STUDY PROGRAM CHEMISTRY SECOND-CYCLE STUDIES, SPECIALITY: ADVANCED SYNTHESIS IN CHEMISTRY

COURSE CONTENT AND LEARNING OUTCOMES

Year of study: I/1st Semester									
Course	O/ F	Course form				No. of class hours	Assessment method	ECTS credits	Scientific disciplines to which the course is related
		L	S	Lab	Other				
Safety in a chemical laboratory	O	15		15		30	E/Z	2	Chemical sciences
Advanced organic chemistry (Block I)	O	90	30	75		195	E/Z/Z	17	Chemical sciences
Health and safety course	O				4	4	Z	0	
Elective Courses I *	F					105	Z	10	Chemical sciences
Polish for Foreigners**	O		30			30	Z		
					Total	**364**	**2E**	**29**	

* Elective Courses from the Table below with a list of courses

** Polish course is obligatory for foreigners only, subject to separate University regulations. 5 ECTS credits gained for this course do not count for the total of 120 ECTS credits required to complete the curriculum and get the degree.

Year of study: I/2nd Semester								
Course	O/ F	Course form			No. of class hours	Assessment method	ECTS credits	Scientific disciplines to which the course is related
		L	S	Lab				
Advanced inorganic chemistry (Block II)*	O	60	45	90	195	E/Z/Z	17	Chemical sciences
Molecular modeling	O	20	15	30	65	E/Z/Z	9	Chemical sciences
Polish for Foreigners**	O		30		30	E	5**	
Language course***	F		60		60	E	4***	
				Total	**350**	**4E**	**30**	

** Polish course is obligatory for foreigners only, subject to separate University regulations. 5 ECTS credits gained for this course do not count for the total of 120 ECTS credits required to complete the curriculum and get the degree.
*** Elective language course, level B2+

Total number of ECTS credits , 1st Semester: 29
Total number of ECTS credits , 2nd Semester: 30
Total number of hours of classes, 1st Semester: 364
Total number of hours of classes, 2nd Semester: 350

Year of study: II/3rd Semester								
Course	O/ F	Course form			No. of class hours	Assessment method	ECTS credits	Scientific disciplines to which the course is related
		L	S	Lab				
Master's Degree Project***	O						17	Chemical sciences
Elective Courses II*	F				150	E	14	Chemical sciences
				Total	**150**	**1E**	**31**	

*Elective Courses from the Table below

*** Upon choosing the topic of his/her Master thesis, the student carries out the Master's Degree Project in one of the research groups at the Faculty. The number of class hours is project-specific, and hence, remains undefined. The project ends with the writing of a master's thesis and its defense at the master's exam.

Year of study: II/4th Semester								
Course	O/ F	Course form			No. of class hours	Assessment method	ECTS credits	Scientific disciplines to which the course is related
		L	S	Lab				
Entrepreneurship and protection of intellectual property	O	15			15	E	2	Economics and finance/Law
Communication, speech freedom and other human rights and freedoms in democratic society	O	30			30	Z	3	Communication and media studies
Master's Degree Project***	O					Z	19	Chemical sciences
Master's Seminar	O		30		30	Z	6	Chemical sciences
				Total	**75**	**1E**	**30**	

*** Upon choosing the topic of his/her Master thesis, the student carries out the Master's Degree Project in one of the research groups at the Faculty. The number of class hours is project-specific, and hence, remains undefined. The project ends with the writing of a master's thesis and its defense at the master's exam.

Elective Courses I and II*	F	Course form			No. of class hours	Assessment method	ECTS credits	Scientific disciplines to which the course is related
		L	S	Lab				
Combinatorial chemistry	F	15		30	45	Z	4	Chemical sciences
Applications of chemical materials	F	30			30	Z	3	Chemical sciences
Computer design and modeling of new materials	F	30		15	45	Z	4	Chemical sciences
Chemistry in action: ideas and applications	F	45			45	Z	4	Chemical sciences
Catalysis and green chemistry	F	15		45	60	Z	6	Chemical sciences
Biological inorganic chemistry	F	30			30	Z	3	Chemical sciences
Bioorganic chemistry	F	15		15	30	Z	3	Chemical sciences
Protein chemistry	F	15		15	30	Z	3	Chemical sciences
Molecular magnetism	F	15		15	30	Z	3	Chemical sciences
Analytical methods in cultural heritage research	F	30		15	45	Z	4	Chemical sciences

Total number of ECTS credits , 3rd Semester: 31
Total number of ECTS credits , 4th Semester:: 30
Total number of hours of classes, 3rd Semester: 150
Total number of hours of classes, 4th Semester: 75

Total number of hours during studies: 935
Total number of ECTS credits: 120, including 63 ECTS in electives (52.5%)

EXPLANATIONS
O/F - Character of the course: O – mandatory, F – elective.
Course form: L – lecture, Lab – laboratory, S, K – seminar.
Assessment method: E – exam, Z – passing with grade.

Course content. Learning outcomes assigned to courses.

l.p.	Course	Course content	Learning outcomes for the course
1.	Safety in a chemical laboratory	Safety culture and ethic. Basic safety rules in chemistry laboratory, experiment planning and organization of work. Preparing for emergency response: chemical spills, fire, first aid in chemistry laboratory. Understanding and communicating laboratory hazards: signs, symbols, and labels. Information resources about laboratory hazards and safety: safety data sheets (SDS/MSDS), GHS. Recognizing laboratory hazards of toxic substances and biological agents. Basic concepts in toxicology: toxicants, toxins and poisons, measuring toxicity, acute and chronic toxicity. Recognizing laboratory physical hazards: flammables, corrosives, incompatible chemicals, reactive chemicals, peroxides, electrical hazard, hazard from low or high pressure systems, cryogenic hazard, radiation related hazard. Risk assessment and managing. Personal protective equipment and engineering control. Chemical management: inspections, storage, local transport, wastes, and security.	K_W01, K_W07 K_K01
2.	Advanced organic chemistry (Block I)	*Contemporary organic synthesis* Role of organic synthesis in contemporary chemistry and chemical industry. Types of synthetic transformations. Oxidations and reductions in organic chemistry. Reagents and their applications. Methods of carbon-carbon bond formation. Aldol-type condensations, reactions with carbanions, coupling reactions (oxidative, reductive, and catalytic). Synthesis of carbocycles. Synthesis of heterocyclic and macrocyclic systems. Strategy and planning in organic synthesis. Retrosynthetic analysis, synthons, umpolung. Analytical methods in organic synthesis. Publication standards. *Practical organic chemistry* Scientific information in the organic chemistry. Safety in the organic chemistry laboratory. How to conduct a lab book and a synthetic documentation? Modern laboratory equipment. Separation and purification of the reaction products. High vacuum techniques – vacuum/inert gas line, Schlenk techniques, vacuum distillation. Work in a controlled atmosphere. Glove-box as a convenient tool for protecting substrates/products from decomposition. Purification of reagents and solvents. Chromatography as a powerful tool for identification and separation of products. Special reaction techniques (photochemical and microwave synthesis, solid phase synthesis). Visualisation of the experimental data. *Analytical methods in organic chemistry* NMR spectroscopy. Mass spectrometry. Other analytical methods useful in organic chemistry *Laboratory* The laboratory course creates an opportunity to face all steps necessary in organic synthesis. It starts with a purification of reagents and solvents, required for further work, including a distillation in inert atmosphere. All prepared purified chemicals will be used for a microscale synthesis. Some experiments will require the use of moisture and oxygen-sensitive reagents. In this case high vacuum/inert gas Schlenk methodology will be applied. Multistep synthesis will be also conducted. The isolation and purification (crystallization, distillation and chromatography) of the final product will be an important part of the course.	K_W01, K_W03, K_W05, K_W07, K_U01, K_U03, K_U07, K_U08 K_K02, K_K03, K_K04,

		Vacuum distillation will be used as a method of removal of high-boiling solvents and separation of mixtures (high vac and bulb-to bulb technique). Variety of chromatographic procedures will be also presented.	
3.	Advanced inorganic chemistry (Block II)	*Lecture, seminar* Fundamental theories describing metal-carbon bonds. Synthesis, characterization and applications of organometallic compounds. Metal hydride and carbonyl compounds. Elementary steps in catalytic reactions. Mechanisms of catalytic reactions. Structure-reactivity relationships. Application of catalytic reactions in industrial processes. Inorganic supramolecular chemistry. The role of coordination bonds in the formation of supramolecular assemblies, macrocyclic complexes, selective binding of cations and anions, self-organization of metal complexes. Supramolecular aspects in bioinorganic chemistry, optical and magnetic materials, molecular electronics, chemical sensors. Inorganic-organic hybrid materials, metal-organic frameworks. The concept of a node and a linker in a coordination polymer. Classification of coordination polymers. Zeolites and their inorganic-organic analogues. Covalent organic frameworks. Isoreticular approach in the design of coordination polymers. Solvothermal synthesis and mechanochemistry. Topology and isomerism in coordination polymer frameworks. Theoretical and experimental description of porosity in solids. Dynamic coordination networks. Sorption and separation of gases and vapors in porous materials. Heat of adsorption. Porous materials in catalysis. Coordination polymers as drug delivery systems. Electroactive materials. *Laboratory* Preparation of selected coordination compounds under inert atmosphere with the use of advanced laboratory techniques. Physico-chemical characterization of obtained compounds.	K_W01, K_W07, K_U01, K_U02, K_U05, K_U08, K_U09, K_K03,
4.	Language course (B2+ level)	Vocabulary and grammar resources of the English language corresponding to proficiency at B2+ level of the Common European Framework of Reference for Languages.	K_U07
5.	Polish for Foreigners (A1 level)	Vocabulary and grammar rules necessary to achieve fluency at level A1 of the Common European Framework of Reference for Languages. topics necessary in communication.	
6.	Molecular modeling	Methods of classical mechanics, force fields. Theoretical basis of quantum chemistry methods: Hartree-Fock method, semi-empirical methods, ab initio SCF methods, basis functions, correlation methods (MPn, CI and CC), density functional methods. Stationary points on the potential energy surface, optimization of the geometrical structure, localization of transition states, modeling of the chemical reaction path. Modeling of the structure and properties of molecular systems in the gas phase and solutions (supermolecular model and continuous environment methods). Theory of intermolecular interactions. Intermolecular interactions - interpretation on the basis of perturbation calculus methods and the supermolecular approach. Application of quantum chemistry methods in molecular spectroscopy. Modeling of the structure and properties of periodic systems: plane waves, Bloch functions, periodic Hartree-Fock method, calculations of band structure and density of states. Modeling of chemical processes using cellular automata methods. Research of molecular systems using Monte Carlo methods. Research on the dynamic properties of molecular systems - methods of molecular dynamics (classical, based on the force field and ab initio). Modeling of chemical processes for nano systems.	K_W03, K_W04, K_W06, K_U01, K_U02, K_U05, K_U09, K_K01, K_K02

7.	Master’s Degree Project	The student completes a master's project, which ends with a master's thesis, choosing a topic proposed and assigned to the research group of the faculty. The project includes a review of the literature on the issues discussed in the master's thesis, synthesis of compounds, the use of physicochemical methods to characterize and explain the properties of the compounds obtained, correlation of the observed properties with current literature data.	K_W01, K_W-03, K_W05, K_W07, K_U01, K_U02, K_U03, K_U05, K_U06, K_K01, K_K03, K_K04
8.	Entrepreneurship and protection of intellectual property	Introduction to a global high technology market. Assessment of individual business skills. Selection of a new business idea from a high technology area. Market evaluation of a new idea/technology. Study of market competitiveness. Possible methods of IP assessment and protection. Raising capital for innovative activity/business. Successive stages of the introduction of a technology to the market. Registration and introduction of a new entity into the market.	K_W08, K_W09, K_W10, K_W11
9.	Communication, speech freedom and other human rights and freedoms in democratic society	Meaning and nature of law and democracy. Sources of law in the Constitution of RP. Legal system. Media in international regulations. Specific responsibilities of media. Advertising Law. The issue and limits of freedom of expression. Rights and obligations of journalists. Law on Competition in activity of media. The issue and protection of copyright and related rights. Digital media law. Right for privacy.	K_W12
10.	Master’s Seminar	Issues of chemistry approved by the Council of the Faculty of Chemistry as topics of diploma theses. The subject matter is related to the profile of the Research Team. Students present presentations-projects from the literature review and the results of their research work.	K_W01, K_U02, K_U04, K_U03, K_U05, K_U06, K_K01, K_K02
11.	Molecular magnetism (Elective course)	Selected issues from the theory of "solid phase" magnetism and molecular systems. Basic units and parameters describing the magnetic properties of compounds. Types of orders in a magnetic field and their characteristics; paramagnetism, antiferromagnetism, ferromagnetism, ferrimagnetism, metamagnetism. The theory of Langevin, Neel. Long range order. Magnetic superexchange in coordination compounds. Parameters defining and determining the magnitude of magnetic interactions. New molecular magnetic materials: molecular magnets, molecular nanowires, spin glasses, superparamagnets, compounds showing the spin-crossover phenomenon. Factors determining SMM behavior: magnetic anisotropy, high spin, relaxation phenomenon, quantum tunneling effect. Selected measurement techniques. Technological applications of molecular magnetics: nanomaterials, microprocessors, computer memory, medical diagnostics. Research on natural and synthetic biosystems. Occurrence and role of magnets in organisms	K_W01, K_W05, K_W06, K_U01, K_U04, K_K01, K_K03
12.	Applications of chemical materials (Elective course)	Classification of materials due to their physicochemical properties. Fullerene chemistry. New materials: graphene, metamaterials, composites and organic materials in optoelectronics. Discussion of the properties of ferroic materials (mainly ferroelectrics and ferroelastics). Presentation of the main research methods for the characterization of ferroic crystals. Discussion of the properties of nonlinear ferroelectric crystals. Organometallic catalysts in the synthesis of organic materials. Types of catalysts, systems in which they are used, their design and applications of nanomaterials	K_W01, K_W06

13.	Combinatorial chemistry (Elective course)	Combinatorial libraries. Natural libraries: immune response, proteins, antibiotics, polyketides, phage systems and viruses. Synthetic and virtual libraries. Combinatorial biosynthesis. General and focused libraries, library design, deconvolution. Chemical diversity, Synthetic and analytical procedures, screening protocols, HTPS. Application of combinatorial libraries in biological and organic chemistry as well as in analytical chemistry and material science. Development of inhibitors and catalysts. Bioinformatics and data mining. Classical organic synthesis, solid phase chemistry and polymer-assisted solution synthesis. Design of a library, synthesis, analysis, prediction of physicochemical and biological properties. Evaluation of synthetic methods. Applications of solid phase synthesis: biopolymers and natural products, combinatorial libraries, analytical applications.	K_W04, K_U04
14.	Computer design and modeling of new materials (Elective course)	General aspects of molecular modelling. Molecular mechanics (MM) methods – formulations, approximations and application to biological and nano systems. Short description of advanced quantum chemical methods: the Hartree-Fock method, semiempirical methods, ab initio methods, basis sets used in ab initio calculations, post-HF methods like MPn, CI and CC. Methods formulated on base on density functional theory (DFT). Prediction of molecular properties important to design of new materials. The Born-Oppenheimer approximation and potential energy surface (PES). Energy minimization and related methods for exploring the PES – determination stable structures, transition state structures and reaction pathways. Genetic algorithms. Quantum chemical topology methods for analysis of the chemical bond nature: Atoms in Molecules (AIM) and Electron Localization Function (ELF). Calculations of excited states – CI and DTDFT methods (structure and properties). Theory of intermolecular interactions – energy decomposition analysis. Modelling of new materials on base of fullerenes and graphene. Design of new medical drugs – QSAR approach.	K_W04, K_U03, K_U04, K_K04
15.	Chemistry in action: ideas and applications (Elective course)	The lecture encompasses selected examples related to many areas of chemistry: Smart contrast agents for medical imaging, molecular machines, sensors, molecular switches, nanotechnology and molecular computers, NO and Viagra story, enantioselective catalysts in pharmaceutical industry, artificial nucleases and antisense technology, optical, conducting and magnetic materials	K_W01, K_W06,
16.	Catalysis and green chemistry (Elective course)	Phenomenon of catalysis, elementary steps of catalytic reactions. Mechanism of catalytic reaction and methods used in mechanistic studies. Evaluation of catalytic activity and reaction selectivity. Characterization of homogenous and heterogeneous catalytic systems. Immobilised catalysts and nanoparticles in catalysis. Application of catalytic reactions in organic synthesis and industry – oxidation, hydrogenation, hydroformylation, carbonylation, metathesis, C-C coupling. Methods used for recovery of catalyst from reaction mixture (biphasic systems, ionic liquids, supercritical fluids). Application of alternative energy sources in catalytic reactions.	K_W01, K_W03, K_W06, K_U01, K_U02, K_U03, K_K03

17.	Biological inorganic chemistry (Elective course)	Metals in biological processes. Essential and toxic metal ions. Relations between chemical properties of metal ions, structure of their complexes and their biological functions. Metalloproteins. Metalloenzymes. Metals in biology of nucleic acids. Transport, storage and homeostasis of metal ions. Sodium and potassium—channels and pumps. Magnesium and calcium in biological systems.Zinc: Lewis acid and gene regulator. Iron: essential for almost all life. Copper: coping with dioxygen. Nickel and cobalt: evolutionary relics. Manganese: water splitting, oxygen atom donor. Molybdenum, tungsten, vanadium and chromium – chemistry and biochemistry. Selected methods of analysis of metal ions complexes with bio-ligands. Metals in medicine, introduction to chemistry of inorganic drugs.	K_W01, K_W06
18.	Protein chemistry (Elective course)	Chemical properties of amino acids. Protein structures. Synthesis of peptides and peptidomimetics. Protein purification and characterization. Chemical and enzymatic modifications of proteins. Implementation of methods presented in the lecture. For protein isolation and analysis.	K_W01, K_W05, K_W06, K_U01, K_U04, K_K01, K_K03
19.	Bioorganic chemistry (Elective course)	Molecules of Life: Chemical bonds and shape of organic molecules, Nucleotides and nucleic acids, amino acids, peptides and proteins, carbohydrates and lipids, „Natural Products” – secondary metabolites, Biological Activity: quantitative aspects of biological activity, examples of molecular targets: receptors, ion channels and their ligands, molecules interacting with nucleic acids, enzyme inhibitors and molecules interacting with proteins involved in cellular adhesion, designing of biologically active compounds. Isolation of natural products from biological sources. Chemical and spectroscopic characterization of organic compounds. Chromatographic methods: TLC, gel filtration, HPLC. Peptide chemistry: synthesis and sequence analysis.	K_W01, K_W05, K_W06, K_U01, K_U04, K_K01, K_K03
20.	Analytical methods in cultural heritage research (Elective course)	Research methodology of archaeological objects and works of art used in conservation chemistry. Physical and chemical methods and techniques (infrared spectroscopy, Raman, ATR, XRD, XRF, SEM-EDX, UV-VIS, digital radiography and others) used in the study of historic objects: painting materials such as pigments, dyes and binders; ceramics and historical building materials; writing materials and paper; metals and alloys; natural resins; wood; minerals; maintenance materials. Degradation processes of historic materials. Issues related to the examination of the authenticity of historic objects. Methods of dating historic objects (e.g. dendrochronology, isotopic methods, thermoluminescence, C14 dating). Identification of the origin of archaeological objects using physicochemical tests. Research on the origin of minerals and precious stones. Synthesis of historical pigments and paints. Development of identification tests for the obtained paints and binders based on qualitative analysis methods. Identification of unknown pigments and binders based on the methods of qualitative analysis and Raman spectrometry. Identification of historic materials using spectroscopic techniques - infrared spectroscopy, ATR, Raman spectroscopy, SEM-EDS. Familiarization with legal and ethical issues related to research in the field of conservation chemistry. Improving the skills of writing reports and processing data obtained from conducted research and searching for scientific information.	K_W01, K_W05, K_W06, K_U01, K_U04, K_K01, K_K03

Description of learning outcomes defined for the curriculum in relations to the second-cycle characteristics of the Polish Qualifications Framework (PQF) for qualifications at level 7.

Symbol of the learning outcome for the curriculum	Learning outcomes for the field of study The graduate of the Master's program in **Chemistry**,	Reference to second-cycle characteristics of PQF
KNOWLEDGE		
K_W01	possesses extended knowledge of chemistry, knows chemical concepts and theories, and their importance in the development of science	P7S_WG
K_W02	is in possession of mathematical knowledge required to understand and describe physical and chemical phenomena of medium complexity	P7S_WG
K_W03	is in possession of extended knowledge of experimental and numerical methods used in chemistry	P7S_WG
K_W04	knows the theoretical background of calculations and IT methods used in solving typical chemical problems	P7S_WG
K_W05	has an in-depth knowledge of the theoretical background of functioning of scientific instruments used in chemistry	P7S_WG
K_W06	is in possession of general knowledge of current trends and discoveries in chemistry	P7S_WG
K_W07	knows the occupational safety rules sufficiently enough to be able to work as an independent researcher or analyst	P7S_WK
K_W08	possesses basic knowledge of legal and ethical regulations related to science and education	P7S_WK
K_W09	knows the basic concepts and regulations of industrial and intellectual property protection and uses patent information resources	P7S_WK
K_W10	knows the principles of creating and developing forms of individual entrepreneurship, including the branch of modern technologies	P7S_WK
K_W11	knows the rules of creation and is able to plan the form of individual professional development in the chemical industry	P7S_WK
K_W12	has extended knowledge about man as a creator of culture, deepened in relation to selected areas of human activity, knows the dilemmas of modern civilization	P7S_WK
SKILLS		
K_U01	is able to plan and carry out experimental research to analyse and solve chemical problems	P7S_UW
K_U02	is able to use acquired knowledge to describe and evaluate the results of research and chemical processes.	P7S_UW
K_U03	is able to use appropriate databases and specialist literature to search for and verify scientific information in the field of chemistry	P7S_UW
K_U04	is able to apply the acquired chemical knowledge in other areas of science	P7S_UW

K_U05	presents, in advanced manner, results and analysis of research, discusses current issues in the field of chemistry forms in Polish and English	P7S_UK
K_U06	has the ability to develop and present current issues in the field of chemistry, communicates with various audiences	P7S_UK
K_U07	Presents language skills described by B2+ specifications of Common European Framework of Reference (CEFR)	P7S_UK
K_U08	understands the need for continuous education and professional development, understands the need to systematically follow the professional literature to broaden the knowledge, is able to organize the learning process	P7S_UU
K_U09	has the ability to organize teamwork and completed assigned individual and group tasks	P7S_UO
SOCIAL COMPETENCIES		
K_K01	is ready to solve problems related to professional work, to initiate activities in the public interest	P7S_KO
K_K02	is critical of the knowledge possessed, promotes a scientific attitude, distinguishes scientific theories from pseudo-scientific views	P7S_KK
K_K03	is ready to perform professional roles, responsibility and the rules of professional ethics and developing the achievements of the profession related to the field of chemistry	P7S_KR
K_K04	plans professional development in an entrepreneurial way	P7S_KO