



The National Technical University of
Ukraine "Igor Sikorsky Kyiv Polytechnic
Institute"



Ecology and Plant Polymers
Technology

Analytical Chemistry. Part 1. Qualitative Analysis

Work program of the discipline (Syllabus)

Details of the discipline

Level of higher education	<i>first (bachelor's)</i>
Field of knowledge	<i>16 Chemical and Bioengineering</i>
Speciality	<i>161 Chemical Technology and Engineering</i>
Educational program	<i>Industrial Ecology and Resource Efficient Cleaner Technologies</i>
Discipline status	<i>Mandatory</i>
Form of study	<i>full-time (day)/remote/mixed</i>
Year of preparation, semester	<i>2nd year, autumn semester</i>
Scope of discipline	<i>5 credits (150 hours)</i>
Semester control/ control measures	<i>Exam</i>
Schedule of classes	<i>4 hours a week (2 hours of lectures and 2 hours of laboratory classes)</i>
Language of instruction	<i>Ukrainian</i>
Information about to the eminent course / teachers	Lecturer: https://eco-paper.kpi.ua/pro-kafedru/vykladachi/vizytky/krisenko-tamara-volodimirivna-2.html Laboratory: https://eco-paper.kpi.ua/pro-kafedru/vykladachi/vizytky/krisenko-tamara-volodimirivna-2.html
Course placement	https://do.ipso.kpi.ua/

The program of the discipline

1. Description of the discipline, its purpose, subject of study and learning outcomes

"Analytical Chemistry. Part 1. Qualitative Analysis" is a fundamental chemical discipline about methods for determining the qualitative composition of compounds and their mixtures. This discipline provides theoretical and practical knowledge about chemical methods of analysis. The knowledge that students receive in the process of studying the discipline "Analytical Chemistry. Part 1. Qualitative Analysis", is a theoretical and practical basis for studying specialized disciplines at senior courses. Work in the laboratory, practical mastering of the basics of various methods of analysis is an important component of the training of highly qualified specialists. Students study the discipline "Analytical Chemistry. Part 1. Qualitative Analysis" requires them to be able to focus on a detailed study of the properties of chemical elements and their compounds, the state of matter in solutions, the assimilation of the theoretical foundations of the most important types of chemical transformations, which are the basis of various methods of analysis. When performing laboratory work on this academic discipline, students acquire the skills to perform the most important chemical operations. Their

knowledge, intelligence, abilities will manifest themselves when performing individual control tasks for analysis.

Subject of the discipline "Analytical chemistry. Part 1. Qualitative Analysis" - the study of the theoretical foundations of analytical methods, the improvement of existing and the development of new methods of analysis, their practical use.

The purpose of the discipline "Analytical Chemistry. Part 1. Qualitative Analysis".

The purpose of studying this discipline is to form in students a complex of knowledge of the theoretical foundations of important types of chemical transformations, methods for identifying the substances under study, a set of skills and abilities necessary to perform basic chemical operations.

In accordance with the purpose of studying the discipline requires the formation of students' **competencies**:

- the ability to abstract thinking, analysis and synthesis;
- the ability to apply knowledge in practical situations;
- the ability to use the provisions and methods of fundamental sciences to solve professional tasks;
- the ability to apply up-to-date experimental methods of working with technological objects in industrial and laboratory conditions.

According to the requirements of the program of the discipline **«Analytical Chemistry. Part 1. Qualitative Analysis"**, after mastering it, students must demonstrate the following programmatic learning outcomes:

- to know mathematics, physics and chemistry at the level necessary to achieve the results of the educational program;
- to correctly use the terminology and basic concepts of chemistry, chemical technologies, processes and equipment for the production of chemicals and materials based on them in professional activities;
- to carry out qualitative and quantitative analysis of substances of inorganic and organic origin, using appropriate methods of general and inorganic, organic, analytical, physical and colloidal chemistry.

2. Pre-requisitions and post-requisitions of disciplines (place in the structural and logical scheme of education according to the relevant educational program)

Study of the discipline **"Analytical Chemistry. Part 1. Qualitative Analysis"** is based on the principles of integration of knowledge gained by students during the first year in the study of the disciplines **"General and Inorganic Chemistry"**. Discipline **"Analytical Chemistry. Part 1. Qualitative Analysis"** is a fundamental chemical discipline that should provide such disciplines as **"Physical Chemistry"**, **"Toxicology"**, **"General Chemical Technology"**.

3. The content of the discipline

Topic 1. Theoretical foundations of qualitative analysis.

Topic 2. Chemical equilibrium in aqueous solutions of electrolytes.

Topic 3. Acid-base levels in aqueous solutions.

Topic 4. Complexation reactions.

Topic 5. Chemical equilibrium in heterogeneous sediment-solution systems.

Topic 6. Oxidation-reduction reactions.

Topic 7. Chemical methods of separation and concentration.

4. Learning materials and resources

Basic literature

1. Reva T.D., Chkhalo O.M., Zaitseva G.M. and others. *Analytical chemistry. Qualitative analysis: teaching-method. posib.* – K.: VSV "Medicine", 2017. – 280 p.
2. Butchenko L.I., Khokhotva O.P., Tereshchenko O.M., Glushko O.V., Krysenko T.V. *Analytical chemistry. Methods of qualitative chemical analysis (theoretical aspects and laboratory workshop): Textbook.* – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, Publishing house "Polytechnic", 2017. – 152 p.
3. Slobodnyuk R.E. *Course of analytical chemistry.* – Kherson: Oldie Plus, 2020. – 256 p.

Further reading

4. Fedushchak N.K., Bidnychenko Yu.I., Kramarenko S.Yu., Kalibabchuk V.O. *Analytical Chemistry.* – Vinnytsia: Nova Kniga, 2012. – 640 p.
5. Shevryakov M.V., Povstyanyi M.V., Yakovenko B.V., Popovych T.A. *Analytical chemistry. Theoretical foundations of qualitative and quantitative analysis.* – Kherson: Ailant, 2011. – 404 p.
6. Bolotov V.V., Svechnikova O.M., Golik M.Yu. and others. *Analytical chemistry.* – Vinnytsia: New Book, 2011. – 424 p.
7. Dorokhova E.M., Prokhorova G.V. *Tasks and questions on analytical chemistry.*— K.: Kyiv. univer., 2001.—282 p.
8. Butchenko L.I., Tereshchenko O.M., Cheryopkina R.I. *Collection of problems in analytical chemistry. Qualitative analysis: textbook.* – Kyiv: ECMO, 2011. – 181 p.
9. *Analytical chemistry. Methods of analytical chemistry in environmental research. Methodical instructions for studying the discipline for students of the direction of training 6.040106 "Ecology, environmental protection and balanced environmental management"/* Butchenko L.I., Khokhotva O.P., Tereshchenko O.M. – K: NTUU "KPI", 2011. – Ch.I. Chemical methods of analysis. –68 p.
10. *Guidelines "Analytical chemistry. Qualitative chemical analysis" to study the discipline for students of all areas of training in the course "Analytical Chemistry" /* Butchenko L.I., Khokhotva O.P., Tereshchenko O.M., Glushko O.V. – K: NTUU "KPI", 2013. – 136 p.

Information resources on the Internet

11. Union of Chemists of Ukraine <http://www.chemunion.org.ua/uk/>
12. Scientific and practical magazine "Methods and objects of chemical analysis" <https://anchem.knu.ua/>

Educational content

5. Methods of mastering the discipline (educational component)

Lectures

Lectures are aimed at:

- provision of modern, holistic, interdependent knowledge of the discipline "**Analytical Chemistry. Part 1. Qualitative Analysis**", the level of which is determined by the target setting for each specific topic;
- ensuring in the process of the lecture the creative work of students together with the teacher;
- education of students' professional and business qualities and the development of their independent creative thinking;
- formation of students' necessary interest and providing direction for independent work;
- determination at the modern level of development of science and technology in the field of chemical technology, forecasting their development for the coming years;
- reflection of the methodological processing of the material (selection of the main thoughts and provisions, underlining the conclusions, repeating them in different formulations);
- acquisition of clarity, combination, if possible, with the demonstration of audiovisual materials, layouts, models and samples;
- teaching in a clear and clear language, explaining all newly introduced terms and concepts;
- accessibility for perception by this audience.

N ^o	<i>Title of the lecture topic and list of main questions (list of didactic means, references to literature and tasks for IWS)</i>	Hours
1	<p style="text-align: center;">Topic 1. Theoretical foundations of qualitative analysis.</p> <p>The subject and tasks of analytical chemistry. Classification of analysis methods. Requirements for reactions that are used in qualitative analysis. Analytical characteristics of chemical reactions: sensitivity, limiting ratio of ions, selectivity, specificity. The division of cations and anions into groups.</p> <p>Literature: [1] pp. 16-23; [5] pp. 78-86 ; [6] pp. 11-14.</p> <p>Tasks on the IWS. Periodic law of D.I. Mendeleev and its importance in analytical chemistry. The value of the chemical and analytical properties of ions in connection with the position of elements in the periodic system.</p>	4
2	<p style="text-align: center;">Topic 2. Chemical equilibrium in aqueous solutions of electrolytes.</p> <p>The law of the current masses. Theory of Electrolytic Dissociation. Calculation of equilibrium concentrations of molecules and ions in solutions of weak electrolytes.</p> <p>Literature: [1] pp. 24-40; [3] pp. 12-26; [6] pp. 31-35.</p> <p>Tasks on the IWS. Dependence of the equilibrium constant on temperature. equilibrium constant and change in standard Gibbs energy. Rate of chemical reactions in solution.</p>	6

3	<p style="text-align: center;">Topic 3. Acid-base levels in aqueous solutions.</p> <p>Ionic product of water. The concept of pH. Calculation of the concentration of protons and pH solutions of strong and weak acids and bases. Hydrolysis. Methods of strengthening and inhibiting hydrolysis. pH solutions of salts that hydrolyze. Buffer solutions: types, mechanism of action, capacity, use in qualitative analysis.</p> <p>Literature: [1] pp. 52-72; [5] pp. 23-34; [6] pp. 24-26, 75-79 .</p> <p>Tasks on the IWS. The protolytic theory of acids and bases of Brensted-Lowry; the electronic theory of Lewis, the theory of Usanovich.</p>	6
4	<p style="text-align: center;">Topic 4. Complexation reactions.</p> <p>Structure and analytical properties of complexes. The effect of pH, the concentration of ligands on the formation of complex compounds. The use of complex compounds in the analysis.</p> <p>Literature: [1] pp. 88-97; [5] pp. 59-72 ; [6] PP. 127-136.</p> <p>Tasks on the IWS. The main provisions of the coordination theory. Factors that affect the stability of complex compounds.</p>	5
5	<p style="text-align: center;">Topic 5. Chemical equilibrium in heterogeneous sediment-solution systems.</p> <p>Conditions of precipitation and dissolution of sediments. The influence of various factors on the solubility of poorly soluble compounds: ions of the same name; strong electrolytes that do not have common ions with sediment; competing reactions of protonation and complexation. The sediments are crystalline and amorphous. The concept of colloidal solutions.</p> <p>Literature: [1] pp. 41-51; [5] pp. 17-22; [6] pp. 41-55.</p> <p>Tasks on the IWS. Fractional deposition. Conditional product of solubility. effect of solvents and temperature on solubility.</p>	6
6	<p style="text-align: center;">Topic 6. Oxidation-reduction reactions.</p> <p>General characteristic of oxidation-reduction reactions. Redox potential and factors that affect it. Nernst's level. Influence of competing reactions of protonation, precipitation and complexation on the direction and completeness of the passage of redox reactions. Equilibrium constant of redox reactions. The use of redox reactions in qualitative analysis.</p> <p>Literature: [1] pp. 73-87; [6] PP. 104-114.</p> <p>Tasks on the IWS . The effect of ionic strength and temperature on the course of oxidation-reduction reactions.</p>	5
7	<p style="text-align: center;">Topic 7. Chemical methods of separation and concentration.</p> <p>Deposition and deposition. Extraction. Sorption. General characteristics of methods.</p> <p>Literature: [1] pp. 98-109; [4] pp. 218-232.</p> <p>Tasks on the IWS . Chemical masking methods.</p>	4
	Just	36

Laboratory classes

The main objectives of the laboratory cycle are:

- ◆ help students systematize, consolidate and deepen theoretical knowledge of a qualitative chemical analysis;
- ◆ teach students the basic skills of working in a chemical laboratory and promote the mastery of skills and abilities to perform chemical analysis;
- ◆ teach students techniques for solving practical problems, promote mastery of skills and abilities to perform calculations and other types of tasks.

N^o	The name of the topic of the laboratory lesson and the list of main questions (list of didactic support, references to literature and tasks for the IWS)	Hours
1	Introduction to qualitative analysis. The effect of common group reagents on metal cations. Cations of group I. The study of fractional reactions to group I cations. Literature: [2] pp. 54-61.	4
2	Cations of groups II and III. Study of fractional reactions to cations of groups II and III. Literature: [2] pp. 61-73.	4
3	Cations of group V. Study of fractional reactions to cations of group IV. Writing a test paper 1. Literature: [2] pp. 74-80.	4
4	Group V cations. Study of fractional reactions to group V cations. Literature: [2] pp. 81-93.	4
5	Cations of group VI. Study of fractional reactions to cations of group VI. Writing test paper 2. Literature: [2] pp. 93-103.	4
6	Anions. The effect of common reagents on anions. The study of fractional reactions to anions of group I. Writing a test paper 3. Literature: [2] pp. 108-117.	4
7	Anions of II and III groups. Study of fractional reactions to anions of groups II and III. Literature: [2] pp. 117-135.	4
8	Analysis of individual inorganic substances. Writing a test paper 4. Literature: [2] pp. 138-149.	8
	Just	36

6. Independent work of the student

Independent work takes 52% of the time to study the credit module, including preparation for the exam. The main task of independent work of students is to master knowledge in areas that are not included in the list of lecture questions through personal search for information, the formation of an active interest in a creative approach in educational work. In the process of independent work within the framework of the educational component, the student must learn to analyze the information received and use it to solve the tasks.

N ^o	The name of the topic submitted for independent study	Number of hours of IWS
Topic 1. Theoretical foundations of qualitative analysis		
1	Periodic law of D.I. Mendeleev and its importance in analytical chemistry. The value of the chemical and analytical properties of ions in connection with the position of elements in the periodic system. Literature: [1] pp. 11-12; [4] pp. 87-89.	6
Topic 2. Chemical equilibrium in aqueous solutions of electrolytes.		
2	The dependence of the equilibrium constant on temperature. Equilibrium constant and change in gibbs standard energy. The rate of chemical reactions in solution. Literature: [3] pp. 14-26; [4] pp. 25-32.	6
Topic 3. Acid-base levels in aqueous solutions.		
3	Protolytic theory of acids and bases of Bransted-Lowry; Lewis's electronic theory, Usanovich's theory. The effect of ionic strength and temperature on acid-base equilibrium. Literature: [1] pp. 52-57.	6
Topic 4. Complexation reactions.		
4	The main provisions of the coordination theory. Factors that affect the stability of complex compounds. Literature: [1] pp. 88-97; [5] pp. 59-72.	5
Topic 5. Chemical equilibrium in heterogeneous sediment-solution systems.		
5	Fractional deposition. Conditional product of solubility. The effect of solvents and temperature on solubility. Literature: [1] pp. 41-51.	8
Topic 6. Oxidation-reduction reactions.		
6	The effect of ionic strength and temperature on the course of oxidation-reduction reactions. Literature: [1] pp. 73-81.	5
Topic 7. Chemical methods of separation and concentration.		
7	Chemical masking methods. Literature: [2] pp. 18-21.	4
8	Writing a settlement work	8
9	Exam preparation	30
	Total hours	78

Policy and control

7. Policy of the discipline (educational component)

Rules for attending classes and behavior in the classroom

Attendance is a mandatory component of the assessment. Students are obliged to take an active part in the educational process, not to be late for classes and not to miss them without a good reason, not to interfere with the teacher to conduct classes, not to be distracted by actions that are not related to the educational process.

Rules for assigning incentive and penalty points

- Incentive points can be awarded by the teacher solely for performing creative work in the discipline or additional completion of online specialized courses with the receipt of the appropriate certificate:

<https://www.coursera.org/learn/advanced-chemistry>

<https://www.coursera.org/learn/intro-chemistry>

But their amount cannot exceed 10% of the rating scale.

- penalty points are not provided.

Deadlines and Rescheduling Policy

In case of debts in the discipline or any force majeure circumstances, students should contact the teacher through the available (provided by the teacher) communication channels to solve problematic issues and agree on an algorithm of actions for working out.

Academic Integrity Policy

Plagiarism and other forms of dishonest work are unacceptable. Plagiarism includes the lack of links when using printed and electronic materials, quotes, opinions of other authors. Unacceptable hints and write-offs when writing tests, conducting classes; passing the exam for another student; copying materials protected by the copyright system without the permission of the author of the work.

The policy and principles of academic integrity are defined in Chapter 3 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute <https://kpi.ua/code>".

Academic Conduct and Ethics Policy

Students should be tolerant, respect the opinions of others, formulate objections in the correct form, constructively maintain feedback in the classroom.

The norms of ethical behavior of students and employees are defined in Chapter 2 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute <https://kpi.ua/code>".

8. Types of control and rating system for evaluating learning outcomes (RS)

Distribution of study time by types of classes and tasks in the discipline in accordance with the working curriculum:

Semester	Educational time		Distribution of study hours				Control measures		
	Credits	Acad. h.	Lecture	Practical	Lab. Work	IWS	MCT	SW	Semester control
3	5	150	36	-	36	78	1	1	Exam

The student's rating on the discipline consists of points that he receives for:

- performance and protection of laboratory works (7 works);
- writing a modular test (1 modular test is divided into 2 tests);
- performance of settlement work.

Semester control is the exam.

The system of rating (weight) points and evaluation criteria

1. Performance of laboratory works:

The necessary conditions for **admitting a** student to laboratory work are:

- availability of a protocol for appropriate laboratory work;
- a positive answer to the question of incoming express quality control of the theoretical preparation of the student for laboratory work (express control is carried out in the form of an oral survey conducted at the beginning of the lesson). In case of non-compliance with these conditions, the student is not allowed to perform laboratory work.

Weight score – 3. The maximum number of points for the performance of all laboratory work is equal to:

$$3 \text{ points} \cdot 7 = 21 \text{ points.}$$

Criteria for evaluating the performance of laboratory work

<i>Completeness and signs of completing the task</i>	<i>Points</i>
<i>The work is fully performed and protected (the composition of the solution or substance is determined without errors on the first attempt, the appropriate design (protocol and calculations are presented on time)).</i>	<i>3</i>
<i>Minor shortcomings in the execution and protection (the composition of the determined substance is determined on the second attempt, there are certain shortcomings in the design (the protocol is presented on time and calculations with some delay).</i>	<i>2</i>
<i>Gross shortcomings in execution and protection (work was performed with gross errors, the composition of the substance was determined on the third attempt), inappropriate design (protocol and calculations are not presented on time)</i>	<i>1</i>
<i>Failure to complete a task (Work not done or unprotected)</i>	<i>0</i>

2. Writing a modular test:

1 modular test is divided into 2 tests, 10 points each.

<i>Evaluation criteria</i>	<i>Points</i>
<i>"excellent", complete answer (at least 95% of the necessary information)</i>	<i>10</i>
<i>"good", incomplete disclosure of one of the issues (at least 75% of the required information)</i>	<i>9-8</i>
<i>"satisfactory", ncomplete answer (at least 65% of the necessary information)</i>	<i>7-6</i>
<i>unsatisfactory work (does not meet the requirements for "satisfactory").</i>	<i>5-0</i>

3. Writing a calculation work:

The maximum number of points for writing a settlement work is 9 points.

Points	Evaluation criteria
9	"excellent" - the work is done carefully, in full, the answers are justified, examples and equations of chemical reactions are given, which are discussed in the question
8-7	"good" - theoretical questions and calculations contain minor flaws (or the work is completed with some delay from the deadline)
6-5	"satisfactory" - there are no answers to 1-2 questions or theoretical questions and calculations are presented with certain errors (or the work is completed with a significant delay from the deadline)
4-0	"unsatisfactory" - the task is not completed, or there are gross errors, the work is not credited

According to the results of educational work for the first 7 weeks, the "ideal student" must perform all laboratory work (at the time of certification), write 1 test paper and score 14 points.

According to the results of educational work for 13 weeks of study, the "ideal student" must complete all the laboratory work (at the time of certification) and score 33 points.

4. Exam (oral).

The examination ticket contains two theoretical questions (tasks) and two practical tasks (tasks from the laboratory course and the task). An approximate list of theoretical questions is provided in Chapter 9. Each theoretical question/task and task from the laboratory course is estimated at 10 points, and the task is 20 points according to the following criteria:

Evaluation criteria	Points	
"excellent" - a complete answer, at least 90% of the necessary information (complete, error-free solution of the problem)	10	20-19
"good" - a sufficiently complete answer, at least 75% of the necessary information or minor inaccuracies (complete solution of the problem with minor inaccuracies)	9-8	18-16
"satisfactory" is an incomplete answer. at least 60% of the required information and some errors (the problem is solved with certain shortcomings)	7-6	15-12
"unsatisfactory" - the answer does not meet the conditions to "satisfactory"	5-0	11-0

The condition for admission to the exam is the enrollment of all laboratory works, settlement work, all tests and a starting rating of at least 30 points.

Thus, the sum of rating points is:

$$R_c = 21 + 20 + 9 + 50 = 100.$$

The sum of the starting points and points for the examination test is transferred to the examination mark according to the table:

Points	Score
100...95	Perfectly
94...85	very good
84...75	well
74...65	Satisfactory
64...60	enough
$R < 60$ points	Disappointing
Conditions of admission have not been met	not allowed

9. Additional information on the discipline (educational component)

An approximate list of questions for the discipline exam "Analytical Chemistry. Part 1. Qualitative Analysis".

1. Formulate the subject and tasks of analytical chemistry.
2. Present a classification of analysis methods.
3. Cite the types of reactions used in the analysis and the requirements for them. To characterize the analytical characteristics of chemical reactions: sensitivity, specificity, limiting ratio of ions, selectivity.
4. Formulate the law of the current masses.
5. Formulate the theory of electrolytic dissociation.
6. Calculate the equilibrium concentrations of ions and molecules.
7. Formulate the concept of ionic product of water.
8. Formulate the concept of pH.
9. Calculate the concentrations of protons and pH solutions of strong and weak acids and bases.
10. To define the concept of "hydrolysis".
11. Characterize ways to enhance and inhibit hydrolysis.
12. Calculate the pH of solutions of salts that hydrolyze.
13. Formulate the concept of buffer solutions: types, mechanism of action, capacity, use in qualitative analysis.
14. Characterize the conditions for the formation and dissolution of sediments.
15. Assess the influence of various factors on the solubility of poorly soluble compounds: ions of the same name; strong electrolytes that do not have common ions with sediment; competing reactions of protonation and complexation.
16. Bring the structure and analytical properties of the complexes.
17. Characterize the effect of pH, ligand concentration, impurities of precipitator ions on complexation reactions in qualitative analysis.
18. Give a general description of the oxidation-reduction reactions.
19. To reveal the content of the concept of redox potential and characterize the factors that affect it.

20. To present Nernst's level.
21. To assess the influence of competing reactions of protonation, precipitation and complexation on the direction and completeness of the passage of redox reactions.
22. Derive the expression for the equilibrium constant of redox reactions.
23. Explain the use of redox reactions in qualitative analysis.

The work program of the discipline (syllabus):

Compiled by Ph.D., assoc. prof. Krysenko T.V.

Approved by the department E and PPT (protocol N^o 14 of 18.05.2023)

Approved by the Methodical Commission

Faculty of Chemical Engineering (protocol N^o 10 from 26.05.2023)

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Оригінал

Оцінити вплив конкуруючих реакцій протонування, осадження та комплексоутворення на напрям і повноту проходження окисно-відновних реакцій.