NATIONAL UNIVERSITY OF LIFE AND ENVIRONMENTAL SCIENCES OI RAINE

Department of Analytical and Bioinorganic Chemistry & Water Quality

"CONFIRMED"
Dean of the Plant Protection,
the Biotechnologies and Ecology Faculty
_____ (Prof. Yulia Kolomiets)
"___" _____ 2023

"APPROVED"
at the meeting of the department of analytical
and bioinorganic chemistry &water quality
Protocol № 8dated"24" 04 2023
Head of Department
_____ (Prof. Volodymyr Kopilevich)

"REVIEWED"
Program Coordinator
Ecology Bachelor
_____ (Prof. Volodymyr Bogolyubov)

PROGRAM OF THE COURSE

CHEMISTRY (INORGANIC AND ANALYTICAL)

Specialization 101 - Ecology
Educational program Ecology
Faculty of the Plant Protection, the Biotechnologies and Ecology
Developer: Associate Professor, Cand Chem Sci Larysa Voitenko
(position, academic degree, academic title)

Kyiv – 2023

1. Description of the course

Chemistry (inorganic and analytical)

(назва)

Field of knowledge, specialization, educational program, educational degree		
Educational degree	*Bachelor's*	
Specialization	*101- Ecology*	
Educational program	*Ecology*	
Characteristics of the course		
Type	Compulsory	
Total number of hours	150	
Number of ECTS credits	5	
Number of content modules	4	
Course project (work)	Applicable	
Form of assessment	*Exam*	
Indicators of the course for full-time and part-time forms of study		
	Full-time form of study	Part-time form of study
Course (year of study)	The 1st	No
Semester	The 1st	
Lecture classes	*60 hr.*	*hr.*
Practical, seminar classes	*hr.*	*hr.*
Laboratory classes	*60 hr.*	*hr.*
Self-study	*30 hr.*	*hr.*
Individual assignments	*hr.*	*hr.*
Number of weekly classroom hours for the full-time form of study Self-training	*8 hr.* *2 hr.*	

2. Purpose, objectives, and competencies of the course

Purpose is to develop an understanding of the range and uses of inorganic chemistry and analytical qualitative and quantitative methods for the application in monitoring and research of the environmental objects, and formation of skills in chemical experiment performing.

Objective is to acquire basic concepts, principles, and techniques of modern inorganic and analytical chemistry that would empower students with a chemical mind set and the abilities to solve diverse chemical problems for environmental assessment in an efficient and quantitative way that conveys the importance of accuracy and precision of the analytical results.

Tasks:

- To master knowledge of chemical laws and chemical transformations patterns (chemical transformation and moving of matter) with a focus on professional activity

in the field of environmental sciences and formation of skills in chemical experiment performing

- To study the foundations of inorganic chemistry as a component of fundamental training in the field of natural sciences; knowledge and understanding of the basic principles of the discipline addressed in the different modules and to have understood the topics covered: from the basic principles of chemistry and statistical process applied to biological data of ecological interest to the organization, consultation and analysis of data with appropriate it tools;

- Appling knowledge and understanding: the student will demonstrate applied skills in: i) solving simple analytical problems related to environmental chemistry, ii) consulting scientific sources and databases, iii) understanding the obtained results; iv) understanding chemical terminology; v) use of the basic software for the analysis of chemical data, bibliographic references collection and presentation of results.

- Making judgments: the student will demonstrate autonomy in the efficacious use of the teaching materials made available and in the selection of authoritative scientific sources for the understanding and resolution of basic chemical questions and the use of the main software. These skills are acquired through frontal activities and lab training and also through individual study;

- Communication: during the frontal and lab activities foreseen in the course and in the exam, the student will demonstrate skills in presenting and organizing the concepts acquired with the most appropriate chemical terminology.

- Life long learning skills: the student will be able to use the basic tools acquired to update their knowledge, to improve autonomously their skills by consulting bibliographic material and databases. These skills are perfected through individual study and the activities carried out for the preparation for the final test.

Competence acquisition:

Integral competence (IC): The ability to solve complex specialized problems and solve practical problems in the field of ecology, environmental protection, and sustainable environmental management, which involves the application of basic theories and methods of science about environments that are characterized by complexity and uncertainty of conditions.

General competences (GC):

GC1. Knowledge and understanding of the subject area and professional activity

GC8. Ability to conduct research at the appropriate level

GC10. The ability to evaluate and ensure the quality of performed works.

Professional (special) competences (PC):

PC2. Ability to critically understand basic theories, methods and principles of natural sciences.

PC 3. Ability to understand basic theoretical concepts regulations, concepts and principles of natural and of social and economic sciences.

PC7. Ability to monitor and evaluate current condition of environment based on analytical monitoring data.

Programmatic learning outcomes (PLO):

PLO 3. Understand the basic concepts, theoretical and practical problems in the field of natural sciences, which are necessary for analysis and decision-making in the field of ecology, environmental protection and balanced nature management.

PLO14. Be able to create texts, make presentations and messages for professional audiences and the general public with observance of professional integrity and impossibility plagiarism.

PLO18. Combine the skills of independent and teamwork to achieve results with an emphasis on professional integrity and responsibility for decision-making.

PLO19. Increase the professional level by continuing education and self-education.

PLO21. To be able to choose optimal methods and tools for research, collection and data processing.

3. Program and structure of the subject - for full-time English-speaking students

Modules naming and chapters	Hours						
	Full-time						
	weeks	total	included				
			lectures	Practice training	Lab works	Individual tasks	Independent work
1	2	3	4	5	6	7	8
Content Module 1. Theoretical Foundations of the Inorganic Chemistry. The General Laws of Chemical Transformations							
Topic the 1st. Chemistry as the science that deals with the properties, composition, and structure of substances	1	5	2		2		1
Topic the 2d. Atomic structure of chemical elements	2	6	2		2		2
Topic the 3d. Periodicity of changes in structure and properties of elements and their compounds	3	5	2		2		1
Topic the 4th. Chemical bonding and molecular structure	3	6	2		2		
Total for content module 1	1-3	22	8		8		6
Content Module 2. The general laws of chemical transformations							
Topic the 5th. Chemical kinetics and equilibrium	4	5	2		2		1

1	2	3	4	5	6	7	8
Topic the 6th. Solutions and their properties. Electrolytes and electrolytic dissociation. Ionic equations.	4	8	3		3		2
Topic the 7th. Hydrolysis of salts. Notion of a pH	5	8	3		3		2
Topic the 8th. RedOx processes	6-7	10	4		4		2
Topic the 9th. Complex (coordination) compounds	7	9	4		4		1
Total for content module 2	4-7	40	16		16		8
Content Module 3. Chemistry of elements and qualitative chemical analysis							
Topic the 10th. Subjects and objects of the chemical analysis (analytical chemistry). Methods of quantitative analysis. Subjects of qualitative and quantitative analyses. Methods of qualitative analysis. Analytical reactions and requirements to analytical reactions.	8	6	2		2		2
Topic the 11th. Chemical-analytical properties of the cations on the examples of s-elements belongs to IA and IIA groups, p- elements belongs to IIIA and IVA groups, and d-elements of the IIIB and VB groups.	8-9	16	7		7		2
Topic the 12th. Chemical-analytical properties of the cations on the examples of p-elements belongs to VIIA, VIA, VA, and IVA groups. Qualitative analysis of inorganic substances (salts, acids, bases, oxides).	10-11	16	7		7		2
Total for content module 3	8-11	38	16		16		6
Content Module 4. Theoretical and experimental foundations of the quantitative chemical analysis							
Topic the 13th. Equilibrium in heterogeneous and homogeneous systems. Precipitation and sediment dissolving reactions; their application for qualitative and quantitative analysis	12	10	4		4		2
Topic the 14th. Theoretical foundations of measurement and processing of results in chemical analysis. The essence and task of quantitative measurements and calculations.	12	10	4		4		2
Topic the 15th. Titrimetric methods of quantitative analysis (volumetry). The application of volumetric methods in environmental analysis. Neutralization method.	13	10	4		4		2
Topic the 16th. RedOxmetry in quantitative analysis.	14	10	4		4		2
Topic the 17th. Complexonometry in quantitative analysis.	15	10	4		4		2
Total for content module 4	12-15	50	20		20		10
Total hours:	**1-15**	**150**	**60**		**60**		**30**

4. Seminar topics – do not planned.
5. Practical class topics – do not planned.

6. Laboratory class topics

#	Topic title	Number of hours
1	2	3
1	Introduction. Lab Safety rules. Semimicro qualitative lab techniques. The introduction testing. General chemical properties of main classes of inorganic substances. Chemical name Calculator application (https://www.omnicalculator.com/chemistry/chemical-name)	2
2	Electron formulas compiling. Determination of valence and oxidation number of the chemical elements as a function of their electron configuration. Electron configuration simulation (i.e., https://www.wolframalpha.com/widgets/gallery/view.jsp?id=bd4637e2261cbcdda20d9077e61c712f&reportprob=1)	2
3	Periodicity as an expression of electron shell structures. Visualisation of the periodicity (i.e., https://www.behance.net/gallery/46554621/Visualizing-the-Periodic-System-of-Chemical-Elements)	2
4	Qualitative assessment of chemical bonding types and molecular structure of acids, bases, salts, oxides. Virtual simulation of chemical bonds and visualization of molecules (i.e. "Avogadro" tool https://sourceforge.net/projects/avogadro/files/avogadro/)	2
5	Experimental studding of strong and weak electrolytes from viewpoint of Avogadro's electrolytic dissociation theory. How to compile the ionic equations. How to use the net ionic calculator (i.e., https://www.chemicalaid.com/tools/netionicequation.php?hl=en).	2
6	Experimental studding of hydrolysis of salts in water medium. How to predict and to measure of a pH. How to use a Hydrolysis calculator (i.e., https://www.calculatoratoz.com/en/anionic-salt-hydrolysis-Calculators/CalcList-2611).	3
7	Experimental studding of RedOx processes; chemical nature of Reducing and oxiding agents. RedOx potential and its measuring in water medium. Electron balance and half-reaction methods. How to use a RedOx calculator (i.e., https://calculator-online.net/redox-reaction-calculator/).	3
8	Experimental studding of complexing processes. How to isolate and decompose the coordinative compounds. IUPAC nomenclature of coordinate compounds (https://unacademy.com/content/jee/study-material/chemistry/iupac-nomenclature-of-coordination-compounds/)	4
9	Introduction to qualitative analysis. The action of general group reagents on metal cations.	1
10	Studding of chemical-analytical properties and qualitative tests of s-element cations (on the example of Na^+, K^+, Ca^{2+}, Sr^{2+}, Ba^{2+}) and ammonia cation NH_4^+.	3
11	Studding of chemical-analytical properties and qualitative tests of p-element cations (on the example of Al^{3+}, Pb^2).	4
12	Studding of chemical-analytical properties and qualitative tests of d-element cations (on the example of Zn^{2+}, Cu^{2+}, Mn^{2+}, Fe^{2+}, Fe^{3+}, Ag^+).	3
13	Studding of chemical-analytical properties and qualitative tests of anions belongs to p-elements of VIIA, VIA, VA, IVA and IIIA groups (on the example of B^{3+}, C^{4+}, Si^{4+}, N^{3+}, N^{5+}, P^{5+}, O^{-1}, S^{4+}, S^{6+}, Cl^-, Br^-, I^-	3

1	2	3
14	Analytical classification of the main bioactive cations. Separation and identification of I-IV cation groups according to the ammine-phosphate classification.	2
15	Analytical classification of the main bioactive anions. Separation and identification of anions SO_4^{2-}, SO_3^{2-}, CO_3^{2-}, PO_4^{3-}, Cl^-, Br^-, I^-, NO_2^-, NO_3^-.	2
16	The identification methods of the inorganic substances qualitative analysis. Two experimental control tasks for the analysis of chemical parameters.	4
17	Experimental strategies of quantitative analysis: weighing, measuring vessels, filtering. Volumetric analysis. Calculations in volumetric analysis. Neutralization method. Preparation of primary and secondary standard solutions. Experimental control tasks: - Concentration of alkali in water solution; - Determination of temporary water hardness of water sample.	10
18	RedOx volumetric methods of quantitative analysis. Preparation of primary and secondary standard solutions of Permanganatometry and Iodometry. Experimental control tasks: - The permanganatometric determination of Fe(II) concentration in water solution of Mohr's salt; - The iodometric determination of Cu(II) content in solid copper vitriol.	4
19	Complexonometric volumetric method of quantitative analysis. Preparation of primary and secondary standard solutions of Trilonometry method. Experimental control tasks: - Determination of total water hardness of water sample; - Determination of Calcium content in water solution.	4
	Total hours:	**60**

7. Independent work topics

#	Chapter	Hours
1	**2**	**3**
1	Stoichiometric Laws. Application and limitation	2
2	Atomistic theory developing.	2
3	The foundations of condensed matter chemistry	2
4	Chemical reactions rate and chemical equilibrium in the environmental systems	2
5	Solutions and their concentrations	1
6	Intramolecular hydrolysis	1
7	Redox potentials. Standard electrode potentials of metals. Galvanic elements. The direction of redox reactions. Electrolysis as a redox process. Corrosion of metals as a redox process	2
8	Isomerism of complex compounds. The state of complex compounds in solution.	1
9	Special chemical properties and structure of water as medium of life origin. Features of the biological action and chemistry of selenium and its compounds	1
10	Inorganic chemistry of Arsenic subgroup	1
11	Silicon compounds in the biosphere. Borides and borates, polyborates. Aluminates and aluminosilicates.	1
12	Strontium and barium as Calcium analogs; their role in living nature. Lithium, Rubidium and Cesium and their compounds in plant and animal metabolism	1
13	Biological functions of Copper(II), Zinc, Manganese. Toxic effects of Cadmium and Mercury and their compounds.	2

1	2	3
14	Types of analytical reactions and reagents, their characteristics; classification of analytical reagents and calculations of reaction sensitivity indicators.	2
15	Experimental techniques of qualitative inorganic analysis. Dry and wet reactions. Semimicro apparatus and semimicro analytical operations. Micro apparatus apparatus and microanalytical operations. Spot test analysis.	1
16	Training calculations of concentration units recalculations in the environmental application (heavy metals analysis, salty waters mineralization, etc)	1
17	The ionic strength of natural water systems (salty sea waters, blood, cell juice etc.). Osmosis and ionic strength. Calculation of common ion effect and environmental problems (how to immobilize the heavy metals in soils etc.). Ionic strength calculator (https://www.omnicalculator.com/chemistry/ionic-strength)	2
18	pH graphic method determination. How to prepare of buffer solutions. TRIS solution – preparation and application. How to calculate titration curves of acid mixture titration. Choice of the best acid-base indicators and their preparation.	1
20	Assessment of reliability of analytical data. Reproducibility and correctness of experimental data. Types of systematic errors. Individual and instrumental systematic errors. Determination of systematic error and its influence on the results of the analysis. Random error. Basic concepts of classical statistics.	2
21	RedOx calculation of ionic species of metals of changing valencies in natural systems (iron, manganese). RedOx potential of natural waters and soils. Chemical oxygen demand (COD) of natural waters as application of RedOx volumetric methods in the environmental analysis.	1
22	Chelates as a food additives, drugs, and analytical reagents. Using of complexones in environmental sanitation.	1
	Total hours:	**30**

8. Samples of control questions, tests for assessing the level of knowledge acquisition by students

List of theoretical questions

1. Subjects and tasks of inorganic chemistry.
2. The foundations of atomic-molecular theory. Notions of an atom, molecule, ion, simple and complex compounds, chemical formulas. Allotropy.
3. Types of the chemical reactions.
4. The laws of stoichiometry (law of Safe, Equivalents etc).
5. The mole concept, Avogadro's Number. Relations of amount of substance, numbers of moles.
6. Evolution of atomic ideas.
7. The dual nature of electron.
8. Names and physical content of quantum numbers.
9. General rules for electronic formulas compilation - principle of energy minimum, Pauli exclusion Principle, Rule of Klechkovsky, Hund's Rule.
10. "Filling" of electrons on the examples Cu, Cr, Pd.
11. Electron formulas. Mechanism of exiting.
12. Valence as a function of electron configuration.
13. Types of the chemical bonding (ionic, covalent, metallic, hydrogen).
14. Abnormal water properties as a result of hydrogen bonding. Intermolecular hydrogen bonding in the structure of DNA double helix.
15. The Periodical Law and Mendeleev's Periodical Chart of the chemical elements.
16. Classification of inorganic substances.
17. Relations between the main classes of inorganic substances.

18. The amphoterity as acid-base duality.
19. The preparation and properties of the main classes (oxides, bases, acids, salts).
20. Structural-graphic formulas of chemical compounds. Examples.
21. Solutions. Basic units of concentration (mass concentration, molarity, normality, titr). Recalculations of units.
22. Theory of electrolytic dissociation. Degree of dissociation. Strong and weak electrolytes.
23. Main classes of inorganic substances from viewpoint of theory of electrolytic dissociation.
24. Ionic reactions. Conditions of interactions in the solutions of electrolytes. Examples.
25. Ionic product of water. Notion of pH. Acid-base indicators.
26. Hydrolysis of salts. Types of hydrolysis. Determination of pH.
27. Notion of oxidation numbers. Types of Redox reactions.
28. Balancing of Redox reactions by method of electron balance.
29. Acids as strong oxiding agents. Reactions of metals, metalloids, and non-metals with acids.
30. Werner's theory of complex compounds.
31. Structure of complex compounds. Preparation of complex compounds. Their naming, isomerism. Complexes in environmental sanitation.
32. Isomerism of complex compounds.
33. Endemic diseases of humans and animals as the result of chemical disproportion of the non-biotic environment.
34. Subjects and objects of the chemical analysis (analytical chemistry).
35. Methods of quantitative analysis – chemical and physical-chemical.
36. Subjects of qualitative and quantitative analyses.
37. Methods of qualitative analysis – macro-, semimicro-, micro-, and ultramicromethods.
38. Analytical reactions and requirements to analytical reactions. Examples of qualitative reactions of different visual effects (sedimentation, colorizing etc.)
39. "Dry" and "wet" qualitative tests. Pyrochemical methods (idea of borax bead tests, flame tests), microcrystalline analysis, analysis in drops in filter paper.
40. Notions of specific, selective, and group reactions and reagents. Examples.
41. Principles of cations classification – acid-base, sulfide, ammine-phosphate. The main group reagents.
42. Analytical purity of reagents. Ukrainian and international degrees of purity (classification техн, ч, чда, хч, осч; Analytical reagent AR, Guaranteed Reagent (GR) etc.)
43. Expression of Concentration: 1. percent (mass) concentrations; 2. Molar, 3. Normal (equivalent), and 4. Titr.
44. Formulas of recalculations of concentration units.
45. Heterogeneous equilibrium. Equilibrium In Saturated Solutions of Slightly Soluble Substances. Solubility product. Molar and mass solubility. Examples of calculations.
46. Factors effecting solubility: temperature, common ion effect, pH effect. Notion of ionic power (strength), active coefficients, and active concentrations.
47. Subject of gravimetric analysis. Equipment and tools (filter paper series). The experimental strategy. Calculations in gravimetric analysis.
48. Tananaev's rule. Amorphous and crystalline sediments. Requirements to sediments in gravimetric analysis. Rules of sedimenting.
49. Ionic product of water. pH notion. Biological function depending pH. Measuring pH.
50. pH calculations of strong acids and bases, weak acids and bases.
51. pH calculations of different salts solutions.
52. Buffer solutions. Calculate of a pH of buffer solutions.
53. Titration curves, equivalent points, titration jump. Acid-base indicators. Choice of indicators. Equivalent law in volumetry.
54. Neutralization method. Standard and working solutions, possibilities of method. Determination of water temporary hardness.

55. RedOx volumetry. The Nernst equation. How to calculate the electrode potential of redox systems. Electromoving force (EMF) of redox systems. RedOx indicators.
56. Theoretical foundations of permanganatometry and iodometry/iodatometry.
57. Complexonometry. Bases of method. Standard and working solutions, possibilities of method. Metallochromic indicators. Determination of total temporary hardness.

MODULE TEST 1.
CLASSIFICATION OF INORGANIC SUBSTANCES

Scores

1. What substances may react one with other (by pairs)? 2,5 scores
SiO_2, $Sr(OH)_2$, $Be(OH)_2$; HClO.
2. Write all possible equations of the reactions between RbOH and H_3BO_3 (Be attentive: may form neutral, acidic and basic salts). 3
3. Write the equation of reactions: 4
$H_4P_2O_7 + Al_2O_3 \rightarrow$
$Be(OH)_2 + LiOH \rightarrow$
$Na_2SO_4 + H_2SO_4 \rightarrow$
$SrHPO_4 \xrightarrow{t}$
4. Compile the structural-graphic formula of $Fe_2(SO_4)_3$ 0,5
Totally, scores: 10

Test questions

	Question 1. Group qualitative reactant of Cu^{2+} cations is (according to ammonium-phosphate classification):
A	Red blood salt;
B	Yellow blood salt;
C	Ammonium hydrophosphate;
D	Concentrated ammonia.
	Question 2. Qualitative reaction of CH_3COO^- anion with strong acid is accompanied by visual effect of:
A	Blue colorizing of solution;
B	Brown ring;
C	Special odour;
D	Crimson colorizing of solution.
	Question 3. For semimicro qualitative analysis it is used:
A	Near 100 g of solid and 100 mL of liquid reactants;
B	Near 10 g of solid and 1 L of liquid reactants;
C	Near 0,001 g of solid and 0,1 mL of liquid reactants;
D	Near 0,05 g of solid and 1 mL of liquid reactants.
	Question 4. Solution of potassium permanganate in the burette is levelled on:
A	The highest point of the meniscus;
B	The lowest point of the meniscus;
C	The middle point of the meniscus;
D	The zero point of the meniscus.
	Question 5. Accuracy of weighting of analytical balances is:
A	±0,0001 g;
B	±5 g;
C	±0,01 g;
D	±0,1 g.
	Question 6. Mass of H_2SO_4 (M=98,00 g/mol), dissolved in 2000 mL of solution, if for titration of 10 mL of this solution it was used 12,3 mL of 0,01 N NaOH):
A	1,2054 g;
B	2,4108 g;
C	3,4567 g;
D	0,1205 g.
	Question 7. What mixture has buffer properties:
A	$NH_4Cl + NH_4HCO_3$;

B	$NH_4Cl + NH_4OH$;
C	$HCl + NH_4Cl$;
D	$NH_4Cl + NH_4H_2PO_4$.
	Question 8. For qualitative determination of Mg^{2+} ion of Ammonia or Sodium Hydrophosphate it is prevented the presence in solution:
A	Cations of alkali metals;
B	Anions;
C	Cations of the 2d group;
D	All cations of the 2^d, 3^d and 4^{th} groups (according to ammonia-phosphate classification).
	Question 9. In analytical determinations it doesn't use chemicals of such purity:
A	Technical grade;
B	Extra Pure grade;
C	Pharmacopoeia grade;
D	For Analytical Purpose.
	Question 10. Mass of $CaCl_2 \cdot 6H_2O$ (M=219,08 g/mol) for precipitation of Calcium in the form of $CaC_2O_4 \cdot H_2O$ (M=146,11 g/mol) is:
A	1,4994 g;
B	0,7497 g;
C	0,4998 g;
D	0,9996 g.
	Question 11. Buffer solution has such main property:
A	To stabilize ionic strength or pH of solution;
B	To stabilize density of solution;
C	To stabilize temperature of solution;
D	To stabilize color of solution.
	Question 12. It is necessary for preparation of coarse-crystalline precipitate:
A	To precipitate of hot diluted solutions;
B	To precipitate of cold diluted solutions;
C	To precipitate of hot concentrated solutions;
D	To precipitate of cold concentrated solutions.
	Question 13. pH of 0,01 N HIO_3 (pK=10,64) is:
A	6,32;
B	10,64;
C	7,00;
D	1,12.
	Question 14. ppm – this is…:
A	Percent per mass;
B	Parts per million;
C	Parts per mass;
D	per cent per million.
	Question 15. Equivalent mass of H_3BO_3 (M=61,83 g/mol) in neutralization processes is equal to:
A	61,83 g/g-eq;
B	10,31 g/g-eq;
C	20,61 g/g-eq;
D	122,66 g/g-eq.
	Question 16. Such system of cation classification doesn't exist:
A	Acid-base;
B	Phosphate;
C	Hydrochloride;
D	Buffer.
	Question 17. Qualitative reaction of Pb^{2+} anion with KI after re-crystallization in presence of acetic acid is accompanied by visual effect of:
A	Blue colorizing of solution;
B	Brown ring;
C	Yellow-goldish precipitation ("Gold rain");
D	Crimson colorizing of solution.
	Question 18. Equivalent concentration is shown:
A	Quantity of moles of soluble substance per 1 L of solution;
B	Quantity of equivalents of soluble substance per 1 L of solution;

C	Quantity of moles of soluble substance per 1 kg of solution;
D	Quantity of moles of soluble substance in per 100 mL of solution.
	Question 19. According to Tananaev's recommendations, mass of amorphous precipitate is the best of all would be:
A	Near 0,2 g;
B	Near 0,5 g;
C	Near 1 g;
D	Near 1 mol.
	Question 20. Sign of heterogeneous system is:
A	Presence of precipitate and solution simultaneously;
B	One aggregate state of all phases;
C	Absence of separated surfaces between phases;
D	Mixing of all components.
	Question 21. SO_3^{2-} and SO_4^{2-} anions may be separated one from other by adding:
A	Concentrated ammonia;
B	Silver nitrate;
C	Sulphate acid;
D	Barium chloride and action of diluted HCl into formed precipitates.
	Question 22. Equivalent mass of Ca^{2+} cation (A (Ca)=40,08) in reaction with Trilon B is:
A	40,08 g-eq/g;
B	20,04 g-eq/g;
C	10,02 g-eq/g;
D	5,01 g-eq/g.
	Question 23. Metallochromic indicators in complexonometry are:
A	Weak bases;
B	Weak acids;
C	Red-Ox systems;
D	Ligands, formed colored unstable complexes with metal cations.
	Question 24. The most sensitive reactant of Na^+ determination is:
A	$K[Sb(OH)_6]$;
B	$Zn(UO_2)_3(CH_3COO)_8$ in presence of acetic acid;
C	Chugaev's reactant;
D	$NH_4H_2PO_4$.
	Question 25. Red-Ox potential of the system MnO_4^-/Mn^{2+} at pH=3 ($E^0(MnO_4^-/Mn^{2+})=+1,52V$), when $[MnO_4]=[Mn^{2+}]=1$ mol/L, is:
A	+1,80 V;
B	-1,80 V;
C	+1,24 V;
D	-1,52 V.
	Question 26. The best indicator for titration of 0,1 N acetic acid by 0,1 N Sodium hydroxide is ($pH_{equivalent\ point}=8,16$):
A	Methyl Violet (pT=1,4);
B	Cresol red (pT=7,5);
C	Meta cresol purple (pT=8,2);
D	Orange G (pT=12,8).
	Question 27. Equivalent mass of $KMnO_4$ for titration in acidic medium is ($M(KMnO_4)=158$ g/mol):
A	158 g/g-eq;
B	52,7 g/g-eq;
C	79,0 g/g-eq;
D	31,6 g/g-eq.
	Question 28. Percent concentration is shown:
A	Mass of solute in 100 mL of solution;
B	Mass of solute in 100 g of solution;
C	Mass of solute in 1 kg of solution;
D	Mass of solute in 1000 mL of solution.
	Question 29. Equivalent point of titration in neutralization reaction corresponds to:
A	Starting of indicator color change;
B	Finishing of indicator color change;
C	pH in the starting of titration jump;

D	pH in the centre of titration jump;
	Question 30. The most sensible test for borate anion determinations is:
A	Reaction with Sodium hydroxide;
B	Flame test with concentrated sulphate acid and alcohol;
C	Test with $BaCl_2$;
D	Test with $AgNO_3$.

Exam test

Екзаменаційні питання (theoretical questions)

1. 10 points Describe the evolution of atomic concepts (Dalton's - Thomson's – Rutherford's – Bohr's – Schrödinger's models). What difference is between "electron orbit" and "electron orbital"? The dual nature of electron. Compile graphic formulas of electrons' distributions in ground and excited states on the example of Phosphorus P (# 15).

2. 10 points Describe the basic notions of gravimetry: subject, series – physical and precipitation, advantages and disadvantages; equipment and tools needed; steps in gravimetric analysis; requirements to sediments in gravimetric analysis; types of sediments; rules of sedimentation.

Тестові завдання різних типів (test question of different types)

1. 1 point Classify the compounds and their chemical bonding (see Electronegativity Chart):

A.	N_2	**1**	Covalent non-polar
B.	C_2H_4	**2**	Covalent polar
C.	$SrCl_2$	**3**	Ionic
D.	Co	**4**	Metallic
E.	K_3N		

2. 1 point The pH of a certain solution is 3. What is the concentration of H^+(aq) ions in the solution?

A.	$1 \cdot 10^{-5}$ M	**B.**	$1 \cdot 10^{-7}$ M	**C.**	$1 \cdot 10^{-3}$ M	**D.**	3 M	**E.**	0,3 M

3. 1 point Note colour of acid-base indicator methyl orange in the water solution of $(NH_4)_2SO_4$:

A.	Pink	**B.**	Colourless	**C.**	Blue	**D.**	Yellow

4. 1 point The concentration of lead Pb in polluted soil is 1,3 ppm. Express this concentration in unit mg/kg of soil.

5. 1 point What is the Normality (equivalent concentration) of a solution prepared by dissolving 7,58 grams of Potassium nitrate ($M(KNO_3)$=101,10 g/mol) in enough water to prepare 250 mL of solution?

A.	0,0937 g-eq/L;	**D.**	3,0650 g-eq/L;
B.	0,3000 g-eq/L;	**E.**	3,3400 g-eq/L;
C.	1,8950 g-eq/L;	**F.**	None of these.

6. 1 point Note indicator, using in the neutralization method *(possible more that one true variant)*:

A	Starch	C	Methyl orange
B	Phenolphthalein	D	Eriochrome black T

7. 1 point Determine correspondence of titration methods and their primary standard substances.

A	Neutralization	1	$H_2C_2O_4$ (oxalic acid)
B	Complexonometry	2	$Na_2B_4O_7$ (borax)
C	Iodometry	3	$KMnO_4$ (potassium permanganate)
D	Permanganatometry	4	$ZnSO_4$ or Zn (metallic)

8. 1 point Calculate pH of 10 N hydrochloride acid HCl (to consider as a strong acid, dissociated completely):

A	1	B	10	C	0	D	-1

9. 1 point Calculate mass of $FeSO_4 \cdot 7H_2O$ (MW=278,01 g/mol) for the Iron gravimetric determination on the form of Fe_2S_3 (MW=207,89 g/mol) according to the Tananaev's recommendation.

10. 1 point Calculate molar and mass solubility (in mol/L and g/L) of $BiPO_4$ ($K_{SP} = 1{,}0 \cdot 10^{-23}$, M= 303,95 g/mol).

9. Teaching methods

Before teaching a course, the instructor must identify what she or he intends for the students to learn. For most inorganic & analytical chemistry instructors, this usually involves an assessment of what methods and techniques to include and at what depth to cover them. There are many other skills, though, that will be important to students for their future success. Most university classes in inorganic & analytical chemistry are taught in a lecture format. An alternative to lecturing is the use of cooperative learning. Cooperative learning offers the potential to develop skills such as teamwork, communication, and problem-solving that is more difficult to impart in a lecture format. The laboratory component of inorganic & analytical chemistry courses is often an underutilized learning resource. More often than not, the lab is used to demonstrate fundamental wet and instrumental analysis techniques and develop elementary laboratory skills. The chemical lab

should also be used to develop meaningful problem-solving skills and to demonstrate and have students participate in the entire chemical process.

A teaching method comprises the principles and methods used for students teaching. Commonly used teaching methods for studding subject "Inorganic & analytical chemistry" include on-time participation, demonstration, recitation, memorization, or combination of these.

Explaining, or lecturing, is the process of teaching by giving spoken explanations of the subject that is to be learned. Lecturing is often accompanied by visual aids to help students visualize an object or problem.

Demonstrating is the process of teaching through examples or experiments. For example, a chemistry teacher must teach an idea by performing an experiment for students. A demonstration may be used to prove a fact through a combination of visual evidence and associated reasoning.

Demonstrations in inorganic & analytical chemistry and own experiment are permit to obtain experimental skills needed for environmental monitoring etc. Memorization of a list of facts is a detached and impersonal experience, whereas the same information, conveyed though demonstration, becomes personally relatable. Demonstrations help to raise student interest and reinforce memory retention because they provide connections between facts and real-world applications of those facts. Lectures, on the other hand, are often geared more towards factual presentation than connective leaning.

Collaboration allows students to actively participate in the leaning process by talking with each other and listening to other points of view. Collaboration establishes a personal connection between students and the topic of study and it helps students think in a less personally biased way. Group projects and discussions are examples of this teaching method. Teachers may employ collaboration to assess students' abilities to work as a team, leadership skills, or presentation abilities.

10. Forms of assessment

The main forms of knowledge control are control works and tests that are executed by students using E-learn platform.

They include:

1. Lab work protocols assessment;
2. Tests;
3. Module control works.

The point rating of each kind of activity is established depends on its complexity.

Examinations. Exam is a final step in the study of the whole or part of the discipline and are designed to test students' knowledge on the theory and identify the skills apply the acquired knowledge in solving practical problems, as well as independent work skills with educational and scientific literature.

Student's rating of knowledge of an academic discipline consists of training work rating – 70 points and final attestation – 30 points. Thus, rating of content modules, that are constituents of an academic discipline, makes 70 points. Rating of content modules as well as attestation rating is also measured by 100-point-scale.

Distribution of grades received by students. Evaluation of student knowledge is carried out on a 100-point scale and is converted to national grades according to Table 1 "Regulations and Examinations and Credits at NULES of Ukraine" (order of implementation dated 26.04.2023, protocol № 10).

In order to determine the rating of a student (listener) in the discipline $\mathbf{R_{dis}}$ (up to 100 points), the rating from the exam $\mathbf{R_{ex}}$(up to 30 points) is added to the rating of a student's academic work $\mathbf{R_{aw}}$ (up to 70 points): $\mathbf{R_{dis} = R_{aw} + R_{ex}}$.

Student rating, points	National grade based on exam results	
	Exams	Credits

90-100	Excellent	Passed
74-89	Good	
60-73	Satisfactory	
0-59	Unsatisfactory	Not passed

11. Educational and methodological support

The training materials for educational components were published in a related course and can be accessed at the following link: https://elearn.nubip.edu.ua/course/view.php?id=4107

1. Methodological guidelines “Inorganic and analytical chemistry for bachelor students specialty 201 – “Agronomy”. Voitenko L.V., Kopilevich V.A., Prokopchuk N.M. Savchenko D.A., Kravchenko O.O. – Kyiv: Експо-Друк., 2022. - 219 p.
2. Laboratory manual on Inorganic and Analytical Chemistry. Savchenko D.A., Voytenko L.V., Prokopchuk N.M.- Kyiv: Експо-Друк., 2017. - 216 p.Неорганічна та аналітична хімія: підручник / В.А. Копілевич, Д.А. Савченко, Т.І. Ущапівська. – К.: Редакційно-видавничий відділ НУБіП України. 2020. – 596 с.
3. Неорганічна та аналітична хімія: навчальний посібник у формі лабораторного практикуму// Д.А. Савченко, В.А. Копілевич, Т.І. Ущапівська, Н.М. Прокопчук. – К.: ДДП «Експо-Друк». 2021. – 329 с.
4. Analytical Chemistry. Manual for Bachelor’s Students // Voytenko l.V., Kosmaty V.E., Kopilevich V.A. – Kyiv: NAUU publ., 2007. – 199 pp.
5. Analytical Chemistry. Workbook for Bachelor’s Students // Voitenko l.V., Kosmaty V.E., Savchenko D.A., Kopilevich V.A. – Kyiv: NUBiP Publ., 2014. – 140 pp.

12. Recommended sources of information

1. General and Inorganic Chemistry: textbook/V.O. Kalibabchuk, V.V. Ohurtsov, V.I. Halynska et al.; edited by V.O. Kalibabchuk. – Kyiv : AUS Medicine Publishing, 2019. – 456 p.
2. Introduction in General, Organic and Biochemistry, 7th Edition, by Morris Hein, Leo R. Best, Scott Pattison and Susan Arena, Brooks/Cole Publishing Co., 2021. – 872 pp.
3. Inorganic Chemistry, second edition, D. F. Shriver, P. W. Atkins, and C.H. Langford; W. H. Freeman and Co., New York, 2004, 913 pp.Harvey D. Modern Analytical chemistry (electron copy). McGraw-Hill Education, 2000. – 556 pp.
2. Ф.Г. Жаровський, А.Т. Пилипенко, І.В. П'ятницький. Аналітична хімія. – К.: ”Вища школа”, 1982. – 543 с.
3. Vogels’ Textbook of Macro and semimicro qualitative inorganic analysis https://archive.org/details/VogelsQantitativeChemicalAnalysis
4. Harvey D. An Electronic Textbook for Introductory Cources in Analytical chemistry. http://www.freebookcentre.net/chemistry-books-download/An-Electronic-Textbook-for-Introductory-Courses-in-Analytical-Chemistry.html
5. Quantitative Analysis Analytical Chemistry by Dr. Michael J. Prushan http://www.freebookcentre.net/chemistry-books-download/Quantitative-Analysis-Analytical-Chemistry.html
6. Prof. Clemens F Kaminski Analytical Chemistry Notes http://www.freebookcentre.net/chemistry-books-download/Analytical-Chemistry-Notes-(PDF-55P).html
7. ISO 6353-2:1983 Reagents for chemical analysis – Part 2: Specifications – First series.
8. ISO 6353-2:1983/Add.2:1986(en) Reagents for chemical analysis — Part 2: Specifications — First series ADDENDUM 2.
9. ISO 6058:1984. Water quality – Determination of calcium content – EDTA titrimetric method.
10. ISO 6059:1984 Water quality – Determination of the sum of calcium and magnesium – EDTA titrimetric method.

11. Periodical Table - http://www.webqc.org/periodictable.php.
12. Calculator of Molar weight (FW) http://www.graphpad.com/quickcalcs/Molarityform.cfm
13. Units convertor - http://www.webqc.org/unitconverters.php.
14. pH calculator - http://www.webqc.org/phsolver.php.
15. Calculating titrating curves - http://chemwiki.ucdavis.edu/Core/Physical_Chemistry/Equilibria/Acid-Base_Equilibria/pH_Titration_Curves.
16. Acid-base indicators - http://www.ch.ic.ac.uk/vchemlib/course/indi/indicator.html
17. RedOx indicators choice - http://community.asdlib.org/imageandvideoexchangeforum/2013/07/26/selecting-an-indicator-for-8a-redox-titration/
18. Sigma-Aldrich reagents - https://www.sigmaaldrich.com/
19. Qualitative tests of anions
    https://www.youtube.com/watch?v=ExB1r4m7Bb8
    https://www.youtube.com/watch?v=_8jxWtYuVjg
    https://www.youtube.com/watch?v=xergf70U7hQ
    https://www.youtube.com/watch?v=xJFG8tozVzw
    Separate anions testing:
    https://www.youtube.com/watch?v=9VbQO6bv6HQ –carbonate test
    https://www.youtube.com/watch?v=Mk3EDAKU_BU – borate flame test
    https://www.youtube.com/watch?v=TFcAo9ktZSA– borate flame test
    https://www.youtube.com/watch?v=FdVO1zX6doA – phosphate test