Ministry of Education and Science of Ukraine

V.N. Karazin Kharkiv National University
Department of Chemical Metrology

APPROVE

Dean of the Faculty of Chemistry


Oleg KALUGIN

31 08 2023

Working program of the academic discipline
Analytical chemistry
(the name of the academic discipline)

level of higher education: first bachelor's level
field of knowledge: 10 natural sciences
specialty: 102 chemistry
educational program: educational and professional program "Chemistry"
specialization
type of discipline: compulsory
faculty: chemical

2023 / 2024 academic year

The program is recommended for approval by the academic council of the Faculty of Chemistry

30 08 2023, protocol №8

PROGRAM DEVELOPERS:
Leonova N.O., PhD, associate professor of the Department of Chemical Metrology
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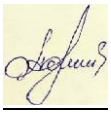
The program was approved at the meeting of the Department of Chemical Metrology
Protocol 29 08 2023 № 2

Head of the Department of Chemical Metrology


Oleg YURCHENKO
(signature)

The program has been agreed with the guarantor of the educational and professional program - Chemistry
Guarantor of the educational and professional program - Chemistry


Oleg KALUGIN
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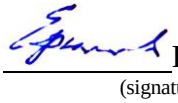
The program was approved by the scientific and methodical commission of the Faculty of Chemistry
Protocol 29 08 2023 № 1

Head of the Scientific and Methodological Commission of the Faculty of Chemistry


Pavlo YEFIMOV
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INTRODUCTION

Analytical Chemistry is one of the main courses for students who are educated in Chemistry according to the educational level Bachelor. The course deals with the study of theoretical bases and principles of chemical analysis methods as well as it forms skills of practical use of these methods. Significant attention in course is attended the concepts of metrology, questions of data processing and presentation of analysis results.

The purpose of the course is giving the knowledge about methods of theoretical research of chemical-analytical processes in homogeneous and heterogeneous systems. The course intends not only to give knowledge about methods of chemical analysis and practical implementation of them, but also to teach students to understand the general characteristics of physical and chemical phenomena in the base of analysis. The cases of use of main analysis methods, metrological characteristics of these methods, metrological basis of optimization of analytical procedure and methods of theoretical study of analysis uncertainties are studied in course. The purpose of the course is formation of the ability to perform the operations of chemical experiment, to choose the optimal conditions of analytical determinations, to self-determine the chemical composition of separate objects of analysis

1. Description of the academic discipline

1.1. The purpose of teaching the academic discipline: to form theoretical ideas about the methods used to obtain fundamental chemical data on the composition of chemical compounds, substances and materials, and to form skills in the practical application of these methods.

1.2. The main tasks of studying the discipline:

1.2.1. Formation of the following general competencies:

GK1. Ability to abstract thinking, analysis and synthesis.
GK2. Ability to learn and master modern knowledge.
GK3. Ability to work in a team.
GK4. Ability to adapt and act in a new situation.
The ability to be critical and self-critical.

1.2.2. *Formation of the following professional competences*:

PC2. Ability to recognize and analyze problems, apply sound methods of solving problems, make sound decisions in the field of chemistry.
PC3. The ability to evaluate and ensure the quality of the performed work based on the requirements of chemical metrology and professional standards in the field of chemistry.
PC7. Ability to perform typical chemical laboratory research.
PC8. The ability to carry out quantitative measurements of physico-chemical quantities, describe, analyze and critically evaluate experimental data.
PC9. Ability to use standard chemical equipment.
PC10. Ability to master new areas of chemistry through self-study.
PC11. The ability to formulate ethical and social problems facing chemistry and the ability to apply ethical standards of research and professional activity in the field of chemistry (academic integrity).
PC15. Ability to independently measure the chemical composition of individual objects of analysis and independently perform the simplest operations of a chemical experiment.

1.3. Number of credits - 10

1.4. Total hours - 300

1.5. Characteristics of the academic discipline

Normative / by choice
Full-time education
A year of training - 3rd
Semester - 5th, 6th
Lectures - 64 hours
Laboratory classes - 96 hours
Self-study hours – 140 hours
Speciality: Applied chemistry, Kharkiv Institute, HNU&KNU (students 2020 Intake) and Polymer Chemistry, Kharkiv Institute, HNU&KNU
Course Department: School of Chemistry, KNU

1.6. Planned learning outcomes

P01. Understand key chemical concepts, basic facts, concepts, principles and theories related to the natural, life and earth sciences, as well as chemical technologies at a level sufficient for their professional application and to enable further in-depth understanding of specialized areas of chemistry.
P03. Describe chemical data in symbolic form.
P04. Understand the basic patterns and types of chemical reactions and their characteristics.
P08. Know the principles and procedures of physical, chemical, physico-chemical research methods, typical equipment and devices.
P09. Plan and perform a chemical experiment, apply suitable methods and techniques for preparing solutions and reagents.
P13. Analyze and evaluate data, synthesize new ideas related to chemistry and its applied applications.
P14. To carry out experimental work with the aim of testing hypotheses and researching chemical phenomena and regularities.
P15. Ability to use acquired knowledge and skills for calculations, display and modeling of chemical systems and processes, processing of experimental data.
P17. Work independently or in a group, get a result within a limited time with an emphasis on professional integrity and scientific integrity.
P20. Interpret experimentally obtained data and correlate them with relevant theories in chemistry.
P29. Know: means of theoretical research of chemical-analytical processes in homogeneous and heterogeneous systems; general characteristics of physical and chemical phenomena on which the analysis is based; conditions of application of the main methods of analysis and metrological characteristics of these methods; metrological principles of analytical procedure optimization and means of theoretical research of analysis errors. Be able to: perform the simplest operations of a chemical experiment, predict the optimal conditions for conducting analytical determinations, independently measure the chemical composition of individual objects of analysis.

2. Thematic plan of the educational discipline

Chapter 1. Presentation of theoretical material (5th semester)

Topic 1. Introduction.

Subject and problems of analytical chemistry. Classification of chemical analysis methods: chemical, physical, biological methods; methods of detection, distribution and determination; structural, elemental and component analysis; macro-, micro- and ultra-microanalysis. Classification of objects of analysis. The main stages of the development of

analytical chemistry, its role in the development of natural science, technology.

Topic 2. Chemical equilibrium. Acting masses law (AML). The simplest calculations based on AML.

The main types of chemical reactions. General and balanced concentration, activity, activity coefficients. AML constants. Effect of temperature and ionic strength of the solution on the constants of AML. Possibility of chemical transformation on the basis of AML constants. Calculation of AML constants for reactions of arbitrary complexity.

Acid-base reactions. Modern concepts of acids and bases (Lewis theory, Brensted-Laury theory). Acid-base properties of the solvent. Autoprotolysis constant, ionic product. Protonation of bases and dissociation of acids. Step reactions. The connection between the general and step constants of the AML. Hydroxocomplexes of metals. Complex formation. General and graded stability constants of complexes. Redox reactions. Electrode potential and the Nernst equation. Equilibrium in heterogeneous systems. Dissolving sediment. Solubility product.

The simplest applications of AML for the theoretical study of chemical systems: forecasting the possibility of chemical transformations, sequence of precipitation.

Topic 3. General characteristics of detection methods. Qualitative analysis.

Analytical reactions in solution and visual effects: release of sediment or gas, formation of colored compounds. Organic reagents for the detection of inorganic components. Functional-analytical groups, their location in the reagent molecule. Selectivity of reagents. Increasing the selectivity of analytical reactions by separating and masking components.

Extraction and sorption are methods of separation and concentration. Quantitative characteristics of extraction: the relationship between the coefficient and the distribution constant, the degree of extraction, the extraction constant, the pH of the semi-extraction. Separation efficiency: completeness of separation and selectivity. Extractants for separation and isolation of inorganic components. Sorption mechanisms.

Detailed and systematic analysis. Scheme of systematic analysis as a combination of separation and detection methods. The principles of the distribution of components into analytical groups using the example of the acid-base scheme for the analysis of cations. Other schemes of systematic analysis of cations. Systematic analysis of anions, differences from the analysis of cations. Visual test methods. Fixation of analytical reagents on carriers. Examples of analytical reactions. Application of test methods in.

Topic 4. Buffer solutions.

Calculation of pH and equilibrium composition in solutions of strong and weak acids and bases. pH buffer solutions. The principle of buffer action. Buffer capacity. Calculations related to the preparation of buffer solutions: calculation of the pH of the buffer solution; calculation of total concentrations of buffer components with a given pH value.

Topic 5. Metrological characteristics of analysis methods. Basics of statistical processing of measurement results.

Basic concepts of metrology. Measurement errors: systematic and random. Quality indicators of measurement results: accuracy, correctness, precision and its indicators - repeatability (convergence) and reproducibility, intra-laboratory precision. Units of measurement of chemical composition. Analytical signal. Grading characteristic, grading function, grading graph. Classification of methods according to the method of measurement (direct methods, molar property methods, term methods). The main metrological characteristics of the methods and methods of measuring the chemical composition: limits of the content range, which determine; limit of definition; sensitivity; selectivity; robustness; labor intensive; duration; hardware equipment.

Topic 6. Chemical methods of determination. Titrimetry, principle of the method, basic concepts.

The principle of the method and basic concepts: titrant, stoichiometric point and end point of titration. Calculations in titrimetry. Use of quantities related to the equivalent of a substance. Equivalence number. Titrant, methods of standardization, requirements for substances - primary standards. Measurement of the volume of the solution. Volume measurement errors. Checking the capacity of measuring utensils. Classification of titrimetry methods according to the type of reaction. Direct, reverse and indirect titrimetric determinations. Titration curves.

Topic 7. Acid-base titration.

Reagents and indicators. Interval of indicator color transition, titration indicator, their relationship with the AML constant for the indicator reaction. Factors affecting the transition of the color of the indicator. Standardization of acid and alkali solutions. Titration curves. The effect of protolysis strength and concentration on the titration jump. Calculation of pH in EP.

Examples of practical application of acid-base titration. Titration of mixtures of acids and bases.

Topic 8. Complexometric titration.

Aminopolycarboxylic acids, their complexes with metals. Advantages of complexones as titrants. Metallochromic indicators. Methods of complexonometric determination: direct, reverse, lateral, by displacement. Titration curves. Factors affecting the shape of the curves: concentration of metal ions, stability of the complex, competing reactions.

Examples of practical application of complexonometry. Determination of metals in a mixture.

Topic 9. Redox titration.

Electrode potential and the Nernst equation. Standard and formal potentials. Methods of EP indication: self-indication, specific indicators, redox indicators. Color transition interval of pH-dependent and pH-independent redox indicators.

Examples of practical application of redoximetry. Permanganatometry. Determination of peroxide, oxalate, water hardness. Dichromatometry. Features and advantages of the dichromatometry method. Iodometry and iodimetry; reaction equations, components to be determined. Sources of errors in iodometry (volatility and disproportionation of iodine, oxidation of iodide, instability of thiosulfate solution) and methods of their elimination. Starch as a specific indicator for iodine. Bromatometry.

Chapter 2. Laboratory classes (5th semester)

Topic 10. Analytical properties and systematic analysis of cations and anions.
Topic 11. Acid-base titration.
Topic 12. Complexometric titration.
Topic 13. Redox titration.

Chapter 3. Presentation of theoretical material (6th semester)

Topic 14. Electrochemical methods of analysis. Potentiometry.

General characteristics of electrochemical methods of analysis. Classification of electrochemical methods according to the nature of the analytical signal. Electrochemical cell; indicator (working) and auxiliary electrodes; reference electrode; the inner and outer part of the electrochemical cell.

Potentiometry. Analytical signal. Electrodes based on oxidation-reduction reactions: electrodes of the 1st and 2nd kind, potential equation. Reference electrodes: silver chloride and

calomel. Membrane electrodes based on solid and liquid membranes. The membrane potential equation. Glass electrode for determination of pH, interfering ions. Cells with and without transfer.

Grading characteristic of potentiometry. Grading parameters, their physical meaning. Potentiometric titration. Integral and differential titration curves, their construction. Indicator electrodes in acid-base, precipitation, complexometric and redox titrations. Examples of practical application of potentiometric titration.

Practical applications of potentiometry. Determination of pH, electrodes, standard buffer solutions as means for calibration. Determination of fluorides; reagents that unmask fluoride ions in real objects of analysis, a buffer for regulating the total ionic strength. Determination of nitrates and chlorides.

Topic 15. Phenomena when current flows through an electrolytic cell. Electrogravimetry. Coulometry.

Electrolytic cells. The potential of the working electrode, the Nernst equation. Electrode polarization. Depolarizing substances. Dependence of the current strength on the electrode potential. Stages of the electrochemical process: mass transfer and charge transfer. Diffusion, convection, migration.

The principle of coulometric analysis. Faraday's law. Means of determining the amount of electricity. Electrogravimetry. Working electrode, definition conditions. Use of cathodic and anodic reactions. Electrolysis at constant current, constant electrode potential, constant applied voltage. Practical application of electrogravimetry.

Coulometry with control of the potential of the working electrode (direct coulometry). Selection of the potential value in the analysis of multicomponent solutions. Coulometry at constant current (coulometric titration). Examples of coulometric titration: electrogenerated iodine, hydroxide ions, hydrogen, iron (II).

Topic 16. Polarography and voltammetry. Amperometric titration

The principle of formation of an analytical signal. Mercury drop electrode. Polarographic cell, electrodes. Voltampere wave, its production; characteristics of the current-voltage curve. Ilkovich equation, grading characteristic of voltammetry.

Amperometric titration with one and two polarized electrodes. Tiration curves for different cases.

Topic 17. Optical methods of analysis. Introduction.

Light and its characteristics. Terms and units of radiant energy. The main characteristics of radiation: wavelength, frequency, wave number, power and intensity of radiation. Spectrum of electromagnetic radiation. Correspondence of areas of electromagnetic radiation to types of transitions in matter. Ultraviolet, visible and infrared region of the spectrum.

Energy transitions in atoms. The ground and excited electronic state of an atom. Atomic spectra of emission and absorption, qualitative and quantitative characteristics of a spectral line: wavelength and intensity. Relationship of intensity with the number of emitting particles. Spectral line width, causes of line broadening.

Topic 18. Atomic emission analysis (AEA).

Schematic diagram of the device in AEA. Sources of atomization and excitation: flame, inductively coupled plasma, their comparative characteristics. Sample introduction methods. Analytical signal detection methods (photocells, photographic plate). Processes in atomizers and AEA errors. Grading characteristic of AEA. Self absorption. Detection and determination of components in AEA: last line method, comparison spectra, homologous pairs, internal standard; methods of three standards, constant schedule, control standard, terms. Flame emission spectroscopy, components to be determined. The influence of the matrix of the object of analysis

on the results of AEA. Spectroscopic buffers.

Topic 19. Atomic absorption analysis (AAA).

Requirements for the monochromatization of radiation in accordance with the specifics of atomic absorption spectra. Sources of monochromatic radiation: lamp with a hollow cathode, electrodeless lamps. The main types of atomizers: direct-flow burner, burner with preliminary mixing, non-flame atomizer - graphite cuvette. Advantages and disadvantages of different types of atomizers.

Processes in the atomizer and sources of errors: flame emission, background absorption, errors due to sample atomization. Influence of the matrix of the object of analysis. Means of elimination of errors. Grading characteristic in AAA, Bouguer's law.

Comparative characteristics of AEA and AAA, areas of their application.

Topic 20. Molecular absorption spectrometry (spectrophotometry).

Scheme of electronic levels of the molecule. The total energy of a molecule is the sum of three components. Ground and excited electronic states. Peculiarities of molecular spectra in the UV and visible regions of the spectrum. Absorption spectra of molecules and other particles in solutions: maximum absorption, half-width of the absorption band. The main nodes of devices for MAS. Radiation sources, monochromators (light filters, dispersing prisms, diffraction gratings) and detectors in photocolorimeters and spectrophotometers for UV and visible spectrum.

The Bouguer-Lambert-Behr law and the MAS grading characteristic. Additivity of absorption. Coefficient of molar absorption, its dependence on the type of electronic transitions. Causes of deviations from the basic law of light absorption and methodical errors of MAS. Optimal range of absorption.

MAS methods: direct and difference (differential) spectrophotometry, methods of graduation graph and terms, spectrophotometric titration, multicomponent analysis. Application of organic reagents in the determination of inorganic components.

Examples of practical application of MAS: determination of one and two components. Extraction-photometric determination.

Topic 21. Chromatography and electrophoresis. Principle and classification of methods.

The principle of chromatographic separation. Stationary and mobile phases. Classification of chromatography methods according to the nature of phases, separation mechanism and experimental technique. Chromatography methods (frontal, eluent, displacement chromatography). Chromatogram, its characteristics: retention time, retained volume, half-width and standard deviation of the chromatographic peak, peak height and area. Capacitance coefficient, its relationship with the distribution coefficient. Characteristics of separation efficiency and selectivity. The concept of theoretical plates.

Principles, principles and classification of electrophoretic methods. Gel electrophoresis: carriers and equipment. Capillary electrophoresis: principles and equipment.

Topic 22. Thin-layer and paper chromatography

Chromatography on a column and in a plane (paper, thin layer). Sorbents and solvents for thin-layer chromatography. Obtaining and processing of chromatograms on thin-layer plates, methods of developing zones. Retention factor, its relationship with the distribution coefficient. Resolution, selectivity. Peculiarities of paper chromatography. Application of planar chromatography for separation and detection of inorganic and organic components. Eluents.

Topic 23. Gas chromatography

Gas-solid phase and gas-liquid chromatography. Carrier gases. The Van Deemter

equation, the optimal velocity of the mobile phase. Sorbents. Columns. The main components of a gas chromatograph. Detectors: flame ionization, thermal conductivity detector, electron capture detector. Principles of operation of detectors. Temperature programming as a way of optimizing the characteristics of chromatographic separation.

Identification of components. Kovach's indices. Methods of quantitative chromatographic analysis: normalization, absolute graduation, internal standard.

Defined components. Reaction gas chromatography. Application of gas chromatography in environmental control, analysis of food products, pharmaceuticals.

Topic 24. Liquid chromatography

Types of stationary and mobile phases. Normal-phase and reversed-phase chromatography. Capillary columns. The main nodes of the chromatograph. Detectors: fluorimetric, refractometric, photometric, electrochemical. Gradient elution. Ion exchange and ion chromatography.

Chapter 4. Laboratory classes (6th semester)

Topic 25. Potentiometric titration with a glass electrode and potentiometric redox titration.

Topic 26. Determination by direct potentiometry using ion-selective electrodes.

Topic 27. Flame-emission determination of alkali metals in mineral waters.

Topic 28. Atomic absorption determination of heavy metals in juices, waters and petroleum products.

Topic 29. Photometric determination of metal ions and phenol in water.

Topic 30. Kinetic determination of dichromate ions.

Topic 31. Separation and determination of components by the method of thin-layer chromatography.

Topic 32. The method of gas chromatography in the analysis of organic substances.

3. The structure of the academic discipline

Names of sections and topics	Number of hours			
	Full-time			
	Total	***Including***		
		lecture	***Lab ex***	***Self-study***
1	***2***	***3***	***4***	***5***
Chapter 1. Presentation of theoretical material (5th semester)				
Topic 1. Introduction.	***1***	***1***		***-***
Topic 2. Chemical equilibrium. Acting masses law (AML). The simplest calculations based on AML	***7***	***3***		***4***
Topic 3. General characteristics of detection methods. Qualitative analysis.	***9***	***5***		***4***
Topic 4. Buffer solutions.	***5***	***1***		***4***
Topic 5. Metrological characteristics of analysis methods. Basics of statistical processing of measurement results.	***2***	***2***		
Topic 6. Chemical methods of determination. Titrimetry, principle of the method, basic concepts.	***8***	***4***		***4***
Topic 7. Acid-base titration.	***9***	***5***		***4***
Topic 8. Complexometric titration.	***9***	***5***		***4***
Topic 9. Redox titration	***10***	***6***		***4***

Together by chapter 1	***60***	***32***		***28***
Chapter 2. Laboratory classes (5th semester)				
Topic 10. Analytical properties and systematic analysis of cations and anions.	***17***		***12***	***5***
Topic 11. Acid-base titration.	***17***		***12***	***5***
Topic 12. Complexometric titration.	***17***		***12***	***5***
Topic 13. Redox titration.	***17***		***12***	***5***
Together by chapter 2	***68***		***48***	***20***
Together by chapter 1 and 2	***128***	***32***	***48***	***48***
Chapter 3. Presentation of theoretical material (6th semester)				
Topic 14. Electrochemical methods of analysis. Potentiometry.	***5***	***1***		***4***
Topic 15. Phenomena when current flows through an electrolytic cell. Electrogravimetry. Coulometry	***10***	***3***		***6***
Topic 16. Polarography and voltammetry. Amperometric titration	***8***	***2***		***6***
Topic 17. Optical methods of analysis. Introduction.	***6***	***2***		***4***
Topic 18. Atomic emission analysis (AEA).	***8***	***4***		***4***
Topic 19. Atomic absorption analysis (AAA).	***8***	***4***		***4***
Topic 20. Molecular absorption spectrometry (spectrophotometry).	***8***	***4***		***4***
Topic 21. Chromatography and electrophoresis. Principle and classification of methods.	***6***	***2***		***4***
Topic 22. Thin-layer and paper chromatography	***6***	***2***		***4***
Topic 23. Gas chromatography	***8***	***4***		***4***
Topic 24. Liquid chromatography	***8***	***4***		***4***
Together by chapter 3	***80***	***32***		***48***
Chapter 4. Laboratory classes (6th semester)				
Topic 25. Potentiometric titration with a glass electrode and potentiometric redox titration	***12***		***6***	***6***
Topic 26. Determination by direct potentiometry using ion-selective electrodes.	***12***		***6***	***6***
Topic 27. Flame-emission determination of alkali metals in mineral waters.	***10***		***6***	***4***
Topic 28. Atomic absorption determination of heavy metals in juices, waters and petroleum products.	***10***		***6***	***4***
Topic 29. Photometric determination of metal ions and phenol in water.	***12***		***6***	***6***
Topic 30. Kinetic determination of dichromate ions.	***12***		***6***	***6***
Topic 31. Separation and determination of components by the method of thin-layer chromatography.	***12***		***6***	***6***
Topic 32. The method of gas chromatography in the analysis of organic substances.	***12***		***6***	***6***
Together by chapter 4	***92***		***48***	***44***
Together by chapter 3 and 4	***172***	***32***	***48***	***92***
Total hours	***300***	***64***	***96***	***140***

4. Topics of laboratory classes

№	Topic name	Number of hours

		Full time
10	Analytical properties and systematic analysis of cations and anions.	12
11	Acid-base titration.	12
12	Complexometric titration.	12
13	Redox titration.	12
25	Potentiometric titration with a glass electrode and potentiometric redox titration.	6
26	Determination by direct potentiometry using ion-selective electrodes.	6
27	Flame-emission determination of alkali metals in mineral waters.	6
28	Atomic absorption determination of heavy metals in juices, waters and petroleum products.	6
29	Photometric determination of metal ions and phenol in water.	6
30	Kinetic determination of dichromate ions.	6
31	Separation and determination of components by the method of thin-layer chromatography.	6
32	The method of gas chromatography in the analysis of organic substances.	6
	Total	96

5. Tasks for self-study work

№	Types, content of self-study work	Number of hours
		Full-time
	5th semester	
1	***Topic 1. Introduction.***	-
2	***Topic 2. Chemical equilibrium. Acting masses law (AML). The simplest calculations based on AML.*** Calculation tasks: calculation of chemical equilibrium constants for a linear combination of reaction equations; determining the sequence of precipitation; drawing up a system of component balance equations.	4
3	***Topic 3. General characteristics of detection methods. Qualitative analysis.*** Analytical properties and systematic analysis of cations and anions.	4
4	***Topic 4. Buffer solutions.*** Calculation tasks: calculation of pH in solutions of acids, bases and in buffer solutions; preparation of buffer solutions with a specified pH value.	4
5	***Topic 5. Metrological characteristics of analysis methods. Basics of statistical processing of measurement results*** Calculation tasks: statistical processing of measurement results, verification of statistical hypotheses	
6	***Topic 6. Chemical methods of determination. Titrimetry, principle of the method, basic concepts.***	4
7	***Topic 7. Acid-base titration.*** Calculation tasks: stoichiometric calculations in acid-base titration.	4
8	***Topic 8. Complexometric titration***. Calculation tasks: stoichiometric calculations in complexonometry.	4
9	***Topic 9. Redox titration.*** Calculation tasks: stoichiometric calculations in redoximetry.	4

10	***Topic 10. Analytical properties and systematic analysis of cations and anions*** (***Laboratory classes***). Designing a laboratory journal: recording the equations of chemical reactions for cations and anions; compilation of report cards for theoretical and experimental control tasks on the analysis of a mixture of cations.	5
11	***Topic 11. Acid-base titration.*** (***Laboratory classes***). Drawing up a laboratory journal: recording the results of titrations and calculating the concentration of analytes in the sample; statistical processing of the analysis results obtained by all students of the group.	5
12	***Topic 12. Complexometric titration.*** (***Laboratory classes***). Drawing up a laboratory journal: recording the results of titrations and calculating the concentration of analytes in the sample; statistical processing of the analysis results obtained by all students of the group.	5
13	***Topic 13. Redox titration*** (***Laboratory classes***). Drawing up a laboratory journal: recording the results of titrations and calculating the concentration of analytes in the sample; statistical processing of the analysis results obtained by all students of the group.	5
	6th semester	
14	***Topic 14. Electrochemical methods of analysis. Potentiometry.*** Calculation tasks: calculation in direct potentiometry; calculation of potentiometric titration results.	4
15	***Topic 15. Phenomena when current flows through an electrolytic cell. Electrogravimetry. Coulometry.*** Calculation tasks: calculations in coulometry.	6
16	***Topic 16. Polarography and voltammetry. Amperometric titration*** Calculation tasks: calculations in voltammetry.	6
17	***Topic 17. Optical methods of analysis. Introduction.*** Basic concepts, classification of methods.	4
18	***Topic 18. Atomic emission analysis (AEA).*** Calculation tasks: calculations in atomic emission spectroscopy.	4
19	***Topic 19. Atomic absorption analysis (AAA).*** Calculation tasks: calculations in atomic absorption spectroscopy.	4
20	***Topic 20. Molecular absorption spectrometry (spectrophotometry).*** Calculation tasks: calculations in spectrophotometry.	4
21	***Topic 21. Chromatography and electrophoresis. Principle and classification of methods***.	4
22	***Topic 22. Thin-layer and paper chromatography*** Calculation tasks: calculating the results of thin-layer chromatography.	4
23	***Topic 23. Gas chromatography*** Calculation tasks: calculation of gas chromatography results.	4
24	***Topic 24. Liquid chromatography*** Calculation tasks: calculation of liquid chromatography results.	4
25	***Topic 25. Potentiometric titration with a glass electrode and potentiometric redox titration.*** (***Laboratory classes***). Drawing up a laboratory journal: recording the results of rough and exact titrations; calculation of acid concentration in the sample.	6
26	***Topic 26. Determination by direct potentiometry using ion-selective electrodes.*** (***Laboratory classes***). Drawing up a laboratory journal: recording the results of the calibration of the potentiometric cell, calculating the mass fraction of the analyte in the sample under study by the method of the calibration graph.	6

27	***Topic 27. Flame-emission determination of alkali metals in mineral waters.*** (***Laboratory classes***). Preparation of a laboratory journal: recording the results of graduation and the results of determining the mass concentration of Na^+ and K^+ in mineral waters by the method of a graduation schedule.	4
28	***Topic 28. Atomic absorption determination of heavy metals in juices, waters and petroleum products*** (***Laboratory classes***). Drawing up a laboratory journal: recording the results of sample preparation using ultrasound, calibration and the results of determining the mass concentration of heavy metals in the tested samples by the method of a graduation graph.	4
29	***Topic 29. Photometric determination of metal ions and phenol in water.*** (***Laboratory classes***). Drawing up a laboratory journal: recording the results of graduation and the results of determining the mass concentration of metal ions and phenol in the tested samples by the graduation graph method.	6
30	***Topic 30. Kinetic determination of dichromate ions.*** (***Laboratory classes***). Drawing up a laboratory journal: recording the results of measuring kinetic dependencies, calibration and the results of determining the content of dichromate ions in the sample under study.	6
31	***Topic 31. Separation and determination of components by the method of thin-layer chromatography.*** (***Laboratory classes***). Drawing up a laboratory journal: recording the results of the calculation of the main TLC characteristics.	6
32	***Topic 32. The method of gas chromatography in the analysis of organic substances.*** (***Laboratory classes***). Drawing up a laboratory journal: recording the results of the calculation of the main characteristics of the chromatogram of a mixture of organic substances	6
	Total	140

6. Individual tasks

Not provided for in the curriculum.

7. Assessment methods

The combination of usual assessment and final examination. Among them, the usual assessment score accounts for 60% (homework, arrangement of laboratory work, work in class); final examination score accounts for 40%, using the form of closed-book examination.

When studying the first part of the Analytical Chemistry course in the fifth semester, the program provides: 32 academic hours of lectures, 48 hours of laboratory classes, an exam. The maximum number of points that a student can score for three program blocks is 60, of which (maximum):

Activity	***5th semester***	
	Points	
	Block #1 Qualitative analysis	Block #2 Quantitative analysis. Titrimetry.
Carrying out a laboratory workshop	20	30
Preparation of laboratory works		
Total points	20	30

Attendance at lectures	10	
Total points for 2 blocks	60	
Final control (exam)	40	
	6th semester	
	Points	
	Block #1 Electrochemical and Optical methods of analysis	Block #2 Chromatography and electrophoresis.
Total points	30	20
Attendance at lectures	10	
Total points for 2 blocks	60	
Final control (exam)	40	

A student can get the maximum point for laboratory work (LW) if he submits an admission to work, completes the work in a timely manner, performs the necessary calculations and issues a laboratory journal. If the student completed or passed the LW late for no good reason, the number of points for the LW cannot exceed 50% of the maximum score.

The deadline for submitting homework is indicated in the CALENDAR PLAN FOR THE GENERAL COURSE "ANALYTICAL CHEMISTRY", which is available in the educational laboratory. The number of points for homework completed after the specified deadline cannot exceed 50% of the maximum number of points. The total number and content of questions and calculation tasks in the task is determined by the teacher who conducts practical classes in the group, and he also fills out the student's performance card.

A student is admitted to the final control (examination) if he has scored at least 25 points for all mandatory types of educational activities for three program blocks and completed the course work. The total grade for the study of the discipline in the fifth semester, which is entered in the student's record book, is issued according to the following system:

The sum of points for all types of educational activities during the semester	**Rating**
90 — 100	excellent
70 — 89	good
50 — 69	satisfactory
1 — 49	unsatisfactory

Recommend textbooks

1. *Fundamentals of analytical chemistry* (Skoog, Douglas A.; West, Donald M.) Allen J. Bard. J. Chem. Educ., 1963, 40 (11), p 614. DOI: 10.1021/ed040p614.2.

2. Analytical Chemistry and Quantitative Analysis (David S. Hage, James R. Carr, James D. Carr) Prentice Hall, 2011ISBN0321596943, 9780321596949 p. 696

3. Analytical Chemistry: Theoretical and Metrological Fundamentals 2007th Edition (Klaus Danzer) Hardcover: 316 pages/ Publisher: Springer; 2007 edition (December 20, 2006) ISBN-10: 3540359885, ISBN-13: 978-3540359883

4. Analytical Chemistry 1st Edition (Robert Kellner , Matthias Otto , H. Michael Widmer , Jean-Michel Mermet) Hardcover: 942 pages, Publisher: Wiley-VCH; 1 edition (March 9, 1998), ISBN-10: 3527286101, ISBN-13: 978-3527286102.

5. Handbook of Analytical Techniques, 2 Volume Set Hardcover – April 11, 2001 (Helmut Günzler), Alex Williams), Hardcover: 1198 pages, Publisher: Wiley-VCH; 1 edition (April 11, 2001), ISBN-10: 3527301658, ISBN-13: 978-3527301652.