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

Department of Ecology and Plant Polymers Technology

Analytical chemistry – 2. Quantitative 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	*full-time/remote/mixed*
Year of preparation, semester	*2nd year, spring semester*
Volume of discipline	*5,5(165)*
Semester control/ control measures	*Exam*
Schedule of classes	*4 hours a week (2 hours of lecture and 2 hours of laboratory 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 understand basic theories, methods and principles of 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 2. Quantitative analysis

Section 1. General characteristics of quantitative analysis methods

Topic 1. *Problems and methods of quantitative chemical analysis.*

Section 2. Metrological characteristics of analysis methods

Topic 1*. Classification of errors. Correctness and accuracy of analysis, standard deviation.*

Section 3. Selection and preparation of the sample for analysis

Topic 1*. Sampling. Preparation of the sample for analysis.*

Section 4. Gravimetric (weight) analysis

Topic 1. *The essence of the gravimetric method.*

Topic 2. *The main stages of gravimetric analysis.*

Section 4. Titrimetric analysis method

Topic 1. *General provisions of the method.*

Topic 2. *Method of acid-base titration.*

Topic 3. *Methods of deposition and complex formation.*

Topic 4*. Methods of oxidation-recovery in titrmetric analysis.*

4. Training materials and resources

Basic literature

1. Analytical chemistry. Methods of quantitative chemical analysis (problem solving)/ Ukl.I.Butchenko; O.P.Khohotva, O.M.Tereshchenko, etc. – Kyiv: NTUU "KPI them. Igor Sikorsky Kyiv Polytechnic Institute, 2017. – 173 p.

2. Compendium of lectures on the discipline "Analytical Chemistry" for students of specialties 161 "Chemical Technologies and Engineering", 162 "Biotechnology and Bioengineering", Kamianske, for all forms of education / Compiler Kovalenko A.L. - Kamenskoye: DSTU, 2018 - 99 p.

3. Acid-basic titration. Module 1. Acid-basic titration and its application in chemical and pharmaceutical analysis.

4. Murayeva O. O. Compendium of lectures on the discipline "Analytical Chemistry" (for students of 2-3 courses of full-time and part-time forms of study in the field of training 6.060103 – Hydrotechnics (Water Resources)) / O. O. Murayeva; Kharkiv, National University of The City O.M. Beketov. – Kharkiv: O.M. Beketov National University, 2015. – 81 p.

5. Tsyganok L.P. Analytical chemistry. Chemical methods of analysis: textbook / L.P.Tsyganok, T.O.Bubel, A.B.Vyshnikin, O.Y.Vashkevich; edited by prof. L.P.Tsyganok - Dnipropetrovsk: DNU named after O.Gonchar, 2014.- 252 p.

6. 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.

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

8. 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.

Secondary

9. Voronych O.G., Basel Y.R., Studenyak Y.I., Fershal M.V. Analysis of technical objects: Educational and methodical manual. – Uzhgorod, 2016. – 72 p.

10. Methods of measuring environmental parameters: subruch. / G. I. Hryn, V. I. Mohonko, O. V. Suvorin, etc. – Severodonetsk: V. Dahl SNU view, 2019. – 420 p.

11. Girina N.P., Shlyapina A.V., Kovalchuk I.S. Laboratory work technique: manual, 2nd type– K.: "Medicine", 2019. – 304 p.

12. Basel Ya.R., Shkumbatyuk R.S., Voronych O.G., Sukhareva O.Yu., Maga I.M., Textbook on the course "Analytical Chemistry", Part 2. Quantitative chemical analysis. - Uzhgorod: in-vo PE "Stef", 2012. - part 2. -87 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).*

Program of discipline

1. Methods of mastering the discipline (educational component)

Lectures are aimed at: providing modern, holistic, interdependent knowledge in the discipline "Analytical Chemistry – 2. Quantitative 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;

– determination at the current level of development of science in the field of analytical chemistry, forecasting its development for the coming years;

– 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 of this audience.

s/p	*Title of the lecture topic and list of main questions (list of didactic means, references to literature and tasks on the IW)*
1-2	***Section 1. General characteristics of quantitative analysis methods*** *Topic 1.1. Problems and methods of quantitative chemical analysis* *Classification of methods of quantitative chemical analysis* ***Section 2. Metrological foundations of analytical chemistry*** *Topic 2.1. Metrological characteristics of analysis methods* *Classification of errors. Correctness and accuracy of analysis, standard deviation. Systematic and random errors.* ***Literature: [1] P. 7-20; [4] P. 4-5; [5] 29-30.*** *Tasks on the IWS. Significant numbers and rounding rules.*
3	***Section 3. Selection and preparation of the sample for analysis*** *Topic 3.1. Sampling, sample preparation* *Sampling. Preparation of the sample for analysis.* ***Literature: [1] P. 20-21; [5] 30-33.*** *Tasks on the IWS. Methods of transferring metals and alloys to the solution.*
4-6	***Section 4. Basic methods of analysis*** *Topic 4.1. Gravimetric analysis method*

	The essence of the gravimetric method. Calculation of the weight. Formation of sediment. The structure of the sediment. The main stages of gravimetric analysis. Filtering, washing, drying and roasting sediments. Requirements for gravimetric shape. Calculations in gravimetric analysis. Use of gravimetric methods. ***Literature: [1] P. 20-52; [2] 34-40; [5] Cc. 107-115*** *.* *Tasks on the IWS. Devices, utensils and reagents in gravimetric analysis.*
7-8	*Topic 4.2. Titrimetric analysis method* *General provisions of the method. Standardization of solutions. The main methods of titration. Indicators. Classification of methods. Calculation in the titrimetric method.* ***Literature: [1] P. 54-58; 68-70; [4] 13-20****.* *Tasks on the IWS. Methods of expressing concentrations in titrimetric analysis .*
9-11	*Topic 4.3. Method of acid-base titration* *Working solutions. Indicators in acid-main titration. Titration curves. Titration errors.* ***Literature: [1] 73-94; [2] CC 40-49; [3] 17-39****.* *Tasks on the IWS. Analysis of carbonate and phosphate mixtures.*
12-13	*Topic 4.4. Acid-base titration in non-aqueous solutions* *Titration of acids in non-aqueous solvents. Titration of bases in non-aqueous solvents. Determination of the moment of the end of titration.* ***Literature: [5] 164-168****.* *Tasks on the IWS. Solvents used in the method of analgesic titration.*
14-15	*Topic 4.5. Methods of deposition and complex formation* *General characteristics of methods. Mercurometry. Indicators. Method of complexonometry. Indicators of the complexonometry method.* ***Literature: [1] Cc. 96-134, [4] P. 39-51****.* *Tasks on the IWS. Method of argentometry. Method of mercurimetry.*
16-18	*Topic 4.6. Methods of oxidation-recovery in titrmetric analysis* *Titration curves. Method indicators. Method of permanganatometry. Working solutions. Practical application. Chromatometry method. Working solutions. Indicators Practical application.* *Method of iodometry. Working solutions. Indicators Practical application.* ***Literature: [1] Cc. 135-144, [4] P. 82-96****.* *Tasks on the IWS. Determination of permanganate oxidation of water (Kubel method).*

Laboratory classes (computer workshop)

In the system of professional training of students, laboratory classes occupy 22% of the classroom load.

Laboratory work allows students the ability to work with chemical reagents, dishes and devices, carry out a chemical experiment and conduct primary scientific research.

The topics of laboratory work cover the main sections of quantitative 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.

N	Content of laboratory work	Number of hours
1	2	3
1	Gravimetric analysis. Weighing in on technical and analytical Libra. Determination of iron content (III) in solution.	4
2	Titrymetric analysis. Method of neutralization. Preparation of working solutions and establishing their concentration.	4
3	Determination of the content of temporary hardness of water, acetic acid, ammonium hydroxide.	2
4	Determination of sodium phosphate content.	4
5	Complexonometry. Preparation of working solutions and establishing their concentration. Definition of general and constant hardness of water, mass fraction of magnesium (zinc) in technical Sample.	4
6	Redox methods. Preparation of working solutions and determination their concentration. Permanganatometric determination of iron (II).	4
7	Chromatometric determination of iron (II).	4
8	Method of iodometry. Preparation of working solutions and determination their concentration. Determination of sodium arsenite.	4
9	Determination of the mass fraction of the cuprum in the technical sample by the method iodometry.	4
10	MCT	2
Total hours		36

6. Independent work

Independent work of students takes 56% 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 questions, through personal search for information, the formation of an active interest in creative approach in educational work and in the implementation of calculation and graphic work.

No s/p	Name of the topic submitted for independent IWS	Number of hours of IWS
Section 1. General characteristics of quantitative analysis methods. Section 2. Metrological characteristics of analysis methods		
1	Significant numbers and rounding rules Literature: [1] C. 9 – 15.	9
Section 3. Selection and preparation of the sample for analysis		
2	Methods of transferring metals and alloys to the solution. Literature: [9] 36-37; [10] 364-367.	5
Section 4. Basic methods of analysis		
3	Topic 4.1. Gravimetric analysis method Devices, utensils and reagents in gravimetric analysis. Quantitative separation by deposition method. Literature: [11] C. 27 – 83; 149 – 169.	7

4	*Topic 4.2. Titrimetric methods of analysis* *Methods of expressing concentrations in titrimetric analysis.* *Characteristics of solvents.* *Literature: [1] C. 56 – 58; [5] C. 146 – 147.*	*5*
5	*Topic 4.3. Method of acid-base titration* *Analysis of carbonate and phosphate mixtures.* *Literature: [3] C. 34 – 43.* *Topic 4.4. Acid-base titration in non-aqueous solutions* *Definition of Barbital.* *Literature: [12] C. 40 – 42.* *Topic 4.5. Methods of deposition and complex formation* *Argentometry method.* *Literature: [4]. 51-54.* *Topic 4.6. Methods of oxidation-recovery in titrmetric analysis* *Determination of permanganate oxidation of water (Kubel method).* *Determination of dichroma oxidation (CCK) of water.* *Literature: [5]. 60 - 68.*	*18*
4	*HCW* *Literature: 1 - 12.*	*15*
5	*MCT 1-5*	*4*
6	*Exam*	*30*
Total hours		*93*

Politics and control

6. 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.

7. Types of control and rating system for assessing 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
4	5,5	165	36	-	36	93	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) four control works (MKR is divided into 4 works lasting 22 minutes);
2) performance of 9 laboratory works;
3) performance HCW;
4) answer to the exam.

System of rating (weight) points and evaluation criteria:

1. Modular control.

Weight point – 5. The maximum number of points for all control works is equal to:
5 points x 4 robots = 20 points.

Criteria for evaluation of control works

Mark	Completeness of the answer
5	*"excellent" – a complete answer (at least 90% of the necessary information);*
4	*"good" – a sufficiently complete answer (at least 75% of the required information), or a complete response with minor inaccuracies;*
3	*"satisfactory" – incomplete response (at least 60% of the required information) and minor errors;*
2 - 0	*"unsatisfactory" – the task is not completed, the MCT is not counted.*

2. Laboratory work.

Weight point – 2 points.

point	Completeness of the answer
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	*two ions were redefined (underperformed), when protecting the work, a significant error or inaccuracy was made*

3. HCW.

Weight point – 17 points.

Point	*Completeness of the answer*
17 - 16	*impeccable, creative performance of work*
15 – 13	*a sufficiently complete answer (at least 75% of the required information), with minor shortcomings*
12 – 10	*work done with certain errors*
9- 0	*work is not counted (task not completed or there are gross errors)*

The condition for the first certification is to receive at least 8 points and perform all laboratory work at the time of certification. The condition of the second certification is the receipt of at least 22 points, the implementation of all laboratory works at the time of certification and the enrollment of settlement and graphic work.

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

At the exam, students perform a written test. Each task contains four questions (tasks). Each question (task) is evaluated with 10 points according to the following criteria

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

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

$$R_C = 5*5+9*2+17 = 60 \text{ points.}$$

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:

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

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

Points. $R = R_C + R_{ЕКЗ}$	*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 R_C <26	*Not allowed*

8. Additional information on the discipline (educational component)

An approximate list of questions that are submitted for semester control

1. General provisions of quantitative analysis. Subject and value of quantitative analysis.
2. Explain the tasks and methods of quantitative chemical analysis, its significance and development.
3. Determination of the main components and determination of impurities.
4. Classification of chemical methods of quantitative analysis.
5. Gravimetric analysis. The essence of the method. The main stages of gravimetric analysis.
6. Filtration, washing, drying and calcination of sludge. Requirements for gravimetric shape.
7. Calculations in gravimetric analysis. Use of gravimetric methods.
8. General provisions of the titrimetric method of analysis. The essence of the method. Requirements for reactions in titrimetric analysis.
9. Methods of titration.
10. Titration curves. General method of calculating titration curves.
11. Classification of methods of titrimetric analysis.
12. Calculations in titrimetric analysis. Fundamentals of processing the results of quantitative analysis.
13. Titration with acids and bases. Working solutions of the acid-base titration method.
14. Titration curves and their calculations.
15. Differential titration with two indicators.
16. Selection of the indicator and calculation of indicator errors.
17. Examples of application of the method of acid-base titration
18. Titration in non-aqueous solutions. The essence of the method of non-aqueous titration.
19. Solvents in non-aqueous titration. Standard solutions.
20. Indicators. Application of non-aqueous titration in the analysis.
21. Methods of deposition and complexation. Classification of methods by type of dyes.
22. Argentometry. Mercurimetry.
23. Method of complexometry. The essence of the method. Working solutions.
24. Complexes of metal ions with complexons. Indicators of the complexometry method.
25. Examples of the use of chemical analysis methods in the control of chemical production and environmental protection

Work program of the discipline (syllabus):

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

Approved by the Department of E and TRP (protocol № 14 of 08.06.2022)

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