of the atom.

A group reagent is dilute hydrochloric acid, which reacts with group II cations to form hard-to-dissolve chlorides. When heated, the solubility of lead chloride in water increases, while the solubility of silver and mercury chlorides does not change. This property allows the Pb^{2+} cation to remove $[\text{Hg}_2]^{2+}$ and Ag^+ . The analytical method of removing cations is also used to remove $[\text{Hg}_2]^{2+}$ and Ag^+ cations. Mercury (I) chloride reacts with ammonia solution to form dimercurammonium chloride. It is unstable and breaks down. The following diagram clearly shows the current processes:

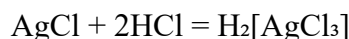
Reaction Scheme:



↓



When using concentrated hydrochloric acid, soluble complex acids are formed:



The information in the tables reduces the time needed to create different types of presentations.

Stage II: Chemical Bases of Toxic Effect of Heavy Metals - Integration with Ecology

Integration motivates students to study chemistry and helps them become competitive individuals. Students learn that heavy metals have a molecular weight above 50 and a density exceeding 5 g/cm^3 . In small amounts, they are essential for organisms, but excessive levels can lead to poisoning. Heavy metals in animal and human body:

- damages the central nervous system;
- changes blood composition;
- negatively affects the functions of the cardiovascular system, liver, lungs, kidneys and other organs;
- can cause acute physiological changes, malignant tumor, allergy, dystrophy, physical and neurological degenerative processes, which are characterized by symptoms similar to Alzheimer's and Parkinson's diseases.

According to **Knorte's** (1974) **stress index**, heavy metals rank third among pollutants as toxic substances. 3 main ways of their spread were identified: 1. **abiotic** (wind erosion, water circulation), 2. **biotic**; 3. **anthropogenic**. From the second analytical group of cations, lead and mercury are particularly highly toxic. [2]

Table #2: Historical Heavy Metal Toxicity Events and Modern Regulations

Heavy Metal	Historical Event / Period	Health Effects Observed	Current WHO/FAO Standards	Modern Sources of Exposure
Lead (Pb)	Roman Empire (c. 146 BC – 476 AD): Lead content in bones 100× higher than modern humans; widespread use of lead pipes and vessels	• Neurological disorders • Developmental delays • Osteoporosis • Collapse of	• Water: 0.03 mg/L • Air: 0.0003 mg/m³ • Daily intake: 0.2–0.3 mg (food), 0.02 mg (water) • LD₁₀₀: < 5 mg/kg	• Tetraethyl lead in fuel • Industrial dust and vapors • Lead-glazed ceramics • Packaging materials

		Roman society (hypothesized)		• Cigarette smoke (13 µg per cigarette)
Lead (Pb)	Greenland Ice Core Analysis: Elevated lead levels during Roman period confirmed in ice samples	• Historical atmospheric pollution • Long-range environmental impact	Same as above	• Fuel combustion byproducts • Mining and smelting • Battery manufacturing
Mercury (Hg)	Industrial Revolution (18th–19th centuries): Mercury used in felt production; Hatters' disease documented	• Severe neurological disorders • “Mad Hatter” syndrome • Tremors and psychosis	• Water: 0.0005 mg/L • Air: 0.0005 mg/m³ • LD₁₀₀: < 5 mg/kg	• Combustion emissions • Electrical industry • Pulp and paper production • Caustic soda manufacturing • Mercury-based fungicides
Mercury (Hg)	Minamata Disease, Japan (1956): Industrial mercury discharge into coastal waters	• Severe neurological damage • Birth defects • Paralysis and death	Same as above	• Volcanic activity (natural) • Mercury-rich geological formations • Coal combustion • Improper disposal of medical waste

Table #3: Current Environmental and Safety Standards for Group II Heavy Metals

Heavy Metal	WHO Drinking Water Limit	Air Quality Limit	Daily Food Intake (FAO)	Toxicity Classification	Primary Health Impacts	Key Biochemical Mechanism
Lead (Pb)	0.03 mg/l (30 ppb)	0.0003 mg/m ³	0.2-0.3 mg/day (adult)	LD ₁₀₀ < 5 mg/kg (highly toxic)	Heart pain - Hemoglobin synthesis decrease - Malignant tumors - Birth defects - Osteoporosis	Bone deposition (serious depositor) - Vitamin D metabolism disruption - Cell energy balance disturbance - Genetic apparatus damage
Mercury (Hg)	0.0005 mg/l (0.5 ppb)	0.0005 mg/m ³	Not established (minimize exposure)	LD ₁₀₀ < 5 mg/kg (highly toxic)	Severe neurological disorders - Brain damage - Immune system suppression -	Interaction with -SH protein groups: 2R-SH + Me ²⁺ → R-S-Me-S-R + 2H ⁺ -

					Metabolic disruption	Enzyme inactivation Protein structure alteration
Silver (Ag)	0.1 mg/l (100 ppb)	Not established	Trace amounts (0.02 mg/kg body weight)	Low toxicity (used medicinally)	Oligodynamic effect (antibacterial) Generally safe at low concentrations	Bacterial inhibition Sterile zone formation Antimicrobial action

Detailed Toxicological Profiles

Lead, Plumbum, Pb is one of the most common and dangerous toxicants. The facts of human poisoning with this element c. BC was described by Greek doctors. According to historians, lead pottery played a crucial role in the collapse of the Roman Empire. The lead content in the bones of the Romans was 100 times higher than that of modern people. The Romans used lead to make water pipes and vessels. Analyzing ice from Greenland icebergs has shown high lead concentrations in the human body during the Roman Empire.

Currently, this element is intensively polluting the biosphere. According to FAO data, an adult person receives 0.2-0.3 mg of lead daily with food and 0.02 mg with water - a biotic way of contamination with heavy metals. Anthropogenic sources of pollution are: dusty, vaporous, liquid wastes of the enterprise, fuel combustion products, transport emissions (to increase the detonation number, 1% $(C_2H_5)_4Pb$ is added to tetraethyl lead). [9]

Contamination of food products with lead occurs from packaging material, lead-glazed ceramic dishes. Bone is a serious depositor. High concentration of Pb causes osteoporosis, decalcification of bones, disturbance of D-vitamin metabolism, changes in cell energy balance and genetic apparatus. In case of chronic poisoning, peritonitis develops, which is caused by damage to the kidneys. Experimental data have confirmed that when 1 mg of Pb dust is absorbed, pains in the heart area, decrease in hemoglobin synthesis, development of malignant tumors, pathologies in the offspring are observed. 1 stick of cigarette contains 13 μg of Pb, 1.5 μg gets into the tobacco smoke and 1/3 goes into the blood. According to the International Health Organization (WHO), the maximum permissible concentration of Pb in drinking water is ppb (part per billion) = $\frac{1}{10^9}$, part per billion or 0.03 mg/l, in air - 0.0003 mg/m³. [6] The dose of toxic compounds is determined by LD₅₀ and LD₁₀₀ (Lethal Dose) - a dose that causes the death of 50% or 100% of experimental or test animals when taken orally once. The dose is determined by concentration. All substances with a low LD are toxic. Lead and mercury are especially toxic, since LD₁₀₀ < 5 mg/kg. Even in the distant future, the amount of maximum permissible concentration equal to (and even less than) the modern demand should not cause any disease, pathological or genetic change in the body.

Mercury, (hydrargyrum, **Hg**) and its compounds are the most volatile of heavy metals, which is the main reason for its spread and is especially dangerous for living organisms. When inhaled, it passes from the lungs into the blood, enters the brain, which causes severe neurological disorders. The neurotoxic effect is caused by its interaction with the -SH group of proteins: $2R-SH + Me^{2+} \rightarrow R-S-Me-S-R + 2H^+$. As a result of their blocking, the properties of protein substances of tissues change and the properties of hydrolytic, redox enzymes are inactivated, the immune system decreases. Mercury negatively affects the metabolism of nutrients, vitamin C, calcium, copper, zinc, protein substances.

Industrial mercury polluters include heating combustion, electrical and pulp industries, caustic soda production, and the use of mercury-containing fungicides. Among the natural sources, volcanic eruptions, mountain rocks, and mercury deposits are noteworthy.

Solutions of mercury (I) salts contain the group - Hg - Hg - and during dissociation they give us a complex

cation $[\text{Hg}_2]^{2+}$. All mercury salts are toxic. According to WHO, the maximum permissible concentration of Hg in drinking water is 1 ppb or 0.0005 mg/l, in air - 0.0005 mg/m³.

Integration with Human Life Safety

We can highlight several issues in the process of teaching chemistry and human life safety: the main risks and dangers of chemical laboratories, first aid for severe poisoning, thermal and severe burns, the nature and degree of harmful effects of toxic compounds on human health.

Stage III: Importance and Use of Metal Cations in Medicine - Integration with Medicine

Silver does not belong to a biogenic element, but it is necessary for the normal functioning of a number of organs of living beings. A small concentration of silver ions increases the body's ability to fight against infectious diseases, since bacteria do not multiply around it, a sterile zone is formed. It is characterized by oligodynamic (Greek Oligos – small, Dinamus – strength) action. Traces of ultratrace element silver (0.02 mg/kg) are found in all living organisms. The highest content of silver in the human body is in the brain (0.03 mg).

Medical Preparations of Metal Cations of Analysis Group II [10]

Silver (Ag^+) Compounds:

- **Silver solutions** are used to stabilize drugs, especially to extend the shelf life of eye drops;
- **Silver nitrate, Argenti nitras** - a pharmacopoeial drug, with antiseptic, bactericidal properties, is used in the form of a 1-2% aqueous solution for the treatment of eye and skin diseases, during inflammation of the mucous membrane, in urology, as a burning agent - in dermatology, to treat wounds in surgery; A weak solution of silver and ammonia complex used in medicine called Amargen works more effectively.
- **Protargol (8%) and Chologol (70%)** are highly dispersed powders of colloidal metallic silver, each crystal (1 μm) is surrounded by a protein shell of albumin (Protargol) or collagen (Chologol). It is used to rinse the urethra, in conjunctivitis, chronic gastritis, stomach ulcer disease, in dermatology;
- **Colloidal nanosilver** is a natural antibiotic, antimycotic, antiviral, anthelmintic remedy.
- **Electrolytic silver** is used in hygiene to deodorize drinking water, mineral water, food products, in medical and preventive practice.

Lead (Pb^{2+}) Compounds:

- $\text{Pb}(\text{CH}_3\text{COO})_2 \cdot 3\text{H}_2\text{O}$ and PbO are used in medical practice. They have astringent, antiseptic action.
- During X-ray therapy, diagnosis, a 2-3 mm layer of lead is enough to protect people from X-ray radiation. The apron, helmet, gloves of the medical personnel of the X-ray rooms are made of rubber containing lead.

Mercury (Hg) Compounds:

- HgCl_2 – is an astringent, burning and antiseptic agent for ulcers (dilution 1:1000), for disinfection;
- HgI_2 – for the treatment of syphilis;
- HgNH_2Cl – as an ointment, in dermatology;
- Hg_2Cl_2 – calomel, as a business, bilious, diuretic agent.

The student sees the purpose of the task, the practical aspects of these ions, compounds of elements, the need for human health and the connection with everyday life.

Stage III-B: Case Studies and Active Learning Exercises

This stage introduces real-world scenarios to strengthen students' critical thinking, problem-solving skills, and appreciation of chemistry's societal relevance. Through active learning exercises, students apply theoretical knowledge to practical situations involving heavy metal contamination, occupational safety, and environmental management.

Case Study 1: Lead Contamination in Drinking Water

Scenario

A small community of 5,000 residents discovers elevated lead levels in its drinking water (0.08 mg/L), nearly triple the WHO limit (0.03 mg/L). The source is traced to aging lead pipes installed 80 years ago. Children exhibit symptoms of lead exposure, including learning difficulties and behavioral changes.

Student Tasks (Condensed):

- Calculate daily lead intake from water and compare it to FAO guidelines.
- Assess health risks and identify vulnerable groups.
- Propose three practical remediation strategies and a monitoring plan.
- Draw historical parallels with lead use in the Roman Empire and modern cases (e.g., Flint, Michigan).

Learning Outcome:

Students develop skills in toxicological risk assessment, historical comparison, and public health communication.

Case Study 2: Mercury Exposure in Industrial Settings

Scenario:

A 42-year-old employee at a chemical plant using mercury cell technology presents with tremors and memory loss. Air monitoring reveals mercury vapor levels of 0.0012 mg/m³, exceeding WHO limits. Blood tests confirm elevated mercury levels.

Student Tasks (Condensed):

- Calculate daily and cumulative mercury exposure.
- Explain Hg²⁺ interaction with protein –SH groups and its neurological effects.
- Recommend protective equipment, engineering controls, and biological monitoring.
- Assess environmental risks and compare natural vs. anthropogenic mercury sources.

Laboratory Component:

Students simulate mercury detection using potassium iodide, observing the characteristic Hg₂I₂ precipitate.

Learning Outcome:

Students apply biochemical principles to occupational toxicology, design safety protocols, and evaluate ethical responsibilities in industrial health.

Active Learning Module: Pollution Management Simulation

Students work in small groups as environmental consultants addressing heavy metal contamination in a mixed-use area. The scenario involves elevated levels of lead (Pb) and mercury (Hg) in soil, water, and air near a former battery recycling site, affecting 1,200 residents and local agriculture.

Tasks include:

- Prioritizing risks using WHO/FAO standards
- Designing short- and long-term remediation strategies
- Selecting appropriate analytical methods
- Developing a public communication plan

Learning Outcome:

Students integrate toxicological data, environmental policy, and analytical chemistry to solve complex, real-world contamination challenges collaboratively.

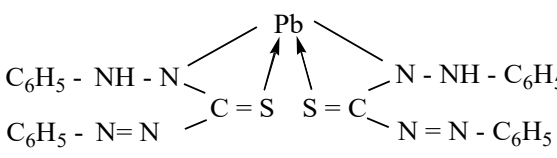
Stage IV: Private Reactions for Identification of Group II Cations

After getting acquainted with the theoretical basis of the work, practical aspects are discussed. The analytical methods used during the test shall be:

- specific;
- sensitive;
- in relation to the precise norms defined by the article of the pharmacopoeia (in the case of medicinal products) or other normative-technical document;
- short execution time;
- requires a minimum number of research objects.

Systematization of a large volume of information in the form of a table contributes to its better perception, long-term memorization, material processing, deepening and activation of given knowledge. The student is introduced to the specific work, its theoretical and methodological material, the purpose and principle of the experiment, the course of the experiment and the procedure for drawing up the protocol. **Procedural knowledge** is organized by activities, helps to build research skills and enables the application of theoretical knowledge with practical aspects. This method serves to acquire this type of knowledge.

Table #4: Particular Identification Reactions

Cation	Reaction number, reagent	The product of the reaction and its properties
Ag^+	1. KOH, NaOH	Ag_2O – black precipitate, dissolves in ammonia.
	2. K_2CrO_4	Ag_2CrO_4 – brick-red precipitate.
	3. KBr, KI	AgBr – pale yellow precipitate.
		AgI – yellow precipitate.
Pb^{2+}	1. KOH, NaOH	$\text{Pb}(\text{OH})_2$ – white precipitate; Dissolves in acids, alkalis.
	2. H_2SO_4 – sulfates	PbSO_4 – white precipitate; Soluble in alkalis and ammonium acetate.
	3. K_2CrO_4 , $\text{K}_2\text{Cr}_2\text{O}_7$	PbCrO_4 – yellow precipitate.
	4. I^- – iodide ion	PbI_2 – yellow precipitate. Dissolves in excess I^- - iodide ion.
	5. Diphenyldithiocarbazon (dithizone)	 kompleksi (witel i)
	6. S^{2-} – Sulphide ion	

		PbS – A black precipitate dissolves in nitric acid.
[Hg ₂] ²⁺	1. KOH, NaOH 2. K ₂ CrO ₄ 3. SnCl ₂ Cu Diphenylcarbazide (Dph) $\begin{array}{c} \text{NH} - \text{NH} - \text{C}_6\text{H}_5 \\ \diagup \quad \diagdown \\ \text{O} = \text{C} \\ \diagdown \quad \diagup \\ \text{N} = \text{N} - \text{C}_6\text{H}_5 \end{array}$ 5. KI	Hg ₂ O – Black precipitate. Hg ₂ CrO ₄ – Red precipitate. Hg – Black precipitate. Hg – Black precipitate. Amalgam on copper. [Hg(Dph) ₂] – Violet or blue precipitate. $\begin{array}{c} \text{C}_6\text{H}_5 - \text{NH} - \text{N} \quad \text{Hg} - \text{N} - \text{NH} - \text{C}_6\text{H}_5 \\ \quad \quad \quad \diagup \quad \diagdown \quad \quad \quad \diagup \quad \diagdown \\ \quad \quad \quad \text{C} = \text{O} \quad \quad \quad \text{O} = \text{C} \\ \quad \quad \quad \diagdown \quad \diagup \quad \quad \quad \diagdown \quad \diagup \\ \text{C}_6\text{H}_5 - \text{N} = \text{N} \quad \quad \quad \text{N} = \text{N} - \text{C}_6\text{H}_5 \end{array}$ → Hg ₂ I ₂ – A dark green precipitate dissolves in excess iodide K ₂ [HgI ₄] +Hg

Stage V: the control task is carried out in groups (maximum 3-4 students). Group (collaborative) work –

teaching with this method involves dividing students into groups and giving them an experimental task. Work is distributed in advance. Each student is in the role of a detective and tries to discover the cation or cations contained in a solution of unknown composition using the given system analysis method, with the help of a scheme, independently writes and organizes the results of the experiment in a workbook, interprets his own observations and draws conclusions as a result of judgment, thus instilling in him the desire to constantly strive to satisfy curiosity, which is a necessary prerequisite for the formation of enthusiasm for scientific research work. Thus, work is carried out in groups, but decoration is done individually. This strategy ensures maximum involvement of all students in the learning process. Through the control task, students' theoretical knowledge is checked and it helps to develop critical thinking. They are given the opportunity to become researchers themselves, and this process is facilitated by the teaching material provided with methodically organized tables and diagrams that show the way how they arrived at this discovery.

It is represented by the acid-base classification of group II

Current analysis scheme of cations by systematic method

The purpose of the work: detection of group II cations in the research solution.

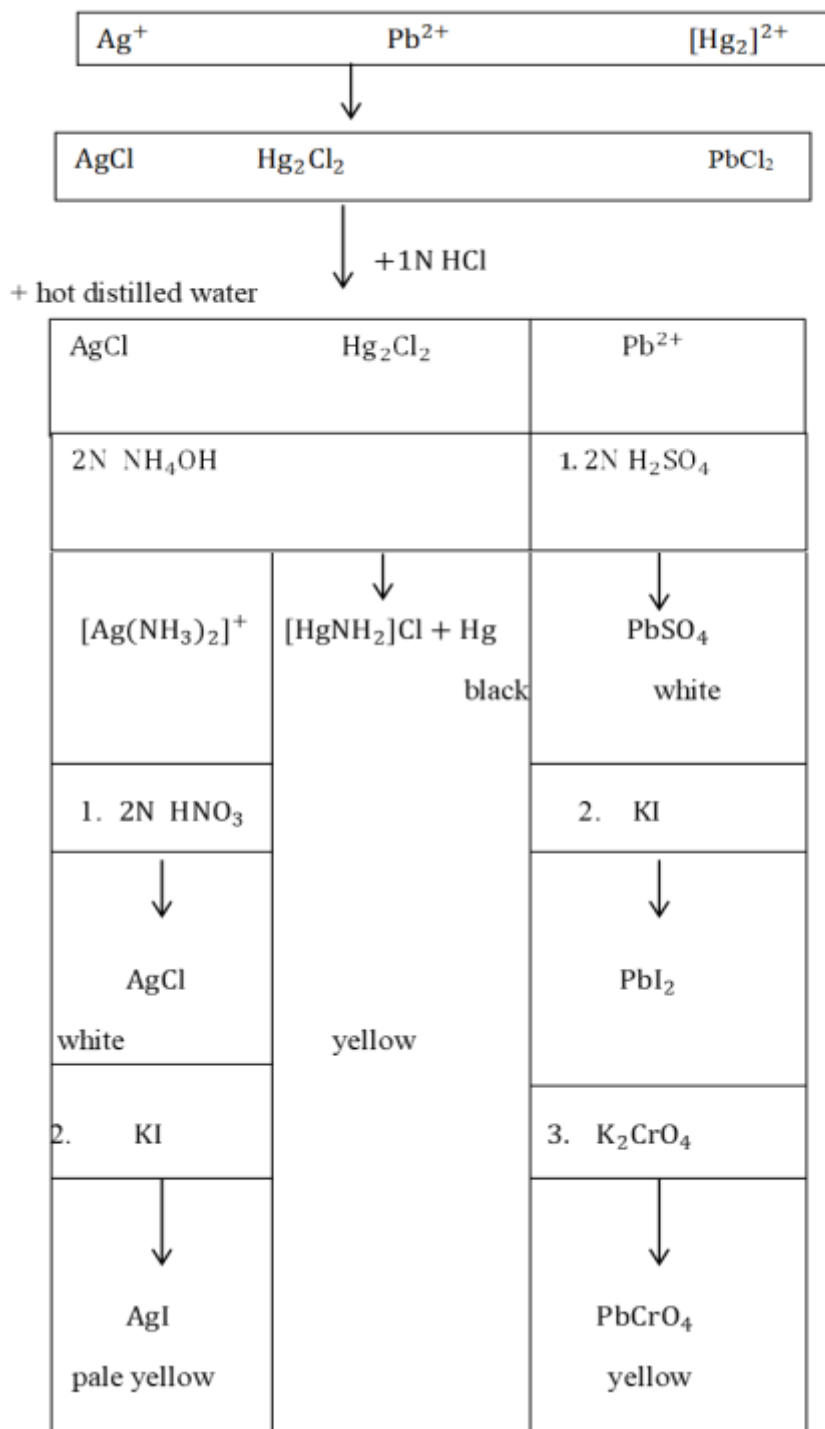
Assignment: students should determine group II cations in the research solution, and for this purpose they use the method of systematic analysis.

The course of the experiment: 20-30 drops of the test solution are placed in a conical flask, and 2N hydrochloric acid solution is added. The experiment separates and centrifuges the precipitate. The precipitate is processed 2-3 times with hot water and centrifuged again. Lead (II) chloride dissolves in the solution, while silver chloride and mercury (I) chloride form a precipitate.

- Discovery of Pb²⁺ cation.** 3-5 drops of the centrifuge are added to the potassium iodide solution. A yellow precipitate of lead iodide PbI₂ is formed, which dissolves when heated, and is separated again as a golden needle-like precipitate when cooled.

2. **Discovery of $[\text{Hg}_2]^{2+}$ cation.** Ammonium alkali is added to the precipitate and mixed. In the presence of $[\text{Hg}_2]^{2+}$ cation, the precipitate turns black. Under the action of NH_4OH , silver chloride passes into the solution in the form of a complex salt, while HgNH_2Cl salt and mercury remain in the precipitate. The precipitate is centrifuged.
3. **Discovery of Ag^+ cation.** The centrifuge is divided into two parts. Potassium iodide solution is added to one of them, nitric acid to the other. In the presence of Ag^+ cation, a yellow precipitate of silver iodide will precipitate in the first test tube, and a white precipitate of silver chloride will precipitate in the second. [5]

Scheme of analysis of group II cations



The experiment is carried out with appropriate comments. If it is difficult for the student to make a conclusion, the teacher should lead him to the correct formulation with the help of questions and tests. Only in this case the work is considered completed.

VI stage: drawing up the results of private reactions and mixture analysis of the II analytical group according to the given schemes.

The results of private reactions and mixture analysis of the II analytical group are drawn up according to the given tables in the workbooks, which are filled in according to the results of the performed experiment:

Private reactions of cations II analytical group

Table # 3

1	2	3	4	5	6
Number	Reagent	Cation reaction equation	Reaction equation	Conditions for the reaction	Characterization of the product obtained

Analysis of a mixture of cations of the analytical group

Table# 4

1	2	3	4	5	6	7
Sample number	Research ion	Reagent	What did we see?	Conclusion	Sediment composition	Solution composition

Stage VII: Weekly laboratory work is evaluated with 1 point. The goal of the weekly laboratory evaluation is to ensure students are progressing in their understanding of analytical group II cations and can effectively apply theoretical knowledge to practical experiments. It determines the research procedures, collects data, analyzes them, draws conclusions based on reasoned reasoning, adheres to ethics and safety norms while conducting research work. [11] The evaluation process is designed to be transparent, with students receiving feedback on their performance in each criterion weekly. This helps them track their progress and improve in specific areas.

Evaluation of laboratory work 0

Table # 5

	Evaluation criteria	points	comment
1.	Doing homework - tests, tasks	0-1	Criteria: Completeness and accuracy of assigned homework and preparatory tasks. 0 points: Homework incomplete or inaccurate. 1 point: Homework completed fully and accurately.
2.	General characterization of the cations of the II analytical group, consideration of the theoretical part of private reactions with the teacher	0-5	Criteria: Participation in discussions, ability to explain theoretical aspects, and characterization of cations. 0-2 points: Limited understanding or incorrect explanations. 3-4 points: Moderate understanding with minor inaccuracies. 5 points: Comprehensive and accurate understanding.

3.	Planning of the experiment, detailed description of its progress, conducting identification reactions under the guidance of a laboratory assistant, a teacher	0-2	Criteria: Organization of experimental steps, adherence to safety norms, and proper execution. 0 points: Poor planning or failure to execute safely. 1 point: Partial planning and execution. 2 points: Well-planned and safely executed experiment.
4.	Filling in the workbook in the form of tables, diagrams, confirmation by the signature of the laboratory assistant	0-1	Criteria: Accuracy and neatness of recorded results in tables/diagrams. 0 points: Workbook incomplete or disorganized. 1 point: Workbook complete and well-organized.
5.	Presentation of work, use of information and communication technologies	0-1	Criteria: Effectiveness in presenting results using ICT tools (e.g., slides or diagrams). 0 points: Lack of ICT usage or ineffective presentation. 1 point: Clear and well-supported presentation with appropriate tools.
6.	final evaluation	1	This point is awarded based on the overall performance and adherence to safety and ethical norms.

Students will receive both verbal and written feedback from the instructor and laboratory assistant. Feedback will focus on strengths, areas for improvement, and recommendations for the next session. Weekly points are cumulative and contribute significantly to the final laboratory grade. Consistent performance across all evaluation criteria is essential for achieving a high overall score.

Stage VIII: synthesis of information - multi-component analysis of the study material

The study of Analytical Group II cations provides students with a structured framework to understand the fundamental principles of chemical analysis and their real-world applications. Through the combination of theoretical instruction, practical experiments, and interdisciplinary integration, this methodology fosters a deep understanding of the chemical properties and behavior of cations in various contexts.

The implementation of the base-acid classification system as the primary analytical method enhances students' logical and critical thinking skills. This system not only simplifies the identification and separation of cations but also promotes environmentally safer practices compared to traditional methods like the sulfide analysis. By emphasizing principles such as solubility, amphotericity, and complex formation, students gain a clear understanding of the chemical behavior of metals like silver, mercury, and lead, which are crucial for advanced studies and research.

The integration with ecology, medicine, and human life safety underscores the relevance of chemistry in addressing societal challenges. For example, the toxicological study of heavy metals like lead and mercury demonstrates the environmental and health implications of chemical substances. Similarly, the applications of silver compounds in medicine illustrate the importance of analytical chemistry in developing effective treatments and improving human health.

The hands-on approach through laboratory experiments enables students to connect theoretical knowledge with practical execution. The systematic analysis of cations, the use of group reagents, and the identification of reaction products are key skills that prepare students for careers in science and technology. Moreover, the

structured evaluation system ensures that students develop research skills, adhere to safety and ethical standards, and refine their experimental techniques.

By synthesizing information across disciplines, students are encouraged to think critically and holistically about the chemical processes around them. The emphasis on creative teaching methods, such as collaborative group work, detailed feedback, and the use of ICT tools, equips them with the skills needed to tackle complex problems and excel in professional environments.

In conclusion, the study methodology of Analytical Group II cations provides a comprehensive educational experience that integrates theory, practice, and interdisciplinary applications. By mastering these concepts, students are empowered to understand and address chemical, environmental, and societal issues, laying a strong foundation for their future endeavors in science and beyond.

Integration of Theoretical and Practical Knowledge

The implementation of the base-acid classification system as the primary analytical method enhances students' logical and critical thinking skills. This system not only simplifies the identification and separation of cations but also promotes environmentally safer practices compared to traditional methods like sulfide analysis. By emphasizing principles such as solubility, amphotericity, and complex formation, students gain a clear understanding of the chemical behavior of metals like silver, mercury, and lead, which are crucial for advanced studies and research.

The systematic approach presented in this methodology follows a clear pedagogical progression:

Foundation (Stage I): Students begin with fundamental chemical principles, electronic configurations, and group reagent behavior, establishing the theoretical framework necessary for all subsequent work.

- 1. Contextualization (Stages II-III):** The integration with ecology, medicine, and human life safety underscores the relevance of chemistry in addressing societal challenges. For example, the toxicological study of heavy metals like lead and mercury demonstrates the environmental and health implications of chemical substances. The historical examples presented in Table #2 provide students with compelling evidence of chemistry's long-term impact on human civilization, from the Roman Empire's lead poisoning to modern environmental regulations. Similarly, the applications of silver compounds in medicine (Stage III) illustrate the importance of analytical chemistry in developing effective treatments and improving human health.
- 2. Active Application (Stage III-B):** The newly introduced case studies bridge the gap between theoretical knowledge and practical problem-solving. Students engage in realistic scenarios involving lead contamination in water supplies, occupational mercury exposure, and silver-based purification systems. These exercises develop critical thinking skills, quantitative assessment abilities, and appreciation for the complexity of real-world environmental and health challenges. By grappling with scenarios that have no single "correct" answer, students learn to evaluate trade-offs, consider multiple stakeholder perspectives, and make evidence-based recommendations.
- 3. Technical Mastery (Stages IV-V):** The hands-on approach through laboratory experiments enables students to connect theoretical knowledge with practical execution. The systematic analysis of cations, the use of group reagents, and the identification of reaction products are key skills that prepare students for careers in science and technology. The introduction of modern instrumental techniques (AAS, ICP-MS) alongside classical methods ensures students understand both the historical foundations and contemporary practice of analytical chemistry. The extended control tasks push beyond simple identification to include quantitative estimation, regulatory compliance assessment, and environmental risk evaluation.
- 4. Documentation and Assessment (Stages VI-VII):** The structured evaluation system ensures that students develop research skills, adhere to safety and ethical standards, and refine their experimental techniques. Progressive evaluation throughout the semester encourages continuous improvement while maintaining high

standards. The detailed documentation requirements teach professional scientific communication skills essential for careers in chemistry, environmental science, and public health.

Interdisciplinary Connections and Societal Relevance

One of the strongest features of this methodology is its emphasis on interdisciplinary integration:

Chemistry ↔ Ecology: Students learn how chemical principles govern environmental contamination, bioaccumulation, and ecosystem health. The three pathways of heavy metal spread (abiotic, biotic, anthropogenic) from Knorte's stress index provide a framework for understanding human impact on natural systems. The comparison of historical and modern contamination levels (Table #2 and #3) demonstrates both the progress made through environmental regulation and the ongoing challenges of industrial society.

Chemistry ↔ Medicine: The medical applications of Group II cations (Stage III) show students that analytical chemistry is not merely academic but directly improves human health. From silver's oligodynamic antibacterial action to lead shielding in X-ray rooms, students see how chemical knowledge translates to practical medical applications. Understanding both the therapeutic uses and toxicological dangers of these elements develops nuanced thinking about risk-benefit analysis in healthcare.

Chemistry ↔ History: The archaeological and historical examples (Roman Empire lead poisoning, Greenland ice cores, industrial revolution mercury exposure) demonstrate that chemistry provides tools for understanding human history. Students learn that chemical analysis can answer historical questions and that historical patterns inform modern safety standards. This connection makes chemistry feel relevant beyond the laboratory.

Chemistry ↔ Public Policy: The WHO and FAO regulatory standards presented throughout the document show students how scientific evidence informs public health policy. The case studies requiring students to make recommendations for contaminated communities or industrial safety improvements prepare them for potential roles in environmental regulation, occupational health, or policy advocacy.

Development of Critical Competencies

This methodology systematically develops multiple competencies essential for modern scientific practice, such as analytical skills, critical thinking, problem-solving, communication, ethical awareness, traditional approaches, among others. The study methodology of Analytical Group II cations presented in this article provides a comprehensive educational experience that integrates theory, practice, and interdisciplinary applications. By synthesizing information across disciplines, students are encouraged to think critically and holistically about the chemical processes around them. The emphasis on creative teaching methods, such as collaborative group work, detailed feedback, and the use of ICT tools, equips them with the skills needed to tackle complex problems and excel in professional environments.

The historical context provided through examples like Roman lead poisoning and Greenland ice core analysis helps students understand that chemistry is not a static body of knowledge but an evolving science that has shaped and continues to shape human civilization. Toxicological information and regulatory standards teach students that chemical knowledge carries ethical responsibilities and that analytical chemists play crucial roles in protecting public health and environmental quality.

The case studies and active learning exercises introduced in Stage III-B transform abstract chemical concepts into concrete problem-solving scenarios. Students learn that identifying a yellow lead iodide precipitate is not merely an academic exercise but a skill that could help diagnose environmental contamination threatening a community's health. They understand that recognizing mercury's interaction with protein -SH groups explain real neurological symptoms in occupationally exposed workers. They appreciate that silver's oligodynamic effect represents a practical alternative to chemical disinfectants in healthcare settings.

The integration of classical wet chemistry methods with modern instrumental techniques prepares students for the realities of contemporary analytical practice. They learn that while AAS and ICP-MS offer superior

sensitivity and speed, the fundamental understanding gained through hands-on qualitative analysis remains essential for method development, troubleshooting, and interpreting instrumental results. This balanced perspective ensures graduates are not merely technicians who can operate equipment but knowledgeable scientists who understand the chemistry underlying their measurements.

The progressive evaluation system, with its emphasis on continuous improvement and multi-faceted assessment, develops not only technical competence but also communication skills, collaborative abilities, and professional habits. Students learn that scientific work requires not just correct results but also clear documentation, effective presentation, and ethical conduct. The weekly feedback mechanism ensures students receive guidance for improvement rather than simply receiving scores.

By mastering these concepts and skills, students are empowered to understand and address chemical, environmental, and societal issues. They leave the course not only able to identify Group II cations but also capable of: assessing environmental contamination risks, evaluating occupational safety protocols, interpreting regulatory standards, communicating technical information effectively, integrating knowledge across disciplinary boundaries, thinking critically about complex real-world problems.

This methodology thus lays a strong foundation for students' future endeavors in science and beyond, whether they pursue careers in analytical chemistry, environmental science, public health, education, or related fields. More importantly, it cultivates scientifically literate citizens who understand the role of chemistry in society and can contribute to informed decision-making about environmental and health issues affecting their communities

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