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STATE UNIVERSITY OF MEDICINE AND PHARMACY
«NICOLAE TESTEMITANU»

Department of Biochemistry

BIOORGANIC CHEMISTRY

BRIEF PRACTICAL GUIDE

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Chief of Department –
univ. professor Leonid LYSYI

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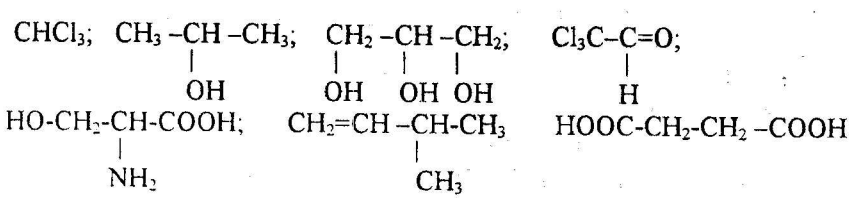
THEME №1. THE BASIC PRINCIPLES OF CLASSIFICATION AND NOMENCLATURE OF ORGANIC COMPOUNDS

QUESTIONS AND EXERCISES

1. Give the classification of organic compounds. Write the structure: a) of aromatic hydrocarbons: benzene; naphthalene; anthracene; phenanthrene. b) of heterocyclic compounds: pyrrole; imidazole; pyridine; pyrimidine; purine.
2. Write the structural formulas of radicals: methyl, ethyl, propyl, isopropyl; phenyl.
3. Name according the systematic nomenclature IUPAC the following compounds:



4. Name according the systematic nomenclature the malic acid and specify functional groups: HOOC - CH - CH2 - COOH
   OH
5. Write constitutional formulas of compounds: Propanon-2; 2-oxopentandioic acid; propantriol-1,2,3; Propenoic acid; butenedioic acid.
6. Write the structure of methane (1-methyl, 4-isopropylcyclohexane) and specify to what class of compounds concerns.
7. Menthol (2-isopropyl, 5-methylcicl6hexanol-1) is included into composition of a medical preparation "Validol". White the structure of menthol.

THEME №2. SPATIAL CONSTITUTIONS OF ORGANIC COMPOUNDS. STEREOISOMERIA.

1. Give the definition to notions "structure", "configuration", "conformation". What kinds of formulas are used to image the configuration and conformation?

2. Represent using corresponding formulas the constitution, configuration and conformation of ethanol, ethylamine, chlorethane.
3. Represent the structure, configuration and conformation of n-butane. What from conformations is the steadiest?
4. Write the structure, configuration and steady conformations of colamine (2-aminoethanol-1), included into the composition of phospholipids of cellular membranes.
5. Write the structure and steadiest conformation of cyclohexane. Specify axial and equatorial bonds.
6. Represent the structure and configuration of the substituted atoms of carbon and steadiest conformation of 1,3-dibromocyclohexane.
7. Give the definition to notions: asymmetric carbon atom, enantiomers, racemates, stereoisomers.
8. What substance is used as a configuration standard for determine the enantiomers belonging to D- and L-stereochemical series? Represent the Fisher projection of this substance as D- and L- enantiomers.
9. Represent the enantiomers of lactic acid (2-hydroxy-propanoic acid) using Fisher projection formulas. Specify D- and L- enantiomers.
10. Write the formulas of all stereoisomers of tartaric acid (2,3-dihydroxybutanedioic acid). Specify D- and L - stereoisomers.

THEME №3. CONJUGATION AS A FACTOR OF RISING OF MOLECULAS STABILITY. RECIPROCAL INFLUENCE OF ATOMS IN MOLECULAS OF ORGANIC COMPOUNDS.

QUESTIONS AND EXERCISES

1. Give the definition of notion "conjugation". Specify the kind of conjugation in moleculas of phenol, toluene, aniline, butanediene-1,3, chlorobenzene.
2. Give the definition of notion "energy of conjugation". What is the difference between the energy of conjugation of hexatriene-1,3,5 and of benzene? Explain, why they are not alike?

3. Give the definition of notion "aromaticity". Write the structural formula of naphthalene, anthracene, phenanthrene, pyrrole, pyridine, pyrimidine, imidazole, purine. Explain, why they are aromatic compounds.
4. Show the electronic structure of pyrrolic and pyridinic nitrogen atom. Explain why pyrrole is a heterocyclic system with an excess of electronic density and pyridine is a π-deficient system?
5. What is the positive inductive effect and negative inductive effect? Represent graphically inductive effects of substitutes in the following molecules: chlorethane, methanol, toluene, aniline, p-aminobenzoic acid.
6. Give the definition of notion "mezomeric effect". Represent graphically, indicating the sign of this effect of substitutes in molecules of following substances: salicilic acid (2-hydroxybenzoic acid), n-nitroaniline, p-aminophenol, benzaldehyde, chlorbenzene.
7. Which substitutes are called electron-donor (ED) and electron-acceptor (EA)? Determine what kind of substitute is amino-group in ethylamine, aniline.
8. Indicate the electronic effects' type and sign of: a)hydroxyl group in p-cresol (p-methylphenol), phenol, ethanol; b) amino group in aniline, ethylamine, p-aminobenzoic acid; c) chloride atom in chlorobenzene, benzyl chloride, chloroethane, vinyl chloride.

THEME №4. ACID AND ALKALIN PROPERTIES OF ORGANIC COMPOUNDS. REACTIONS OF ELECTROPHILIC ADDITION AND ELECTROPHILIC SUBSTITUTION.

QUESTIONS AND EXERCISES

1. Give the definition of the notion "acid" accoding to the Brønsted's theory. Enumerate factors, which influence on the activity of organic compounds.
2. Arrange in series on decreasing of acidity the following compounds: ethanol, ethanethiol, phenol; ethanol, 2-chloroethanol, 2,2-dichloroethanol; phenol, p-aminophenol,

p-nitrophenol; propanol-1, ethandiol-1,2, propantriol-1,2,3, ethanol, phenol, acetic acid.

3. Give the definition of the notion "base" accoding to the Brønsted's theory. Which factors determine the basicity of an organic compound.
4. Arrange in series on decreasing of basicity the following compounds: ethanol, ethantiol, ethylamine; ethanol, diethyl ether, diethyl sulphide; ethylamine, aniline, p-methylaniline; ethylamine, diethylamine, aniline.
5. Which are the criterions of classification of organic reactions? What types of reagents exist? Give some examples.
6. Write reactions of the hydrochlorination of the ethylene and propylene. Describe the mechanism of A_E reactions and name products.
7. Write reactions of the hydration of the ethylene and propylene. Describe the mechanism of AE reactions and name products.
8. Write reactions of bromination and methylation of benzene. Specify conditions and describe the mechanism of SE reactions.
9. Effect of substitutes on S_E reactions. Specify, what functional groups are substitutes of 1th and 2th type. Give some examples.
10. Write reactions bromination of phenol and benzoic acid. Specify conditions and name products.

LABORATORY WORK

1. Sodium ethylate obtaining and hydrolysis.

Materials: absolute ethanol, sodium metallic, indicator - phenolftaleine, dry test-tubes, rubber corks, water.

Bring in 3 drops of absolute alcohol and a small piece of sodium metallic to a dry test-tube. For hydrogen accumulation the test-tube must be closed with a rubber cork. When the reaction is finished approach the test-tube to the flame and take off the cork. It take place an explosion with a whistling sound, which confirm the burning of hydrogen and air mixture. Add 2-3 drops of water and a drop of phenolftalein solution in ethanol to the white sediment of sodium ethylate, which was obtained. What do you observe? What is the cause of red colour

appearance? Write the reactions, which have been produced in this experience.

2. *Sodium phenolate obtainind and decomposition with acids.*

Materials: phenol crystals, NaOH 10 %, HCl 10%, water, dry test-tubes.

Bring in several crystals of phenol and 3 drops of water to a dry test-tube and shake well. What do you observe? Add several drops of sodium hydroxide to the obtained emulsion till the solution become transparent. Then acidulate the obtained solution with several drops of hydrochloric acid (HCl) 10%. The solution become turbid (muddy) again. Why? Write the reactions' equations, the observations and the conclusion of this experience.

3. *Basicity of aliphatic and aromatic amines*

Materials: diethylamine, aniline, HCl 10% solution, saturated solution of picric acid, water, universal indicator, test-tubes.

Introduce in twos drops of water in two test-tubes. Add a drop of aniline (C_6H_5-NH_2) in the first test-tube, and a drop of diethylamine ((C_2H_5)$_2$NH) in the second one. Shake well both test-tubes. What do you observe? Determine the pH of obtained solution in each test-tube using the universal indicator. What do you observe?

Add a drop of hydrochloric acid 10% to the solution of aniline in water. What do you observe? Why the solution becomes transparent? Add 3-4 drops of saturated solution of picric acid to the solution of diethylamine. What do you observe? Why the solution colour changes? In some time a sediment of diethylamine picrat is falling. Write the equations of reactions between aniline and hydrochloric acid; between diethylamine and picric acid (2,4,6-trinirtophenol).

4. *Bromination of unsaturated compound.*

Materials: solution of oleic acid in carbon tetrachloride (CCl_4), solution of bromine in carbon tetrachloride, dry test-tubes.

Introduce 1-2 drops of oleic acid in CCl_4 and 4-5 drops of bromine in CCl_4 in a dry test-tube. What do you observe? Why does the solution decolouration take place? Write the reaction of oleic acid bromination and indicate its mechanism. What is the practical importance of this reaction?

5. Tribromine aniline obtaining

Materials: aniline, bromine water, test tubes.

Introduce a drop of aniline and 5-6 drops of water in a test-tube and shake well. Add several drops of bromine water till a white sediment of 2,4,6-tribromineaniline will be formed. Write the reaction of 2,4,6-tribromineaniline obtaining. Why does this reaction occur so easy in such soft conditions?

The bromination reaction occur quantitatively and is used for aniline determination in pharmaceutical analysis.

THEME №5. REACTIONS OF NUCLEOPHILIC SUBSTITUTION (SN-REACTION) AND ELIMINATION (E-REACTION) WITH THE PARTICIPATION OF SATURATED CARBON ATOM

QUESTIONS AND EXERCISES

1. How do you can explain the capacity of halogen derivatives (halides), alcohols, thiols and other saturated compounds to participle in nucleophilic substitution reactions?
2. On the example of reaction of bromid ethyl with sodium hydroxide explain S_N2 mechanism.
3. Write the reaction of tret-butyl bromide with the aqueous solution of sodium hydroxide. Describe the $S_N1$mechanism.
4. Write the reaction of ethyl bromide interaction with sodium ethoxide; potassium cyanide; ammonia; ethylamine; diethylamine. Name the reaction products and indicate its belonging to the class of organic compound.
5. Give an example of the biological alkylation.
6. Write reactions of the interaction of ethanol and 2-propanol with hydrogen bromide (HBr). Describe the mechanism.
7. What factors favour the elimination reaction with participation of saturated carbon atom? Represent the general scheme of reaction.

8. Write the reaction of propyl bromine and ethyl bromine dehydrohalogenation. Specify conditions and describe the mechanism.
9. Write reactions of ethanol and propanol dehydration. Specify conditions and describe the mechanism.

LABORATORY WORK

1. The obtaining of ethyl cloride from ethanol

Materials: sodium chloride, ethanol, sulfuric acid (concentrate), dry test-tubes.

Introduce 2 test-spoons of sodium chloride in a dry test-tube and add 5-6 drops of ethanol. Then add 4 drops of concentrate sulfuric acid to the obtained mixture. Shake well the content of the test-tube and heat it attentively at the flame till the boiling. Avoid the abundant elimination of hydrogen chloride. If hydrogen chloride is eliminated intensively interrupt the heating immediately, then heat anew. Repeat this process 3 times, then heat the content of test-tube more intensive and approach the entrance of the test-tube to the flame. The ethyl chloride, which are eliminated, is catching fire and burns with a green flame as a ring around the entrance of the test-tube. Write the reaction of the ethyl chloride from the ethanol and describe its mechanism.

Ethyl chloride boils at +12°C and at room temperature quickly exhales. It is used in medicine for fast external anesthesia.

2. Determination of the quality of chloroform

Materials: chloroform – 1% solution, silver nitrate– 0,5% solution, potassium iodide – 5% solution, 1% solution of starch.

The reactions of the determination of products of the $CHCl_3$ breakdown after action of the light and the oxygen from air are at the base of the method of the chloroform quality determination. The final products of oxidation are HCl, CO_2 and Cl_2.

HCl is detected at interaction with silver nitrite, and free chlorine at action of potassium iodide.

The experiment: for HCl identification introduce in a test-tube 2 drops of chloroform (destined for investigations), 3 drops of distilled water and 1 drop of 0,5% solution of silver nitrate.

Shake well the content of the test-tube and observe the processes.

For identification of Cl_2 introduce in a test-tube 3 drops of $CHCl_3$, 5 drops of distilled water and 1 drop of 5% solution of potassium iodide. Shake well the content of the test-tube and observe the processes.

When chloroform contains Cl_2 the inferior stratum of chloroform acquires a pink color. If the pink color is absent add 1 drop of starch solution. What do you observe? What conclusion can you do from this experiment? Write the reactions of HCl and Cl_2 identification.

Chloroform is applied to narcosis at surgical operations. It is necessary for storing in small tightly closed bottles from a dark brown glass.

3. Obtaining of iodoform from ethanol

Materials: ethanol, solution of iodine in potassium iodide, 10% solution of sodium hydroxide, test-tubes.

The principle of method consists in oxidation of ethanol in acetaldehyde, which after that interacts with an excess of hipoiodic acid (HOI) and than with the sodium hydroxide.

Experiment. Introduce in a test-tube a drop of ethanol, 3 drops of solution of iodine in potassium iodide and shaking well add 1-2 drops of 10% solution of sodium hydroxide till the solution become colourless. While worming the test-tube in the hands we observe the appearance of a yellow precipitate or the solution become turbid and an intense and persistent smell characteristic for iodoform appears. If the yellow precipitate doesn't appear, add 1-2 drops of iodine in potassium iodide and shake well.

The reaction of transformation of ethanol in iodoform is frequently used for ethanol identification.

4. Dehydrations of ethanol

Bring in 8 drops of the concentrated sulfuric acid, 4 drops of ethanol and half of spatula of aluminium oxide to a dry test-tube. Occlude the test-tube by a cork with a gas tube and the end of the tube introduce in the second test-tube with 5 drops of bromine water. Heat up the first test-tube above the flame of the burner. As soon as bromine water will be

decolorized, immediately introduce the end of the gas tube in the beforehand prepared third test-tube with 2 drops of 1% solution of potassium permanganate ($KMnO_4$) and 5 drops of water. Continue warming to a decolorization of solution of potassium permanganate. Then remove the third test-tube and burn at the end of the gas tube isolated gas, which burns the a luminous flame.

Write the scheme of the reaction of ethanol dehydration and reaction for detection of a product of a dehydration.

THEME №6. REACTIONS OF NUCLEOPHILIC ADDITION (AN - REACTION). ALDEHYDES AND KETONES

LABORATORY WORK

1. Oxidation of formic aldehyde by ammoniacal solution of silver oxide (reaction of "silver mirror")

Take two test tubes and in each of them put on 1 drop of 5% solution of silver nitrite ($AgNO_3$) and 1 drop of 10% solution of sodium hydroxide (NaOH). To the received sediment add drop by drop 10% solution of ammonia till its complete dissolution. Then in the first test-tube add 2 drops of 40 % solution of formaline, and in the second - 2 drops of acetone. At cautious warming in the first test-tube the black sediment is obtained and can form on walls of the test-tube a shining mirror sediment. This reaction is named the reaction of "silver mirror". In the 2-nd test-tube the sediment formation is not observed.

2. Oxidation of formic aldehyde by copper hydroxide (II)

Introduce in each of two test-tubes 5 drops of 10% solution of sodium hydroxide and 5 drops of water, then add 2 drops of 2% solution of copper sulfate ($CuSO_4$). Add 3 drops of 40% solution of formaline to the formed sediment of cupper hydroxide (II) in the first test-tube, and 3 drops of acetone to the sediment formed in the second. Heat up cautiously test-tubes to boiling. In the 1-st test-tube the sediment gets at first yellow colour, then - red and if the test-tube is clean, on its walls can be deposit the metal copper (copper mirror). The change of

sediments colour is explained by a various degree of copper oxidation.

$Cu(OH)_2 \rightarrow CuOH \rightarrow Cu_2O \rightarrow Cu$

In the 2-nd test-tube the black sediment of copper oxide (II) drops out.

3. Staining reaction on aldehydes with fuxine sulphurous acid.

On the subject glass put 1 drop of colourless solution of fuxine sulphurous acid. Add to solution 1 drop of formaline. In what colour the solution was stained? The reaction is used for detection of aldehydes.

4. The identification of acetone by its transforming in iodoform

This reaction is used in clinical laboratories and has practical value for diagnostics of sugar diabetes.

Materials: solution of iodine in potassium iodide, 10% solution of sodium hydroxide, acetone, test-tubes.

Introduce in a test-tube two drops of solution of iodine in potassium iodide and add drop by drop 10% solution of sodium hydroxide until the test-tube's content become colourless. Add to the obtained solution a drop of acetone. What do you observe? Why does a white-yellow precipitate with a characteristic smell appear? Write the scheme of iodoform formation's reaction.

QUESTIONS AND EXERCISES

1. Electron structure and reactionary ability of carbonyl group. The most important representatives of aldehydes and ketones .
2. Describe the mechanism of nucleophilic addition on carbonyl group. The role of the substitutes and of the acid catalysis.
3. Write reactions of interaction of acetaldehyde (propionic aldehyde) with methyl (ethyl, propyl) alcohols. Describe the mechanism and name the obtained acetals and semiacetals.
4. Write reactions of the formaldehyde and thichloracetaldehyde hydration.

5. Write reactions of interaction of acetaldehyde and benzaldehyde with methyl amine, aniline. Describe the mechanism.
6. Write reactions of aldol condensation of acetaldehyde, propionic aldehyde. Describe the mechanism and name reaction products.
7. Write the iodoform reaction for discovering the acetone. What is the importation of the reaction?
8. Write reactions for obtaining of cyclic semiacetals of 4-hydroxybutanal and 5-hydroxypentanal.
9. Write reactions of oxidation of acetaldehyde by copper hydroxide (II) and by silver oxide in aqueous solution of ammonia (Tollens reactiv).
10. Write reactions of regeneration of acetaldehyde, acetone, methylethylketone. Name products of reactions.

THEME №7. REACTIONS OF NUCLEOPHILIC (S_N-REACTIONS) SUBSTITUTION. CARBONIC ACIDS AND THEIR FUNCTIONAL DERIVATIVES

LABORATORY WORK

1. Identification of oxalic acid as calcium salt

Place in the test-tube several crystals of oxalic acid and add 4-5 drops of water up to complete dissolution. Take 1 drop of solution by a pipette and put on the subject glass. Add to it 1 drop of solution of calcium chloride. A crystalline sediment is formed.

It is possible to meet the crystals of calcium oxalate at clinical research of urine; at the patients with renal stone illness they have the form of post envelopes and are visible well under a microscope. Write the equation of reaction.

2. Preparation of ethyl acetate

Materials: sodium acetate (anhydride), ethanol, sulphuric acid (concentrated), dry test-tubes.

Introduce in a dry test-tube 1 spatula of sodium acetate (anhydride), 3 drops of ethanol and 2 drops of concentrated sulphuric acid. Heat attentively the mixture at the gas flame until the boiling. The eliminated vapours have a pleasing smell,

which is characteristic for ethyl acetate. The reaction is used for ethanol identification. Write the equations of reactions.

3. Identification of acetic acid

Pour out 1 ml of acetic acid in a test-tube, in another place a spatula of sodium acetate and 3 drops of water. Add in each test-tube several drops of solution of iron chloride. A yellow - red staining appears in the test-tube with sodium acetate, because of iron acetate forming. Why in the first test-tube the red staining is not formed? Write the equation of reaction.

4. Formation of biuret from urea

Place in a dry test-tube a spatula of urea. Cautiously heat it. The urea melts at the beginning, then it decomposes with ammonia elimination. In the test-tube the biuret is formed. After the test-tube cooling add 5 drops of water and vigorously shake it; the biuret solves. To this solution add 2 drops of copper sulfate and 2 drops of sodium hydroxide. A characteristic staining appears. Write the equations of reactions.

QUESTIONS AND EXERCISES

1. Represent the electron structure of the carboxyl group and of the carboxylate anion. Give the classification and name the most important representatives of carbonic acids.
2. Describe the general mechanism of reaction of nucleophilic substitution in carbonic acids and their functional derivatives.
3. Write reactions of formation and hydrolysis of ethyl (methyl, propyl) ethers of acetic acid. Describe the mechanism.
4. Write reactions of obtaining of functional derivatives: of acetic anhydride, chlorine anhydride of propionic and benzoic acids, of acetyl phosphate.
5. Write reactions of obtaining and hydrolysis of amides of acetic, propionic, benzoic acids.
6. Write reactions which proceeding at warming of malonic, oxalic, and glutaric acids.
7. Esther condensation. Write reaction of condensation of ethyl acetate. Describe the mechanism. Biological value of this reaction.

THEME №8. SAPONIFIED LIPIDS. OXIDATION AND REDUCTION OF ORGANIC COMPOUNDS.

LABORATORY WORK

1. Formation of insoluble calcium salts of superior fatty acids

Place 5 drops of soap solution in the test-tube and add 1 drop of solution of calcium chloride ($CaCl_2$). A white sediment appears. Write the reaction of formation of calcium salt of stearic acid.

2. Oxidation of oleic acid by solution of potassium permanganate

Place 2 drops of oleic acid in a test-tube, add 2 drops of 5% solution of sodium carbonate (Na_2CO_3) and 2 drops of 2% solution of potassium permanganate ($KMnO_4$). Shake the test-tube some times. Note what coulor changes take place in the test-tube. Write the equation of reaction.

3. Determination of the quality of diethyl ether

Diethyl ether, which is used for the narcosis, at the storage under influence of solar light and at the presence of oxygen of air is oxidized forming peroxide compounds and other products, for example, acetaldehyde.

a) Identification of peroxides.

Introduce in a test-tube 4-5 drops of diethyl ether, add 2-3 drops of 10% solution of potassium iodide and 2 drops of 10% solution of hydrochloric acid. At presence of peroxides the ether will be staining in yellow colour because of elimination of free iodine. If colouring is difficult to distinguish, add in the test-tube 2 drops of 0,5% solution of starch.

b) Identification of aldehyde.

Introduce in other test-tube 3-4 drops of diethyl ether and add 3 drops of fuxine sulphurous acid solution. At presence of acetaldehyde a pink staining appears gradually.

QUESTIONS AND EXERCISES

1. Represent the structure of saturated and unsaturated superior fatty acids taking into consideration the stereoisomeria.
2. Write the schemes of reactions for triacylglycerides obtaining: palmito-oleo-stearine, oleo-linoleo-stearine, linoleo-palimito-stearine.
3. Write reactions of acid and alkaline hydrolysis of triacylglycerides - dioleo-stearine, linoleo-dioleine, dipalmito-stearine.
4. Write reactions of triacylglycerides hydration: oleo-linoleo-palmitine, dioleo-stearine, linoleo-dioleine. Name obtaining fats.
5. Write the structure of phospholipids on example of kephalins: palmito-olei-phosphatidilcolamine, stearo-linoleo-phosphatidil-colamine. Describe their acid and alkaline hydrolysis.
6. Write the structure and describe acid and alkaline hydrolysis of phosphatidilcholines: stearo-oleo-phosphatidilcholine, palmito-linoleo-phosphatidilcholine.
7. Write the stucture of sphingolipids (ceramids and sphingomielines) and cerebroside which contains stearic, linolenic acids.
8. Write the scheme of peroxide oxidation reaction of oleic and palmito-oleic acids.
9. Write the scheme of β- oxidation reaction of palmitic and stearic acids.

THEME №9. HETEROFUNCTIONAL ORGANIC COMPOUNDS, PARTICIPATING IN METABOLISM PROCESSES

QUESTIONS AND EXERCISES

1. Write the structure and scheme of reactions of biosynthesis of biogenic amines: colamine, choline, noradrenaline and epinephrine. What is their biological role?
2. Write specific reactions which proceed at warming of α-hydroxypropionic, β-hydroxybutiric, γ-hydroxyvalerianic, α-

aminoacetic, β-aminopropionic, γ-aminobutyric acids. Name the received products.

3. Write reactions of acid hydrolysis of γ-valerolactone and γ-valerolactam.
4. What products are formed at warming the lactic and citric acids with the concentrated sulfuric acid. Write the schemes of reactions.
5. Write reactions of interaction of α-hydroxypropionic, γ-aminobutyric acids with the following reagents: a) NAOH; b) C_2H_5OH (H^+).
6. Write the projection formulas of D- and L-stereoisomers of lactic, malic and tartaric acids.
7. Give definition of the tautomerism. Write tautomeric form of the acetyl acetic ether, oxalyl acetic acid.
8. Write reactions of decarboxilation of acetyl acetic and oxalyl acetic acids. What compounds are included into group of "ketone bodies"?

LABORATORY WORK

1. Demonstration of two carboxyl groups presence in tartaric acid.

Introduce in a test-tube 1 drop of 15% solution of tartaric acid, 2 drops of 5% solution of potassium hydroxide and shake the test-tube up to the white crystals slightly soluble in water of acidic potassium salt of tartaric acid (potassium hydrotartrate) begin to be formated. Then add in the test-tube 4-5 drops of solution of potassium hydroxide. Thus the crystalline sediment gradually solves, as potassium tartrate is formed – a salt which is well soluble in water. Keep solution for the following experience. Write the equations of reactions.

2. Demonstration of hydroxil groups presence in tartaric acid.

Introduce in a test-tube 5 drops of solution of copper sulfate and 2 drops of 10% solution of sodium hydroxide. A light-blue sediment of copper hydroxide immediately drops out. Add to it the solution of potassium salt of tartaric acid (from the previous experience). It take place a dissolution of a light-blue sediment and formation of a transparent blue solution known

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under the name of Felling reactive, which does not decompose at warming and is used for detection of glucose.

3. Decomposition of citric acid

In the dry test-tube, supplied with a gas elimination tube, place a spatula of citric acid and 10 drops of concentrated sulfuric acid and heat up. The end of the gas elimination tube lower in a test-tube which contain 5 drops of solution of barium hydroxide. After solution grows turbid, move the gas elimination tube to other test-tube, which contain 2 drops of solution of iodine in potassium iodide, previously decolorized by addition of 1-2 drops of 10 % solution of sodium hydroxide; the pale yellow sediment drops out.

Citric acid, being a α-hydroxy acid, decomposes under action of sulfuric acid with formation of acetone, carbon dioxide and formic acid.

Write the equations of reactions for detection of acetone and carbon dioxide.

4. Ketone decomposition of acetoacetic ester

In the test-tube with a gas elimination tube place 5 drops of acetoacetic ester and 5 drops of 10% solution of sulfuric acid. Heat up cautiously the test-tube and the end of gas elimination tube lower in the first test-tube with 5 drops of barium hydroxide solution. After solution grows turbid, move the gas elimination tube in the second test-tube which contain 2 drops of iodine solution in potassium iodide, previously decolorized by addition of several drops of 10% solution sodium hydroxide. In the second test-tube the pale yellow sediment with a characteristic smelt of iodoform drops out. Write the equations of reactions.

THEME №10. PHYSIOLOGICALLY ACTIVE DERIVATIVES OF THE HETEROCYCLIC SERIES

QUESTIONS AND EXERCISES

1. Write the formulas of furan, pirrole and thiophene. Into composition of what biologically active compound are they included?

2. Write the structure of indol, tryptophan and serotonin. What is their biological importanse?
3. Write the structure of pyridine and show the chemical properties of pyridine.
4. Write the structure of medicinal compounds which include the pyridine cycle: niacin, nicotinamide (vit. PP), isonicotinic acid, tubazide ftivazide, and oxine.
5. Write the structure of imidazole and its derivatives: histidine and histamine.
6. Write the structure of medicinal preparations - derivatives of pyrazole: antipyrine, amidopyrine, analgine, butadione.
7. Write the formula of pyrimidine. Explain presence of lactim-lactam tautomerism at the barbituric acid. Write the structure of barbiturates: barbitale, fenobarbitale, cyclobarbitale.
8. Write the structure of purine and its derivatives: xanthine, theophylline, theobromine, coffeine, uric acid. What is their biological importance?

LABORATORY WORK

1. Reaction of antipyrine and amidopyrine with iron chloride

Introduce in a test-tube several crystals of antipyrine, add 5 drops of water and 1 drop of 1% solution of iron chloride. An intensive and stable orange-red staining appears. For comparison place in other test-tube several crystals of amidopyrine. Add 5 drops of water and 1-2 drops of iron chloride. A violet staining appears, but it is evanescent.

The staining of antipyrine in presence of iron chloride is caused by formation of a complex compound - ferropyrine, and of amidopyrine – by formation of oxidation products.

The reaction with iron chloride is qualitative, permitting to distinguish the amidopyrine from antipyrine.

2. Reaction of antipyrine and amidopyrine with nitrous acid

Introduce in one test-tube several crystals of antipyrine, in another – of amidopyrine. In both test-tubes add 2 drops of water, 2 drops of 10% solution of sulfuric acid and 2 drops of 5% solution of sodium nitrite in each. In the first test-tube a

emerald-green staining appears, and in the second test-tube – an unstable violet staining.

The reaction with nitrous acid is used in pharmaceutical practice for difference antipyrine and amidopyrine from each other.

3. Solubility of uric acid and its sodium salt in water

Place in a test-tube a small quantity of uric acid. Add on drops 8 drops of water and be convinced, that the uric acid does not solve. However, is worth adding 1-2 drops of 10% solution sodium hydroxide, as the turbid solution is instantly clarified in consequence of formation of the easily soluble sodium salt. Keep solution for the following experience. Write the equations of reactions.

4. Identification of uric acid (murexid reaction)

On subject glass with the help of the pipette place 2 drops of solution of sodium salt of uric acid. Add 1 drop of the concentrated nitric acid and cautiously evaporate it above the flame of the burner. As soon as the solution will be evaporated and a weak reddening of the stain on the place of the former drop appears, stop warming. When the glass will cool down, near the stain place 1 drop of 10% solution of ammonia. On the place of contact the appearance of a strip of purple-violet colour is observed (murexid reaction)

Murexid reaction is applied at analysis of urinary stones, and also to identifying the coffeine, theobromine and other purine bases, as qualitative reaction to the purine ring.

THEME №11. α-AMINOACIDES. PEPTIDES.

QUESTIONS AND EXERCISES

1. Write the projective formulas of enantiomers of the following amino acids: Ile, Tre, Ala, Asp.
2. Write the schemes of reactions of following amino acids with:
   a) diluted solution of NaOH; b) hydrochloric acid.
3. Write the scheme of reactions of interaction of serine, alanine, glicine with:
   a) copper (II) sulfate in alkaline mediums; b) ethanol in acid medium; c) formic aldehyde; d) nitrous acid

4. What products result at the decarboxilation of the following amino acids: His, Trp, Ser, Gln. Write the scheme of reactions.
5. Write reactions of the oxidative deamination of the following amino acids: Asp, Glu, Tyr.
6. Write the scheme of reactions of transamination of alanine, serine, isoleucine with oxalil acetic acid.
7. Write the structure of tripeptides: Gly-Val-Ile, Val-Phe-Leu, Tre-Cys-Ala, Tre-Met-Gly and also write down the scheme of determination of N- terminal amino acids by the Edman method.

LABORATORY WORK

1. Reaction of glycine with formaldehyde.

Introduce in a test-tube 5 drops of 1% solution of glycine and add 1 drop of the indicator methyl red. The solution is coloured in yellow (in neutral medium). To the received mixture add an equal volume of formalin. A red colouring appears (in acid medium).

This reaction, named "formol titration", is used for quantitative determination of carboxyl groups in amino acids by titration with alkali. Write the reaction of glycine with formaldehyde.

2. Formation of complex salt of copper with glycine.

Introduce in a test-tube 1 ml of 1% solution of glycine. Add on the tip of a spatula a dry copper (II) carbonate and heat up mixture to boil. The solution is coloures in dark blue colour because of formation of soluble complex salt of copper with glycine. Write the equation of reaction.

3. Biuret reaction on peptide bond.

Introduce in a test-tube 5-6 drops of solution of ovalbumin, add equal volume of 10% solution of sodium hydroxide and on the wall add 1-2 drops of solution of copper (II) sulfate. The appearance of a characteristic red - violet colouring is observed. Write the reaction of copper (II) ions with biuret.

4. Xanthoproteic reaction of proteins.

Introduce in a test-tube 10 drops of solution of ovalbumin and 2 drops of the concentrated nitrogenous acid. Cautiously heat up the test-tube, permanently shaking it. The solution and the sediment is coloured in yellow. Cooling the test-tube, add cautiously 2-3 drops of 10% solution of sodium hydroxide till a bright orange colour appears.

THEME №12. CARBOHYDRATES. MONOSACCHARIDES.

QUESTIONS AND EXERCISES

1. How the monosaccharides are classified? Write the structure of the most important pentoses and hexoses. On the configuration of which carbon atom their belonging to D- or L- stereochemical series is determined?
3. What stereoisomers is named epimers? Write the structure of epimers of D-glucose.
4. What stereoisomers is named anomers? Write the cyclo-oxo-tautomerism of D-glucose, D-galactose, D-ribose, D-fructose.
5. Write the reactions of obtaining of glycosides at interaction of alcohol with α-D-glucopyranose; β-D-ribofuranose; β-D-fructofuranose. Name them and carry out the hydrolysis in acid medium.
6. Write the reactions of interaction of D-glucopyranose, D-galactopyranose and D-ribofuranose with dimethyl-sulphate in alkaline medium. Name the products of reactions and carry out their hydrolysis in acid medium.
7. Write the reactions of D-glucopyranose, D- galactopyranose, D- fructofuranose with acetic anhydride. Name the received ethers and carry out their hydrolysis.
8. Write the scheme of reaction for obtaining glucoso-6-phosphate in organism.
9. Write the oxidation reactions of D-glucose for obtaining the gluconic, glucaric and glucuronic acids. Specify the conditions.
10. Write the reactions of reducing of D-glucose, D-mannose, D-xylose, D-fructose.

11. Write the reactions for synthesis of ascorbic acid (vit.C) from the glucose.

LABORATORY WORK

1. Demonstration of presence of hydroxyl group in D-glucose

Introduce in a test-tube 2 drops of 0,5% solution of D-glucose and 6 drops of 10% solution of sodium hydroxide. To the received mixture add 1 drop of 2% solution of copper sulfate ($CuSO_4$). The formed sediment of copper hydroxide $Cu(OH)_2$ is fast dissolved and the transparent blue solution is obtained. The received solution keep for the following experience. Write the equation of reaction.

2. Reduction of copper (II) hydroxide by D-glucose in alkaline medium.

To the blue solution, received in the previous experience, add some drops of water and heat up solution to boil. At warming the colour of solution change from blue up to yellow - red. This reaction is named Trommer assay and is used for discovering glucose in solution. Write the equation of reaction.

3. Reduction of ammonia solution of silver hydroxide by glucose

Introduce in a test-tube 1 drop of 5% solution of silver nitrite ($AgNO_3$), add 2 drops of 10% solution of sodium hydroxide and 3-4 drops of 10% aqueous solution of ammonia up to dissolution of the formed sediment of silver hydroxide. The received ammoniacal solution of silver hydroxide is named Tollens reagent and is used for determination of the glucose.

Add to received reagent 1 drop of 0,5% solution of glucose and slightly heat up the test-tube till the solution gets a brown staining. Further reaction goes without warming and the metal silver drops out as a black sediment or precipitates on walls of the test-tube as a mirror. Write the equation of reaction.

4. Selivanov reaction on fructose.

Introduce in a test-tube some grains of resorcine, 2 drops of concentrated hydrochloric acid and 2 drops of 0,5% solution

of fructose. Heat up solution and boil it some seconds. Gradually the liquid gets a red staining.

The reaction is caused by the formation of an unstable compound - 5-hydroxymethylfurfurol. Under action of hydrochloric acid hydroxymethylfurfurol is condensed with resorcine, giving a coloured compound. Write the equation of reaction of formation of 5- hydroxymethylfurfurol.

THEME №13. OLIGO- AND POLYSACCHARIDES

QUESTIONS AND EXERCISES

1. Write the structural formulas of disaccharides: maltose, cellobiose, lactose and saccharose. Specify the type of the glycosidic bond between monosaccharide residues.
2. Write cyclo-oxo-tautomeric forms of maltose and lactose using the Haworth formulas.
3. Write reactions of maltose and lactose oxidation by copper (II) hydroxide in alkaline medium.
4. Write reactions of the hydrolysis of disaccharides: maltose, cellobiose, lactose and saccharose. Specify conditions and name the received monosaccharides.
5. What polysaccharides are named homopolysaccharides? Write the structure of a fragment of the amylose macromolecule. What natural polysaccharide includes the amylose in its structure?
6. Write the structure of a small fragment of the macromolecule of amylopectin. Specify the types of glycosidic bonds. What is importance of starch?
7. Write the structure of a small fragment of the macromolecule of glycogen. What is importance of glycogen?
8. What polysaccharides are referred to dextrans? Write the structure of a small fragment of dextran macromolecule and specify the types of glycosidic bonds between monosaccharide residues.
9. What polysaccharides are referred to heteropolysaccharide?. Write the structure of a fragment of macromolecules of hyaluronic acid, hondroitinsulphate, heparine. Specify the types of bonds between monosaccharide residues of these heteropolysaccharide.

LABORATORY WORK

1. Absence of the reducing properties at the saccharose:

Introduce in a test-tube 1 drop of 1% solution of saccharose, 6 drops of 10% solution of sodium hydroxide and 5-6 drops of water. Add 1 drop of 2% solution of copper sulfate $CuSO_4$. The transparent blue solution of complex salt of copper (II) with saccharose is formed. Cautiously heat up the test-tube above the flame up to boiling, but not boil. The change of solution colour does not occur. Remember, that with D-glucose in similar conditions it take place a colouring of solution in yellow - red.

Write the structure of saccharose and specify the cause of absence of reducing properties at saccharose.

2. Reducing properties of lactose

Introduce in a test-tube 1 drop of 1% solution of lactose and 6 drops of 10% solution of sodium hydroxide. Add 1 drop of 2 % solution of copper sulfat $CuSO_4$. The transparent blue solution of complex salt of copper (II) with lactose is formed. Add for a dilution some drops of water. Cautiously heat up the test-tube above the flame up to boiling of solution. At warming the colour of solution is changing in yellow-red. Remember, that with D- glucose it is observed a similar result (Trommer assay is positive), whereas in experience with saccharose in the same conditions the colouring of solution does not change. Write the equation of reaction.

3. Qualitative reaction for starch.

Introduce in a test-tube 2 drops of 0,5 % starch paste, 2-3 drops of water for dilution and 1 drop of a very diluted solution of iodine. The solution is colouring in dark blue colour. Heat up the solution; it decolorizing; at refrigerating the colouring restores.

The formation of a dark blue staining is named iodine-starch reaction.

4. Acid hydrolysis of starch.

Introduce in a test-tube 3-4 drops of 0,5% paste. Add 2 drops of 10% solution of sulfuric acid H_2SO_4 and place the test-

tube in the boiling water bath. The turbid solution of paste becomes transparent in 20 min. If the assay on iodine-starch reaction is negative, add in the test-tube 8 drops of 10% solution of sodium hydroxide for forming the alkaline medium. Then add 1 drop of 2 % solution of copper sulfat $CuSO_4$, heat up solution to boiling. The change of colouring in yellow-red is observed. The positive Trommer assay attests a complete hydrolysis of starch. Write the scheme of reaction.

THEME №14. NUCLEIC ACIDS

QUESTIONS AND EXERCISES

1. Write the structure of pyrimidine bases which enter into composition of nucleic acids and name them.
2. Write the structure of purine bases and name them.
3. On the example of a thymine and guanine show lactim-lactam tautomerism. What form is more stabile?
4. What is a nucleoside? Write the structure of adenosine, thymidine, guanosine.
5. Write the scheme of the hydrolysis reactions of uridine and adenosine, specify the conditions and name the reaction products.
6. What is a nucleotide? Write the structure of nucleotides AMP, UMP, GMP, give their complete name and specify the esteric and glycosidic bonds.
7. Write the reaction of nucleotides hydrolysis on the example of citidilic and adenilic acids. Specify conditions and name the reaction products.
8. What is primary structure of nucleic acids? Write the structure of a segment of DNA with a sequence of the bases TGA; ACG, GTC, CAT.
9. Write the structure of a segment of RNA with a sequence of the bases CUG; ACU, GUA, UGC.
10. Write the structure of adenosine triphosphate - ATP and specify its biological importance.
11. Write reactions of formation of corresponding α-amino acil adenilates of the following α-amino acids: valine, leucine, serine, phenilalanine.

12. Write the structure of coenzymes NAD^+ and FAD, specify their importance.
13. Write the scheme of reversible redox reactions with participation of the coenzyme NAD^+ for ethanol and lactic acid.

THEME №15. ISIPRENOIDS. STEROIDS.

QUESTIONS AND EXERCISES

1. What are the terpenes? Formulate the isoprene rule. Give the classification of terpenes.
2. Write the structural formulas of limonene, menthol, mentane, pinene, camphoras and specify their isoprene parts.
3. What are the carotenoids? Write the structure of β-carotene, retinol, retinal and specify their isoprene parts. What is the biological importance of vitamin A?
4. Write the structure and conformation of 5α- and 5β - sterane.
5. Write the structural formulas of hydrocarbons underlying of steroids structure (estran, androstane, pregnane, cholestane).
6. Write the structure of a cholesterin, ergosterin and vitamin D. What is their biological role in the metabolism?
7. Write structural formulas of steroide hormones: corticosterone, hydrocortisone, androsterone, testosteron, estrone, estradiole, progesterone. Their biological importance.
8. Write the structure of cholic acids: cholic, glycocholic and taurocholic acids. What is their biological importance?
9. Write the structure of agycones of cardiac glycosides: dighitoxigenine and strofantidine.