Chemistry in Medicine within the course Medical Biochemistry and Chemistry

Objectives of the course: The knowledge that students acquire in the course of Chemistry in Medicine is aimed at understanding the basic chemical principles that will be applied to biochemical reactions and physiological processes. Knowledge of the structure and reactivity of biomolecules will be applied primarily in the learning of biochemistry, physiology, pharmacology, but also in the understanding of toxicology, as well as ecological and nutritional aspects of health.

Course outcomes: After attending the Chemistry in Medicine course, the student should know:

- Properties of solutions and colloidal solutions, concepts of molarity and osmolarity.
- Principles of chemical kinetics, equilibrium, acid-base equilibrium; basic thermodynamic functions.
- Mechanisms of heavy metal toxicity.
- Determination of direction and spontaneity of biological redox reactions based on electrochemical potential.
- Reactivity of unsaturated compounds and functional groups in biomolecules (hydroxyl, thiol, carbonyl, carboxyl and amino groups). Types and importance of isomerism in organic molecules.
- Toxicity of persistent organic compounds.
- The structure and properties of heterocyclic compounds as a part of biologically important molecules.
- Structure and properties of proteins, carbohydrates, lipids, nucleic acids.
- Basic rules of work and techniques in a chemical laboratory; to recognize laboratory vessels, correctly use an automatic pipette, pipette, to measure on an analytical balance and know how to fill a Erlenmeyer flask and read a burette.
- To make a solution of a specific concentration and make serial dilutions of the solution.
- To understand the principle of colorimetry and spectrophotometry, to be able to make a standard curve and use it to determine the unknown concentration of the solution.
- To apply volumetric methods for determining the concentration of electrolytes in a solution.
- To perform characteristic reactions of functional groups in organic and biologically significant compounds.
- To use bioinformatics databases and tools for the analysis of proteins, carbohydrates and lipids, as well as to use reference chemical databases in order to determine the effects of selected inorganic and organic substances on health.

The Structure of the Course:

Semester	Lectures	Seminars	Labs	Other	Summ	ESP points
III	30	15	27	/	72	/

Methodical units – winter semester

Lectures		
No.	**Topic**	**Classes**
1	Water. Structure, chemical and physical properties of water. Influence of chemical structure on solubility, intra and intermolecular bonds. Covalent bond and non-covalent interactions. The structure of biomolecules as a consequence of interaction with water, the formation of micelles and bilayers as a mode of organizing amphipathic molecules in water. Solutions. Properties of colloidal solutions. Colloidal solutions of biomacromolecules (solutions of proteins, nucleic acids). Stability of colloidal solutions. Principles of dialysis, hemodialysis; Isoelectric point of colloids.	3 classes and 15 minutes
2	Thermodynamic changes during chemical reactions in living systems. Free energy as an indicator of spontaneity in biochemical reactions. Exergone and endergone reactions. Chemical kinetics. Factors affecting the rate of reaction. Transition state, activation energy. Molecularity and chemical reaction order. Chemical equilibrium, equilibrium constant, Le Chatelier's principle. Standard free energy and equilibrium constant in biochemical reactions	3 classes and 15 minutes
3	Electrolytes. Theories of acids and bases. Dissociation constant of acids and bases. Acid-base balance. Amphoteric electrolytes. Ionic product of water, concentration of H^+ ions and pH of body fluids. Neutralization. Salts: types, hydrolysis, toxicity. Solubility product.	3 classes and 15 minutes
4	Structure and classification of organic molecules. Double bond reactivity, geometric isomerism. Types of reactions in organic chemistry. Aromatic compounds, properties and reactivity. Hard-to-degrade organic pollutants as a health hazard. Heterocyclic compounds and their derivatives in biomolecules.	3 classes and 15 minutes
5	Reactivity of the hydroxy group in alcohols and phenols: oxidation, dehydration, esterification. Biologically important dihydroxyphenol derivatives: hydroquinone/quinone and coenzyme Q. Sulfhydryl group: reactivity in biomolecules (oxidation to disulfide, formation of thioesters with acids, formation of insoluble salts with heavy metals - heavy metal poisoning). Carbonyl group in aldehydes and ketones: properties and reactions of nucleophilic addition to the carbonyl group, Amines, aminoalcohols and biogenic amines.	3 classes and 15 minutes
6	Carboxylic acids. Derivatives of carboxylic acids (anhydride, ester, amide group). Derivatives of carbonic acid. Redox reactions of organic and biomolecules. Standard and biological redox potentials. Relationship between free energy change and redox potential, prediction of spontaneity of chemical reaction. Free radicals: reactive forms of oxygen and nitrogen, mechanism of formation, physiological role. Antioxidants: enzymatic and non-enzymatic. Oxidative stress and the consequences of the action of free radicals with large intracellular molecules: lipids, proteins, DNA.	3 classes and 15 minutes
7	Structure, stereochemistry and reactions of amino acids. Peptide bond. Biologically important peptides. Structural levels of proteins: primary, secondary, tertiary and quaternary. Domains-structural and functional specificity.	3 classes and 15 minutes
8	Structure and properties of saturated and unsaturated fatty acids, simple and complex lipids. Structure and properties of purine and pyrimidine bases, nucleosides and nucleotides. Structure and properties of nucleic acids (RNA and DNA). N-glycosidic bond in nucleosides and phosphoester bond in nucleotides. The importance of the anhydride bond in di- and triphosphonucleotides (ADP, ATP).	3 classes and 15 minutes

9	Protein-ligand interactions. Biomolecules as catalysts. Basics of proteomics technology. Carbohydrates. Stereochemistry and reactivity of monosaccharides. Reducing and non-reducing disaccharides. Polysaccharides.	3 classes and 15 minutes

Seminars		
No.	**Topic**	**Classes**
1	Classification of solutions according to state of matter and particle size of the dissolved phase. Characteristics of solutions. Dissolution of gases in water (Henry's law), concept of osmole and osmolarity. Concentrations of solutions: mass, quantity, molal; ionic concentrations. Calculation tasks.	1 class and 30 minutes
2	Energetics: enthalpy, entropy and free energy. Spontaneity of reactions. Kinetics of biologically important chemical reactions. Connecting endergonic and exergonic reactions as a thermodynamic basis for the functioning of metabolism. Energy-rich bonds and the role of ATP in energy-coupled reactions. Calculation tasks.	1 class and 30 minutes
3	Equilibria in aqueous solutions, buffers and their capacity, Henderson-Hasselbach equation. Blood and kidney buffer systems. Calculation tasks.	1 class and 30 minutes
4	Structure and isomerism of organic compounds. Recapitulation of general chemistry materials.	1 class and 30 minutes
5	Biologically significant reactions of functional groups: - esterification of the -OH group with organic and inorganic acids (phosphoric and nitric acid), - formation of hemiacetal and acetal; cyclic hemiacetals as dominant structures of monosaccharide in aqueous solutions. -addition of ammonia and amines to carbonyls (formation of imines - Schiff's bases). -aldol-addition, formation of nucleophile and reaction with carbonyl group (condensation of acetyl coenzyme A with α-ketoacids and lengthening of the chain by 2 C-atoms)	1 class and 30 minutes
6	Structure, stereochemistry and reactivity of biologically important substituted acids (hydroxy, oxo). Redox reactions of organic and biomolecules. Most important biological redox systems (NAD^+ | NADH; glutathione (ox. form) | glutathione (red.form); pyruvate | lactate; dehydroascorbate | ascorbate).	1 class and 30 minutes
7	Conformational changes of proteins *in vivo* and *in vitro* (denaturation, renaturation). Protein stability in physiological conditions. Complex proteins.	1 class and 30 minutes
8	Complex lipids: classification and properties; structure of membranes. Sterols, steroids, bile acids, hormones, vitamins.	1 class and 30 minutes
9	Medically significant carbohydrate reactions. Glycoproteins and glucosaminoglucans in medicine.	1 class and 30 minutes

Lab		
No	**Topic**	**Classes**
1	Basic techniques of work in the laboratory. Use of scales, pipettes, micro-pipettes. Making a solution of a certain concentration: by measuring the solid substance and diluting the solution.	3
2	Determination of the activation energy of the sucrose hydrolysis reaction in an acidic environment using the colorimetric method.	3

3	Buffers, mechanism of action, capacity. Preparation of buffer solution. Calculation tasks from the buffer. Serial dilutions of solutions.	3
4	Serum electrolytes. Quantitative determination of ions Ca^{2+}, Cl^-, HCO_3^-.	3
5	Reactions of hydroxy, amino, mercapto, carboxyl functional groups. Reactions of urea. Reactions of substituted acids.	3
6	Oxido-reduction reactions of organic molecules. Colloidal solutions of bio macromolecules.	3
7	Colored and precipitation reactions of proteins. *In silico* protein analysis.	3
8	Hydrolysis of triglycerides and specific reactions of the obtained components. Addition to unsaturated fatty acids. Quantitative determination of cholesterol. Acid hydrolysis of nucleoproteins. Identifying building components of nucleoproteins. *In silico* analysis of lipids.	3
9	Reduction reactions of mono- and disaccharides. Color reactions of monosaccharides. Sucrose inversion. Hydrolysis of starch with HCl. In silico analysis of carbohydrates.	3

Absences and making up for missed classes

The student has the right to a total of two absences from the seminar during classes, without compensation. He makes up for the third absence from the seminar with an appropriate request and justification, in agreement with the teacher who taught him. A student can miss a maximum of 3 labs, but he is obliged to make up for all missed labs in the make-up periods of which he will be informed in a timely manner. The student is obliged to prepare the seminar and/or exercise/s that he/she makes up for. In case of a large number of absences, the provisions of the Rules of Procedure on the organization and performance of integrated academic studies at the Faculty of Medicine are applied (Article 21).

Continuous testing of knowledge

Chemistry knowledge is evaluated by taking tests covering three areas:
1) general chemistry, 2) organic chemistry and 3) chemistry of natural products. Each of the areas carries 32 points and it is necessary for the student to achieve more than 50% of correct answers, i.e. 17 points in each of the three areas, i.e. minimum 3 x 17 = 51 to pass chemistry.
Passed chemistry is valid permanently and is a requirement for passing Medical Biochemistry.
Tests are taken twice during classes:
I The first test is taken in the fourth week of classes and covers the following area: General Chemistry,
II The second test is taken in the tenth week of classes and covers two areas:
1) Organic chemistry and 2) Chemistry of natural products.

Students who do not pass one, two or all three areas within the I and II tests can take the unpassed areas through the final tests in the test dates before each exam period, upon notification to the department. Students will be informed in a timely manner about the dates and methods of applying for the exam, as well as the dates of the exam.

Structure of the final exam and requirements for passing it

The final exam is in the form of tests by subjects, as described in the previous paragraph. Passed tests are valid permanently and are a requirement for passing the Biochemistry exam.

Forming the final grade

The maximum number of points that a student can obtain in Chemistry is 100:
- 3 areas of 32 points each
- regularity in attending theoretical classes (maximum 4 points).

Additional points (maximum 9) can be obtained by the student through homework, active participation and continuous evaluation of knowledge in seminars and exercises.

A part of points from Chemistry in the final grade in the subject Medical Biochemistry and Chemistry is 30%. The final grade is calculated by multiplying the points obtained in Chemistry (51-100) by 0.3 and adding them to the points obtained in Medical Biochemistry multiplied by 0.7:

(points in Chemistry x 0.3) + (points in Medical Biochemistry x 0.7) = total points.

The calculated total points are then translated into a final grade in the course Medical Biochemistry and Chemistry.

Recommended literature

1. SELECTED CHAPTERS FROM THE BOOK „FUNDAMENTALS OF GENERAL, ORGANIC AND BIOLOGICAL CHEMISTRY", McMurry, Ballantine, Hoeger, Peterson, Publisher: *Pearson;* 8th *Edition*, 2016.
2. SELECTED CHAPTERS FROM THE BOOK „INTRODUCTION TO CHEMISTRY: GENERAL, ORGANIC AND BIOLOGICAL CHEMISTRY", (v. 1.0), e-book
3. A PRACTICAL GUIDE TO CHEMISTRY EXERCISES WITH A WORKBOOK AND A COLLECTION OF NUMERICAL PROBLEMS for 2nd year students of the Faculty of Medicine. Translated 6th Serbian Edition, Editor of 6th English Edition Kristina Gopčević PhD, Editor of Serbian

edition: Ivanka Karadžić, PhD. Authors: Kristina Gopčević, PhD., Ivanka Karadžić, PhD, Vesna Vujić, PhD, Ksenija Stojanović, PhD, Vesna Dragutinović, PhD, Danijela Krstić, PhD, Branimir Radosavljević, PhD, Nataša Avramović, PhD, Lidija Izrael-Živković PhD and Rade Bašić, Faculty of Medicine, University of Belgrade, 2023.

List of teachers and associates

Kristina Gopčević, PhD, full professor

Danijela Krstić, PhD, full professor

Nataša Avramović, PhD, assoc. professor

Lidija Izrael-Živković, PhD, assoc. professor

Ana Medić, PhD, assist. professor

Saša Vatić, MSci chem, assistant

Teodora Djukić, MSci biochem, assistant

Zorana Lopandić, MSci biochem, assistant

Contacts:

Function	Name and Surname	Phone No	e-mail
Course director	Kristina Gopčević, full professor	+381 11 360 71 37	kristina.gopcevic@med.bg.ac.rs
Department secretary	Ana Medić, assist. prof.	+381 11 360 71 38	ana.medic@med.bg.ac.rs
Coordinator for on-line teaching	Saša Vatić, assistant	+381 11 360 71 38	sascha.vatic@med.bg.ac.rs
The technical secretary of the department	Mirjana Vuletić	+381 11 360 70 58	mirjana.vuletic@med.bg.ac.rs

Social networks and other communication channels
QR code to access the course on the Moodle platform