Federal State Autonomous Educational Institution of Higher Education
PEOPLES' FRIENDSHIP UNIVERSITY OF RUSSIA named after Patrice Lumumba
RUDN University
Science faculty

educational division -faculty/institute/academy

COURSE DESCRIPTION

The study of disciplines is implemented within the professional education programme of higher education:

«Bioenergies and Biorefineries»
higher education programme profile/specialisation title

implemented in the field of training/specialty:

04.04.01 «Chemistry»
field of studies / speciality code and title

2024

Course Title	Actual problems of modern chemistry
Course Workload	11 Credits /396 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Introduction.	Topic 1.1 The genesis of problematics in organic chemistry. Various search strategies for biologically active organic compounds: targeted synthesis and creation of molecular diversity.
Module 2. Modern methods of isolation of organic compounds	Topic 2.1 Classical methods of isolation of organic compounds (filtration, distillation, recrystallization, extraction, chromatography).
	Topic 2.2 Solid-phase synthesis. The use of ionic liquids. Perfluorinated systems.
Module 3. Modern approaches to conducting chemical reactions.	Topic 3.1 Solid-phase synthesis. The use of ionic liquids. Perfluorinated systems. The use of microwave irradiation and ultrasound. Flow synthesis. Reagents based on hypervalent iodine.
Module 4. The use of protective groups in organic synthesis.	Topic 4.1 Basic principles for the introduction and removal of protective groups. Hydroxyl protection. Amino group protection. Protection of the carboxyl group.
Module 5. Modern approaches to the creation of new synthetic methods	Topic 5.1 Basic principles of green chemistry, atom-economy, industrial chemistry.
Module 6. Introduction to metal complex catalysis	Topic 6.1 Fundamentals of complex formation. Catalytic hydrogenation methods. Catalytic methods of oxidation. Cross-coupling reactions. Metal-catalyzed reactions of creating C-C and C-heteroatom bonds. C-H Activation.
Module 7. Introduction to organocatalysis.	Topic 7.1 Basic principles of organocatalysis. Reactions catalyzed by Lewis organic bases; Lewis acids; Brönsted bases; Brönsted acids.
Module 8. Cycloaddition reactions in organic synthesis.	Topic 8.1 The most important classes of cycloaddition in organic chemistry. [2+4] Cycloaddition. [2+3] Cycloaddition. Basic principles of click chemistry.

Course Title	*Russian language in professional activity*
Course Workload	6 Credits /216 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Introductory Phonetic and Grammar Course	Topic 1.1. Pronunciation and spelling
	Topic 1.2. Introductory Listening and Speaking course
	Topic 1.3. Formation of plural nouns. Expression of request
Module 2. Elementary level	Topic 2.1. Gender of nouns. Possessive pronouns.
	Topic 2.2. The expression of time in a simple sentence
	Topic 2.3. The concept of the Russian verb. The creative case of nouns.
	Topic 2.4 The creative case of nouns. The verb «ХОТЕТЬ». ……

	Topic 2.5. A model of past tense formation from verbs with constant stress based on
	Topic 2.6. A model of the formation of the past tense from verbs with variable stress.
	Topic 2.7. Constructions «нужно» + infinitive, «можно» + infinitive, «Что нужно (можно)» + infinitive
	Topic 2.8. Complex future tense of verbs.
	Topic 2.9. The verb «учиться» in the present, past and future tenses.
	Topic 2.10. The verb «говорить» in the present, past and future tenses. Imperative.
	Topic 2.11. The verb «учить» in the present, past and future tenses.
	Topic 2.12. Expression of the absence of the subject (there is no subject). The etiquette of a telephone conversation.
	Topic 2.13. Constructions «У меня есть (был, будет)» и «У меня нет (не было, не будет)»
	Topic 2.14. Construction «Мне нравится». Comparison of typical contexts of the use of the verbs «любить» and «нравиться».
	Topic 2.15. Prepositional case of the place.
	Topic 2.16. The expression of time in a simple sentence. Prepositional verbs.
	Topic 2.17. The etiquette of a telephone conversation. Formation of a simple comparative degree of adverbs
	Topic 2.18. The creative case in the meaning of the compatibility of action
	Topic 2.19. A general idea of the verbs of movement. Accusative case to indicate the direction of movement.
	Topic 2.20. The verbs of the group «идти» and «ходить» in the future and past tense.
Module 3. Basic level.	Topic 3.1. Systematization of cases. Prepositional case and its meanings. Verbs that require the prepositional case. The genitive case and its meanings. Genitive case with prepositions для, без, от, около, из, у, с, вокруг, мимо. Types of the verb. The use of НСВ and СВ in the past tense, in the infinitive and imperative.
	Accusative case and its meanings. Transitive verbs. Accusative case of the direction. Verbs of movement with the prefixes у-, в- and вы-.
	The dative case and its meanings. Verbs that require the dative case. The dative case in impersonal constructions. Predicative adverbs denoting the feelings and state of a person.
	The creative case and its meanings. The creative case in the meaning of the instrument of action. The creative case with prepositions с, рядом с, над, под, перед, между. Verbs that require the creative case.

Course Title	*Foreign language in professional activity*
Course Workload, ЗЕ/ак.ч.	6 Credits /216 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Academic skills in Master's research activities.	Topic 1.1. Development of speaking, writing, listening, purposeful reading skills within the following topics: Education and Studying, Science and its Commercialisation, Job, Career and Employee's skills, Managing scientific and business communication, Studying in Russia and Abroad, Academic and Educational Mobility.
	Topic 1.2. Formation of basic competencies of effective communication within the framework of the stated issues of academic and business discourses.
Module 2. Practical course of professionally-oriented translation	Topic 2.1. The specifics of professionally-oriented translation.
	Topic 2.2. Terminological realities of professionally-oriented translation.
	Topic 2.3. The subject field of professionally-oriented translation (on the example of the direction of training of students)
Module 3. Preparation for writing and defending the WRC in English	Topic 3.1. Requirements for the structure, content and language of the WRC. Stylistic and punctuation design of the WRC.
	Topic 3.2. Requirements for the design of the bibliography.
	Topic 3.3. Requirements for the preparation and presentation of a scientific presentation.

Course Title	Bioenergy
Course Workload	4 Credits / 144 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Biofuels	Topic 1.1 An introduction, current status, merits and demerits, characterization techniques of biomass, comparisons between fossil fuels and biofuels. Energy demands (quiz), energy facts and prospects for the future.
Module 2. Types of biofuels and classification. Liquid biofuels (first generation)	Topic 2.1 Biodiesel. Preparation and types (first vs second generation). Processes. Prospects and perspectives. The food vs fuel and related issues.
	Topic 2.2 Bioethanol. Preparation and types (first vs second generation). The food vs fuel issue and the blend wall. Prospects and perspectives.
Module 3. Liquid biofuels (Second generation): constraints, impacts and benefits of lignocellulose conversion pathways	Topic 3.1 Biodiesel vs green diesel. Processes and technologies. Prospects and perspectives.
	Topic 3.2 Bioethanol: lignocellulosic biomass, syngas fermentation to bioethanol. Preparation and processes. Prospects and perspectives.
	Topic 3.3 Other biofuels (synthetic fuels). BTL. Pyrolysis oils. SunFuel. Other synthetic fuels. Preparation and processes. Prospects and perspectives.
Module 4. Gaseous biofuels.	Topic 4.1 Biogas: a promising clean energy technology.

	Preparation and processes. Purification. Examples. Prospects and perspectives.
	Topic 4.2 Hydrogen: technologies for renewable hydrogen production, hydrogen production from electrolysis, technico-economic evaluation of hydrogen energy by flow sheeting simulation and economic evaluation, assessment of combined renewable sources and hydrogen storage for residential applications
Module 5. Solid Fuels	Topic 5.1 Solid Fuels. Pellets. Preparation and processes. Heat and power applications. Prospects and perspectives.
Module 6. Life cycle assessment of biofuels	Topic 6.1 Life cycle assessment of biofuels. Systems analysis and possibilities. Prospects and perspectives.

Course Title	Modern organic synthesis and pharmacology
Course Workload	4 Credits / 144 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Pharmacology	Topic 1.1 Introduction to Pharmacology
	Topic 1.2 Physicochemical properties of Active Pharmaceutical Ingredients (APIs). Ionization of pharma compounds. Acidic APIs. Basic APIs. Isoelectric point. pKa and pKb. Partition coefficient.
	Topic 1.3 Pharmacokinetics and pharmacodynamics: Concepts and examples. Pharmacokinetics: Absorption and distribution of APIs. Bioavailability. Pharmacodynamics. Pharmacological receptors. Agonist and antagonist molecules. APIs classification: structural specific and inespecific APIs
	Topic 1.4 Structural characteristics of APIs and Pharmacological action. Stereoisomery. Optic, geometric and conformational isomers and pharmacological action. Chemical Isostery. Concept. Bioisosterism. Classic and non classic bio-isosterism
	Topic 1.5 Rational design of APIs. Pharmacological design. Pharmacomodulation. QSAR methods for pharma design. Hammet equation. Taft equation. Hansch method. Method of Free-Wilson. QSAR-3D methodologies. Examples.
	Topic 1.6 Metabolic pathways of APIs. Definition of toxicology. Basic principles of toxicology. Synergism, potentiation and antagonism. Dose-response relationships. Xenobiotics and endogenic substances. Examples. Pharma metabolism. Metabolic reactions (Phase I, Phase II). Metabolic routes. Examples for common pharmaceuticals.
Module 2. Modern Organic synthesis	Topic 2.1 Green metrics and Green Chemistry in Pharma Introduction and applications of fundamental green metrics into modern synthesis; solvent selections and applications of sustainable solvent systems in modern approaches to organic synthesis and catalysis. Atom economy. E-factor. Functional Oriented Synthesis (FOS).
	Topic 2.2 Real examples of application of Green Chemistry principles I in Pharma synthesis: Synthesis of Sildenafil (Viagra®, Pfizer), Synthesis of

	Talampanel (LY300164, Lilly Research Laboratories, Green Chemistry Award 1999), Synthesis of Ganciclovir (Cytovene®, Roche, Green Chemistry Award 2000).
	Topic 2.3 Real examples of application of Green Chemistry principles II in pharma synthesis: Synthesis of Sertraline (Zoloft®, Pfizer, Green Chemistry Award 2002), Synthesis of Aprepitant (Emend®, Merck & Co., Green Chemistry Award 2005); Synthesis of Sitagliptin (Juvenia™, Merck & Co. Green Chemistry Award 2006).
	Topic 2.4 Flow approaches to sustainable pharmaceuticals synthesis

Course Title	Alternative/new tools for organic synthesis
Course Workload	4 Credits / 144 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Microwave irradiation and inductive heating	Topic 1.1 Introduction
	Topic 1.2 Theoretical description of the activation mode
	Topic 1.3 Description of the equipment
	Topic 1.4 Examples of application in organic chemistry and catalysis: N-heterocycles (pyrrole, indole, pyridine, pyrrolidine), cross coupling reactions, click chemistry, synthesis of nano-materials and nano-composite, oligomerization of glycerol, microwave pyrolysis, decarboxylative reaction, synthesis of Iloperidone, synthesis of Olanzapine, synthesis of HMF/furfural, hydrogenation of HMF/furfural, synthesis of solketal, glycerol esterification
Module 2. Photochemistry	Topic 2.1 Introduction
	Topic 2.2 Theoretical description of the activation mode
	Topic 2.3 Description of the equipment
	Topic 2.4 Real examples of application in organic chemistry and catalysis: Synthesis of Ibuprofen, synthesis of HMF/furfural, photocatalytic oxidation of HMF/furfural
Module 3. Sonochemistry	Topic 3.1 Introduction
	Topic 3.2 Theoretical description of the activation mode
	Topic 3.3 Description of the equipment
	Topic 3.4 Real examples of application in organic chemistry and catalysis: Pinacol cross coupling, synthesis of HMF/furfural, synthesis of heterogeneous catalyst
Module 4. Electrochemistry	Topic 4.1 Introduction
	Topic 4.2 Theoretical description of the activation mode
	Topic 4.3 Description of the equipment
	Topic 4.4 Real examples of application in organic chemistry and catalysis: oxidation of HMF/furfural, reduction of HMF/furfural, synthesis of diesel
Module 5. Mechanochemistry	Topic 5.1 Introduction
	Topic 5.2 Theoretical description of the activation mode
	Topic 5.3 Description of the equipment

	Topic 5.4 Real examples of application in organic chemistry and catalysis: synthesis of HMF/furfural, synthesis of 6-hydroxy-2H-pyran-3(6H)-ones from furfuryl alcohol, synthesis of glycerol carbonate
Module 6. Plasma	Topic 6.1 Introduction
	Topic 6.2 Theoretical description of the activation mode
	Topic 6.3 Description of the equipment
	Topic 6.4 Real examples of application in organic chemistry and catalysis: oxidation of alcane.
Module 7. Flow chemistry	Topic 7.1 Introduction
	Topic 7.2 Description and influence of the parameters: residence time, reactor design, source, temperature, pressure
	Topic 7.3 Description of the equipment
	Topic 7.4 Real examples of application in organic chemistry and catalysis: Synthesis of Diphenhydramine hydrochloride, Synthesis of Lidocaine hydrochloride, Synthesis of Diazepam, Synthesis of Fluoxetine hydrochloride, hydrogenation of HMF/furfural.
Module 8. Flow chemistry combining microwave, induction, photochemistry, sonochemistry, electrochemistry, mechanochemistry, plasma	Topic 8.1 Introduction
	Topic 8.2 Theoretical description of the activation mode
	Topic 8.3 Description of the equipment
	Topic 8.4 Real examples of application in organic chemistry and catalysis: (microwave) synthesis of HMF/furfural, (induction) synthesis of Iloperidone, synthesis of Olanzapine, (photochemistry) oxidation of HMF/furfural, (sonochemistry) Pinacol cross coupling, (electrochemistry) oxidation of HMF/furfural, reduction of HMF/furfural, oxidation of glycerol, (mechanochemistry) synthesis of biodiesel, (plasma) oxidation of alkane.

Course Title	Bioproducts and Biorefineries
Course Workload	5 Credits / 180 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Introduction to Bioproducts and Biorefineries	Topic 1.1 Introduction to Bioproducts and Biorefineries. Types of Bioproducts. Biofuels Concept. Biorefineries: concept and types. Examples. Platform molecules: concept and examples. Bioproducts from biomass/waste: different platforms.
Module 2. Bioproducts from biomass/waste	Topic 2.1 Oil platform. Types of bioproducts. Oleaginous feeds (fatty acids). Chemistry of fatty acids and transformations. Examples. Glycerol as platform molecule: chemistries and transformations. Examples (e.g. epichlorohydrin, Solvay). Bioproducts: chemicals, surfactants and others
	Topic 2.2 Carbohydrate platform. Carboxylic acids (succinic, fumaric, itaconic, levulinic acid and related platform molecules). Chemistries and transformations. Examples. Sorbitol as a platform molecule.
	Topic 2.3 Ethanol platform. Chemicals from ethanol.

	Transformations. Examples
	Topic 2.4 Syngas platform. Chemicals from syngas. Transformations. Examples
Module 3. Extraction of bioproducts from biomass/waste	Topic 3.1 Extraction of bioproducts from biomass/waste. Examples. Specialty Chemicals. Pharmaceuticals. Essential oils. WEEEs valorization.
Module 4. Materials from biomass/waste	Topic 4.1 Biopolymers (Starch, chitosan/chitin, PLA, PHAs, etc.). Extraction from biomass. Modification/functionalization. Examples. Applications
	Topic 4.2 Biomaterials from biomass/waste. Biomaterials for construction. Biomaterials in the automotive sector. Biomaterials for packaging. Biomaterials for miscellaneous applications
Module 5. Biorefineries	Topic 5.1 Biorefinery concept. Introduction. Types of biorefineries. Type I, Type II and Type III. Key examples.
	Topic 5.2 Techno-economic assessment applied to two key examples. LCA, concept and examples
	Topic 5.3 Safety in biorefineries. Sustainable biorefining. Process Safety issues and process intensification. Examples.
Module 6. Conclusions and prospects	Topic 6.1 Conclusions and prospects. Overview of the course. Lessons learnt. Perspectives and future of biomass/waste for useful products.

Course Title	Advanced Organic Synthesis
Course Workload	5 Credits / 180 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. General principle of restrosynthesis, stereochemistry and thermochemistry	Topic 1.1 General principles of retrosynthesis, stereochemistry and thermochemistry. Introduction, examples and possibilities.
Module 2. Reactions of Carbon Nucleophiles with Carbonyl Compounds	Topic 2.1 Reactions of Carbon Nucleophiles with Carbonyl Compounds, applications in synthesis. Strategies for controlling the reactivity and the stereochemistry.
Module 3. Functional Group Interconversion by Substitution, Including Protection and Deprotection	Topic 3.1 Definition of protecting group and their classification. Strategies for the introduction and removal of protecting groups, Examples and applications. Definition of orthogonality with protecting groups.
Module 4. Electrophilic Additions to Carbon-Carbon Multiple Bonds	Topic 4.1 Reactivity of unsaturated compounds with electrophiles. Definition of electrophile. Reactivity, regiochemistry and stereochemistry of electrophilic additions.
Module 5. Organometallic Compounds of Group I and II Metals	Topic 5.1 Organolithium and organomagnesium in synthesis. Structure and reactivity relationship. Applications in modern synthesis. Tactics for generation and use.
Module 6. Reactions Involving Transition Metals	Topic 6.1 Synthetic strategies involving transition metals. Cross coupling reactions mediated by transition metals.
Module 7. Carbon-Carbon Bond-Forming Methodologies.	Topic 7.1 Basic knowledge in the formation of C-C bonds. Main routes and strategy for C-C bond formation. Examples

Module 8. Reactions Involving Carbocations, Carbenes, and Radicals as Reactive Intermediates	Topic 8.1 Introduction to the structure and reactivity of reactive intermediates: carbocations, carbenes and radicals. Applications in synthesis.
Module 9. Organocatalysis	Topic 9.1 Principles of organocatalysis, strategies for planning an organocatalytic reaction, types of organocatalytic reactions.
Module 10. Photocatalysis	Topic 10.1 Basic principles of photocatalysis, simple examples of photocatalytic reactions
Module 11. Multistep Synthesis	Topic 11.1 Planning a Multistep Synthesis, strategies for multistep synthesis

Course Title	Catalyst (nanomaterials) design and applications
Course Workload	3 Credits / 108 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Introduction to synthesis and design of nanomaterials	Topic 1.1 Introduction to synthesis and design of nanomaterials. Types of nanomaterials. Nanoparticles. Nanosclusters. Supported systems. Types of support. Examples. Methodologies to synthesize nanomaterials.
Module 2. Design of catalysts/nanomaterials. Conventional vs alternative	Topic 2.1 Microwave synthesized catalysts. Basic Principles. Methodology. Examples and applications
	Topic 2.2 Mechanochemically synthesized catalysts. Basic Principles. Methodology. Examples and applications
	Topic 2.3 Photochemically synthesized catalysts. Basic Principles. Methodology. Examples and applications
	Topic 2.4 Sonochemical synthesized catalysts. Basic Principles. Methodology. Examples and applications
	Topic 2.5 Electrochemically synthesized catalysts. Basic Principles. Methodology. Examples and applications
	Topic 2.6 Continuous flow synthesized catalysts. Basic Principles. Methodology. Examples and applications
	Topic 2.7 Other catalytic systems (including combinations). Basic Principles and various combinations. Methodology. Examples and applications
Module 3. Catalyst deactivation phenomena. Types and measures to control them.	Topic 3.1 Catalyst deactivation phenomena. Types and measures to control them. Catalyst Characterization (SEM, XRD, TEM, XPS, UV-Vis, etc.). Deactivation phenomena. Poisoning. Fouling/coking. Sintering. Phases transformations/chemical reactions. Leaching. Attrition/Crushing. Explanations and examples. How to detect deactivation (key characterization)
Module 4. Conclusions and prospects	Topic 4.1 Conclusions and prospects. Catalyst design perspectives and examples.

Course Title	Catalysis: from Basic principles to applications. Homogeneous, Heterogeneous, PhotoCatalysis, Biocatalysis, Electrocatalysis
Course Workload	3 Credits / 108 academic hours

Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Introduction to Catalysis	Topic 1.1 Introduction to Catalysis. Catalysis as a pillar of our future society. Types of catalysis. Examples.
Module 2. Homogeneous catalysis. Basics, principles and examples	Topic 2.1 Homogeneous catalysis. Basics, principles and examples. Catalyst design. Applications.
Module 3. Heterogeneous catalysis. Basics, principles and examples	Topic 3.1 Heterogeneous catalysis. Basics, principles and examples. Catalyst design. Applications.
Module 4. Photocatalysis. Basics, principles and examples	Topic 4.1 Photocatalysis. Basics, principles and examples. Photocatalyst design. Applications.
Module 5. Biocatalysis. Basics, principles and examples	Topic 5.1 Biocatalysis. Basics, principles and examples. Biocatalyst design. Applications.
Module 6. Electrocatalysis. Basics, principle and examples	Topic 6.1 Electrocatalysis. Basics, principle and examples. Electrocatalyst design. Applications.
Module 7. Differences and similarities. A comparison between Catalysis types	Topic 7.1 Differences and similarities. A comparison between Catalysis types. Pros and cons. Possibilities and combinations of catalytic processes (e.g. chemo-biocatalysis). Perspectives and combination with modern tools (e.g. flow chemistry)
Module 8. Conclusions and prospects	Topic 8.1 Conclusions and prospects

Course Title	Experimental lab 1
Course Workload	3 Credits / 108academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Alkylation of aromatics (batch vs microwave vs flow)	Topic 1.1 Alkylation of aromatics (batch vs microwave vs flow). Explanation. Lab experiments.
Module 2. Catalyst synthesis (supported metal nanoparticles), batch vs microwave vs flow	Topic 2.1 Catalyst synthesis (supported metal nanoparticles), batch vs microwave vs flow. Explanation. Lab experiments.
Module 3. Esterification/etherification of glycerol (batch vs microwave vs flow)	Topic 3.1 Esterification/etherification of glycerol (batch vs microwave vs flow). Explanation. Lab experiments.
Module 4. Dehydration of xylose (batch vs microwave vs flow	Topic 4.1 Dehydration of xylose (batch vs microwave vs flow). Explanation. Lab experiments.
Module 5. Synthesis of biodiesel from WCO (batch vs microwave vs flow)	Topic 5.1 Synthesis of biodiesel from WCO (batch vs microwave vs flow). Explanation. Lab experiments.

Course Title	Experimental lab 2: Biorefineries and Bioproducts
Course Workload	4 Credits / 144 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Synthesis of	Topic 1.1 Synthesis of biodiesel. Explanation. Lab applied

biodiesel	work
Module 2. Extraction of biochemicals from biomass/waste	Topic 2.1 Extraction of biochemicals from biomass/waste. Explanation. Lab applied work
Module 3. Synthesis of soap via saponification reaction	Topic 3.1 Synthesis of soap via saponification reaction. Explanation. Lab applied work
Module 4. Preparation of mesoporous carbonaceous materials from starch	Topic 4.1 Preparation of mesoporous starch from plain starch. Explanation. Lab applied work
	Topic 4.2. Preparation of mesoporous carbonaceous materials from mesoporous starch. Explanation. Lab applied work

Course Title	Experimental lab 3: Advanced Organic Synthesis
Course Workload	4 Credits / 144 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Monophasic reactions: liquid/liquid reaction	Topic 1.1 Monophasic reactions: liquid/liquid reaction. Examples. Preparation of an Ionic Liquid/Deep Eutectic solvent.
Module 2. Multiphasic reactions: liquid/liquid reactions	Topic 2.1 Multiphasic reactions: liquid/liquid reactions. Examples. Saponification reaction.
Module 3. Liquid/solid reactions	Topic 3.1 Liquid/solid reactions. Examples. In-situ preparation of copper azide
Module 4. Liquid/gas reactions and	Topic 4.1 Liquid/gas reactions. Examples. Selective hydrogenation of alkynes (e.g. phenylacetylene)
Module 5. Liquid/solid/gas reactions	Topic 5.1 Liquid/solid/gas reactions. Examples. Heterogeneously catalysed aerobic oxidation of alcohols
Module 6. Miscellaneous	Topic 6.1 Miscellaneous. Various additional reactions. Examples. Experimental lab on a key reaction (TBC)
Module 7. Presentation and Q&A session	Presentation and Q&A session

Course Title	Artificial intelligence and additive technologies in chemistry
Course Workload	2 Credits / 72 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Artificial Intelligence in Chemical Research	Topic 1.1 Introduction to artificial intelligence for chemists The concept of artificial intelligence (AI), the history of its development and its main applications in science and technology. Overview of the use of AI in chemistry to solve scientific and practical problems. Basic principles and approaches of AI, the difference between machine learning and deep learning.

Course Title	Artificial intelligence and additive technologies in chemistry
Course Workload	2 Credits / 72 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
	Topic 1.2 Fundamentals of machine learning and neural networks Key aspects of machine learning and neural networks. Types of learning (with teacher, without teacher, with reinforcement), algorithms and models, and their application in chemical research. Fundamentals of building, training and validating AI models.
	Topic 1.3 Applications of AI in organic synthesis An overview of advanced developments in the use of AI in organic synthesis. Innovative application of machine learning for reactivity prediction, optimization of reaction conditions and development of new reaction pathways. Practical examples from current research.
	Topic 1.4 Tools and databases for working with AI in chemistry Key tools, software and databases that are used to work with AI in chemistry. Issues of data availability, data preprocessing, and the importance of quality of data collection for successful AI applications. Examples of popular platforms and tools.
Module 2. Fundamentals of additive technologies for chemical research	Topic 2.1 Introduction to additive technologies for chemists An overview of additive technologies, their history and development, and basic principles and capabilities for chemical research. Advantages of additive technologies over traditional manufacturing methods, including their ability to rapidly iterate designs, customize, and create complex structures.
	Topic 2.2 Types of additive technologies and 3D printing Various additive manufacturing techniques and technologies such as stereolithography (SLA), selective laser sintering (SLS), layer-by-layer deposition method (FDM) and others. Their main characteristics, advantages and limitations for use in chemical research.
	Topic 2.3 Materials for additive manufacturing in chemistry Overview of materials used in additive manufacturing including plastics, metals, ceramics and composites. Suitability of materials for use in chemical research including chemical compatibility, heat resistance and mechanical properties.

Course Title	Artificial intelligence and additive technologies in chemistry
Course Workload	2 Credits / 72 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
	Topic 2.4 Applications of additive technologies in organic synthesis Specific applications of additive technologies in organic synthesis, including the fabrication of reactors, purification systems, and other laboratory devices. 3D printing applications that promote innovation in synthesis methodology, experiment optimization, and cost reduction.
	Topic 2.5 Development and integration of additive technologies into laboratory practice The process of developing and integrating additive technologies, device design, and tools for laboratory practice. Stages of design, material selection, printing and testing. Safety and cost effectiveness issues. Recommendations for getting started with additive technologies in the laboratory, including equipment selection.
Module 3. Artificial intelligence and additive technologies in modern organic synthesis and biomass valorization processes	Topic 3.1 Fundamentals of integrating AI and additive technologies in chemistry An overview of the opportunities offered by the combined use of AI and additive technologies in chemical synthesis. Basic principles and strategies for integrating these approaches to develop new chemical processes and devices. Examples of successful applications that demonstrate the potential of the combined approach.
	Topic 3.2 Development of customizable catalysts using AI and 3D printing Development of customizable catalysts using the analytical capabilities of AI to predict catalytic activity and selectivity, and the application of additive technologies to their physical creation. The benefits of creating catalysts specifically tailored to specific reactions and opportunities for innovation in synthetic chemistry. Process design of biomass valorization.
	Topic 3.3 Automation of organic synthesis using AI and additive technologies Using AI to automate organic synthesis processes, including reaction planning and control of reactors produced by

Course Title	Artificial intelligence and additive technologies in chemistry
Course Workload	2 Credits / 72 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
	additive manufacturing methods. Strategies for integrating these approaches to create flexible, highly efficient and autonomous chemical production systems.
	Topic 3.4 The future of synthesis: AI and additive technologies as drivers of innovation and sustainability A look at the future prospects for the use of AI and additive technologies in organic synthesis. Potential directions for the development of these technologies, including the creation of smart materials, new approaches in process and device design, and the impact on sustainability and green chemistry. Challenges and opportunities for researchers and engineers in synthetic chemistry, biomass conversion and sustainability.

Course Title	Emerging contaminants: from fate to environmental remediation
Course Workload	2 Credits /72 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. Introduction to emerging contaminants. Properties and behaviors of emerging pollutants	Topic 1.1. Introduction to emerging contaminants. Properties and behaviors of emerging pollutants
Module 2. Types of emerging contaminants	Topic 2.1. Organic pollutants (dyes, etc.)
	Topic 2.2. Pharmaceuticals
	Topic 2.3. PFAS
	Topic 2.4. Micro and nanoplastics
	Topic 2.5. Nanomaterials
	Topic 2.6. Others (miscellaneous)
Module 3. Fate and mobility in the environment	Topic 3.1. Distribution and speciation (airborne, water, soil, etc.)
	Topic 3.2. Compounds and intermediates. Toxicity and environmental concerns
	Topic 3.3.
Module 4. Environmental remediation. Degradation and removal	Topic 4.1. Physico-chemical degradation methods
	Topic 4.2. Photocatalytic degradation method

Course Title	The method of working with databases
Course Workload	2 Credits /72 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. “Classical” sources of chemical information – abstract journals of Russian	Topic 1.1. Familiarization of students with the main sources of chemical information search in the presented abstract journals, methods of searching for information of interest,

Chemical, Chemical Abstracts, Beilshtein.	possibilities of presenting and searching for chemical information on the Internet.
	Topic 1.2. Features provided by the electronic version of Chemical Abstracts.
	Topic 1.3. Familiarization with the features of the presentation and search of patent information.
	Topic 1.4. Familiarization with the specifics of the presentation and search of patent information.
Module 2. Search for the necessary synthetic techniques on the "Orgsyn" server	Topic 2.1. Familiarization of students with other electronic free sources of scientific information.
	Topic 2.2. Working with the server http://www.orgsyn.org / and the possibility of searching for methods of synthesis of compounds of interest.
Module 3. Free electronic versions of organic chemistry journals.	Topic 3.1. Working with full-text free electronic journals on the web, features of searching for articles of interest in this publication.
	Topic 3.2. Working with full-text journals of the American Chemical Society.
	Topic 3.3. Ways to search for information on the ACS website.
Module 4. Patent information	Topic 4.1. Search for patents on the website of the American Patent Office USPTO
	Topic 4.2. Search for patents on the website of the European Patent Office
Module 5. Chemical information search capabilities provided by paid services.	Topic 5.1. Sci-Finder
	Topic 5.2. Reaxys
Module 6. Searching system SCOPUS.	Topic 6.1. Working in the search system SCOPUS.

Course Title	Artificial intelligence and additive technologies in chemistry
Course Workload	2 Credits /72 academic hours
Course contents	
Course Module Title	**Brief Description of the Module Content**
Module 1. "Artificial Intelligence in Chemical Research	Topic 1.1 Introduction to artificial intelligence for chemists The concept of artificial intelligence (AI), the history of its development and its main applications in science and technology. Overview of the use of AI in chemistry to solve scientific and practical problems. Basic principles and approaches of AI, the difference between machine learning and deep learning.
	Topic 1.2 Fundamentals of machine learning and neural networks Key aspects of machine learning and neural networks. Types of learning (with teacher, without teacher, with reinforcement), algorithms and models, and their application in chemical research. Fundamentals of building, training and validating AI models.
	Topic 1.3 Applications of AI in organic synthesis An overview of advanced developments in the use of AI in

	organic synthesis. Innovative application of machine learning for reactivity prediction, optimization of reaction conditions and development of new reaction pathways. Practical examples from current research.
	Topic 1.4 Tools and databases for working with AI in chemistry Key tools, software and databases that are used to work with AI in chemistry. Issues of data availability, data preprocessing, and the importance of quality of data collection for successful AI applications. Examples of popular platforms and tools.
Module 2. Fundamentals of additive technologies for chemical research	Topic 2.1 Introduction to additive technologies for chemists An overview of additive technologies, their history and development, and basic principles and capabilities for chemical research. Advantages of additive technologies over traditional manufacturing methods, including their ability to rapidly iterate designs, customize, and create complex structures.
	Topic 2.2 Types of additive technologies and 3D printing Various additive manufacturing techniques and technologies such as stereolithography (SLA), selective laser sintering (SLS), layer-by-layer deposition method (FDM) and others. Their main characteristics, advantages and limitations for use in chemical research.
	Topic 2.3 Materials for additive manufacturing in chemistry Overview of materials used in additive manufacturing including plastics, metals, ceramics and composites. Suitability of materials for use in chemical research including chemical compatibility, heat resistance and mechanical properties.
	Topic 2.4 Applications of additive technologies in organic synthesis Specific applications of additive technologies in organic synthesis, including the fabrication of reactors, purification systems, and other laboratory devices. 3D printing applications that promote innovation in synthesis methodology, experiment optimization, and cost reduction.
	Topic 2.5 Development and integration of additive technologies into laboratory practice The process of developing and integrating additive technologies, device design, and tools for laboratory practice. Stages of design, material selection, printing and testing. Safety and cost effectiveness issues. Recommendations for getting started with additive technologies in the laboratory, including equipment selection.
Module 3. Artificial intelligence and additive technologies in modern organic synthesis and	Topic 3.1 Fundamentals of integrating AI and additive technologies in chemistry An overview of the opportunities offered by the combined use

biomass valorization processes	of AI and additive technologies in chemical synthesis. Basic principles and strategies for integrating these approaches to develop new chemical processes and devices. Examples of successful applications that demonstrate the potential of the combined approach.
	Topic 3.2 Development of customizable catalysts using AI and 3D printing Development of customizable catalysts using the analytical capabilities of AI to predict catalytic activity and selectivity, and the application of additive technologies to their physical creation. The benefits of creating catalysts specifically tailored to specific reactions and opportunities for innovation in synthetic chemistry. Process design of biomass valorization.
	Topic 3.3 Automation of organic synthesis using AI and additive technologies Using AI to automate organic synthesis processes, including reaction planning and control of reactors produced by additive manufacturing methods. Strategies for integrating these approaches to create flexible, highly efficient and autonomous chemical production systems.
	Topic 3.4 The future of synthesis: AI and additive technologies as drivers of innovation and sustainability A look at the future prospects for the use of AI and additive technologies in organic synthesis. Potential directions for the development of these technologies, including the creation of smart materials, new approaches in process and device design, and the impact on sustainability and green chemistry. Challenges and opportunities for researchers and engineers in synthetic chemistry, biomass conversion and sustainability.

HEAD
OF HIGHER EDUCATION PROGRAMME:
Dean of Faculty of Science,

Head of Organic Chemistry **Voskressensky L.G.**

Department

position, department	signature	name and surname