Chemistry of Heterocyclic Compounds and Biomolecules

1. GENERAL

SCHOOL	NATURAL SCIENCES			
ACADEMIC UNIT	CHEMISTRY			
LEVEL OF STUDIES	UNDERGRADUATE			
COURSE CODE	**XO 405**	**SEMESTER**	**4th**	
COURSE TITLE	CHEMISTRY OF HETEROCYCLIC COMPOUNDS AND BIOMOLECULES			
INDEPENDENT TEACHING ACTIVITIES *if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits*			**WEEKLY TEACHING HOURS**	**CREDITS**
Lectures			3	5
Seminars			1	
Laboratory work			-	
Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (d).				
COURSE TYPE *general background, special background, specialised general knowledge, skills development*	Field of Science (Organic Chemistry)			
PREREQUISITE COURSES:	There are no prerequisite courses. However, it is recommended that students should have at least a basic knowledge of General Chemistry and Organic Chemistry.			
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	Greek. Instruction may be given in English in case foreign students attended the course.			
IS THE COURSE OFFERED TO ERASMUS STUDENTS	YES			
COURSE WEBSITE (URL)	https://eclass.upatras.gr/courses/CHEM2056/			

2. LEARNING OUTCOMES

Learning outcomes

The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.

Consult Appendix A

- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B*
- *Guidelines for writing Learning Outcomes*

At the end of this course the student should be able to:

CARBOHYDRATES AND NUCLEIC ACIDS

- Draw the Fischer projection of glucose and the chair conformation of the anomers of glucose from memory.
- Recognize the structures of other anomers and epimers of glucose, drawn as either Fischer projections or chair structures, by noticing the differences from the glucose structure.
- Name monosaccharides and disaccharides, and draw their structures from their names.
- Predict which carbohydrates mutarotate, which reduce Tollens reagent, and which undergo epimerization and isomerization under basic conditions.

- Predict the products of the following reactions of carbohydrates: bromine in water, nitric acid, $NaBH_4$ or H_2/Ni, alcohols / H^+, CH_3I and Ag_2O, NaOH and dimethyl sulphate, acetic anhydride and pyridine, phenylhydrazine, Ruff degradation, Kiliani-Fischer synthesis
- Use the information gained from these reactions to determine the structure of an unknown carbohydrate.
- Use the information gained from methylation and from periodic acid cleavage to determine the ring size.
- Draw the common types of glycosidic linkages and recognize these linkages in disaccharides and polysaccharides.
- Recognize the structures of DNA and RNA and draw the structures of a ribonucleotide and a deoxyribonucleotide.

AMINO ACIDS, PEPTIDES, AND PROTEINS

- Name amino acids and peptides and draw the structures from their names.
- Use perspective drawings and Fischer projections to show the stereochemistry of D- and L- amino acids.
- Explain which amino acids are acidic, which are basic, and which are neutral. Use the isoelectric point to predict whether a given amino acid will be positively charged, negatively charged, or neutral at a given pH.
- Show how one of the following syntheses might be used to make a given amino acid: reductive amination, HVZ followed by ammonia, Gabriel—malonic ester synthesis, Strecker synthesis
- Predict products of the following reactions of amino acids: esterification, acylation, reaction with ninhydrin.
- Use information from terminal residue analysis und partial hydrolysis to determine the Structure of an unknown peptide.
- Show how solution-phase peptide synthesis or solid-phase peptide synthesis would be used to make a given peptide. Use appropriate protecting groups to prevent unwanted couplings.

LIPIDS

- Classify lipids both into the large classifications (such simple lipids, complex lipids, phospholipids etc.) and into the more specific classifications (such waxes, triglycerides, cephalins, lecithins, steroids, prostaglandins, terpenes, etc.)
- Predict the physical properties of fats and oils from their structures.
- Identify the isoprene units in terpenes and classify terpenes according to the number of carbon atoms.
- Predict the products of reactions of lipids with standard reagents. In particular, consider the reactions of the ester and olefinic groups or glycerides and the carboxyl groups of fatty acids.
- Explain how soaps and detergents work, with particular attention to their similarities and differences.

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?

Search for, analysis and synthesis of data and information, with the use of the necessary technology
Adapting to new situations
Decision-making
Working independently
Team work
Working in an international environment
Working in an interdisciplinary environment
Production of new research ideas
Project planning and management
Respect for difference and multiculturalism
Respect for the natural environment
Showing social, professional and ethical responsibility and sensitivity to gender issues
Criticism and self-criticism
Production of free, creative and inductive thinking
Others

By the end of this course the student will, have develop the following skills (general abilities):

1. Ability to demonstrate knowledge and understanding of the essential facts, concepts, theories and application which are related to Organic Chemistry and especially to the chemistry of heterocyclic compounds and biomolecules.
2. Ability to apply this knowledge and understanding to problem-solving in wider Organic Chemistry issues.
3. Ability to expand and apply methodology to the solution of more complex problems.
4. Study skills needed for continuing academic and professional development.
5. Ability to interact with others in chemistry or interdisciplinary problems.

Generally, by the end of this course the students should develop the following general skills:

Searching, analysis and synthesis of facts and information, as well as using the necessary technologies

Adaptation to new knowledge and combination of various concepts of chemistry

Decision making

Autonomous (Independent) work

Opportunity to assess the course and self-assessment

Promotion of free, creative and inductive thinking

3. SYLLABUS

CARBOHYDRATES AND NUCLEIC ACIDS

- Introduction
- Classification of Carbohydrates
- Monosaccharides
- D-L Sugars, Diastereomers, Epimers
- Cyclic Structures of Monosaccharides
- Anomers of Monosaccharides; Mutarotation
- Reactions of Monosaccharides: Side Reactions in Base, Reduction of Monosaccharides, Oxidation of Monosaccharides; Reducing Sugars, Formation of Glycosides, Ether and Ester Formation, Reactions with Phenylhydrazine, Chain Shortening: The Ruff Degradation, Chain Lengthening: The Kiliani-Fischer Synthesis
- Fischer's Proof of the Configuration of Glucose
- Determination of Ring Size; Periodic Acid Cleavage of Sugars
- Disaccharides
- Polysaccharides
- Nucleic Acids: Introduction
- Ribonucleosides and Ribonucleotides
- The Structure of Ribonucleic Acid
- Deoxyribose and the Structure of Deoxyribonucleic Acid
- Additional Functions of Nucleotides

AMINO ACIDS, PEPTIDES, AND PROTEINS

- Structure and Stereochemistry of the *a*-Amino Acids
- Acid-Base Properties of Amino Acids
- Isoelectric Points and Electrophoresis
- Synthesis of Amino Acids: reductive amination, HVZ followed by ammonia, Gabriel—malonic ester synthesis, Strecker synthesis
- Resolution of Amino Acids
- Reactions of Amino Acids: esterification, acylation, reaction with ninhydrin.
- Structure and Nomenclature of Peptides and Proteins
- Peptide Structure Determination
- Solution-Phase Peptide Synthesis
- Solid-Phase Peptide Synthesis
- Proteins

LIPIDS

- Introduction
- Waxes
- Triglycerides
- Reactions of Lipids: hydrogenation of glycerides, Saponification of Fats and Oils, transesterification; biodiesel
- Soaps and Detergents
- Phospholipids, Steroids, Prostaglandins, Terpenes

HETEROCYCLES

- Definition, Diversity and Categorisation of Heterocycles

Nomenclature

- Empirical names
- Method of Substitution
- Hantzsch-Widman system (IUPAC)
- Similarities and differences in reactivity between cyclic and aliphatic analogues

3- and 4--membered heterocycles

- Structure, stereochemistry and reactivity
- Syntheses of epoxides aziridines and β-lactams

Cyclisation reactions

- Kinetics and stereoelectronic effects in heterocyclisations
- Baldwin rules
- The Ring Closing Metathesis reaction in the synthesis of heterocycles
- 1,3 dipolar cycloadditions

5-membered aromatic heterocycles

- Structure, electronic properties
- Degree of aromaticity - aromatic *vs* diene behaviour
- Reactivity and regioselectivity in Electrophilic aromatic substitution reactions
- Reactivity and regioselectivity in Nucleophilic aromatic substitution reactions
- Acidity and Basicity of azoles
- Deprotonation of ring-carbon atoms and side chains
- Syntheses of 5-membered aromatic heterocycles

6-membered aromatic heterocycles

- Structure, electronic properties, nucleophilicity and basicity of azines
- Regioselectivity in Electrophilic aromatic substitution reactions
- Regioselectivity in Nucleophilic aromatic substitution reactions
- The Chichibabin reaction
- Reduction of pyridine rings - NAD/NADH
- Reactivity of substituents - similarities with benzene analogues
- Structure, electronic properties and reactivity of pyridine oxide
- Syntheses of pyridines, pyrazines and pyridazines

Fused aromatic heterocycles

- Nomenclature
- Structure and Reactivity of Indole, Quinoline and Isoquinoline
- Regioselectivity in Electrophilic aromatic substitution reactions

- Regioselectivity in Nucleophilic aromatic substitution reactions
- Syntheses of fused aromatic heterocycles.

4. TEACHING and LEARNING METHODS - EVALUATION

DELIVERY *Face-to-face, Distance learning, etc.*	Physical presence in Lectures and seminars.
USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY *Use of ICT in teaching, laboratory education, communication with students*	Use of Information and Communication Technologies (ICTs) (PowerPoint) in Lectures. Course lectures, in the form of ppt or pdf files, are uploaded in the internet (https://eclass.upatras.gr/courses/CHEM2056/), from where the students can be freely downloaded using password. Communication with the students is established either through mail or through the webpage of the Chemistry Department.
TEACHING METHODS *The manner and methods of teaching are described in detail.* *Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artistic creativity, etc.* *The student's study hours for each learning activity are given as well as the hours of non-directed study according to the principles of the ECTS*	
STUDENT PERFORMANCE EVALUATION *Description of the evaluation procedure* *Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open-ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical examination of patient, art interpretation, other* *Specifically-defined evaluation criteria are given, and if and where they are accessible to students.*	1. Optionally, at least one, half-term written examinations, the first one in the chapter of Biomolecules and the second in the chapter of heterocycles (immediately after the end of the semester). It is prerequisite that the students should at least obtain the grade 4 in the first half-term examination in order to be allowed to participate in the second one. 2. Written examination at the end of the semester - final mark, unless the student passed in half-term examinations. Minimum passing grade: 5. 3. The half-term examinations and the final written examination take place in the Greek language and for the foreign students (for example, ERASMUS students) in the English language. The assessment structure described above focuses on problem solving by combining the concepts and theories taught.

Activity	*Semester workload*
Lectures (3 contact hours per week x 13 weeks)	39
Seminars (1 contact hour per week x 9 weeks) - solving of representative problems	9
Half-term evaluations (2, one in the middle and the other at the end of the semester, 2 contact hours each)	4
Final written examination (3 contact hours)	3
Private study time of the student and preparation for the half-term evaluations and final examination	70
Course total	***125***

5. ATTACHED BIBLIOGRAPHY

1. J. McMurry, "Organic Chemistry", Translation to Greek: A. Varvoglis, M. Orfanopoulos, I Smonou, et al, University of Crete Publications, 2012.
2. L. G. Wade,Jr.,"Organic Chemistry", Translation to Greek: D. Komiotis, et al, A. Tziola and Sons Publications, 2010.
3. J. Clayden, N. Greeves, S. Warren, "Organic Chemistry", Vols I and II, Translation to Greek: G. Kokotos et al, Utopia Publications, 2017.
4. Notes from the teachers