SYLLABUS OF THE SUBJECT
„MEDICAL CHEMISTRY FOR DENTISTRY“
the 1st year, summer session, 2023/2024

Range of education: 24 hours lectures /24 hours seminars and laboratory practices

Responsible for teaching of subject:

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Introduction to study – position of medical chemistry in the medical subjects, system of study, its content, meaning, aim and a brief survey of history.

PRINCIPLES OF CHEMISTRY OF LIVING SYSTEMS

Chemical composition of living systems

- **Chemical bond as part of biological systems** – covalent bond, ionic bond, hydrogen bond, van der Waals forces, hydrophobic interactions. Bonding in coordination compounds – ligand, central atom, complex, coordination number, chelates, important biological ligands.
- **Occurrence of biogenic elements in the organism and their physiological functions** - classification, occurrence and functions of permanent primary and secondary elements and their compounds. Occurrence and functions of trace elements – Fe, Cu, Zn.
- **Radicals** - properties and importance of free radicals in pathophysiological processes of the organism. Fenton and Haber-Weiss reaction, antiradical (antioxidant) systems.
- **Elements and their compounds significant from a toxicological point of view** – As, Cd, Hg, Pb. The essence of the toxic effects of metal ions in the body, absorption, biological half-life. Toxicity of organometallic compounds.; Therapeutic chelating agents.
- **Chemical structure of bones and teeth**

Dispersed systems and their relationship to the organism

- **Basic terms:** Definition and classification of dispersed systems: according to number of phases and physical state of dispersed medium and dispersed phase. Classification according to the size of particles of dispersed phase. Properties of each type
- **Analytical dispersed systems (True solutions)** - general characterization, polar and nonpolar solvents, character of solute, solvatation, hydratation, dissolution of polar and nonpolar solutes, ionic and molecular true solutions, calculations of the composition of solutions. Water as dispersed medium of organism, its other functions in the organism. Colligative properties of solutions, osmotic pressure. Diffusion, osmosis, dialysis. Importance of diffusion in the organism. The application of dialysis and hemodialysis in medicine. Ionogram of blood plasma and intracellular medium, isoionia and its failure in organism.

- **Colloidal dispersive systems** - structure of colloidal particles, properties of colloids and their biological importance. Oncotic pressure. Exchange of compounds between blood and tissues. Edema development. Sol, gel, classification of colloidal solutions – lyophilic, lyophobic, micelles. surface active compounds (tensides, surfactants)
- **Crude dispersed systems** – their properties, examples
- **Biological importance of colloids and crude dispersed systems.**

Chemical reactions in biological systems

- **Kinetics and equilibrium** of chemical and biochemical reactions. The rate of chemical reaction, effect of reagents concentration and temperature on reaction rate, catalysis, rate constant, activation energy. Le Chatelier principle, equilibrium constant and its meaning.
- **Protolytic (acid-base) balance of the internal environment of organism**. Bronsted acids and bases, pH and its calculation for strong and weak acids and bases, the significance of pH for the course of biochemical processes. Systems maintaining the stability of pH of the environment in the organism, buffer systems, maintenance of blood pH.
- **Oxidation, reduction, redox processes and their biological significance**. Dismutation, oxidative and reducing agents, reduction potential. Driving force of redox events.
- **Pathophysiological importance of redox processes in the oral cavity.**
- **Oral cavity and pH.**

Organism as thermodynamic system

- **Characterization of a biological system** from thermodynamic point of view, stationary state of organism.
- Energetic sources, energy conversion and energy utilization in living systems.
- Chemical energy of nutrients and basic mechanism of energy release, biosynthesis of water.
- **The 1st law of thermodynamics, Hess´s law.**
- **The 2nd law of thermodynamics**. **Entropy** and biological system, mutual relationship between information and entropy.
- Significance and transmission of free energy in biological systems, **energy rich compounds**.
- **Gibbs free energy,** standard Gibbs free energy, spontaneity of reactions. Coupling of exergonic and endergonic reactions.

Structure and biochemically significant reactions of organic coumpounds

- Characterization of **the structure and biochemically important reactions** of bioorganic compounds.
- **Biochemically significant reactions** (oxidation, reduction, hydrogenation, dehydrogenation, hydration, dehydration, deamination and decarboxylation reactions, esterification, hydrolysis, formation of hemiacetals and acetals, formation of Schiff bases, aldol condensation and others).
- **The relationship between the structure, properties and biological function** of individual groups of organic compounds (halogen derivatives, alcohols, esters, thioesters, aldehydes, ketones, carboxylic acids and their hydroxy- and oxo-derivatives, biologically significant heterocyclic compounds).
- **Biologically significant amines and thiols** (ethanolamine, choline, histamine).
- **Biologically significant derivatives of carbonic acid and urea**
- **Clinically significant products of metabolism. Formation of ketone bodies and urea.**

- **Reactions of organic acids occurring in the Krebs cycle.**
- **Organic compounds significant from a toxicological point of view.**

Structure, properties and biological function of natural compounds

SACCHARIDES - function, classification and formation of saccharides in the nature.

- **Monosaccharides** - stereochemistry of monosaccharides.
  Optical isomerism and configuration, epimers, cyclo – acyclo isomers, anomers, mutarotation. Fisher´s, Tollen´s and Haworth´s formulas.
  Conformation of monosaccharides. The most frequent mutual transformations of monosaccharides in the organism (epimerisation, isomerisation).
- **Biological importance** of monosaccharides.
- **Reactions of monosaccharides** – oxidation, reduction, esterification, formation of hemiacetals and acetals, formation of glycosidic bond.
- Review of important **derivatives of monosaccharides** – phosphate esters, L-ascorbic acid, uronic acids (detoxification effect of glucuronic acid in normal metabolism), amino saccharides (glucosamine, N-acetylglucosamine), deoxysaccharides.
- **Polysaccharides (glycans)** – classification and structure (molecular structure, conformation).
- **Homoglycans** – types of monomers and bonds between them, biological importance, hydrolysis (starch, glycogen, dextran, chitin).
- **Heteroglycans** – the structure and biological functions (glycosaminoglycans – hyaluronic acid, chondroitin sulphate, dermatan sulphate, heparin).
- **Proteoglycans** - functions in the organism.
- **Glycoproteins** as a part of some enzymes, proteohormones, immunoglobulins
- **Saccharides as risk factor of dental caries.**

LIPIDS - their classification, composition and biological function in organism.

- **Simple lipids** – their classification, their individual components, the structure and bonds between them.
- **Complex lipids** – their classification, their individual components, the structure and bonds between them.
- **Phospholipids** – classification. Glycerophosphoric acid and phosphatidic acids.
  Glycerophospholipids (phosphatidylcholines, phosphatidylethanolamines, phosphatidylserines, plasmalogens, cardiolipins).
  Sphingophospholipids, structure. Ceramide.
- **Glycolipids** (cerebrosides, sulphatides, gangliosides). Composition and properties.
- **Lipoproteins** - their classification, composition and biological function in organism.
- **Physico-chemical properties of the complex lipids** and their biological function. Physiological and pathological enzymatic hydrolysis of phospholipids. Formation of lysolecithins. Amphiphilic character of phospholipids. Hydrophobic and hydrophilic parts of phospholipid molecules and their role in consequent biological properties.
- **Biological membranes.** Principle of lipid organisation in cell membrane.
- **Significance of the lipids in nutrition, Lipases.**
- **Arachidonic acid** - cascade mechanism of its oxidation. Formation of eicosanoids, endoperoxides, prostaglandins, thromboxanes, prostacyclins and leukotriens. Structure, occurrence, biological function and therapeutic utilization of eicosanoids.
- **Steroids** – basic structure. The basic saturated hydrocarbons of steroids (estrane, androstane, pregnane, cholane, cholestane). Classification according to the number of carbon atoms and functional importance. Sterols, cholesterol. Provitamins and vitamins D. Bile acids – cholic acid.
- **Steroids hormones** (corticoids, sex hormones – androgens, gynecogens (estrogens and gestagens). Biological importance of steroids, occurrence in the organism.

- **Terpenes** – isoprene, monoterpenes, sesquiterpenes, diterpenes, triterpenes, tetraterpenes. Basic hydrocarbons and derivatives of terpenes important from biological point of view.

AMINOACIDS (AA):

- **Proteinogenuc amino acids** – structure, properties.
- **Some basic metabolic reactions of AA** in the organism as well as in diagnostics: desaturation deamination, oxidative deamination, decarboxylation, formation of Schiff bases, aminotransferase reactions (transamination), formation of carbamine ion, formation of amides.
- **Biological important amines.**

PEPTIDES - formation, classification, terminology.

- **Biologically important peptides** – anserine, carnosine, glutathione – their role in the organism.
- **Hormons** – oxytocine, vasopresine, calcitonine, insuline, glucagone and their biological significance.
- **Antibiotics** – gramicidine, actinomycine, penicillin (without formulas).
- **Toxins** – ammanitine, phaloidine (without formulas).
- **Opiate peptides** – endorphins, enkephalins (without formulas).

PROTEINS

- **Colloidal character of proteins**, electrical properties, isoelectric point, solubility, salting-out, denaturation and biological properties.
- **Bonds responsible for primary, secondary, tertiary and quaternary structures.**
- **Classification of proteins** – holoproteins, heteroproteins – types of bonds of heterogenic parts with the proteins, importance from the biological viewpoint (H_3PO_4, metal, nucleic acid, etc.).
- **Classification of heteroproteins** – composition, physiological function.
- **Hemoproteins** – structure and function of myoglobin, hemoglobin, cytochroms.
- **Immunoglobulins** – structure and biological function.
- **Proteins of cell nucleus** - histones.

NUCLEIC ACID (NA)

- **Nucleotides** and their building components (saccharide, heterocyclic nitrogen base, phosphoric acid). Nitrogen bases **tautomerism** (lactam-lactim, amino-imino). Minor bases, pseudouridine and other minor nucleosides. The types of **chemical bonds in nucleotides**.
- **Structure of biologically important free nucleotides** – nucleoside polyphosphates, cAMP, FMN, FAD, NAD^+, $NADP^+$, coenzyme A.
- **Nucleic acids – DNA, RNA** – composition, structure, properties, functions in organism. Alternative double-helical structures, supercoiling, basic classes of RNA. Organization of DNA in the cells, genetic information.

OXIDATIVE STRESS

- **Free radicals and their importance** for physiological and pathophysiological processes. Free radical diseases
- **Peroxidation** of unsaturated fatty acids in membranes, toxic effect of free radicals and heavy metals.
- **Effect of oxidative stress to biologically important** molecules – markers of oxidative damage to lipids, proteins and nucleic acids
- **Antioxidant systems in the organism** - their classification and function in protection of organism against the damage with reactive oxygen species.

INTRODUCTION TO ENZYMOLOGY

ENZYMES – BIOCATALYSTS – Catalysis of biochemical reactions

- **General characteristic of the enzymes** - differences between catalysts and biocatalysts. Influence of the enzymes on the decrease of the activation energy. Mechanism of enzyme catalysis - formation of the enzyme – substrate complex.
- **Enzyme reaction rate**
  The rate of single-substrate reactions, mechanism of enzyme reaction, Michaelis-Menten equation, Michaelis constant K_M - graphical evaluation (saturation curve and the curve by Lineweaver and Bürk), multisubstrate reactions – ternary complex mechanism, ping-pong mechanism, types of enzyme catalysis.
- **Active center of the enzymes** – Functional groups of the protein chain of the enzyme - their presence in the binding and catalytic part of the active site. Cofactors – coenzymes, prosthetic groups and their importance in enzyme catalysis. Specificity of effect and substrate specificity. Classification of enzymes according to individual types of specificity. Isoenzymes, lactate dehydrogenase.
- **Units of enzyme catalytic activity** – catal, U, relation between them
- **Regulation of enzyme activity:**
  The influence of physicochemical factors on enzyme activity: pH, temperature, enzyme concentration, substrate concentration, ionic strength and redox potential. Inhibition of enzymes - irreversible inhibition - by iodoacetamide, diisopropylfluorophosphate, specific inhibitions - competitive, non-competitive, uncompetitive, allosteric, their principles, K_M, Vmax, graphic representation according to Michaelis-Menten and Lineveawer Burk. Inhibitors in medicine. Acetylsalicylic acid as a cyclooxygenase inhibitor. Allopurinol as a xanthine oxidase inhibitor. Ethanol as a competitive inhibitor in methanol and ethylene glycol toxicity. Allosteric regulation of enzyme activity - cooperative and sequential model, regulation of activity by modification of the enzyme molecule - covalently modulated enzymes (phosphorylation, dephosphorylation), regulation of enzyme activity by limited proteolysis, regulation of enzyme activity by the action of metal ions. Regulation of enzyme synthesis - induction, repression. Regulated protein degradation - proteasome. Regulation of metabolic pathways - feedback regulation, feed-forward activation.
  Nomenclature of enzymes − trivial and systematic. Basic characteristics of individual classes of enzymes.

VITAMINS AND COENZYMES as a part of the biocatalysts.

- **Vitamins soluble in lipids**
  Vitamin A, vitamin D, vitamin E, vitamin K and the vitamin F.
- **Vitamins soluble in water** and their importance as coenzymes. Vitamins of B-complex and vitamin C
  Vitamins as coenzymes transporting hydrogen and electrones. Nicotinamide coenzymes (NAD^+, $NADP^+$), their structure and mechanism of their action. Flavine coenzymes (FAD, FMN) their structure and mechanism of their action.
  Coenzyme Q, lipoic acid, derivates of the porphyrines.
  Coenzymes transporting groups of atoms - Adenosin-phosphates (ATP, ADP, AMP, cAMP, UDP).
  Coenzyme A, coenzyme F, tiamindiphosphate, pyridoxalphosphate, biocytine, vitamin C - nonenzyme redox system in organism
  Antivitamins

DENTAL MATERIALS ACCORDING TO THEIR CHEMICAL STRUCTURE

- **Ceramic materials** – ceramics and metalloceramics, chemical composition of dental porcelains, structure of silicates and feldspar.
- **Dental alloys** – metal alloys - gold and silver alloys, white gold, noble-minded and compensation alloys, titan alloys and pure titan as dental implants, amalgams (alloys of metals with mercury), composition of amalgam.
- **Resin composites** – methyl methacrylate resins, epoxy resins, BisGMA resins, urethane dimethacrylate resins, monomer systems, compomers.
- **Monomers of dentine adhesives** – structural principle of bifunction molecules, monomer systems of dentine adhesives.
- **Dental cements** – silicate cements, zinc phosphate cements, zinc oxide eugenol cements, zinc polycarboxylate cements, glass-ionomer cements.
- **Impression materials and dental waxes** – elastic materials (nonaqueous elastomers-polysulfide rubber, silicones and polyethers, reversible hydrocoloids - agar and irreversible hydrocoloids – alginates). Nonelastic materials – ZnO-eugenol and gypsum.
- **Biocompatibility of dental materials**

PHYSICO-CHEMICAL ANALYTICAL METHODS

- **Basic classification** and general principles of individual groups of methods.
- **Spectrophotometry** - principle, basic law (name and formula), definition of molar absorption coefficient, absorption spectrum and analytical curve.
  Application of spectrophotometry in biochemistry.
- **Sedimentation and centrifugation** – principles, relative centrifugal force, applications in biochemistry.
- **Thin layer chromatography** – principle, definition of retention factor.

The form of exam: WRITTEN

LITERATURE

Obligatory:

1. **Országhová Z., Žitňanová I. et al.**: Medical Chemistry. Vydavateľstvo UK, Bratislava, 2010, 272 s.

Recommended:

2. **Holum J.R.:** Fundamentals of General, Organic and Biological Chemistry, 6th Edition, John Wiley and Sons Inc., New York, 1998
3. **Van Noor, R**.: Introduction to Dental Materials. 2nd ed. London: Mosby, 2002, 298p.