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

Faculty of Science

educational division (faculty/institute/academy) as higher education programme developer

COURSE SYLLABUS

Alternative / new tools for organic synthesis

course title

Recommended by the Didactic Council for the Education Field of:

04.04.01 «Chemistry»

field of studies / speciality code and title

The course instruction is implemented within the professional education programme of higher education:

«Bioenergies and Biorefineries»

higher education programme profile/specialisation title

2024

1. COURSE GOAL

The goal of the course "Alternative / new tools for organic synthesis" is to raise awareness and train students to alternative/new synthesis tools for molecules of interest. Alternative and innovative technologies will be applied to analyze the fundamental reactivity and mechanisms of classical and new activation modes in organic synthesis.

2. REQUIREMENTS FOR LEARNING OUTCOMES

Mastering the course "Alternative / new tools for organic synthesis" is aimed at the development of the following competences:

Table 2.1. List of competences that students acquire through the course study

Competence code	**Competence descriptor**	**Competence formation indicators** (within this course)
GPC-1	Ability to carry out complex experimental and computational-theoretical studies in the chosen field of chemistry or related sciences using modern equipment, software and databases for professional purposes.	GPC-1.1. Ability to use existing and develop new methods for obtaining and characterizing substances and materials for solving problems in the chosen field of chemistry or related sciences;
		GPC-1.2. Ability to use modern equipment, software and professional databases for solving problems in the chosen field of chemistry or related sciences;
GPC-2	Ability to analyze, interpret and generalize the results of experimental and computational-theoretical work in the chosen field of chemistry or related sciences.	GPC-2.1 Ability to carry out a critical analysis of the results of own experimental and computational-theoretical works and to interpret them correctly
		GPC-2.2. Ability to formulate summary and conclusions based on the results of the analysis of literature data, own experimental and computational-theoretical works in the chosen field of chemistry or related sciences
PC-1	Ability to develop a work plan and to choose adequate methods for solving research problems in the chosen field of chemistry, chemical technology or sciences related to chemistry	PC-1.1. Ability to prepare a general plan of research and detailed plans for individual stages;
		PC-1.2. Ability to select experimental and calculation-theoretical methods for solving the problems based on the available material and time resources

3. COURSE IN HIGHER EDUCATION PROGRAMME STRUCTURE

The course "Alternative / new tools for organic synthesis" refers to the **variable** component of B1 block of the higher educational programme curriculum.

Within the higher education programme students also master other (modules) and / or internships that contribute to the achievement of the expected learning outcomes as results of the course study.

Table 3.1. The list of the higher education programme components/disciplines that contribute to the achievement of the expected learning outcomes as the course study results

Competence code	Competence descriptor	Previous courses/modules*	Subsequent courses/modules*
GPC-1	Ability to carry out complex experimental and computational-theoretical studies in the chosen field of chemistry or related sciences using modern equipment, software and databases for professional purposes.		Actual problems of modern chemistry Advanced Organic Synthesis Catalyst (nanomaterials) design and applications Catalysis: from Basic principles to applications. Homogeneous, Heterogeneous, Photocatalysis, Biocatalysis, Electrocatalysis Experimental lab 1: Flow synthesis and alternative technologies Experimental lab 2: Biorefineries and Bioproducts Experimental lab 3: Advanced Organic Synthesis Student Scientific-Research work Pre-graduation practical training
GPC-2	Ability to analyze, interpret and generalize the results of experimental and computational-theoretical work in the chosen field of chemistry or related sciences.		Actual problems of modern chemistry History and philosophy of science Bioproducts, Biomaterials and Biorefineries Advanced Organic Synthesis Catalyst (nanomaterials) design and applications Catalysis: from Basic principles to applications. Homogeneous, Heterogeneous, PhotoCatalysis, Biocatalysis, Electrocatalysis Experimental lab 1: Flow synthesis and alternative technologies Experimental lab 2: Biorefineries and Bioproducts Experimental lab 3: Advanced Organic Synthesis Student Scientific- Research work Pre-graduation practical training
PC-1	Ability to develop a work plan and to choose adequate methods for solving research		Advanced Organic Synthesis Catalyst (nanomaterials) design and applications Experimental lab 1: Flow

Competence code	Competence descriptor	Previous courses/modules*	Subsequent courses/modules*
	problems in the chosen field of chemistry, chemical technology or sciences related to chemistry		synthesis and alternative technologies Experimental lab 2: Biorefineries and Bioproducts Experimental lab 3: Advanced Organic Synthesis Emerging contaminants: from fate to environmental remediation The methods of working with databases Student Scientific- Research work Pre-graduation practical training

* To be filled in according to the competence matrix of the higher education programme.

4. COURSE WORKLOAD AND ACADEMIC ACTIVITIES

1) The total workload of the course "Alternative / new tools for organic synthesis" is 4 credits (144 academic hours).

*Table 4.1. Types of academic activities during the periods of higher education programme mastering (**full-time training**)**

Type of academic activities		Total academic hours	Training modules			
			1	2	3	4
Contact academic hours		*27*	*27*			
including:						
Lectures (LC)		18	18			
Lab work (LW)		9	9			
Seminars (workshops/tutorials) (S)						
Self-studies		*63*	*63*			
Evaluation and assessment (exam/passing/failing grade)		*18*	*18*			
Course workload	academic hours	**108**	**108**			
	credits	**3**	**3**			

5. COURSE MODULES AND CONTENTS

Table 5.1. Course contents and academic activities types

Course module title	Course module contents (topics)	Academic activities types
Module 1. Microwave irradiation and inductive heating	Topic 1.1 Introduction	LC
	Topic 1.2 Theoretical description of the activation mode	LC
	Topic 1.3 Description of the equipment	LW
	Topic 1.4 Examples of application in organic	LW

Course module title	Course module contents (topics)	Academic activities types
	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	LC
	Topic 2.2 Theoretical description of the activation mode	LC
	Topic 2.3 Description of the equipment	LW
	Topic 2.4 Real examples of application in organic chemistry and catalysis: Synthesis of Ibuprofen, synthesis of HMF/furfural, photocatalytic oxidation of HMF/furfural	LW
Module 3. Sonochemistry	Topic 3.1 Introduction	LC
	Topic 3.2 Theoretical description of the activation mode	LC
	Topic 3.3 Description of the equipment	LW
	Topic 3.4 Real examples of application in organic chemistry and catalysis: Pinacol cross coupling, synthesis of HMF/furfural, synthesis of heterogeneous catalyst	LW
Module 4. Electrochemistry	Topic 4.1 Introduction	LC
	Topic 4.2 Theoretical description of the activation mode	LC
	Topic 4.3 Description of the equipment	LW
	Topic 4.4 Real examples of application in organic chemistry and catalysis: oxidation of HMF/furfural, reduction of HMF/furfural, synthesis of diesel	LW
Module 5. Mechanochemistry	Topic 5.1 Introduction	LC
	Topic 5.2 Theoretical description of the activation mode	LC
	Topic 5.3 Description of the equipment	LW
	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	LW
Module 6. Plasma	Topic 6.1 Introduction	LC
	Topic 6.2 Theoretical description of the activation mode	LC
	Topic 6.3 Description of the equipment	LW
	Topic 6.4 Real examples of application in organic chemistry and catalysis: alkane oxidation.	LW
Module 7. Flow chemistry	Topic 7.1 Introduction	LC
	Topic 7.2 Description and influence of the	LC

Course module title	Course module contents (topics)	Academic activities types
	parameters: residence time, reactor design, source, temperature, pressure	
	Topic 7.3 Description of the equipment	LW
	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.	LW
Module 8. Flow chemistry combining microwave, induction, photochemistry, sonochemistry, electrochemistry, mechanochemistry, plasma	Topic 8.1 Introduction	LC
	Topic 8.2 Theoretical description of the activation mode	LC
	Topic 8.3 Description of the equipment	LW
	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 chemistry) alkane oxidation.	LW

* - to be filled in only for **full** -time training: *LC - lectures; LW - lab work; S - seminars.*

6. CLASSROOM EQUIPMENT AND TECHNOLOGY SUPPORT REQUIREMENTS

Table 6.1. Classroom equipment and technology support requirements

Type of academic activities	Classroom equipment	Specialised educational / laboratory equipment, software, and materials for course study (if necessary)
Lecture	A lecture hall for lecture-type classes, equipped with a set of specialised furniture; board (screen) and a set of devices for multimedia presentations.	Projector, motorized screen for projectors, wi-fi
Lab work	A classroom for laboratory work, individual consultations, current and mid-term assessment; equipped with a set of specialised furniture and machinery.	A set of specialized furniture; specialized equipment of the chemical laboratory: fume hood SHVP-4, fume hood SHVP-2, rotary evaporator Hei-value digital G3B, rotary evaporator IKA, digital devices for determining the melting point SMP10; electronic laboratory scales

Type of academic activities	Classroom equipment	Specialised educational / laboratory equipment, software, and materials for course study (if necessary)
		AND EK-610, MK-M flask heaters of different volumes, drying cabinet, magnetic stirrer MRHei-Mix S, magnetic stirrer with heating MRHei-Standart, refractometer, combined laboratory water bath, vacuum chemical station RS3001 VARIO-pro, circulation cooler Rotacool Mini, rotary plate pump vacuum RZ2.5, membrane vacuum chemical pump MZ2CNT, Steinel thermal air blower, Spectroline UV lamp, electronic vacuum controller with CVC3000 detect Vacuumbrand valve, stainless steel emergency cabin SHVV, chemical dishes, refrigerator; wi-fi
Self-studies	A classroom for self-studies (can be used for seminars and consultations), equipped with a set of specialised furniture and computers with access to the electronic information and educational environment.	**Faculty of Science Reading Room** Ordzhonikidze D.3. Coworking area Monday - Friday 10.00 – 22.00 **Reading room of the main building of the RUDN** Coworking area Monday - Saturday 9.00 - 23.00 Hall No. 2 Monday - Thursday 10.00 - 17.45 Friday 10.00 - 16.45 Hall No. 6 Monday - Thursday 10.00 - 17.45 Friday 10.00 - 16.45

* The premises for students' self-studies are subject to **MANDATORY** mention

7. RECOMMENDED SOURCES FOR COURSE STUDIES

Main sources:

1. Microwaves in Chemistry Applications, Fundamentals, Methods and Future Trends 1st Edition 2021, Authors: Aparna Das, Bimal Banik, ISBN: 9780128228951
2. Handbook of Electrochemistry, Ed. C.G. Zoski, Elsevier, 2007.
3. Advances in Photochemistry, volumes 1 to 27, Series Online ISSN: 1934-4570 Series DOI: 10.1002/SERIES2020
4. Sonochemistry: From Basic Principles to Innovative Applications, Eds. J.C. Colmenares, G. Chatel, Topics in Current Chemistry, Springer, 2017.
5. Mechanochemistry: Fundamentals, Applications and Future: Faraday Discussion 241, February 2023.
6. Flow Chemistry – Fundamentals, Eds. Ferenc Darvas, Volker Hessel, György Dorman Walter de Gruyter GmbH & Co KG, 2014.
7. Flow Chemistry: Integrated Approaches for Practical Applications, Ed. Santiago Luis, E. Garcia-Verdugo, https://doi.org/10.1039/9781788016094, RSC 2019.
8. L. D. Field, S. Sternhell y J. R. Kalman, Organic Structures from Spectra, Wiley, 2002.
9. Green Chemistry in the synthesis of pharmaceuticals, S. Kar, H. Sanderson, K. Roy, E. Benfenati, J. Leszczynski, Chem. Rev. 2022, 122, 3637-3710.
10. Green Chemistry and Sustainability metrics in the pharmaceutical manufacturing sector, J. Becker, C. manske, S. Randl, Current Opinion in Green and Sustainable Chemistry 2022, 33, 100562

Additional sources:

1. Website of the American Chemical Society ACS Publications: Chemistry journals, books, and references https://pubs.acs.org/
2. http://www.thieme.com/journals-main
3. http://onlinelibrary.wiley.com/
4. http://www.springer.com/gp/products/journals
5. Server with the ability to search for methods for synthesizing compounds http://www.orgsyn.org/

Internet sources

1. Electronic libraries with access for RUDN students:
- RUDN Electronic Library System (RUDN ELS) http://lib.rudn.ru/MegaPro/Web
- EL "University Library Online" http://www.biblioclub.ru
- EL "Yurayt" http://www.biblio-online.ru
- EL "Student Consultant" www.studentlibrary.ru
- EL "Lan" http://e.lanbook.com/
- EL "Trinity Bridge"

2. Databases and search engines:
- electronic foundation of legal and normative-technical documentation http://docs.cntd.ru/
- Yandex search engine https:// www .yandex.ru/

- Google search engine https://www.google.ru/
- Scopus abstract database http://www.elsevierscience.ru/products/scopus/
- www.scholar.google.ru

*Training toolkit for self- studies to master the course *:*

1. A set of lectures on "Alternative / new tools for organic synthesis"
2. The laboratory workshop on "Alternative / new tools for organic synthesis"

* The training toolkit for self-studies to master the course is placed on the course page in the university telecommunication training and information system under the set procedure.

8. ASSESSMENT TOOLKIT AND GRADING SYSTEM* FOR EVALUATION OF STUDENTS' COMPETENCES LEVEL UPON COURSE COMPLETION

The assessment toolkit and the grading system* to evaluate the competences formation level (competences in part) upon the course study completion are specified in the Appendix to the course syllabus.

* The assessment toolkit and the grading system are formed on the basis of the requirements of the relevant local normative act of RUDN University (regulations / order).

DEVELOPERS:

Organic Chemistry Department		**Christophe Len**
position, department	signature	name and surname
Organic Chemistry Department		**Rafael Luque**
position, department	signature	name and surname
Organic Chemistry Department		**Luigi Vaccaro**
position, department	signature	name and surname

HEAD OF EDUCATIONAL DEPARTMENT:		
Organic Chemistry Department		**Voskressensky L.G.**
name of department	signature	name and surname

HEAD OF HIGHER EDUCATION PROGRAMME:		
Dean of Faculty of Science,		**Voskressensky L.G.**

Head of Organic Chemistry Department		
position, department	signature	name and surname