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

Department of Ecology and Plant Polymers Technology

Analytical chemistry – 1. Qualitative analysis

Working program of the discipline (Syllabus)

Details of the discipline	
Level of higher education	***First (Bachelor)***
Branch of knowledge	*10 Natural Sciences*
Speciality	*101 Ecology*
Educational program	*OPP Environmental Safety*
Status of discipline	*Normative*
Form of training	*part-time/remote/mixed*
Year of preparation, semester	*2nd year, autumn semester*
Volume of discipline	*5(150)*
Semester control/ control measures	*Exam*
Schedule of classes	
Language of instruction	*Ukrainian*
Information about the course /teachers	Lecturer: *Ph.D., Assoc., Oksana Tereshchenko, okter789@gmail.com* Laboratory: *Ph.D., Assoc., Oksana Tereshchenko, okter789@gmail.com*
Course placement	https://do.ipo.kpi.ua/course/view.php?id=2514

Program of discipline

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

Analytical chemistry is the science of methods for determining the composition of substances and their mixtures. It consists of two main sections – qualitative and quantitative analysis.

The task of qualitative analysis is to identify or identify elements, groups of atoms, ions, molecules in chemical compounds. With qualitative analysis, studies of any unknown or synthesized substance begin.

With the help of quantitative analysis, the relationship between the constituent parts of the substance, as well as individual components in mixtures, is established.

Analytical is of great scientific and practical importance. Thus, on the basis of chemical analysis data, quantitative laws of chemistry were formulated, atomic masses of elements, chemical formulas of substances and chemical compounds were established.

Today, analytical research is not only the establishment of the qualitative and quantitative composition of compounds, but also the study of their structure, conformations and basic patterns of the course of chemical processes.

Analytical chemistry is closely related to the technical and natural sciences, its methods and achievements are extremely widely used in ecology in order to determine the quality of natural environment objects - air, natural surface and groundwater, soils, plant and animal organisms.

Of great importance is the identification and quantitative determination of individual chemical elements that make up living organisms, determine their normal physiological activity and the ability to migrate to the environment.

Classical chemical methods (gravimetry and titrimethria) due to the simplicity of execution and equipment, sufficient accuracy are widely used in environmental research and now, both in quantitative and qualitative analyses.

***The subject of the discipline "Analytical Chemistry"** is the formation of students' knowledge of the theoretical foundations of chemical analysis and practical skills and skills of its implementation in a production or chemical laboratory.*

The purpose of the discipline "Analytical Chemistry"

The purpose of studying this discipline is to ensure the assimilation of the theoretical foundations of chemical analysis, mastering the methods of determining the qualitative and quantitative composition of substances and preparing an environmental engineer for creative, independent work. In accordance with the purpose of training bachelors of ecology in this specialty requires the formation of the following competencies among students:

- the ability to critically comprehend the basic theories, methods and principles of the natural sciences.

According to the requirements of the program of the discipline "Analytical Chemistry", students after its assimilation must demonstrate the following programmatic learning results:

- to understand the basic environmental laws, rules and principles of environmental protection and nature management;

- to understand the basic concepts, theoretical and practical problems in the field of natural sciences that are necessary for analysis and decision-making in the field of ecology, environmental protection and optimal use of nature;

- to raise the professional level by continuing education and self-education;

- to carry out laboratory researches with use of modern devices, to provide sufficient accuracy of measurement and reliability of results, to process the obtained results.

2. Prerequisitions and requisition of disciplines (place in the structural and logical scheme of training according to the relevant educational program)

The study of the discipline "Analytical Chemistry" requires knowledge that is formed on the basis of the disciplines " Chemistry and Fundamentals of Biogeochemistry ", " Specific Topics of Biogeochemistry ", "Physics", "Higher mathematics", the discipline "Analytical Chemistry" provides the disciplines "Rationing of anthropogenic impact on the environment", "Technoecology", "Physical and colloidal chemistry", "Ecological and natural-technological safety".

3. Contents of the discipline

Module 1. Analytical chemistry – 1. Qualitative analysis

Section 1. Qualitative chemical analysis as the first stage of analytical research.

Topic 1. Subject of analytical chemistry.

Section 2. Chemical equilibrium in real systems

Topic 1. Ion equilibrium in electrolyte solutions

Topic 2. The law of active masses. Theory of electrolytic dissociation

Section 3. The main types of chemical reactions used in analytical chemistry

Topic 1. Equilibrium in the sediment-solution system
Topic 2. Acid-base equilibrium
Topic 3. Chelation
Topic 4. Redox equilibrium

Section 4. Methods of masking, separating and concentrating

Topic 1. Deposition and squat
Topic 2. Extraction
Topic 3. Sorption

4. Training materials and resources

Basic literature

1. Analytical chemistry. Methods of qualitative chemical analysis. (theoretical aspects and laboratory workshop)/ Ukl. L.I.Butchenko; O.P.Khohotva, O.M.Tereshchenko, etc. – Kyiv: NTUU "KPI them. Igor Sikorsky Kyiv Polytechnic Institute, 2017. – 151 p.

2. G.M. Zaitseva, T.D. Reva, O.M. Chikhalo Analytical chemistry.

3. Gab A.I., Shahnin D.B., Malyshev V.V. Analytical chemistry. Qualitative and quantitative analysis. – K.: University "Ukraine", 2018. – 212 p.

4. Analytical chemistry. Qualitative chemical analysis. Methodical instructions for the study of the discipline / Ukl. L.I. Butchenko, O.P. Khohotva, O.M. Tereshchenko, O.V. Glushko – NTUU "KPI", 2013. – 136 p.

5. Butchenko L.I., Tereshchenko O.M., Cheryopkina R.I. Collection of tasks on analytical chemistry.-K.: ECMO, 2011. – 181 p.

Secondary

6. General chemistry: textbook / Panasenko O.I. [et al.]. – Zaporizhzhya, 2015. -422 p.

7. Muzychenko V.P. Medical chemistry: textbook/ V.P. Muzychenko, D.D. Lutsevych, L.P. Yavorska; edited by B.S. Zimenkovskyi – 3rd type, e.g. – K.: VSV "Medicine", 2018 – 496 p.

8. Minaeva V. O. Methods of concentrating inorganic substances: Educational and methodological manual for students of higher educational institutions. – Cherkasy: View. from bohdan Khmelnytskyi National University, 2014. – 313 p.

9. Analytical chemistry. Methods of analytical chemistry in environmental research. Part I. Chemical methods of analysis. Methodical instructions for the study of discipline / Ukl. L.I. Butchenko; O.P.Khohotva, O.M.Tereshchenko – NTUU "KPI", 2010. – 68 p.

Information resources on the Internet

1. *Center for Electronic Learning Materials, access mode: http://193.108.240.69/moodle/*
2. *Journal of inorganic chemistry, access mode: http://www.geokhi.ru/~zhakh*
3. *Electronic Library of Literature on General Chemistry: website. URL: https://techemy.com (hit date: 25.05.2019).*
4. *Center for Electronic Learning Materials: website. URL: http://193.108.240.69/moodle/ (date of appeal: 25.05.2019).*
5. *Bubliotek Academy of Sciences. Information on English Language: website. URL: http://ban.yu.ru (hit date: 25.05.2019).*
6. *Povnotective journals on chemistry in English and Russian: website. URL: http://abc.chemistry.bsu.by/free-journals/ (hit date: 25.05.2019).*

5. Methods of mastering the discipline (educational component)

Lecture removals

Lectures are aimed at: providing modern, holistic, interdependent knowledge from the credit module "Analytical Chemistry-1. Qualitative analysis", the level of which

– determined by the target installation for each specific topic;

–ensuring in the process of lecturing the creative work of students together with the teacher;

– education of students of professional and business qualities and development of their independent creative thinking;

– formation of the necessary interest in students and providing direction for independent work;

–reflection of methodical processing of the material (allocation of main thoughts and provisions, underlining conclusions, repeating them in different formulations);

– teaching in a clear and clear language, explaining all the newly introduced terms and concepts;

– accessibility for perception by this audience.

No s/p	*Title of the lecture topic and list of main questions (list of didactic means, references to literature and tasks on the SRS)*
1	***Section 1. Qualitative chemical analysis as the first stage of analytical research*** *Topic 1.1. Prospects for the development of chemical science and industry Subject of analytical chemistry. Classification of analytical reactions.* ***Literature: [1]. P. 5 – 18; [3]. P. 9 – 24.*** *Tasks on the SRS. Methodological features of analytical chemistry. Formation of analytical chemistry in Ukraine. Main stages of development of analytical chemistry. Periodic law of D.I. Mendeleev and analytical chemistry.* ***Section 2. Chemical equilibrium in real systems*** *Topic 2.1. Ionic equilibrium in electrolyte solutions* *Factors that affect equilibrium in real systems. Simple and complex reactions. The law of the acting masses. Theory of electrolytic dissociation.* ***Literature: [2]. C. 29-41; [5]. C. 4-22.*** *Tasks on the SRS. Calculation of equilibrium concentrations of reaction components during dissociation of weak electrolytes. Thermodynamics and kinetics of chemical reactions and processes.*
2	***Section 3. The main types of chemical reactions used in analytical chemistry*** *Topic 3.1. Equilibrium in the sediment-solution system* *Product of solubility. Solubility of low-soluble compounds. Solubility under the influence of strong acids.* ***Literature: [2]. P. 41 – 47; [5]. C. 94-101, 104-109.*** *Tasks on the SRS. Solubility of sediments due to complex formation. Solubility due to redox reactions. The effect of the solvent on solubility. Fractional deposition and its use in analytical chemistry.*

	Topic 3.2. Acid-base balances in aqueous solutions *Ionic product of water. The concept of pH. Calculation of concentrations of hydrogen ions of acid solutions and bases. Gidroliz. Concentration of hydrogen ions of salt solutions. Buffer solutions.* ***Literature: [2]. P. 52 – 70, [5]. P. 45-72.*** *Tasks on the SRS. Protolytic theory of acids and bases of Bransted-Lowry, electronic theory of Lewis. Gammet acidity function. The effect of ionic strength and temperature on acid-base equilibrium.* *Topic 3.4. Redox equilibrium* *Equations of redox reactions. Redox potential. Equilibrium constant of redox reations. Redox properties of water. The speed and mechanism of oxidation-recovery reactions.* ***Literature: [2]. C. 73-82; [5]. C. 148-165.*** *Tasks on the SRS. The effect of ionic strength and temperature on the course of oxidation-recovery reactions. EMF and change in Gibbs' standard energy.*
3	***Section 4. Chemical methods of separation and concentration*** *Masking, splitting, and concentrating. Deposition and squat. Extraction. Sorption: organic and inorganic sorbents. General characteristics of methods.* ***Literature: [1]. P. 41 – 50; [2]. P. 98 – 112.*** *Tasks on the SRS. Extraction of non-ionized compounds. 57 lecture 5. Extraction of coordination-solvated neutral complex compounds. Extraction of ion associations.*

Laboratory classes (computer workshop)

Laboratory work allows students the ability to work with chemical reagents, dishes and devices, carry out a chemical experiment and conduct primary scientific research. To increase the cognitive activity of students and obtain their primary skills of scientific research, elements of a scientific experiment were introduced into these classical laboratory works, namely:

a) independently select reagents for a particular reaction;

b) explain the course of one reaction and not the course of another, at first glance, similar reaction; and so on.

The topics of laboratory work cover the main sections of qualitative analysis. During the laboratory workshop, conditions are created for the most independent performance of laboratory work by students. Therefore, laboratory classes begin with an express survey on the theoretical material necessary for the performance of work (with evaluation), verification of plans for laboratory work prepared by students in the framework of independent work and ends with an assessment of the student's work in the laboratory and the results obtained by them.

Number Work	*Content of laboratory work*	*Number of hours*
1	*2*	*3*
1	*Introduction to qualitative analysis. The action of general group reagents on metal cations. Cations of the 1st Analytical Group. Systematic analysis of the cations of the 1st analytical group. Cations of the 2nd and 3rd analytical*	*1*

	groups. Systematic analysis of cations of the II and III analytical groups.	
2	*Cations of the 1st Analytical Group. Cations of the V analytical group. Systematic analysis of cations of the 1st and 5th analytical groups. analytical group.*	*1*
3	*Separation of anions into groups. The effect of general reagents on anions. I-a analytical group of anions. Anions II and III analytical groups of anions.*	*1*
4	*Analysis of individual inorganic substances.*	*1*
Total hours		*4*

6. Independent work

Independent work of students takes 90% of the course study time, also includes the preparation of calculation and graphic work and preparation for the exam. The main task of independent work of students is the mastery of scientific knowledge in the field of analytical chemistry, which are not included in the list of lecture issues, through personal search for information, the formation of an active interest in the creative approach in educational work and in the implementation of calculation and graphic work.

No s/p	*Name of the topic submitted for IWS*	*Number of hours of IWS*
Section 1. Qualitative chemical analysis as the first stage of analytical research		
1	*Methodological features of analytical chemistry. Formation of analytical chemistry in Ukraine. The main stages of the development of analytical chemistry. Periodic law of D.I. Mendeleev and analytical chemistry. Methods of analytical chemistry. General scheme of analytical definition.* ***Literature: [3]. P. 9 – 24. [7] c. 5 – 8.***	*5*
Section 2. Chemical equilibrium in real systems		
2	*Calculation of equilibrium concentrations of reaction components during dissociation of weak electrolytes. Thermodynamics and kinetics of chemical reactions and processes.* ***Literature: [5]. C. 4-22; [6] c. 286 – 316.***	*5*
Section 3. The main types of chemical reactions used in analytical chemistry		
3	*Topic 3.1. Equilibrium in the sediment-solution system* ***Literature: [2]. P. 41 – 47; [5].*** *Solubility of sediments due to complex formation. Solubility due to redox reactions. The effect of the solvent on solubility. Fractional deposition and its use in analytical chemistry.* ***Literature: [2]. p. 48 – 49; [5] CC. 94-101, 104-109.*** *Topic 3.2. Acid-base rivages* *Gammet acidity function. The effect of ionic strength and temperature on acid-base equilibrium.* ***Literature: https://www.chem21.info/info/363563/.*** *Topic 3.3. Chelation.* *Werner's theory. Topic 3.3. Chelation*	*19* *18* *19*

	The main characteristics of complex compounds. Equilibrium in solutions of coordination compounds. Resistance constants and changes in Gibbs' standard energy. The effect of temperature on equilibrium in solutions of coordination compounds. *Vernenr's coordination theory. Combination of reactions of complex formation and deposition, complex formation and UVR. Combination of complex formation and deposition reactions, complex formation and OUR* ***Literature: [2]. P. 88 – 98, [5]. P. 127-134; P. 134 – 143; [7] 78–80.*** *Topic 3.4. Redox equilibrium* *The effect of ionic strength and temperature on the course of oxidation-recovery reactions. EMF and change in Gibbs' standard energy.* ***Literature: [5] P. 173 – 176.***	*19*
4	***Section 4. Methods of masking, separating and concentrating.*** *Extraction of non-ionized compounds. 57 lecture 5. Extraction of coordination-solvated neutral complex compounds. Extraction of ion associations.* ***Literature: [8]. 57-98.***	*5*
5	*Calculation and graphic work* *Literature: 1 - 9.*	*15*
6	*FDM*	*5*
7	*Exam*	*30*
Total hours		*140*

Politics and control

7. Policy of discipline (educational component)

Rules for attending classes and behavior in classes

For objective reasons (for example, illness, international internship), training can take place individually (online in agreement with the dean of the faculty). Students are obliged to take an active part in the educational process, not to be late, not to be distracted by actions that are not related to the educational process.

Rules for assigning incentive and penalty points

Semester certification is carried out in the form of an exam. To assess the results of training, a 100-point rating system and a university scale are used.

Encouraging points can be credited by the teacher only for the performance of creative works in the discipline or additional passage of online specialized courses with the receipt of the appropriate certificate (in agreement with the teacher):

- *https://www.edx.org/course/basic-analytical-chemistry;*
- *https://www. lectorium. tv>chemistry.*

The certificate was not re-issued (previously granted last semester). The amount of incentive points may not exceed 25% of the rating scale.

Deadline and overlay rules

Works that are submitted in violation of deadlines without good reason are rated lower (up to 75% of the planned number of points). The transfer of modules takes place with the permission of the lecturer if there are valid reasons (for example, sick leave).

Evaluation of laboratory work is carried out on the basis of the result of the work and its protection.

Academic Integrity Policy

Write-offs during control works and exams are prohibited (including using mobile devices). Works should have correct text links to the literature used.

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

Policy of academic behavior and ethics

Students should be tolerant, respect the opinion of others, object to form in the correct form, constructively maintain feedback in the classroom.

The norms of ethical behavior of students and employees are defined in Section 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 (RCOs)

Distribution of teaching time by types of classes and tasks from the credit module according to the working curriculum

Semester	School time		Training hours				Control measures		
	Loans	akad.h	Lectz.*	Pract.*	L/r*	IWS	MCT	HCW	Semester certification
3	5	150	6	-	4	140	1	1	Exam

** - in accordance with the number of students in the group, the number of lecture, practical and laboratory classes can be proportionally changed taking into account individual classes*

The student's rating from the credit module consists of points that he receives for:

1) two control works (MKR is divided into 4 works lasting 22 minutes);
2) performance of 9 laboratory works;
3) performance of HCW;
4) answer to the exam.

System of rating (weight) points and evaluation criteria:

1. Modular control.

Weight point – 15.

Criteria for evaluation of control works

Mark	Completeness of the answer
15-14	"excellent" – a complete answer (at least 90% of the necessary information);
13-11	"good" – a sufficiently complete answer (at least 75% of the required information), or a complete response with minor inaccuracies;
10-9	"satisfactory" – incomplete response (at least 60% of the required information) and minor errors;
8 - 0	"unsatisfactory" – the task is not completed, the CD is not counted.

2. Laboratory work.

Weight point – 2 points.

Mark	Getting the job done
2	Impeccable performance of the experimental part of the work, protection – unmistakable knowledge of the theoretical foundations and methods of work
1	reissued (underperformed) no more than one ion, when protecting the work made insignificant errors or inaccuracies
0	more than two ions have been redefined (underperformed). Work with an unsatisfactory result is not counted and should be redesigned, while protecting the work there is no understanding of the theoretical foundations and methods of work

3. Calculation- HCW.

Weight point – 22 points.

Mark	*Completeness of the answer*
22 – 21	*impeccable, creative performance of work*
20 – 17	*a sufficiently complete answer (at least 75% of the required information), with minor shortcomings*
16 – 13	*work done with certain errors*
12 – 0	*work is not counted (task not completed or there are gross errors)*

The condition for admission to the exam is the enrollment of all control, laboratory works, calculation and graphic work and a starting rating of at least 36 points.

At the exam, students perform written control work. Each task contains four questions (tasks). Each question (task) is estimated at 10 points according to the following criteria

Mark	*"excellent" – a complete answer (at least 90% of the necessary information);*
10 – 9	*"good" – a sufficiently complete answer (at least 75% of the required information), or a complete response with minor inaccuracies;*
8 – 7	*"satisfactory" – incomplete response (at least 60% of the required information) and minor errors;*
6	*"unsatisfactory" – the task is not completed, the CD is not counted.*
5 – 0	*"excellent" – a complete answer (at least 90% of the necessary information);*

Thus, the rating semester scale of the credit module is:

$$R_C = 4 \cdot 2 + 1 \cdot 15 + 22 = 60 \text{ points.}$$

The component of the exam is equal to 40% of R:

$$R_{екз} = 40 \text{ points.}$$

Thus, the rating scale of the credit module is:

$$R = R_C + R_{EK3} = 60 + 40 = 100 \text{ points.}$$

The sum of starting points and points for the examination test is transferred to the examination score in accordance with the table.

Points. *R =RC + REK3*	*Examination assessment*
100…95	*Perfectly*
94…85	*Very good*
84…75	*Fine*
74…65	*Satisfactorily*
64…60	*Enough*
Less than 60	*Unsatisfactorily*
There are not credited laboratory work or not credited calculation and graphic work or RC <26	*Not allowed*

9. Additional information on the discipline (educational component)

An approximate list of questions that are submitted for semester control

1. The subject of analytical chemistry. Classification of analytical reactions. Types of reactions used in the analysis.

2. Periodic law and periodic system of DI Mendeleev and its significance in analytical chemistry. The value of chemical-analytical properties of ions in connection with the position of elements in the periodic table.

3. Analytical characteristics of chemical reactions: limit of determination, sensitivity, specificity, limit ratio of ions.

4. Ionic equilibria in electrolyte solutions.

5. Simple and complex reactions. The law of acting masses.

7. Theory of electrolytic dissociation.

8. Calculation of equilibrium concentrations of reaction components during dissociation of weak electrolytes.

9. Deposition reactions. Describe the conditions of dissolution and formation of sediments.

10. The product of solubility. Influence of ions of the same name on the solubility of sediments.

11. Solubility of precipitates in acids.

*12. Solubility of sediments in the formation of complexes***.**

13. Sediments are crystalline and amorphous.

14. Acid-base equilibria in aqueous solutions.

15. Ionic product of water. The concept of pH.

16. Concentration of hydrogen ions of solutions of acids and bases.

17. Hydrolysis. Concentration of hydrogen ions of salt solutions.

18. Buffer solutions.

19. Complex compounds in hydrogen solutions.

20. Complex compounds with anions of strong and weak acids.

21. The effect of pH, concentration of ligands on the formation of complex compounds.

22. The use of complex compounds in the analysis.

23. Oxidation-reduction reactions. 3 general characteristics.

24. Redox potential. Nernst equation.

25. Redox potential and direction of redox reduction.

26. Equilibrium constant of the redox reaction.

27. The effect of pH on the depth of redox reactions in analysis.

28. Methods of masking, separation and concentration. Deposition and co-precipitation. General characteristics of methods.

29. Methods of masking, separation and concentration. Extraction. General characteristics of methods.

30. Sorption, organic and inorganic sorbents used in the analysis. General characteristics of methods.

Work program of the discipline (syllabus):

Compiled by Assoc. Prof., Ph.D., Tereshchenko O.M.

Approved by the Department of E and TRP № 14 of 08.06.2022

Approved by the Methodical Commission of the faculty [1] (protocol № 10 from 24. 06. 2022)