Danylo Halytsky Lviv National Medical University

Department of Pharmaceutical, Organic and Bioorganic Chemistry

APPROVED
Acting First pro-rector
for the Academic Work
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EDUCATIONAL PROGRAM IN THE DISCIPLINE "ORGANIC CHEMISTRY"

Second (master's) educational level
Field: 22 "Health"
Specialty: 226 "Pharmacy, industrial pharmacy"
for second-year students of pharmaceutical faculty

Discussed and approved
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INTRODUCTION

The syllabus for "Organic Chemistry"
in accordance with the Project of Standard of Higher Education of *the second (master's) level*
Field: 22 *"Health"*
Specialty: 226 "Pharmacy"
Master's Degree Programme in Pharmacy

Description of the discipline (abstract)

The discipline "Organic Chemistry" is devoted to the systematic study of the chemical behavior of organic compounds in relation to their structure and the formation of creative chemical thinking on this basis. It is necessary for the successful understanding of specialized disciplines, as well as for practical activity.

The main goal of Organic Chemistry as a fundamental discipline is to provide a scientific approach to solving such problems as pharmaceutical analysis, phytochemical and chemico-toxicological analysis, as well as synthesis, evaluation of quality and technology of medical preparations and their storage conditions.

Training of specialists who need knowledge of Organic Chemistry requires not only theoretical base but also the versatile practical skills for chemical experiments.

The tasks of Organic Chemistry are to determine the structure of organic molecules both natural and synthetic; studying and understanding of the chemical transformations of organic molecules based on the nature of functional groups; detection of relationships between molecular and electronic structure of compounds and their physiological and pharmacological effects, revealing the patterns of the chemical transformations; studying the aspects of obtaining, purification, and analysis of organic compounds.

The structure of the discipline	**The number of credits, hours**				**Year of study**	**Type of control**
	Total Credit hours	**Auditorium**		**Self-study**		
		Lectures	**Practical classes**			
Course title: Organic Chemistry *4 thematic modules*	8.0 credits ECTS / 240 h	20	100	120	2nd year (III, IV semester)	exam
Per semester						
1-2 thematic modules	4.0 credits ECTS / 120 h	10	48	62	III semester	
3-4 thematic modules	4.0 credits ECTS / 120 h	10	52	58	IV semester	exam

The subject of the study of the discipline is

1. molecular structure of organic compounds;
2. physical and chemical properties of organic compounds;
3. types of chemical reactions;
4. reactivity of different classes of organic compounds;
5. biological activity of organic compounds;
6. relationship between the structure and properties of organic compounds, including metabolites and drugs;
7. methods of isolation, purification, analysis of organic compounds.

Interdisciplinary connections: - General and Inorganic chemistry; Analytical chemistry; Biophysics; Biology; Biological chemistry; Normal physiology; Pathological physiology; Pharmacology; Histology.

1. The objectives and tasks of the "Organic Chemistry" course

1.1. Objectives of teaching of the "Organic Chemistry" course are:

- mastering of regularity of chemical properties of organic compounds based on their structure; understanding of biochemical processes that occur in biological systems;
- be familiar with basic methods of organic compounds synthesis as the basis for new biologically active substances creation;
- gaining practical skills that will be helpful to learn the standardization techniques and grug quality control.
- disclosure of organic chemistry practical aspects, methods and ways of usage of its achievements in the pharmaceutical practice.

1.2. Tasks of the "Organic Chemistry" course are:

- to teach students the general principles of evaluation of the chemical properties of organic compounds, underlying the synthesis and analysis of organic substances;
- to reveal of organic chemistry practical aspects, the ways and methods of use its achievements in the pharmaceutical practice.

1.3. Competences and learning outcomes that are formed by this subject (the relationship with the normative content of the training of higher education graduates, formulated in terms of learning outcomes in the Standard of Higher Education)

In accordance with the requirements of the Standard of Higher Education, discipline ensures students' acquisition of **competences**:
-general: ЗК 2; ЗК 3; ЗК 4; ЗК 6: ЗК 7; ЗК 10; ЗК 11; ЗК 12; ЗК 14;
-spetial ((professional, subjectional):): ФК 2; ФК 4; ФК 5; ФК 6;ФК 7; ФК 15; ФК 19; ФК 20.

Details of competences according to the descriptors are given in the form of "Matrix of competences".

Matrix of competences

No	Competence	Knowledge	Skills	Communication	Autonomy and responsibility
1.	“3K.2” Ability to apply knowledge in practical situations	Know the methods of implementing knowledge in solving practical problems	Be able to use professional knowledge to solve practical situations	Establish links with practitioners	Be responsible for the timeliness of decisions
2.	“3K.3” The striving to save the environment	To know the problems of environmental protection, the requirements of the sanitary and hygienic regime and the conditions of labor protection		Develop measures to preserve and protect the environment	Be responsible for the implementation of environmental protection measures within its competence
3.	“3K.4” The ability to abstract thinking, analysis and synthesis; the ability to study and to be trained up-to date	Know the current trends in the industry and analyze them	Be able to analyze professional information, make informed decisions, acquire Be able to form requirements for environmental protection, compliance with sanitary and hygienic regime and conditions of labor protection; interpret the requirements of laws and regulations on labor protection; draw conclusions about the presence of harmful factors during the performance of professional duties; to provide labor protection of pharmaceutical personnel modern knowledge	Establish appropriate connections to achieve goals	Be responsible for the timely acquisition of modern knowledge
4.	“3K.6” Knowledge and understanding of the subject area and comprehension of the profession	Know the structure and features of professional activity	Be able to carry out professional activities that require updating and integration of knowledge	To form a communication strategy in professional activity	Be responsible for professional development with a high level of autonomy
5.	“3K.7” Ability to adapt and act in a new situation	Know the elements of working and social adaptation; factors of successful adaptation to the new environment. decision-making	Be able to form an effective strategy of personal adaptation to new conditions	Interact with a wide range of people (colleagues, management, experts in other fields) in the event of new situations with the elements unpredictability	Be responsible for decision making
6.	“3K.10” Ability to choose communication strategy, ability to work in a team and with experts from other fields of knowledge / types of economic activity	Know the tactics and strategies of communication, laws and ways of communicative behavior	Be able to choose ways and strategies of communication to ensure effective teamwork	Use communication strategies and interpersonal skills	Be responsible for the choice and tactics of communication

7.	“ЗК.11” Ability to assess and ensure the quality of performed work	Know the methods of evaluating performance indicators	Be able to ensure the quality of professional work	Establish connections to ensure quality work	Be responsible for the quality of work
8.	“ЗК.12” Ability to perform research at the appropriate level	Know the components of the health care system, planning and evaluating research	Search for scientific sources of information; to make a choice of methods of carrying out scientific research; use methods of mathematical analysis and modeling, theoretical and experimental research in pharmacy	Use information data from scientific sources	Be responsible for the development and implementation of planned projects
9.	“ЗК 14”. Ability to preserve and multiply moral, cultural, scientific values and achievements of society based on understanding the history and patterns of development of the subject area, its place in the general system of knowledge about nature and society and in the development of society, techniques and technologies. active recreation and a healthy lifestyle	Critical understanding of problems in the field and on the border of fields of knowledge	Ability to solve problems in new or unfamiliar environments with incomplete or limited information, taking into account aspects of social and ethical responsibility		Ability to continue studies with a high degree of autonomy
10.	“ФК 2”. Ability to provide advice on prescription and over-the-counter drugs and other products of the pharmacy range; pharmaceutical care in the selection and sale of over-the-counter drugs by assessing the risk / benefit, compatibility, indications and contraindications based on the health status of a particular patient, taking into account biopharmaceutical, pharmacokinetic, pharmacodynamic and physicochemical characteristics of the drug and other pharmaceutical products.	Know the physicochemical properties of drugs	Provide information on the regime, timing and requirements for storage of drugs of various dosage forms at home in accordance with list 4, using knowledge of chemical, physicochemical, properties	Provide counseling and pharmaceutical care when dispensing over-the-counter drugs	Be responsible for the provision of pharmaceutical care when dispensing over-the-counter drugs
11.	“ФК 4”. Ability to ensure rational use, obtain the necessary information from identified sources to ensure conditions for quality and	Know the chemical structure of drugs; relationship "chemical structure - pharmacological action"	Carry out a comparative characterization of drugs in accordance with list 1b, taking into account the chemical	Obtain the necessary information from identified sources to ensure the conditions for quality and	Be responsible for the soundness of management decisions to improve the quality of pharmaceutical care

	safe pharmaceutical care of prescription and over-the-counter drugs and other pharmaceutical products in accordance with physicochemical, pharmacological characteristics, biochemical, pathophysiological features of a particular disease and its pharmacotherapeutic regimen.		structure, mechanism of action and pharmacological properties in order to determine the advantages and disadvantages of individual drugs.	safe pharmaceutical care	
12.	"ФК 5" Ability to monitor the effectiveness and safety of the use of drugs by the population according to the data on their clinical and pharmaceutical characteristics, as well as taking into account subjective signs and objective clinical, laboratory and instrumental criteria for examination of the patient	Know the principles of clinical, laboratory and instrumental evaluation of the effectiveness / ineffectiveness and safety of drugs	Collect, recognize and identify from various sources, analyze and interpret information on adverse reactions and / or lack of efficacy of the drug	To draw conclusions based on the analysis of information on side effects of drugs	Be responsible for analyzing information on the efficacy and safety of medicines
13.	"ФК 6" Ability to identify drugs, xenobiotics, toxins and their metabolites in body fluids and tissues, to conduct chemotoxicological studies to diagnose acute poisoning, drug and alcohol intoxication	Know the physicochemical properties of drugs of inorganic and organic nature; aliphatic monohydric and polyhydric alcohols, alkyl halides; aldehydes, ketones, monohydric phenols and organic acids; mineralization of organic medicinal compounds; chemical and instrumental methods of analysis. Qualitative and quantitative analysis.	Taking into account the distribution of toxins in the body, metabolism, and other factors, select biological objects of analysis and evaluate the results obtained, using the physicochemical and pharmacological characteristics of toxic substances	Analyze drugs and their metabolites in body fluids and tissues	Be responsible for the results of chemical and toxicological research
14.	"ФК 7" Ability to ensure proper storage of medicines and other products of the pharmacy range in accordance with their physico-chemical properties and the rules of Good Storage Practice (GSP) in health care facilities.	Know the physicochemical properties of drugs	Ensure appropriate storage conditions for toxic, narcotic and equivalent drugs, as well as dosage forms with them	Carry out constant monitoring of proper storage of medicines and medical devices at pharmaceutical enterprises	Be responsible for the storage of medicines and medical devices in accordance with Good Storage Practice (GSP) in healthcare facilities
15.	"ФК 15". Ability to organize and participate in the production of medicines in the context of pharmaceutical companies, including the selection and	Know the methods of extraction and synthesis of organic compounds; methods of isolation and purification of organic compounds	Stabilize pharmaceuticals, taking into account the biological, physico-chemical, technological properties of active substances and	Choose the optimal technological process of manufacturing drugs of industrial production	Be responsible for compliance with Good Manufacturing Practice.

	justification of the technological process, equipment in accordance with the requirements of Good Manufacturing Practice (GMP) with the appropriate development and design of the necessary documentation. Determine the stability of drugs		excipients, using the necessary reagents		
16.	"ФК 19" Ability to organize and control the quality of medicines in accordance with the requirements of the current State Pharmacopoeia of Ukraine and good practices in pharmacy, to determine methods of sampling for control of medicines and to standardize them in accordance with current requirements, to prevent the spread of falsified medicines	Know the physicochemical properties of drugs; methods of qualitative and quantitative analysis of drugs	Determine the main physical characteristics of drugs (melting point, boiling point and pour point) by physical methods	Carry out quality control of medicines and their certification.	Be responsible for certifying and preventing the spread of counterfeit medicines
17.	"ФК 20". Ability to develop methods for quality control of medicines, including active pharmaceutical ingredients, medicinal plant raw materials and excipients using physical, chemical, physicochemical, biological, microbiological, pharmacotechnological and pharmacoorganoleptic control methods	Know the elemental analysis and analysis by functional groups; functional analysis of organic compounds by functional groups; general methods of analysis of inorganic and organic drug compounds; chromatographic methods of identification, optical activity and specific rotation. spectral methods of analysis	Determine the functional groups of active substances of organic nature in accordance with list 1a in raw materials, intermediate products, finished products	Develop methods of quality control of pharmaceutical products.	Be responsible for the validity of the developed quality control methods

Learning outcomes:

Integrative final learning outcomes, the formation of which contributes to the discipline: ПРН 1; ПРН 2; ПРН 4; ПРН 10; ПРН 12; ПРН 14; ПРН 16; ПРН 17; ПРН 30; ПРН 32.

"ПРН 1" carry out professional activities in social interaction based on humanistic and ethical principles; identify future professional activities as socially significant for human health.
"ПРН 2" to apply knowledge of general and professional disciplines in professional activities;
"ПРН 4" to use the results of independent search, analysis and synthesis of information from various sources for solving typical tasks of professional activity;
"ПРН 10" Adhere to the norms of communication in professional interaction with colleagues, management, consumers, work effectively in a team.
"ПРН 12" to use methods of performance indicators evaluation; to reveal reserves for improving of labor productivity.
"ПРН 14" to determine the advantages and disadvantages of drugs of different pharmacological groups, taking into account their chemical, physicochemical, biopharmaceutical, pharmacokinetic and pharmacodynamic features. To recommend to consumers over-the-counter medicines and other products of the pharmacy range with the provision of counseling and pharmaceutical care.
"ПРН 16". to determine factors influencing the processes of absorption, distribution, deposition, metabolism and excretion of the drug and due to the condition, features of the human body and physicochemical properties of drugs.
"ПРН 17" to use data from clinical, laboratory and instrumental studies to monitor the effectiveness and safety of drugs.
"ПРН 30" to ensure quality control of medicines and document its results. Manage quality risks at all stages of the life cycle of medicines.
"ПРН 32" to determine the main organoleptic, physical, chemical, physicochemical and pharmacotechnological indicators of medicines, to substantiate and choose methods of their standardization, to carry out statistical processing of results in accordance with the requirements of the current State Pharmacopoeia of Ukraine.

As the result of the study of the "Organic Chemistry" course

***Student should know*:**

- basic principles of classification, nomenclature and structural isomerism of organic compounds;
- types of chemical bonds, conjugated systems, electronic effects, acidity and basicity of organic compounds as a basis of their reactivity;
- classification principles of organic reactions by the direction, the way of bond breaking and the their mechanisms;
- structure, nomenclature, isomerism, preparation methods and chemical properties of hydrocarbons, halogen-, oxygen-, sulfur- and nitrogen-containing derivatives of hydrocarbons, hetero-functional compounds, heterocyclic compounds, biopolymers and bioregulators;
- the names and the purposes of laboratory glassware and equipments;

be able to:

- use chemical and reference literature, work with tables and graphical material;
- to assemble a some laboratory apparatuses;
- master the methods of purification of liquid and solid organic compounds as well as to be able to determine their purity;
- determine the physical constants of organic compounds;
- carry out the elemental analysis;
- use laboratory methods of preparation of certain organic compounds;
- carry out specific reactions/ identification tests for basic functional groups;
- carry out the synthesis and analysis of organic compounds.

2. Information volume of subject matter

To study the academic discipline 8.0 credits ECTS, 240 hours are given.

Structure of the discipline according to the content modules:

Thematic module 1. Nomenclature, classification, methods of identification and purification of the organic compounds. Reactivity of the hydrocarbons.

Topic 1. Introduction into practical work. Classification, nomenclature, and structural isomerism of the organic compounds.

The main statement of the theory of chemical structure of organic compounds and its significance for the development of organic chemistry.Fundamental concepts of organic chemistry: homology, hydrocarbon radical, substituent, functional group, poly- and heterofunctionality, isomerism. Classification of organic compounds. The main classification features of organic compounds - structure of the carbon skeleton and the nature of the functional group. Elements of structure that determine the reactivity of compounds. Genetic relationship between classes of organic compounds. Nomenclature systems in organic chemistry - trivial, rational, IUPAC system.Types of formulas in organic chemistry: empirical, molecular, structural. Abbreviated and simplified structural formulas.Structural isomerism: carbon skeleton isomerism, position isomerism, functional group isomerism.

Topic 2. Types of the chemical bonds and atoms interactions in the molecules of the organic compounds. Laboratory equipments.

Atomic and molecular orbitals.Types of hybridization: sp3, sp2, sp.Types of chemical bonds (covalent, ionic, coordination, semipolar). The concept of hydrogen bonding and its importance in the formation of structures of the molecule of proteins and nucleic acids.Electronic structure of σ- and π-bonds. Their characteristics (length, energy, polarity, polarization.Types of chemical bond broking (homolytic, heterolytic), intermediate particles (carbocations, carbanions, free radicals), their electronic structure. Types of reagents (electrophiles, nucleophiles, free radicals).Conjugation and its types (π, π- and p, π-conjugation). Influence of electron delocalization on increasing the stability of conjugate systems. Conjugation energy. Conjugated systems with open and closed chain. Aromaticity and its criteria.Interaction of atoms: induction and mesomeric electronic effects. Electron-donor and electron-acceptor substituents, their influence on the reactivity of molecules.The main types of laboratory glass. Chemical utensils and equipment used in organic synthesis.

Topic 3. Methods of the purification of the organic compounds. Determination of the physicochemical constants of the organic compounds.

The most important equipment used in organic synthesis is for weighing, measuring, heating, cooling and filtering.Types of distillation (simple distillation, distillation with dephlegmator, steam distillation, vacuum distillation) and their use.Extraction from solid mixtures and liquids. Solvent requirements for extraction.

Recrystallization (utensils and equipment, solvent selection, use of adsorbents, heating of liquids, filtration).Drying of solids and liquids.Sublimation.Column and thin-layer chromatography. Establishing the individuality of organic compounds. Rf.Determination of the heating temperature.Determination of boiling pointDetermination of refractive index.Determination of density.

Topic 4. Stereochemistry the biologically active compounds.

Configurations and conformations of molecules.Conformations of open chains (ethane type: n-butane, 1,2-dibromoethane, ethylene glycol).Conformations of cyclohexane. Axial and equatorial bonds.Methods of representation the spatial structure of molecules: Newman's projections, Fisher's formulas, stereochemical formulas.Stereoisomerism: geometric (cis, trance) and mirror.Chirality of molecules. Optical isomerism. Enantiomers.Diastereomerism.Relative configuration. Glyceraldehyde is a configuration standard.D- and L-stereochemical series of chiral molecules.Optical activity and racemates. Concept about ways to separate optical antipodes. Mesoforms.Relationship of spatial structure with biological activity.

Topic 5. Determination of the organic compounds structures. Classification of the organic reactions and reagents.

The main stages of establishing the structure of organic compounds.Features of elemental analysis of organic compounds.Discovery of Carbon and Hydrogen in Organic Compounds.Discovery of Nitrogen and Sulfur in organic compounds.Discovery of halogens in organic compounds.The concept of chemical elemental analysis of organic compounds.Methods for determining the molecular weight of organic compounds. Derivation of the gross formula.Derivation of formulas of simple organic compounds (law of radicals).The practical significance of qualitative and quantitative analysis of organic compounds.Spectral methods of research of organic compounds. IR, UV, PMR and mass spectra.Characteristic frequencies of the most important functional groups (hydroxyl, carbonyl, amine groups).Classification of chemical reactions by direction.Classification of chemical reactions by the method of disconnection.Intermediate particles of chemical reactions are carbocations, carbanions and free radicals, their electronic structure.Electrophilic and nucleophilic reagents.Reagent and substrate.Mechanisms of chemical reactions.The role of the catalyst in the course of chemical reactions.

Topic 6. Saturated hydrocarbons (alkanes, cycloalkanes). Unsaturated hydrocarbons (alkenes, alkynes, alcadienes).

Nomenclature and isomerism of alkanes. Alkyl radicals. Primary, secondary and tertiary carbon atoms.Industrial and laboratory methods of alkane synthesis. Characterization of chemical bonds in alkane molecules. Reactions of radical substitution of SR in saturated hydrocarbons and factors influencing their course.Chemical properties of alkanes (halogenation, sulfochlorination, nitration, oxidation, cracking).Classification, isomerism, nomenclature and methods of extraction of cycloalkanes. Geometric isomerism of cycloalkanes. Cis-trans decalines.Characterization of chemical bonds in cycloalkane molecules. "Banana" bonds in the cyclopropane molecule.Chemical properties of cycloalkanes depending on the size of the cycle. Reactions of hydrogenation,

halogenation, hydrohalogenation, narrowing and expansion of cycles.Industrial and medical-biological significance of alkanes and cycloalkanes.Nomenclature, isomerism and methods of synthesis of unsaturated hydrocarbons.Electronic structure of multiple bonds.Electrophilic addition reaction A_E. σ and π-Complexes, their stability. Factors influencing the course of the electrophilic addition reaction.Chemical properties of unsaturated hydrocarbons (hydrogenation reactions, halogenation, hydrohalogenation, hydration, oxidation, polymerization).
Markovnikov's rule and its modern interpretation.The peculiarity of the chemical behaviour of conjugated dienes. Diene synthesis (Diels-Alder reaction). CH-Acidity of alkynes. Identification of unsaturated hydrocarbons. The industrial, biological and practical significance of individual representatives.

Topic 7. Mononuclear aromatic compounds. Polynuclear aromatic compounds. Non-benzoid aromatic compounds. Final test.

Features of the structure of benzene. General criteria of aromaticity. Hückel's rule.Nomenclature and structural isomerism of mononuclear arenas.Synthesis methods. Chemical properties of mononuclear arenes. Electrophilic substitution reactions (SE). Structure of π- and σ-complexes.Reactions of halogenation, nitration, sulfonation, alkylation, acylation.Addition reactions.Oxidation reactions of benzene and its homologues.Influence of electron-donor and electron-acceptor substituents on the direction and rate of electrophilic substitution reactions. Orients of the I and II kind.The orientation in the S_E reaction in disubstituted benzene.Identification of mononuclear arenas.Individual representatives, their properties and uses.Polynuclear arenas. Classification, electronic structure, aromatic character. Conjugation energy.Naphthalene, synthesis methods. Chemical properties (electrophilic substitution reactions, addition, oxidation). Orientation rules in the naphthalene cycle. Spatial isomerism of decalin. Individual representatives.Anthracene, phenanthrene. Synthesis. Chemical properties (electrophilic substitution reactions, addition, oxidation). Hydrogenated phenanthrene as a structural fragment of morphine alkaloids and steroids.Carcinogenic polynuclear condensed arenes.Biphenyl. Synthesis methods, chemical properties. Benzidine.Diphenylmethane. Synthesis. Chemical properties. Methylene group activity. Sinestrol.
Triphenylmethane. Extraction, chemical properties. CH-acidity of the methine group. Structure of triphenylmethyl cation, anion and radical. Dyes of the triphenylmethane series. Brilliant green, phenolphthalein.
Non-benzoid aromatic systems: cyclopentadienyl anion, ferrocene, cycloheptatrienyl cation (tropilium ion), azulene. The reason for their aromaticity.

Thematic module 2.Halogen-, oxygen-, sulfur- and nitrogen-containing organic compounds.

Topic 8. Halogen-derivatives of hydrocarbons. Methods of halogenation.

Classification, nomenclature and isomerism of halogenated saturated, unsaturated and aromatic hydrocarbons.Methods of synthesis of mono-, di- and polyhalogenated hydrocarbons. Mechanisms of reactions of introduction of halogen into molecules of organic compounds (S_R, S_N, A_E, S_E).Reactivity of halogenated hydrocarbons.Characteristics of the carbon-halogen bond. Factors affecting the mobility of halogen atoms.Nucleophilic substitution reactions in haloalkanes and halogenarenes. Mechanisms of S_N1 and S_N2 reactions. Stereochemical aspects of nucleophilic substitution reactions.Cleavage reactions (elimination). The mechanism of E1 and E2 reactions. Zaitsev's rule.Factors influencing the course of competitive reactions of nucleophilic substitution and elimination.Unsaturated halogen derivatives (addition, polymerization, nucleophilic substitution and elimination of vinyl and allyl halides).Deactivating and activating effect of halogen on the course of electrophilic substitution reactions (SE) in halogenarenes.Interaction of alkyl halides with metals (Grignard, Wurtz and Wurtz-Fittig reactions).Identification of halogenated hydrocarbons.Individual representatives, their medical, biological and industrial significance.Methods of halogenation of organic compounds (halogenation pathways and halogenating agents).Identification of halogenated hydrocarbons.Individual representatives, their medical, biological and industrial significance.Methods of halogenation of organic compounds (halogenation pathways and halogenating agents).

Topic 9. Monoalcohols, ethers. Methods of halogenation (continuation).

Monohydroxy alcohols and ether: classification, nomenclature, and isomerism. Methods of preparations and properties.Peculiarity of the chemical behavior of saturated (primary, secondary, and tertiary) an unsaturated alcohols.Effect of the intermolecular association on physical properties and spectral characteristics of alcohols.
Acid and basic characteristics of the organic compounds. Brønsted – Lowry theory of acids and bases; types of acids (OH- and CH-acids). Conjugated acids and bases.Factors determining acidity and basicity.Industrial, biological and medical use of the alcohols.

Topic 10. Polyalcohols, phenols, naphthols. Thioalcohols.

Classification, nomenclature, isomerism, and chemical properties of the polyhydroxy alcohols, phenols, amino phenols, and naphtoles.Methods of preparation and chemical properties polyhydroxy alcohols, phenols, amino phenols.Identification of the diols and triols.Electronic structure of the phenolic hydroxyl.Acidic and basic properties of the polyhydroxy alcohols, phenols, naphtoles and thiols. Electrophilic substitution reactions (S_E) of phenol.Identification reactions for the monohydroxy and polyhydroxy phenols and their oxidation by different oxidizers.Nomenclature and preparation of the thiols and thioethers.Derivatives of the polyhydroxy alcohols phenols, and thioethers as drugs.

Topic 11. Amines. Acidic and basic properties of organic compounds. Nitro-compounds. The methods of nitration of the organic compounds.

Definition, classification, representatives, nomenclature and isomerism of amines.Comparative characteristics of the physical properties of amines and their salts.Methods of obtaining aliphatic and aromatic amines.Acid-base properties and their dependence on the electronic effects of substituents on the nitrogen atom in a number of amines.Salt formation with different acids and inverse conversion of salts into amine bases.Amines as nucleophilic reagents. Alkylation and acylation of amines. Formation of Schiff's bases.Reactions of primary, secondary and tertiary amines of aliphatic and aromatic series with nitric acid.Influence of amino group on the reactivity of the aromatic nucleus. Halogenation, sulfonation and nitration of aromatic amines.Definitions: amination, deamination, diazotization, nitrosation.Amino group identification reactions. Isonitrile test.Detection of amino groups by UV and IR spectra.Acidic and basic properties of organic compounds. Theories of Bransted and Lewis. Types of organic acids (OH-, SH-, NH- and CH-acids). The concept of pKa.Factors affecting the acidity and basicity of organic compounds.Classification, nomenclature and isomerism of nitro compounds.Methods of obtaining. Nitration methods. Nitrating agents.Chemical transformations of nitro compounds.Acy-nitro-tautomerism in a number of nitro compounds.Influence of nitro group on reactivity of carbohydrogen radical.Nitration of aromatic hydrocarbons and its mechanism.Methods for identification of nitro compounds. Interaction with nitric acid.Reduction to amines.Spectral characteristics.

Topic 12. Diazo- and azocompounds. The methods of nitration of the organic compounds (continuation). Azo-dyes. The methods of diazotation and azocoupling. Final test.

Diazo compounds. Classification, structure, nomenclature and isomerism.Methods of synthesis of diazonium salts. Diazotization reaction, conditions of its course and mechanism.Reactivity of diazonium salts. The structure of the diazocation.Reactions of diazonium salts with nitrogen evolving as an indirect method of removing the amino group from the aromatic nucleus and a method of obtaining various derivatives of aromatic hydrocarbons.Reaction of diazonium salts without nitrogen evolving.Azo compounds, their structure, nomenclature and isomerism.Methods of preparation of azo compounds. Reaction of azocoupling, conditions of its course, mechanism and importance.Physical and chemical properties of azo compounds.Azo dyes (methyl orange, methyl red) and their indicator properties.Theories of color. Chromophores, auxochromes.Importance of azo compounds in parmalinysis, for synthesis of drugs, dyes and indicators.Diazotization reaction. Conditions and mechanism of its performing. Diazotizing agents and necessary catalysts.Reactivity of diazo compounds.Azo coupling reactions. Conditions and mechanism of azo compound reaction (diazo and azo components). Factors that prevent its implementation.Physical foundations of the theory of color. The concept of chromophores and auxochromes.Azo compounds as azo dyes, acid-base indicators (methyl orange, methyl red) and pharmaceuticals (salazopyridazine, salazodimethoxine).Significance of diazo and azo combination reactions in organic synthesis and formalanalysis.

Thematic module 3. Biologically important carbonyl compounds. Heterofunctional compounds.

Topic 13. Aldehydes and ketones.

Classification, nomenclature and isomerism of aldehydes and ketones.Methods of preparation of aldehydes and ketones. Ways of direct introduction of the carbonyl group into the aromatic nucleus.Electronic structure of carbonyl group. Reaction centers in molecules of aldehydes and ketones.The mechanism of nucleophilic addition reactions.Influence of electronic effects and spatial factors on the course of AN reactions.The role of acid and basic catalysis.Reversibility of AN -reactions.Addition of water, alcohols, sodium hydrogen sulfite, cyanide acid, organomagnesium compounds.The mechanism of addition-elimination reactions.Obtaining imines, oximes, hydrazones and semicarbazones.Use of oxime and hydrazone formation reactions in qualitative analysis.Reactions involving the CH-acid center.The structure of enolate ion.Keto-enol tautomerism.Condensation of aldol and croton types.Haloform reaction.Redox properties of aldehydes and ketones.Specific properties of aromatic carbonyl compounds.Interaction with ammonia.Cannitsaro's reaction.Cross aldol condensation.Benzoin condensation.Electrophilic substitution reactions in the benzene nucleus.Quinones. Methods of production and chemical properties.Identification of aldehydes and ketones.Some representatives and their biological and medical significance (formaldehyde, acetaldehyde, acetone, acrolein, crotonic aldehyde, benzaldehyde, vanillin, acetophenone, benzophenone).

Topic 14. Monocarboxylic acids. Dicarboxylic acids. Metods of acylation.

Classification, nomenclature and isomerism of monocarboxylic acids.Obtaining methods.The structure of the carboxyl group and the carboxylate anion as p, π-conjugate systems.Acidic properties of carboxylic acids, salt formation. Dependence of acidic properties on electronic effects of substituents. Acidity and basicity of organic compounds. The concept of pKa. Brønsted–Lowry theories.Nucleophilic substitution reactions at a trigonal carbon atom, reaction mechanism. The role of acid and basic catalysis.Influence of carboxyl group on the course of chemical reactions on the hydrocarbon radical.CH-Acidity of α-carbon atom (Gel-Folgard-Zelinsky reaction, ester (ester) condensation). Addition against Markovnikov's rule in α, β-unsaturated acids. Deactivating and orienting action of the carboxyl group in electrophilic substitution reactions (S_E) in aromatic carboxylic acids.

Methods for identification of carboxylic acids. Some representatives of monocarboxylic acids (formic, acetic, propionic, butyric, valeric, isovaleric, acrylic, methacrylic, benzoic, cinnamic acids). Polyacrylic.Classification, nomenclature and isomerism of dicarboxylic (dibasic) acids.Obtaining methods.Acidic properties of dicarboxylic acids. Structure and stability of carboxylate anion and dianion. Comparative evaluation of the pKa of some aliphatic acids.Mono- and bifunctional derivatives of dicarboxylic acids.The relation of dicarboxylic acids to heat.Influence of carboxyl groups on the course of chemical reactions involving a hydrocarbon radical.Representatives of dicarboxylic acids and their practical use: oxalic, malonic, succinic, adipic, maleic, fumaric, phthalic acids. Phenolphthalein. Nylon.Identification of individual representatives of dicarboxylic acids.General characteristics and significance of the acylation reaction.Acylating agents and their activity.Acylation of alcohols and phenols.Acylation of amines.C-Acylation of aromatic hydrocarbons and their derivatives (Friedel-Crafts reaction). Reaction mechanism.

Topic 15. Functional derivatives of carboxylic acids. Soaps, tweens, waxes. Derivatives of carbonic acid. Methods of acylation (continuation).

Esthers. Nomenclature, obtaining methods, hydrolysis, amonolysis, transesterification.Anhydrides, halides as the main acylating reagents, their synthesis and properties.Amides of acids, nomenclature. Obtaining methods. Acid-base properties, hydrolysis, cleavage by hypobromites, dehydration.Hydrazides, nitriles. Their structure, nomenclature, synthesis methods and properties.Soaps. Synthetic soap substitutes.Waxes, twins. Their structure. Beeswax. Spermaceti.Carbonic acid derivatives: acid chlorides, amides, urethanes.Urea (carbonic acid diamide). Its properties: hydrolysis, salt formation, interaction with nitric acid and hypobromites.Guanidine (imineurea). Basic properties.

Topic 16. Halogeno-, hydroxy- and oxo-acids.

Halogeno-, hydroxy- and oxo-acids, their structure, classification, nomenclature and isomerism.Stereochemistry of halogeno-, hydroxy acids (enantiomeric, diastereomeric, optical activity, relative configuration, racemates, meso-forms).Halogeno- acids. Methods of synthesis.Acidic properties depending on the number of halogen atoms and the relative position of halogen and carboxyl group. Formation of salts, esters, halides, amides.Nucleophilic substitution reactions involving a halogen atom (conversion of halogen acids to hydroxy acids).Practical usage (chloroacetic, α-bromo-valeric acid).Hydroxy acids (alcohol and phenolic acids)Synthesis methods. Properties as bifunctional compounds. The iconversion of α-, β- and γ-hydroxy acids to heating.Cleavage of α-hydroxy acids under the action of sulfuric acid.Decarboxylation of phenolic acids.Practical significance (lactic, γ-butyric, malic, tartaric, citric, salicylic, gallic, o-hydroxycinnamic acids and their derivatives).Oxoacids. Methods of obtaining. Properties as bifunctional compounds. Specific properties (decarboxylation of α- and β-oxo acids).Tautomerism, dual reactivity, cleavage and synthetic importance of acetoacetic ester; acetone (ketone) bodies. Practical usuge (pyruvic, oxaloacetic, α-ketoglutaric acids).

Topic 17. Aminoalcohols, aminophenols, aminoacids. Derivatives of *p*-aminobenzoic and sulfanilic acids. Methods of sulfonation. Final test.

Amino alcohols, aminophenols, amino acids, their structure, nomenclature, isomerism.Chemical properties of amino alcohols (choline and colamine) *in vivo* and *in vitro*.Catecholamine - dopamine, norepinephrine, adrenaline, their biosynthesis and properties. Spatial structure of adrenaline and noradrenaline.Chemical properties of aminophenols.Spatial structure of amino acids.Acid-base properties of amino acids.Chemical properties of amino acids as bifunctional compounds.Specific chemical properties of amino acids.Medico-biological significance of amino acids, aminophenols, amino alcohols and their derivatives as metabolites and drugs.p-Aminobenzoic acid. Structure, synthesis methods and chemical properties (acidity, basicity, amphotericity, properties of carboxyl and amine groups)Derivatives of p-aminobenzoic acid - novocaine and benzocaine (anesthesin). Structure, properties and medical significance.Sulfonic acids (sulfonic acids). Structure, chemical properties.Sulfanilic acid. Structure, synthesis, properties and significance in pharmacy.Sulfanilamide drugs - white streptocide (sulfanilamide), sulfacil (Sulfacetamide sodium).Sulfonation reaction. Sulfonating agents.Sulfonation of arenes. Influence of temperature on the direction of naphthalene sulfonation reaction.

Thematic module 4. Heterocyclic compounds. Alkaloids. Natural biopolymers and bioregulators.

Topic 18. Five-membered heterocycles.

Heterocyclic compounds, their classification and nomenclature. Five-membered heterocycles with one heteroatom: pyrrole, furan, thiophene.Aromatic character. The structure of the pyrrole atom of Nitrogen. π-Excess aromatic systems. Acidophobicity of pyrrole and furan. Electrophilic substitution reactions (S_E). Peculiarityes of nitration, sulfonation and halogenation reactions of acidophobic heterocycles.Reduction and oxidation.Specific properties of pyrrole and furan. NH-Acidity of pyrrole, pyrrole salts.Methods for identification of pyrrole, furan and thiophene.Indole (benzopyrrole). Acidophobia. NH-Acid properties. Features of electrophilic substitution reactions.Important derivatives of five-membered heterocycles with one heteroatom: furfural, furacillin, pyrrolidine, tetrahydrofuran, polyvinylpyrrolidone, porphine and metalloporphins (heme, chlorophyll, vitamin B12), indoxyl, indigo, indifoloc-intocarmine, tridocarmino, carbino.Five-membered heterocycles with two heteroatoms (azoles) - pyrazole, imidazole, thiazole, oxazole, isoxazole.Aromaticity. The structure of the nitrogen

atom of the pyridine type.Synthesis methods.Azole tautomerism of imidazole and pyrazole.Acid-base properties.Electrophilic substitution reactions (SE).Reduction.Pyrazolone-3, tautomeric forms pyrazolone-3. Drugs: antipyrine, amidopyrine, analgin. Synthesis of antipyrine.Derivatives of five-membered heterocycles with two heteroatoms that are important: histidine, histamine, benzimidazole, dibazole, 2-aminothiazole (its synthesis and chemical properties).Thiazolidine is a structural fragment penicillin antibiotics.

Topic 19. Six-membered heterocycles.

Six-membered heterocycles, their classification and nomenclature.Six-membered heterocycles with one Nitrogen heteroathom - azines. Structure, aromaticity. Synthesis of pyridine.Chemical properties of pyridine.Reactions involving the nitrogen atom: basic and nucleophilic properties.Electrophilic Substitution Reactions (S_E) and nucleophilic substitution (S_N).Reduction of pyridine. Oxidation of pyridine; pyridine-N-oxide, features of chemical behavior.Homologues of pyridine (α, β, γ-picolins),hydroxy- and aminopyridines. Their synthesis and chemical properties. Pyridoxine (vitamin B_6).Pyridinecarboxylic (nicotinic and isonicotinic) acids and their derivatives (nicotinamide, cordiamine, isoniazid, ftivazide). Application in medicine.Methods of synthesis of quinoline (Skraup synthesis), isoquinoline (Bischler - Napieralski reaction) and their derivatives.Chemical properties of quinoline, isoquinoline, acridine.Quinoline derivatives: 8-hydroxyquinoline, its complexing ability; quinozol, nitroxoline (5-NOC), application.Acridine derivatives: 9-aminoacridine, ethacridine lactate (rivanol). Their application.Six-membered heterocycles with one oxygen atom.Features of the structure of α- and γ-piranes.Structure and chemical properties of α- and γ-pyrones. Pyryl salts, their aromaticity.Benzopyrones: coumarin, chromone, flavone, isoflavone. Structure, chemical properties.Flavonoids: luteolin, quercetin, rutin. Tocopherol (vitamin E).Six-membered heterocycles with two nitrogen heteroatoms - diazines.Structure, syntesis, aromaticity of diazines. Chemical properties. Electrophilic substitution reactions (S_E) and nucleophilic substitution (S_N).Hydroxy- and amino derivatives of pyrimidine (uracil, thymine, cytosine). Their lactam-lactim tautomerism.Barbituric acid: synthesis, properties, tautomeric forms. Derivatives of barbituric acid - barbiturates as drugs.Vitamin B_1, orotic acid. Their biological and medical significance.Thiazine, phenothiazine, their derivatives as drugs preparations.

Topic 20. Fused (condensed) and seven-membered heterocycles. Alkaloids. Nucleic acids.

Classification and nomenclature of condensed heterocyclic compounds.Purine (aromaticity, tautomerism, amphotericity).Hydroxy derivatives of purine: hypoxanthine, xanthine, uric acid. Their tautomerism and acid-base properties.Amino derivatives of purine (adenine, guanine), their tautomeric forms, biochemical significance in the formation of nucleotides and coenzymes.Methylated derivatives of xanthine (caffeine, theophylline, theobromine) as physiologically active compounds with action on the central nervous and cardiovascular systems.Murexide test is a qualitative reaction to compounds containing a purine nucleus.Pteridine. Folic acid. Its antagonism with sulfonamides. Riboflavin.Seven-membered heterocycles. 1,4-benzdiazepine derivatives as tranquilizers.Alkaloids (definition, their importance as biologically active substances and drugs).Representatives of alkaloids: pyridine groups (nicotine, anabasine, lobeline), quinoline (quinine), isoquinoline (papaverine, morphine, codeine), tropane (atropine), indole (reserpine).Purine and pyrimidine bases, minor bases. Lactime-lactam tautomerism and complementarity.Nucleosides. Their nomenclature, structure and scheme of formation. The nature of the bond between the heterocyclic base and the carbohydrate residue. Hydrolysis.Nucleotides as phosphorylated derivatives of nucleosides (nucleoside mono-, di- and triphosphates). Their nomenclature, structure and hydrolysis.Nucleotide coenzymes (ATP, NAD^+, NAD–H, $NADP^+$, NADP–H) and their role in biochemical processes. ATP hydrolysis.Nucleic acids (DNA, RNA) as polynucleotides.The primary structure of DNA and RNA (nucleotide sequence).Secondary structure of DNA and factors that stabilize it.Genetic role of DNA.RNA types. The role of RNA in protein biosynthesis**.**

Topic 21. Monosaccharides.

Monosaccharides, their structure, classification and nomenclature.Stereoisomerism. D- and L-Stereochemical series.Haworth's formulas. Mutarotation.Conformations of cyclic forms of monosaccharides.Chemical properties of monosaccharides:Redox properties.Hemiacetal hydroxyl reactions.O-, N-, S-Glycosides, their relationship to hydrolysis.Esterification and esterification reactions.Monosaccharide identification reactions.Representatives: pentose (D-xylose, D-ribose, L-arabinose), hexose (D-glucose, D-galactose, D-mannose, D-fructose), deoxy sugars (D-deoxyribose). D-glucuronic, D-galacturonic, D-gluconic acid, neuraminic acid.Amino derivatives of monosaccharides: glucosamine, galactosamine.L-ascorbic acid (vitamin C, properties).Products of reduction of monosaccharides: sorbitol, mannitol, dulcite.

Topic 22. Di- and polysaccharides.

Disaccharides, their structure and nomenclature.Reducing disaccharides (maltose, cellobiose, lactose), the relationship between monosaccharide residues and its spatial orientation.Cyclo-oxo-tautomerism and mutarotation of reducing disaccharides.Chemical properties of reducing disaccharides.Non-reducing disaccharides (sucrose), bonds between monosaccharide residues.Chemical properties of non-reducing disaccharides.Sucrose inversion.Polysaccharides, their classification and the principle of construction.Homopolysaccharides: starch (amylose, amylopectin), glycogen, cellulose, dextrans. Spatial structure of amylose and cellulose.Heteropolysaccharides, their structure. Structure and biomedical significance

of glycosaminoglycans (mucopolysaccharides) - chondroitin sulfates, hyaluronic acid, heparin.The concept of mixed biopolymers (glycoproteins, proteoglycans, glycolipids).

Topic 23. Proteinogenic (standard) aminoacids. Peptides. Proteins.

Structure and classification of natural amino acids.Stereoisomerism of α-amino acids, D- and L-Stereochemical series.Bipolar structure of α-amino acids. Isoelectric pointChemical properties of natural amino acids.The structure of the peptide group. Primary structure of peptides and proteins.The concept of secondary, tertiary and quaternary structure of proteins.Synthesis of peptides. Protection and activation of functional groups.Analysis of peptides and proteins.Partial and complete hydrolysis of proteins.Qualitative reactions to α-amino acids and proteins.

Topic 24. Saponifiable lipids. Prostaglandins.

Lipids and their classification.Higher fatty acids (palmitic, stearic, oleic, linoleic, linolenic, arachidonic) are important structural components of saponifiable lipids, their structure, stereoisomerism, properties.The concept of biosynthesis of higher fatty carboxylic acids.Fats (triacylglycerols) as representatives of simple saponifying lipids, their structure, propertiesThe concept of lipid peroxidation (LPO).Complex saponifiable lipids, their structure, classification.Glycerophosphatides - derivatives of phosphatidic acids, their structure and properties.Representatives of glycerophosphatides - lecithin, cephalins, phosphatidylserines, plasmalogen.Structure of sphingolipids: ceramide and sphingomyelins.Glycolipids. The concept of the structure of cerebrosides and gangliosides.Medico-biological significance of saponifiable lipids.Structure, properties and biological role of prostaglandins.

Topic 25. Nonsaponifiable lipids (terpenes, carotenoids, steroids). Final test.

Derivatives of menthane (menthol, terpene), their structure, properties and applications in medicine.Terpenes, their classification (acyclic, monocyclic, bicyclic). Isoprene rule.Acyclic monoterpenes (geraniol, citral).Monocyclic monoterpenes (limonene, menthol, terpine), their medical significance.Bicyclic monoterpenes.Camphor, its structure, synthesis and medical significance.Carotenoids, their structure and biological significance.Retinol (vitamin A). β-Carotene (provitamin A).Chemistry of the light transmission process in the body.Steroids, general characteristics, classification. The structure of the steran. Stereoisomerism: cis-trans-articulation of cyclohexane rings.The structure of hydrocarbons that are the parent of steroid groups (estrane, androstane, pregnane, cholan, cholestan).Derivatives of cholesterol (sterols): cholesterol, ergosterol, vitamin D2.Derivatives of cholane (bile acids): cholic, deoxycholic, glycocholic acids.Derivatives of estrane (female sex hormones): estrone and estradiol. Their structure and biological role.Derivatives of androstane (male sex hormones): androsterone and testosterone. Structure and biological role.Derivatives of pregnane (corticosteroids): corticosterone, deoxycorticosterone, hydrocortisone.Cardiac glycoside aglycones: digitoxygenin; strophanthidine. The general principle of the structure of cardiac glycosides. Monosaccharides that are part of cardiac glycosides: digitoxose, digitalose, cymarose.

3. The structure of the discipline "Organic Chemistry"

Theme	Lectures	Practical classes	Self-study	Individual work
Thematic module 1. Nomenclature, classification, methods of identification and purification of the organic compounds. Reactivity of the hydrocarbons.				
Topic 1. Introduction into practical work. Classification, nomenclature, and structural isomerism of the organic compounds.	1	4	-	-
Topic 2. Types of the chemical bonds and atoms interactions in the molecules of the organic compounds. Laboratory equipments.	1	4	4	
Topic 3. Methods of the purification of the organic compounds. Determination of the physicochemical constants of the organic compounds.	-	4	4	
Topic 4. Stereochemistry the biologically active compounds.	1	4	4	
Topic 5. Determination of the organic compounds structures. Classification of the organic reactions and reagents.	1	4	9	
Topic 6. Saturated hydrocarbons (alkanes, cycloalkanes). Unsaturated hydrocarbons (alkenes, alkynes, alcadienes).	1	4	4	
Topic 7. Mononuclear aromatic compounds. Polynuclear aromatic compounds. Non-benzoid aromatic compounds. Final test.	1	4	8	
Total for the thematic module 1	6	28	33	
Thematic module 2. **Halogen-, oxygen-, sulfur- and nitrogen-containing organic compounds.**				
Topic 8. Halogen-derivatives of hydrocarbons. Methods of halogenation.	1	4	4	-
Topic 9. Monoalcohols, ethers. Methods of halogenation (continuation).	1	4	4	
Topic 10. Polyalcohols, phenols, naphthols. Thioalcohols.	1	4	4	
Topic 11. Amines. Acidic and basic properties of organic compounds. Nitro-compounds. The methods of nitration of the organic compounds.	1	4	12	
Topic 12. Diazo- and azocompounds. The methods of nitration of the organic compounds (continuation). Azo-dyes. The methods of diazotation and azocoupling. Final test.		4	5	
Total for the thematic module 2	4	20	29	
Final assessment				Credit
Thematic module 3. **Biologically important carbonyl compounds. Heterofunctional compounds.**				
Topic 13. Aldehydes and ketones.	1	4	4	-
Topic 14. Monocarboxylic acids. Dicarboxylic acids. Metods of acylation.	1	4	4	
Topic 15. Functional derivatives of carboxylic acids. Soaps, tweens, waxes. Derivatives of carbonic acid. Methods of acylation (continuation).		4	2	

Topic 16. Halogeno-, hydroxy- and oxo-acids.	1	4	6	
Topic 17. Aminoalcohols, aminophenols, aminoacids. Derivatives of *p*-aminobenzoic and sulfanilic acids. Methods of sulfonation. Final test.	1	4	6	
Total for the thematic module 3	4 -	20 3	22 2	
Thematic module 4. **Heterocyclic compounds. Alkaloids. Natural biopolymers and bioregulators.**				
Topic 18. Five-membered heterocycles.	1	4	4	
Topic 19. Six-membered heterocycles.	1	4	4	
Topic 20. Fused (condensed) and seven-membered heterocycles. Alkaloids. Nucleic acids.		4	8	
Topic 21. Monosaccharides.	1	4	4	
Topic 22. Di- and polysaccharides.	1	4	4	-
Topic 23. Proteinogenic (standard) aminoacids. Peptides. Proteins.	1	4	2	
Topic 24. Saponifiable lipids. Prostaglandins.	1	4	6	
Topic 25. Nonsaponifiable lipids (terpenes, carotenoids, steroids). Final test.		4	4	
Total for the thematic module 4	6	32	36	
Total hours 240 / 8.0 ECTS credits	**20**	**100**	**120**	
				Exam

4. Topics of lectures

No	Theme	hours
Thematic module 1. **Nomenclature, classification, methods of identification and purification of the organic compounds. Reactivity of the hydrocarbons.**		
1	Introduction into organic chemistry. Chemical bond and atoms interaction in the organic compounds.	2
2	Methods of the identification of the organic compound structures. Spatial (stereo) structure of the organic compounds. Classification of the organic reactions and reagents.	2
3	Saturated hydrocarbons. Unsaturated hydrocarbons. Aromatic compounds.	2
Total		**6**
Thematic module 2. **Halogen-, oxygen-, sulfur- and nitrogen-containing organic compounds.**		
4	Halogen-derivatives of the hydrocarbons. Mechanisms of the nucleophilic substitution and elimination. Hydroxy-derivatives of hydrocarbons and thio-analogs (alcohols, thioles, phenols)	2
5	Nitrogen-containing organic compounds (amines, nitro-, diazo-, azocompounds, azodyes). Acidic and basic properties of organic compounds.	2
Total		**4**
Thematic module 3. **Biologically important carbonyl compounds. Heterofunctional compounds.**		
6	Aldehydes and ketones. Carboxylic acids and their functional derivatives. Carbonic acid derivatives. Sulfonic acids.	2
7	Heterofunctional compounds.	2
Total		**4**
Thematic module 4. **Heterocyclic compounds. Alkaloids. Natural biopolymers and bioregulators.**		
8	Five-membered heterocycles with one or two hetero atoms. Six-membered heterocycles with one or two hetero atoms. Seven-membered and condensed heterocycles. Alkaloids. The nucleic acid.	2
9	Carbohydrates.	2
10	Proteinogenic amino acids. Peptides. Proteins. Lipids.	2
Total		**6**
Number of lecture hours in the discipline		**20**

5. Topics of practical classes

No	Theme	hours
Thematic module 1. **Nomenclature, classification, methods of identification and purification of the organic compounds. Reactivity of the hydrocarbons.**		
1.	Classification, nomenclature, and structural isomerism of the organic compounds.	4
2.	Types of the chemical bonds and atoms interactions in the molecules of the organic compounds. Laboratory equipments.	4
3.	Methods of the purification of the organic compounds. Determination of the physic-chemical constants of the organic compounds.	4
4.	Stereochemistry the biologically active compounds.	4
5.	Determination of the organic compounds structures. Classification of the organic reactions and reagents.	4
6.	Saturated hydrocarbons (alkanes, cycloalkanes). Unsaturated hydrocarbons (alkenes, alkynes, alcadienes).	4
7.	Mononuclear aromatic compounds. Polynuclear aromatic compounds. Final test.	4
TOTAL		**28**
Thematic module 2. **Halogen-, oxygen-, sulfur- and nitrogen-containing organic compounds.**		
8.	Halogen-derivatives of hydrocarbons. Methods of halogenation.	4
9.	Monoalcohols, ethers. Methods of halogenation (continuation).	4
10.	Polyalcohols, phenols, naphtols. Thioalcohols.	4
11.	Amines. Acidic and basic properties of organic compounds. Nitro-compounds. The methods of nitration of the organic compounds.	4
12.	Diazo- and azocompounds. Azo-dyes. The methods of nitration of the organic compounds (continuation). The methods of diazotation and azo-coupling. Final test.	4
TOTAL		**20**
Thematic module 3. **Biologically important carbonyl compounds. Heterofunctional compounds.**		
13.	Aldehydes and ketones.	4
14.	Monocarboxylic acids. Dicarboxylic acids. Metods of acylation.	4
15.	Functional derivatives of carboxylic acids. Soaps, tweens, waxes. Derivatives of carbonic acid. Methods of acylation (continuation).	4
16.	Halogeno-, hydroxy- and oxo-acids.	4
17.	Aminoalcohols, aminophenols, aminoacids. Derived from *p*-aminobenzoic and sulfanilic acids. Methods of sulfonation. Final test.	4
TOTAL		**20**
Thematic module 4. **Heterocyclic compounds. Alkaloids. Natural biopolymers and bioregulators.**		
18.	Five-membered heterocycles.	4
19.	Six-membered heterocycles.	4
20.	Fused (condensed) and seven-membered heterocycles. Alkaloids. The nucleic acid.	4
21.	Monosaccharides.	4
22.	Di- and polysaccharides.	4
23.	Proteinogenous aminoacids. Peptides. Proteins.	4
24.	Saponifiable lipids. Prostaglandins.	4
25.	Nonsaponifiable lipids (terpenes, carotenoids, steroids). Final test.	4
TOTAL		**32**
Number of practical classes hours on discipline		**100**

6. Out-class works

No	Topic	hours	Type of control
Thematic module 1. **Nomenclature, classification, methods of identification and purification of the organic compounds. Reactivity of the hydrocarbons.**			
1.	Types of the chemical bonds. Types of hybridization of atomic orbitals (Nitrogen, Oxygen). The main characteristics of covalent σ- and π-bonds	4	Verification in the practical classes
2.	Methods of separation and purification of organic compounds	4	
3.	Conformers and isomers. Newman and Fischer projections. Enantiomers and diastereomers.	4	
4.	Physical methods of determination of organic compound structures	4	
5.	Types of chemical reactions. Mechanisms of reactions in organic chemistry.	4	
6.	Reaction of polymerization and polycondensation	4	
7.	Stability of aromatic compounds (polycyclic arenes), Non-benzene aromatic systems	4	
8.	Triphenylmethane dyes	4	
TOTAL		33	
Thematic module 2. **Halogen-, oxygen-, sulfur- and nitrogen-containing organic compounds.**			
9.	Reactivity of halogen-derivatives of the hydrocarbons.	4	Verification in the practical classes
10.	Synthesis and properties of naphthols	4	
11.	Methods of the identification of aromatic and aliphatic amines.	4	
12.	Physical bases of chromophore-auxochrome theory. Structure of azo-dyes	5	
13.	Hard and soft acids and bases	4	
14.	Red/ox reactions of different classes of the organic compounds	4	
15.	Relation between acidic and basic properties of organic compounds. Amphoterism.	4	
TOTAL		**29**	
Thematic module 3. **Biologically important carbonyl compounds. Heterofunctional compounds.**			
16.	Aldol condensation, its analogy *in vivo*	4	Verification in the practical classes
17.	Decarboxylation reactions of carboxylic acids and their role in vivo	4	
18.	Specific reactions of bifunctional carboxylic acids	5	
19.	Drug bearing carbonylic, carboxylic groups, and heterofunctional compounds as a drugs	5	
20.	Stereochemistry of hydroxy and amino acids	4	
	TOTAL	**22**	
Thematic module 4. **Heterocyclic compounds. Alkaloids. Natural biopolymers and bioregulators.**			
21.	Three-, four-, and seven-membered heterocycles	4	Verification in the practical classes
22.	Identification of key monocyclic and fused bicyclic heterocycles	4	
23.	Pyridine-carboxylic acids based drugs	4	
24.	Structure of heteropolysaccharides and their role	4	
25.	Mentane and its derivatives: synthesis, structure, and practical usage	4	
26.	Nucleic acids and their role in transmission of genetic information. Viral RNA. The structure of viruses, Coronaviruses in particular.	4	
27.	Phospholipids: structure, properties and biological role	4	
28.	O-, and N-glycosides: spreading in nature and biological function	4	
29.	Prostaglandins: classification and biological function	4	
TOTAL		**36**	
Number of students' independent work hours on discipline		**120**	

7. Individual tasks

(history of diseases, forensic medical certificates, acts of toxicological research, courseworks and diploma, master's works)

There is not any in working curriculum.

8. Methods of studies

In the process of "Organic Chemistry"disciplines studying the following teaching methods are usedfor students:

- by the cognitiveactivitytype:
  – explanatory-illustrative;
  – reproductive;
  – problematic presentation;
  – the logic of cognition;
  – analitical;
  – inductive;
  – deductive;
- according to the main stages of the process:
  – knowledgeformation;
  – skills and abilitiesformation;
  – knowledge application;
  – generalization;
  – fixing;
  – assesment;
- by thesystem approach:
  – stimulation and motivation;
  – assessment and self-assesment;
- by sources of knowledge:
  – verbal – lecture, explanation;
  – visual – demonstration, illustration;
- according to the individual mental activity level:
  – problematic;
  – partially discovering;
  – explorative;
  – the method of problematic teaching.

Studying Organic Chemistry students use textbooks, lecture notes, methodological guidelines, chemical computer software, molecular models, laboratory devices and glassware necessary for performing experiments.
Methods for organization and accomplishment of studies are:
a) lectures
b) practical classes
c) students' independent study.

The topics of the lecture course cover the problematic issues of the appropriate sections of organic chemistry.

Practical classes are organized as laboratory classes. These classes include: laboratory studies on production and detection of specific classes of organic compounds according to their functional groups, performing specific reactions and organic compounds synthesis, its obtaining, purification and physicochemical constants determination.

Students are recommended to write short-term protocols of laboratory studies, indicating the purpose of the study and the conclusions.

The students also perform educational exercises and solve situational problems. ISIS Draw, Chemistry in motion, HyperChem computer programs, videos and models of molecules are used in practical classes.
The structure of practical classes includes:
- Discussion and explanation of the most complicated issues of the topic;
- Written test;
- Practical (laboratory) work.
- Filling in a practical lesson protocol.
- Summary of the lesson.

9. Methods of control

Types of control: current (routine) and final.

The current control is a regular check of educational trained achievements, fulfiled by the teacher according to syllabus of the discipline. It is carried out on each practical class according to the specific objectives, during the individual work of the teacher with the student for those topics which are not part of the structure of practical classes. The objective (standardized) control of theoretical and practical knowledge and skills of students is used. The following means of the level of students' knowledge assessment are used: testing, situational problems solving, laboratory research activities and their results interpreting and

evaluating, practical skills evaluation. At each practical class the student gives answers on 10 questions (multiple choice questions on the topic of the practical classes, standardized questions, knowledge of which is necessary for understanding the current topic, the issue of a lecture course and individual work related to the current class, demonstrates knowledge and skills of practical abilities in accordance with the topic of the practical class).

The exam is the form of ***final control*** for the discipline "Organic Chemistry" studying.Students, who completed all types of activities provided by the syllabus, attended all practical classesand were scored with thepoints number not less than the minimum.

10. The current control

The current control is realized during the practical classes and aims at checking the learning of educational material. It is recommended to apply objective (standardized) kind of control to check theoretical and practical knowledge of students.

When evaluating the educational activitees achievements of each topic for the current educational activity, the student is assessed with grades in the 4-graiding scale (national). It takes into account all types of activities provided for by the discipline sullabus. A student should gain an assessment from each topic for further conversion of 4- grading scale points into 200-grading scale points. The standardized control of the theoretical part includes 10 tasks. Five of them are the first level tests question, and another five are referred to the tasks of the second level and must be given a written response in addition to the test response. Theoretical students' self-preparation control is performed in writing by answering 10 questions. A correct answer to guestions 1-5 is valued at 1 point, guestions 6-10 valued at 2 point The maximum score for the entire test is 15 points.The minimum score points number a student must gain for the successful assessment of the theoretical part is 8 points.

Assessment of practical skills of students - as a result of the implementation of the practical part - is formalized in the form of a protocol.

Criteria of assessment of current educational activity:

"Excellent" mark receives a student who actively participated in the discussion of the most difficult issues of the topic, gave at least 90% of correct answers to standardized tests, responded to written tasks without any mistake, performed practical work and filled in the protocol.

"Good" mark gets a student who participated in the discussion of the most difficult issues of the topic, gave at least 75% of correct answers to standardized tests, responded to written tasks with some insignificant mistakes, performed practical work and filled in the protocol.

"Satisfactory" mark receives a student who did not take part in the discussion of the most difficult issues of the topic, gave at least 60% of correct answers to standardized tests, responded to written tasks with a lot of mistakes, performed practical work and made the protocol.

"Unsatisfactory" mark receives a student who did not take part in the discussion of the most difficult issues of the topic, gave less than 60% of correct answers to standardized tests, responded to written tasks with gross mistakes or did not give answer, didn't perform practical work and didn't make the protocol.

The students' individual work issues and achievements which are provided by the syllabus in the content of practical training practical class activities, are evaluated during the current control of the topic at the appropriate practical class. The evaluation of the topics submitted for individual study and not included into the content of the practical class training is monitored during the final control.

11. Form of final control of study success

The final control is carried out upon completion of the study of the discipline in the form of the exam.

Only thouse students who completed all types of works provided by syllabus and during study scored points not less than the minimum, and don't have any undone lectures and practical classes are allowed to put the exam. The standardized form of the exam includes control of theoretical and practical knowledge.

The exam is performed during the examination session according to the schedule and includes:

The exam includes: 50 tests (Form A), which are evaluated by 1 point (50 minutes), 6 "open" questions, which are evaluated by 5 points (40 minutes)

The maximum number of points a student can score for an exam is 80.

The minimum number of points during the examination - 50.

12. Scheme of accrual and distribution of scores received by students is as follows:

The maximum number of points that a student can get for current educational activity during study is 120 points.

The minimum number of points that a student score for the current academic activity to enroll in the discipline is 72 points.

Calculating the number of points is performed by the way of calculating the arithmetical average (AA) of student's received marks by traditional rate during the semester the discipline is studied, and rounded to two decimal places. The received value is converted into points by multi-point rate as follows:

$$xX = (AA \times 120)/5$$

For convenience, there is a table of conversion to 200-point rate:

Recalculation of the average mark for current activity into multi-point rate for disciplines, ending with exam.

4-point rate	200-point rate
5	120
4.95	119
4.91	118
4.87	117
4.83	116
4.79	115
4.75	114
4.7	113
4.66	112
4.62	111
4.58	110
4.54	109
4.5	108

4-point rate	200-point rate
4.45	107
4.41	106
4.37	105
4.33	104
4.29	103
4.25	102
4.2	101
4.16	100
4.12	99
4.08	98
4.04	97
3.99	96
3.95	95

4-point rate	200-point rate
3.91	94
3.87	93
3.83	92
3.79	91
3.74	90
3.7	89
3.66	88
3.62	87
3.58	86
3.54	85
3.49	84
3.45	83
3.41	82

4-point rate	200-point rate
3.37	81
3.33	80
3.29	79
3.25	78
3.2	77
3.16	76
3.12	75
3.08	74
3.04	73
3	72
Less then 3	Insuffi-cient

Students out-of classes works is assessed during the current verification of topic on the lesson.

The maximum number of points that a student can get on the exam is 80 points.

The minimum number of points in the exam is 50 points.

The minimum number of points that a student must get during semester of study to be allowed to put the exam is 72 points.

A mark on a discipline is defined as the sum of points for the current educational activity (not less than 72) and marks for the exam (not less than 50).

Points from discipline are converted into ECTS rate, and 4-point (national) rate.

Points from ECTS rate can't be converted into 4-point rate and vice versa. Marks of students, who study in one specialty, and taking into account the number of points gained by him/her in the discipline are ranked by ECTS rate as follows:

ECTS Mark	Statistical index
A	Top 10% of students
B	Next 25% of students
C	Next 30% of students
D	Next 25% of students
E	Last 10% of students

A, B, C, D, E rankings are awarded to students of actual course, who study in one specialty and successfully completed the study of the discipline. Students who received FX, F ("2") ratings are not included in the list of ranked students. Students with an FX score after repassing the exam receive an "E" score automatically.

Score points for students who have successfully completed the program are converted to the traditional 4-point scale by the absolute criteria listed in the table below:

Points from discipline	Mark by 4-point rate
From 170 to 200 points	5
From 140 to 169 points	4
From 139 to the minimum number of points which student must get	3

Below the minimum number of points which student must get	2

Mark written by ECTS can't be converted into traditional scale because the ECTS scale and 4-point scale are independent (do not coincide).

Objectivity of assessment students` educational activities is checked by statistical methods (correlation coefficient between the ECTS mark and mark by national scale).

13. Methodical support

- plan of lectures,
- plans of practical classes,
- tasks for laboratory work, out-of class work,
- questions, tasks and test tasks for current and final control of knowledge and skills of students, after attestation monitoring of acquired knowledge and skills in the discipline.
- Organic Chemistry. Methodical Guide for Practical Classes and Out-of Classes Work for Foreign Students of the Second Year of the Faculty of Pharmacy. Part 1 // Lesyk R., Muzychenko V., Kaminskyy D et all., Львів : ЛНМУ імені Данила Галицького, 2021. 108p
- Organic Chemistry. Methodical Guide for Practical Classes and Out-of Classes Work for Foreign Students of the Second Year of the Faculty of Pharmacy. Part 2 // Lesyk R., Muzychenko V., Kaminskyy D et all., Львів : ЛНМУ імені Данила Галицького, 2021. 131p

14. Literature/textbooks

The main literature

1.J. Komarytsia. Organic Chemistry. Handbook for pharmaceutical students. Lviv 2000.-151 p.

2.B.S.Zimenkovsky, V.A. Muzychenko, I.V.Nizhenkovska, G.O.Syrova. Biological and bioorganic chemistry.Aus Medicine Publishing. Kyiv.2018. – 288 p.

Additional literature

1.Stoker, H.S. (2001). Organic and biological chemistry. Houghton Mifflin. 2001. 556p.

2.L.G. Wade Jr. Organic Chemistry. 8th edition. Pearson. 547p.

3.T. Graham Solomons. Organic Chemistry. Sixth edition. John Willey and Sons, Inc.- 1218 p.

4.Harold Hart, Leslie E. Crain, David J. Hart. Organic Chemistry. A Short Course. Houghton Mifflin Company. – 543 p.

5.David C. Eaton. Laboratory investigation in Organic Chemistry. – McGRAW-HILL BOOK COMPANY. – New York – Toronto. – 893 p.

15. Information resources

1. www.ncbi.nlm.nih.gov/PubMed – free access to the database of scientific research in the field of biomedical sciences.
2. https://pubchem.ncbi.nlm.nih.gov/ free access to the database of scientific data in the field of biomedical sciences.
3. http://www.orgsyn.org - has provided the chemistry community with detailed, reliable, and carefully checked procedures for the synthesis of organic compounds.
4. http://www.organic-chemistry.org - offers an overview of recent topics, interesting reactions, and information on important chemicals for organic chemists.