

МИНИСТЕРСТВО ЗДРАВООХРАНЕНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ
БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ
КАФЕДРА БИООРГАНИЧЕСКОЙ ХИМИИ

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БИООРГАНИЧЕСКАЯ ХИМИЯ:
практический курс для студентов-стоматологов

BIOORGANIC CHEMISTRY:
practical course for dental students

Практикум



Минск БГМУ 2012

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P51

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Ринейская, О. Н.

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Издание содержит методические рекомендации для подготовки к лабораторным занятиям по биоорганической химии на английском языке. К каждой теме даны цель занятия, вопросы для обсуждения, письменные задания, а также указана литература для подготовки. Приведены описания и протоколы лабораторных опытов.

Предназначено для студентов 1-го курса медицинского факультета иностранных учащихся, обучающихся на английском языке по специальности «Стоматология».

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практический курс для студентов-стоматологов
BIOORGANIC CHEMISTRY: practical course for dental students

Практикум на английском языке

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REGISTRATION FORM

Student name _____

№	Theme	Date	Mark	Signature of teacher
1.	Labwork # 1 Classification and nomenclature of organic compounds			
2.	Labwork # 2 Stereoisomerism, its role for biological activity demonstration			
3.	Labwork # 3 Chemical bond structure and atom effects in the organic molecules			
4.	Labwork # 4 Acid-base properties of organic compounds. Oxidation reactions			
5.	Labwork # 5 Classification and mechanisms of reactions in organic chemistry. Reactions of radical substitution (S_R). Electrophilic addition reactions (A_E). Electrophilic substitution reactions			
6.	Labwork # 6 Biologically important reactions reaction of aldehydes and ketones			
7.	Labwork # 7 Carboxylic acid and their derivatives			
8.	Labwork # 8 Concluding test ‘Theoretical fundamentals of basic classes of organic compound structure and reactivity’			
9.	Labwork # 9 Heterofunctional compounds of aliphatic, benzene and heterocyclic series. Metabolites and bioregulators			
10.	Labwork # 10 Lipids. Structure, properties. Lipid peroxidation			
11.	Labwork # 11 Carbohydrates. Monosaccharides			
12.	Labwork # 12 Oligo- and polysaccharides			
13.	Labwork # 13 Structure and reactivity of amino acids acting as heterofunctional compounds			
14.	Labwork # 14 Peptides. their structure, reactivity and importance. The levels of protein organization			
15.	Labwork # 15 Purine and pyrimidine bases. Nucleosides. Nucleotides. Nucleic acids			
16.	Labwork # 16 Concluding test “Biopolimers and their structural componens”			
17.	Labwork # 17 Polymer materials, using in stomatology			
18.	Labwork # 18 Concluding test			

Safety rules during the work in the chemical laboratory

The students are to attend classes in chemical laboratory in cotton gowns. The students are fixed to the constant workplaces, which they should keep in order. When the experiment is carried out, each student should be on his workplace. In the process of work time it is necessary to keep silence, order and cleanliness in the laboratory, avoid haste.

It is strictly forbidden:

- to carry out the experiments, not connected with the indicated practical course;
- to work with reagents in the absence of the teacher;
- to have a meal in the laboratory;
- to taste chemicals.

After the end of the experiment each student should submit an account of the work that have been done, then to wash up chemical crockery, clean a workplace and ask the student on duty to check it.

Responsibilities of the student on duty:

- to get all the necessary equipment from the laboratory assistant;
- to keep an order in the laboratory;
- the student on duty should leave the laboratory the last, after receiving the sanction from the laboratory assistant.

Work with alcohol lamps. Precautions

Careless work with an alcohol lamp can result in a fire, that is why it is necessary to follow the below requirements:

- the wick of an alcohol lamp should tightly enter the aperture of a metal bush; the topping should be put forward for 1 cm and fluffed up;
- the bush should close the aperture of a alcohol lamp tightly; the alcohol lamp should be filled with alcohol no more than $\frac{2}{3}$ of the volume;
- the lighting of an alcohol lamp should be carried only by matches, it is strictly forbidden to light an alcohol lamp from another alcohol lamp, because the bush can stoop and coming out steams of alcohol can be fired;
- to blow out an alcohol lamp only by covering it with bell-glass;

- when heating up substances in chemical glassware it is necessary to heat them at the top or mid-range flame, not touching a wick, because a wick is always cool, and when hot glass contacts with it, glass may burst.

Work with chemical glassware. Precautions

Heating substances in glassware should be performed gradually, slightly rotating it and cautiously shaking from time to time. When heating a test tube with a liquid on the open fire, ejaculation of a liquid is possible. Because of this fact, the aperture of a test tube should be directed aside from you and from your neighbours. Especially it is necessary to avoid injuring the eyes with hot splashes, that is why it is forbidden to bend forward to the test tube and look inside. When heating the test tube, it should be kept at the angle of inclined position (45°), so that splashes will hit walls of a glassware and will not be thrown outside. When working with an exhaust tube it is necessary to keep an eye on the end of an exhaust tube in the liquid, through which gas passes. You can remove an alcohol lamp from under a test tube with a reaction mixture only when the bottom end of an exhaust tube is removed out of a liquid. If the liquid starts to rise in an exhaust tube, it is necessary to let down a test tube immediately, so that the fluid level in it will become lower than the end of an exhaust tube, and to continue heating it up until the gas coming out pushes the liquid out of an exhaust tube.

Work with chemical reagents. Precautions

Reagents necessary for work except for easily inflammable liquids and strong and toxic substances, should be on a working table, placed in supports with the numbered jacks. The little bottle with the corresponding reagent has the same number. Little bottles with liquids are closed by rubber corks with pipettes in them. It is not recommended to take out little bottles from jacks of a support. If you want to take the substance, it is necessary to press the little bottle to a bottom of a jack by your left hand, and cautiously take out a cork with a pipette by your right hand. To take the necessary quantity of a reagent with a pipette and to close the little bottle with the same cork. The spatula (a little glass shovel) is built-in in a cork for taking crystal reagents.

Work with inflammable liquids (IL). Precautions

IL (diethyl ether, alcohol, toluene, acetone, acetoacetic ether) are kept in small quantities in an exhaust cupboard. Experiments with these substances are carried out under draught, far from open fire and the turned on small stoves. If an ignition of the IL happened in a vessel, it is necessary to cover it quickly with a fire-prevention blanket. If the burning liquid has been spilt, it must be extinguished by sand. If the clothes begin to fire, it is necessary to wrap up quickly and densely in a fire-prevention blanket.

Work with acids and alkalis. Precautions

Concentrated solutions of nitric, sulphuric, hydrochloric acids, nitrosulphuric acid are kept in the exhaust cupboard. All experiments with concentrated acids and alkalis are carried out only in the exhaust cupboard. The dilution of concentrated acids is possible only by pouring **acids to water**, not the other way. It is necessary to cover carelessly spilt on the floor acids and alkalis by sand and after that to clean up.

Work with toxicants. Precautions

Toxic organic substances - aniline, methyl amine, toluene, picric acid are kept in an exhaust cupboard. It is necessary to be cautious with these substances, not to inhale their steams, to avoid injuring the hands as they can penetrate through the skin. In case of emergency when these substances got on hands, it is necessary to wash up quickly the hands with warm water and soap. If inhaled the steams - immediately to go out in the fresh air.

First-aid treatment in case of accidents:

- in case of hands are cut with glass first of all it is necessary to remove all the splinters out of the wound, then to treat the wound with an alcohol solution of iodine and to put a bandage;
- in case of thermal burns happen it is necessary to treat the burnt place with the 70 % solution of ethanol;
- in case of burns are caused by solutions of acids or alkalis it is necessary to wash up the burnt site with water quickly and to put an aseptic bandage;

- in case of acids or alkalis hit the eyes it is necessary wash them with water carefully and to refer the victim to the outpatient clinic;
- in case of skin burns caused by bromine it is necessary quickly to wash the injured place off with ethanol and to put anti-burn emulsion;
- in case of burns caused by hot organic liquids it is necessary to wash out the injured place with ethanol;
- in case of burns caused by liquid phenol it is necessary to massage the emerged sites of white skin with a glycerine until normal skin color is restored then to wash with water and to put the gauze bandage moistened with a glycerine solution;
- after providing the first-aid treatment it necessary to address to the health center of the university or to the outpatient clinic.

LABWORK # 1

Theme: CLASSIFICATION AND NOMENCLATURE OF ORGANIC COMPOUNDS

Objective: to study composition unity, configuration and conformation concept for organic molecules

Recommended literature:

1. Zurabyan S.E. "Fundamentals of Bioorganic Chemistry. Textbook For Medical Students", 2006 г. P. 5-32, 74-81.

2. T. W. Solomons. Fundamentals of Organic Chemistry. John Willey&sons, 1994. p. 116-127, 501-504, 643-644, 715-723.

Problems for discussion:

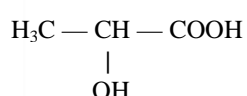
1. Introduction into bioorganic chemistry: the definition of subject, objects learned by bioorganic chemistry.
2. Classification of organic compounds:
 - a) according to the carbon chain structure;
 - b) according to the functional groups.
3. Nomenclature of organic compounds:
 - a) trivial (or common) nomenclature
 - b) systematic nomenclature IUPAC.

Exercises

1. Give the IUPAC names for the following compounds:

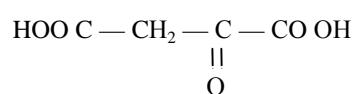
a)

lactic acid



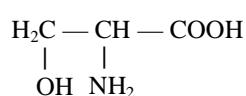
b)

oxaloacetic acid



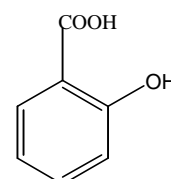
c)

serine

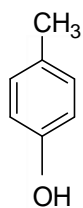


d)

salicylic acid

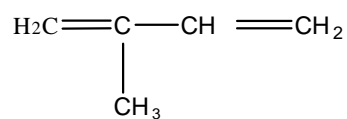


e)

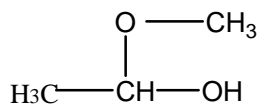


f)

isoprene

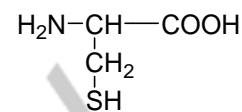


g)



h)

cysteine



2. Write a structural formula for each of the following compounds:

a) 3-hydroxy-3-carboxypentanedioic acid (citric acid)

b) 1,1,2-trichloroethene

c) 2-amino-4-methylthiobutanoic acid

d) 4-methylpentanol-2

e) 4-aminobenzoic acid

a) 2,6-diaminohexanoic acid

Test control

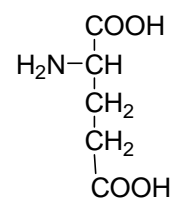
1. Give the IUPAC name for the following amino acid:

a) 2-aminobutanedioic acid

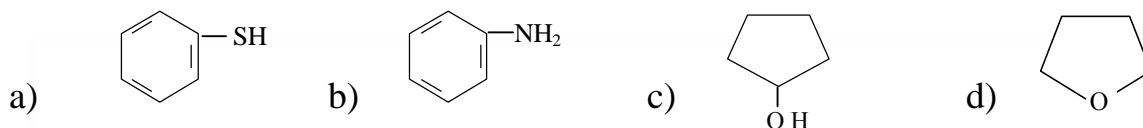
b) 2-aminopropanoic acid

c) 2-aminopentanoic acid

d) 2-aminopentanedioic acid



2. Indicate a heterocyclic compound:



3. Give the IUPAC name for the following compound $\text{CH}_3\text{-CHCl-CH}_2\text{-CHBr-CH}_3$:

- a) 2-chloro-4-bromobutane
- b) 2-bromo-4-chlorobutane
- c) 2-chloro-4-bromopentane
- d) 2-bromo-4-chloropentane

4. Select compounds containing hydroxyl group:

- a) ethanol
- b) phenol
- c) ethanol
- d) 2-hydroxypropanoic acid

5. Indicate methylpropylether:

- a) $\text{CH}_3\text{-O-CH}_2\text{-CH}_3$
- b) $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-O-CH}_3$
- c) $\text{CH}_3\text{-CH}_2\text{-O-CH}_2\text{-CH}_3$
- d) $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-O-CH}_2\text{-CH}_3$

6. Select the unsaturated compounds:

- a) cyclohexane
- b) propenal
- c) pentane
- d) butadiene-1,3

LABWORK #2

Theme: STEREOISOMERISM, ITS ROLE FOR BIOLOGICAL ACTIVITY DEMONSTRATION

Objective: to study the dimensional organization and discuss a stereoisomerism role for interaction specificity on a molecular scale understanding

Recommended literature:

1. Zurabyan S.E. Fundamentals of Bioorganic Chemistry. Textbook for Medical Students, 2006 p. 61-81.
2. T. W. Solomons. Fundamentals of Organic Chemistry. John Willey&sons, 1994. p. 164-198.

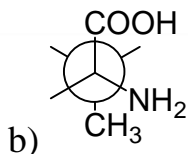
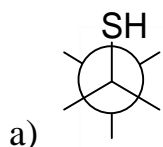
Problems for discussion:

1. Stereoisomerism. Classification of stereoisomers.
2. A spatial structure of a sp^3 -hybridized carbon atom. Configuration. Stereochemical formulas. Molecular models.
3. Ethane configuration and conformations, torsion strain. Newman projections.
4. Butane conformations. Van der Waals strain. Long-chain compound conformations.
5. Carbocyclic compound conformations, angle strain. Cyclohexane conformations. A cyclohexane ring in the biologically important compounds.
6. Chiral and achiral molecules. Chiral centers. Optical activity is the property inherent chiral molecules.
7. Fisher's projective formulas. Enantiomers.
8. Relative D-,L-nomenclature of stereoisomers. Glyceraldehyde as the configuration standard. R, S-system of a configuration designation.
9. Racemic mixtures. Methods of racemic substance division.
10. Diastereoisomerism. Stereoisomers of tartaric acid.
11. Cis-, trans-isomerism. Stereoisomers of butenedioic and oleic acids.

Exercises

1. Write all possible conformations by means of Newman projections for the following compounds.
 - a) ethanethiol
 - b) butane
 - c) butanedioic acid

2. Write the structural formulas for the following Newman projections:



3. Draw the possible chair conformations of the cyclohexanol

4. Draw the preferred conformation of the following compounds:

a) 2-methylcyclohexanol

b) 1,3-dichlorocyclohexane

5. Write D- and L-isomers by means of Fisher projections for the following compounds:

a) 2-aminopropanoic acid

b) 2-hydroxybutanedioic acid

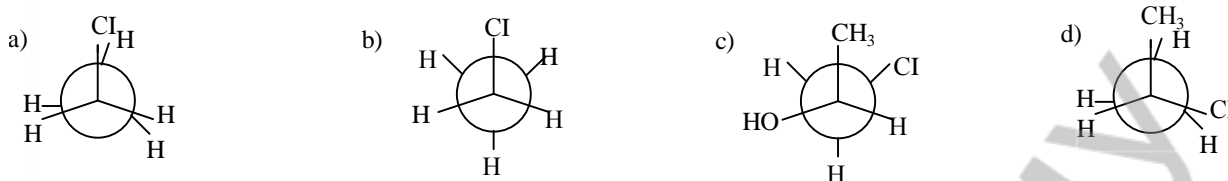
c) 2-amino-3-hydroxybutanoic acid (2 chiral centers)

6. Write R- and S-isomers for the following compounds:

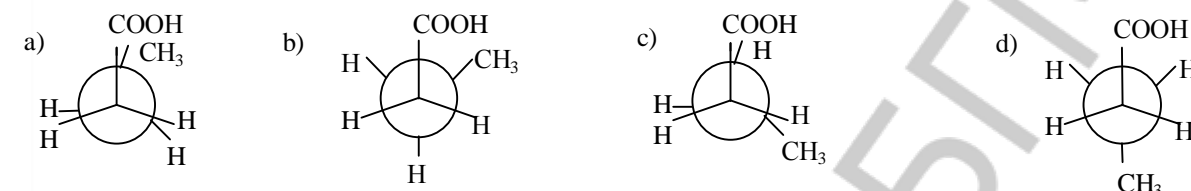
a) 2-hydroxypropanoic acid

Test control

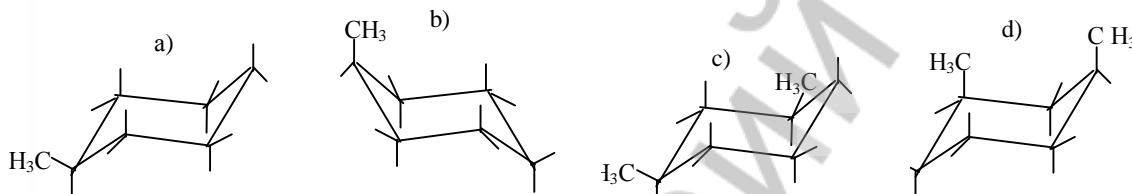
1. Select the most stable chloroethane conformation. Name it.



2. Indicate the most stable butanoic acid conformation:



3. Select the most stable methylcyclohexane conformation:



4. Chiral molecules are:

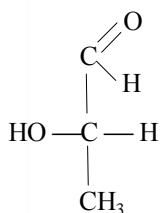
- a) α -hydroxybutyric acid b) β -hydroxybutyric acid
c) γ -hydroxybutyric acid d) γ -hydroxyvaleric acid

5. Enantiomers are:

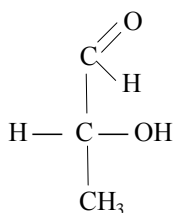
- a) pairs of stereoisomers which concern to each other as a subject and its display in an ideal plane mirror, possess in achiral surroundings identical chemical and physical properties, except for a sign on optical rotation
- b) pairs of stereoisomers which at mixing in equimolar ratio form a racemic substance
- c) pairs of stereoisomers of the same substances not being a mirror image of one another and possessing various chemical and physical properties
- d) pairs of stereoisomers, capable to pass each other due to rotation of atoms or groups of atoms on a line σ -bond

6. Select stereoisomers of the "configuration standard":

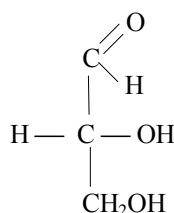
a)



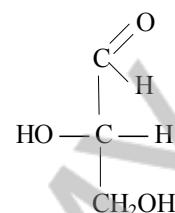
b)



c)



d)



7. What statements concerning racemic mixtures are true:

a) at mixture equimolar quantities D-and L-stereoisomers the inactive mixes named racemic are formed optically

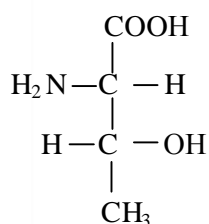
b) racemic substances are formed at chemical synthesis without observance of special conditions

c) racemic substances can be divided on optically active enantiomers by means of only physical methods

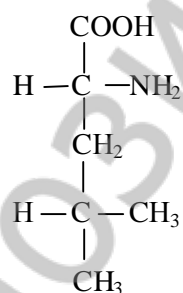
d) from racemic substances can be evolved enantiomers by means of microbiological (biochemical), chemical methods and by an affine chromatography

8. Select the compounds containing two chiral centers:

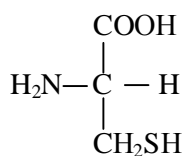
a)



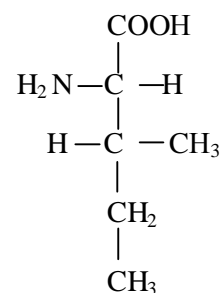
b)



c)



d)



LABWORK # 3

Theme: CHEMICAL BOND STRUCTURE AND ELECTRONIC EFFECTS IN THE ORGANIC MOLECULES

Objective: to develop knowledge about chemical bond structure, dimensional and electronic effects of substituents.

Recommended literature:

1. Zurabyan S.E. Fundamentals of Bioorganic Chemistry. Textbook for Medical Students, 2006 p. 33-44.
2. T. W. Solomons. Fundamentals of Organic Chemistry. John Willey&sons, 1994. p. 27-52.

Problems for discussion:

1. An electronic and dimensional structure of sp^2 -hybridized carbon atom.
2. Conjugated systems. Conjugation energy.
3. Cyclic conjugated systems. Aromaticity. Huckel's rule. Aromaticity of benzoic and non-benzoic systems.
4. Aromaticity of heterocyclic systems (pyrrole, pyridine).
5. Inductive effect.
6. Mesomeric (or resonance) effect.
7. Electron donating and electron withdrawing substituents.

Exercises:

1. Write down structural formula and estimate of the following compounds. What kind of the conjugated system exists in the following compounds?

butadiene-1,3	propenoic acid
propenal	pyrrole
2-methylbutadiene-1,3	pyridine

2. Define aromaticity by the means of Huckel's rule for the compounds:

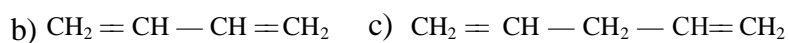
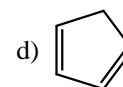
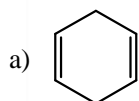
benzene	pyridine (draw the electronic structure of pyridine nitrogen)
phenanthrene	pyrrole (draw the electronic structure of pyrrole nitrogen)
pyrimidine	purine

3. Show the electron density distribution in the molecules with inductive and mesomeric effects:

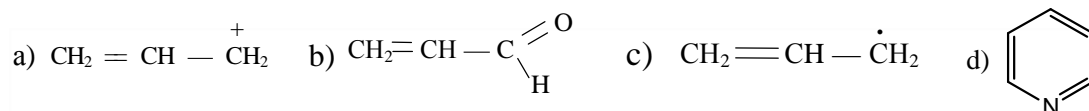
1-chlorbutane	benzoic acid
propanal	toluene
benzylamine	phenol

Test control

1. Indicate formulas of compounds with the conjugated double bonds:



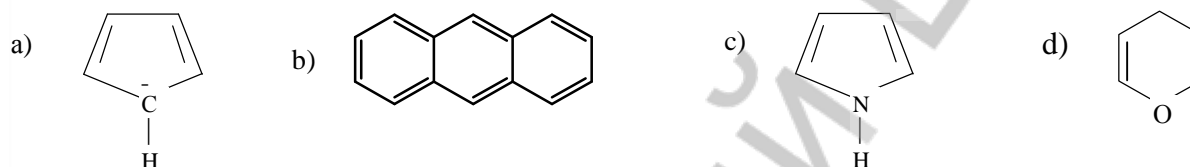
2. Select the compounds with π - π -conjugation:



3. Which of the following statements are correct for aromatic compounds:

- a) low thermodynamic stability
- b) addition reactions are more feature than substitution reactions
- c) substitution reactions are more feature than addition reactions
- d) high stability of compounds to oxidant and temperature action

4. Which of the following compounds are aromatic?



5. Which of the following substituents possesses positive inductive effect?



6. What electronic effects does hydroxyl group possess in benzyl alcohol?



LABWORK # 4

Theme: ACID-BASE PROPERTIES OF ORGANIC COMPOUNDS.

OXIDATION REACTIONS

Objective: to develop knowledge about acidity and basicity of organic compounds, about the factors influencing their expressiveness; to generate skills for qualitative determination of organic compound acidity and basicity.

Recommended literature:

1. Zurabyan S.E. Fundamentals of Bioorganic Chemistry. Textbook for Medical Students, 2006. p. 47-59.
2. T. W. Solomons. Fundamentals of Organic Chemistry. John Wiley&sons, 1994. p. 86-102.

Problems for discussion:

1. The Brensted theory of organic compound acidity and basicity. The Lewis electronic theory of organic compound acidity and basicity. Classification of organic acids.
2. The quantitative and qualitative characteristics of acidity. The factors influencing on the acidic properties of organic compounds.
3. Oxidation reactions of alcohols, thiols and phenols. Antioxidants and their role in processes of vital activity.
4. Basicity. The factors influencing on the basic properties of organic compounds.
5. Amphoteric properties of organic compounds. Hydrogen bonds.

Exercises:

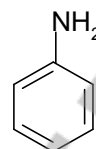
1. Compare acidity of compound in the following groups:
 - a) ethanol and ethanethiol
 - b) propanol-1 and propantriol-1,2,3 (glycerine)
 - c) acetic and monochloroacetic acids
 - d) ethanoic and ethanedioic acids
 - e) phenol and 4-aminophenol

f) propanoic and 2-oxopropanoic acids

g) propanoic and propenoic acid

3. Write the conjugate acid of the following bases:

a) $\text{CH}_3\text{-NH}_2$ b) H_2O c) OH^- d) CH_3COO^- e)



f) $\text{H}_2\text{N}-\text{C}(=\text{O})-\text{NH}_2$

4. Compare basicity of compound in the following groups:

a) dimethyl ether, dimethylamine, dimethylsulfide

b) ethylamine and aniline

c) ethylamine and diethylamine

d) 2-aminoethanol and ethylamine

5. Write the ethanol oxidation reaction *in vivo*.

6. Write the 2-amino-3-mercaptopropionic acid oxidation reaction scheme.

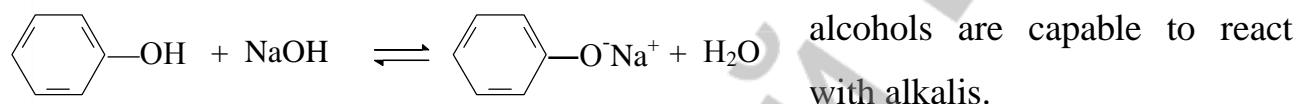
Accomplishment: to 5 drops of NaOH (21) solution add 1-2 drops of solution CuSO₄ (26), shake, add 2 drops of glycerine (4), shake.

Observed changes: _____

Conclusion: _____

3. Sodium phenoxide production and its decomposition

Phenols possess more strong acidic properties than alcohols because stability of phenoxide anion raises according to negative charge delocalization along bond conjugate system. Phenols unlike



Water-soluble sodium phenoxide is formed. Mineral acids replace phenol from phenoxides.



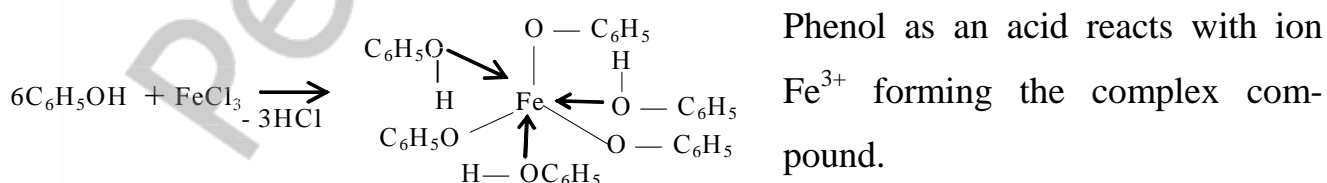
Accomplishment: to 10 drops of phenol water emulsia * add on drops solution of NaOH (21) until transparent solution has been obtained. Add on drops dilute solution of H₂SO₄ (23), and again emulsia is formed.

Observed changes: _____

Conclusion: _____

4. Qualitative test on phenol

This is a qualitative test on the hydroxyl group bound with unsaturated carbon atom.



Accomplishment: to 10 drops of phenol water emulsia * add 1-2 drops of solution of FeCl₃ (8), shake.

Observed changes: _____

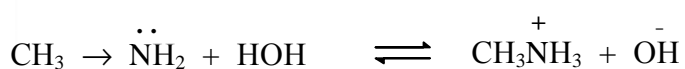
Conclusi-

si-

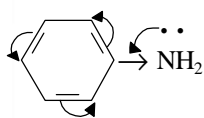
on: _____

5. Comparison of the methyl amine and aniline basic properties

Aliphatic radicals possessing positive inductive effect +I increase electronic density on the nitrogen atom therefore aliphatic amines are stronger bases than ammonia NH₃.



In aromatic amines nitrogen atom unshared electronic pair participates in the aromatic ring π -electronic system therefore aniline is weaker base than methyl amine.



Accomplishment: one litmus band is moistened with water solution of methylamine* and another is with water solution of aniline*.

Observed changes: _____

Conclusi-

si-

on: _____

LABWORK # 5

Theme: CLASSIFICATION AND MECHANISMS OF REACTIONS IN ORGANIC CHEMISTRY

Objective: to study classification and mechanisms of organic reactions and to develop skills of carrying out of qualitative tests for double bond detection in organic compounds.

Recommended literature:

1. Zurabyan S.E. Fundamentals of Bioorganic Chemistry. Textbook for Medical Students, 2006. p. 92-110.
2. T. W. Solomons. Fundamentals of Organic Chemistry. John Wiley & Sons, 1994. p. 267-273, 297-314, 323-328, 340-354, 371-372, 599-612, 614-629, 636-637, 519-522, 525-534.

Problems for discussion:

1. Organic reaction mechanism definition. Homolytic and heterolytic mechanisms of bond cleavage. Classification of reagents in organic reactions
2. Organic reactions classification according to the direction and result of reaction.
3. Reactions of radical substitution (S_R). Alkanes and cycloalkanes.
4. Electrophilic addition (A_E) to alkenes: hydrogenation, halogenation, hydrohalogenation and hydration reactions. The Markovnikov's rule.
5. Mechanism of electrophilic substitution reactions (S_E) in aromatic compounds. I and II sort directing substituents.

Exercises:

1. Describe the mechanism of the following free radical reactions:
 - a) bromination of propane
 - b) chlorination of cyclohexane

2. Describe the reaction mechanism of interaction of the following compounds:

a) ethene and HCl

b) propene and HCl

c) ethene and H₂O

d) propenoic acid and H₂O

e) butene-2-oic acid and H₂O

1. Write the mechanism of the following reactions:

a) chlorination of benzene (AlCl₃ as catalyst)

b) nitration of benzene

c) alkylation of toluene with CH₃Cl (AlCl₃ as catalyst)

Test control

1. What particles are formed as a result of covalent bond heterolytic cleavage:

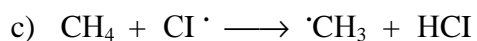
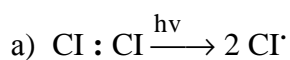
a) two radicals

b) electrophile and nucleophile

c) two electroneutral particles

d) positively and negatively charged ions

2. Select chain termination steps in the chlorination reactions of alkanes:



3. Which of the following reagents react with ethylene according to the A_E mechanism:

a) bromine water

c) KMnO_4 weak solution

b) oxygen

d) water at concentrated solution of H_2SO_4 presence

4. Which of the following compounds is mainly formed as a result of acrylic acid hydrochlorination reaction:

a) 2-chloropropanoic acid

c) 3-chloropropanoic acid

b) chloranhydride of propanoic acid

d) α -chloropropanoic acid

5. Select the nucleophilic reagents:

a) H^+ b) H_2O c) $\text{C}_2\text{H}_5\text{OH}$ d) OH^-

6. Select the electrophilic reagents:

a) $\text{CH}_3\text{-NH}_2$ b) H^+ c) $\text{CH}_3\text{-OH}$ d) $^+\text{CH}_3$

7. The following factors may result in homolysis:

a) acid catalysis

b) base catalysis

c) ultraviolet radiation

d) heating

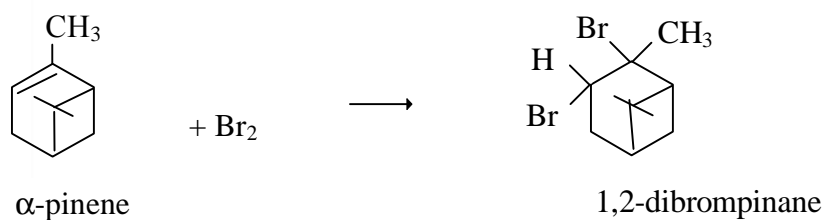
e) using of peroxides

8. Find the accordance between substrate (column I) and typical reaction mechanism (column II):

Column I	Column II
a) butane	1) A_E
b) cyclohexane	2) A_R
c) 2-methyl propene	3) S_R
d) cyclopropane	
e) chloroethene	

Practical part

1. Qualitative test on the alkenes with bromine water.



Accomplishment: to 4 drops of bromine water* add 2 drops of α -pinene* and shake.

Observed changes: _____

Conclusion: _____

2. Qualitative test on the alkenes with potassium permanganate.



Accomplishment: to 6 drops of KMnO₄ (14) solution add 1 drop of α -pinene* and shake.

Observed changes: _____

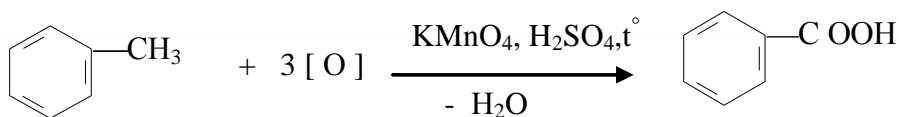
Conclu-

si-

on: _____

3. Toluene oxidation

Oxidation stability is one of the main properties of aromatic systems. Toluene oxidation reaction goes in a side chain but the aromatic kernel is stored:



toluene

benzoic acid

Accomplishment: to 10 drops of KMnO_4 water solution (14) add 10 drops of dilute solution of H_2SO_4 (23) and 5 drops of toluene*, carefully heat and shake.

Observed changes: _____

Conclusion:

LABWORK # 6

Theme: BIOLOGICALLY IMPORTANT REACTIONS REACTION OF ALDEHIDES AND KETONES

Objective: to study features of aldehydes and ketones reactivity and develop skills to carrying out of qualitative reactions on aldehydes, ketones.

Recommended literature:

1. Zurabyan S.E. Fundamentals of Bioorganic Chemistry. Textbook for Medical Students, 2006 p. 133-147/

2. T. W. Solomons. Fundamentals of Organic Chemistry. John Wiley & sons, 1994. p. 642-661, 674-675, 686-689, 692-696.

Problems for discussion:

1. An electronic structure of a carbonyl group. The reactionary centers in aldehydes and ketones.
2. Mechanism of nucleophilic addition reaction (A_N). Addition of water and alcohols. Reactions of aldehydes and ketones with amines. Reduction reactions.

3. Reaction of CH-acidic center. Aldol condensation reactions. Haloform reactions.
4. Oxidation reactions are qualitative tests on aldehyde group. Oxidation reactions of ketones. Disproportionation reactions.
5. Formaldehyde. Application in medicine. Toxicity.

Exercises:

1. Write reaction schemas of ethanal reduction *in vivo* and *in vitro*.
2. Write down the reduction reaction of 2-oxopropanoic acid with $\text{NADH} \cdot \text{H}^+$.
3. Describe the mechanism of acetalization reaction:
 - a) ethanal with methanol
 - b) methanal with propanol-2
4. Describe the mechanism of intramolecular acetalization reaction to form cyclic hemiacetal:
 - a) 5-hydroxyhexanal
 - b) 4-hydroxypentanal

5. Describe the mechanism of interaction of ethanal and methylamine.
6. Write the schema of aldol condensation reaction on an example of 2-methylpropanal.
7. Describe the mechanism of disproportionation reaction for the formaldehyde.

Test control

1. Select reagents by means of which it is possible to find out presence of aldehydic group:

- a) Schiff's reagent
- b) Cu (II) hydroxide when heated
- c) Cu (II) hydroxide at room temperature
- d) $I_2 + NaOH$

2. As a result of reaction of reduction in vivo acetic aldehyde are formed:

- a) ethanol and $NADH + H^+$
- b) ethanol and NAD^+
- c) ethanal and NAD^+
- d) methanol and NAD^+

3. Which compounds are formed as a result of secondary alcohol oxidation:

a)	$\begin{array}{c} \text{C}_3\text{H}_7 - \text{C} \begin{array}{l} \text{// O} \\ \text{- CH}_3 \end{array} \end{array}$	c)	$\begin{array}{c} \text{CH}_3 - \text{CH}_2 - \text{C} - \text{CH} - \text{CH}_3 \\ \quad \quad \quad \text{ } \quad \quad \\ \quad \quad \quad \text{O} \quad \quad \text{CH}_3 \end{array}$
b)	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{C} - \text{C} \begin{array}{l} \text{// O} \\ \text{- H} \end{array} \\ \\ \text{CH}_3 \end{array}$	d)	$\begin{array}{c} \text{CH}_3 - \text{CH} - \text{C} \begin{array}{l} \text{// O} \\ \text{- H} \end{array} \\ \\ \text{CH}_3 \end{array}$

4. What reaction leads to acetal formation:

- a) 1 mol of methanal + 1 mol of propanal

- b) 1 mol of propanal + 1 mol of methanol
- c) 1 mol of ethanal + 2 mol of methanol
- d) 1 mol of propanal + 2 mol of ethanol

5. Indicate the reagents used to obtain Schiff's bases:

- a) propanal and benzaldehyde b) acetaldehyde and ethanol
- c) propanal and aniline d) ethylamine and benzaldehyde

6. Indicate the reaction used to obtain acetal:

- a) propanal and benzaldehyde b) acetaldehyde and ethanol
- c) propanal and aniline d) methylamine and benzaldehyde

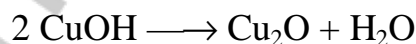
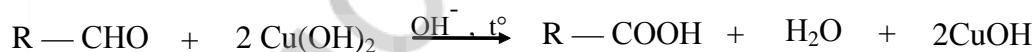
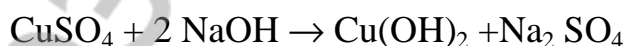
7. Indicate the reaction used to obtain hemiacetal:

- a) propanal and aniline b) acetaldehyde and ethanol (1:2)
- c) methanal and propanol-1 (1:1) d) methylamine and acetaldehyde

Practical part

1. Formaldehyde oxidation with $\text{Cu}(\text{OH})_2$ in alkaline medium

Qualitative tests on aldehydes are connected with easy oxidizability of aldehydic group with oxides or metal hydroxides in medium at heating, thus aldehydes turn into carboxylic acids with the same number of carbon atoms and the ion of metal is reduced. The Trommer's reagent (fresh obtained copper (II) hydroxide) is used as an oxidizer.



Accomplishment: to 1-3 drops of formaline (32) add 10 drops of NaOH solution (21) and 1-2 drops of CuSO_4 (26). Mixture is heated to boiling point.

Observed

chang-

es: _____

Conclusi-

si-

on: _____

2. Reaction of formaldehyde with Schiff's reagent

Reaction goes according to the A_N mechanism with the Schiff's reagent without heating.

Accomplishment: to 3-4 drops of the Schiff's reagent* add 1 drop of formaldehyde solution (32).

Observed changes: _____

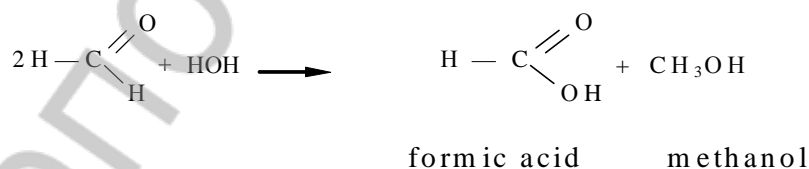
Conclusi-

si-

on: _____

3. Disproportionation reaction of formaldehyde

Disproportionation reaction is interaction of two aldehyde molecules when one aldehyde molecule is reduced to alcohol due to another aldehyde molecule is oxidized to a carboxylic acid. Water formaldehyde solution has acidic medium of reaction.



Accomplishment: to 3-4 drops of formaline (32) add 1 drop of methyl red indicator*.

Observed changes: _____

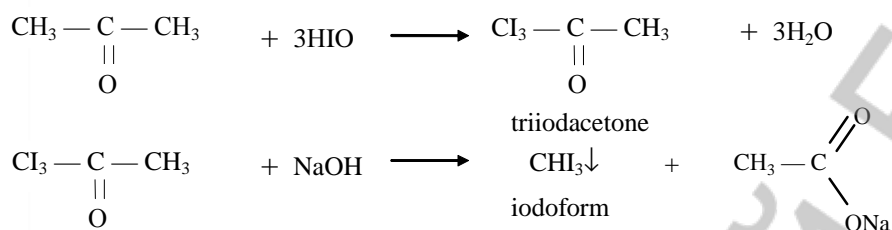
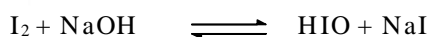
Conclusi-

si-

on: _____

4. Acetone detection by transformation to iodoform (iodoform reaction)

Iodoform reaction is connected with ability of carbonyl containing compounds to substitute hydrogen atom at α -carbon atom on halogen and the following cleavage of carbon-carbon bond with iodoform (CHI_3) formation.



Accomplishment: to 6-8 drops of Lugol (47) solution (I_2 in KI solution) add NaOH solution (21) to disappearing of color, then pour 1-2 acetone drops*.

Observed changes: _____

Conclusi-

si-

on: _____

5. Colored reaction on the acetone with sodium nitroprusside.

Reaction with sodium nitroprussiate $\text{Na}_2[\text{Fe}(\text{CN})_5\text{NO}]$ is used in a clinical practice to discovery of acetone in urine at a diabetes. Aromatic carbonyl compounds do not yield this reaction.

Accomplishment: to 1 acetone* drop add 5 drops of sodium nitroprussiate $\text{Na}_2[\text{Fe}(\text{CN})_5\text{NO}]$ (35) and 3-4 drops of NaOH (21) solution. In 2-3 minutes add 3 drops of acetic acid (36).

Observed changes: _____

Conclusi-

si-

on: _____

LABWORK # 7

Theme: CARBOXYLIC ACID AND THEIR DERIVATIVES

Objective: to study features of carboxylic acids reactivity and develop skills to carrying out of qualitative reactions on carboxylic acids.

Recommended literature

1. Zurabyan S.E. *Fundamentals of Bioorganic Chemistry. Textbook for medical students, 2006 P. 149-159.*
2. T. W. Solomons. *Fundamentals of Organic Chemistry. John Willey&sons, 1994. p. 714-723, 726-735 740-745 752-761.*

Problems for discussion

1. Reactions sites of carboxylic acids and derivatives.
2. Acidic properties of carboxylic acids.
3. Decarboxylation reaction. Biogenic amines. Cyclic anhydrides.
4. Nucleophilic substitution reactions. Esterification reaction.
5. Amides, acyl chlorides, anhydrides. Their hydrolysis.

Exercises

1. Compare the acidity of ethanoic and ethanedioic acids. Write the reaction of salt formation of the stronger acid with $\text{Ca}(\text{OH})_2$.

2. Write down the decarboxylation reaction of the following compounds:

a) malonic acid

b) 2-aminopentanedioic acid

3. Write the esterification reactions of the methanoic acid with propanol-2.

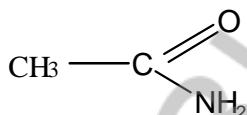
4. Write down the hydrolysis reaction of methyl ethanoate:

a) acidic hydrolysis

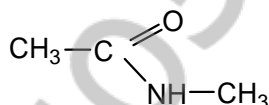
b) alkaline hydrolysis (with NaOH)

6. What products would be obtained from the hydrolysis of each of the following amides:

a)



b)



Test control

1. Indicate the dicarboxylic aliphatic acids:

a) butyric b) oxalic c) malonic d) succinic

2. When heated in the acidic medium butandioic acid can give the following products: a) H₂O b) CO₂ c) propanoic acid d) succinic anhydride

3. Which of the following compounds reacts with acetic acid to form thioester?

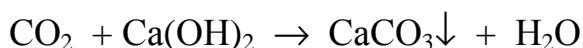
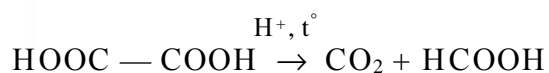
a) ethanol b) ethanthiol c) NH₃ d) SOCl₂

4. Indicate the compounds that can easily undergo the decarboxylation reaction:

on: _____

2. Oxalic acid decarboxylation

Result of the oxalic acid decarboxylation is carbon dioxide which forms CaCO_3 when mixed with the lime water (solution of Ca(OH)_2)



Accomplishment: in dry test-tube add crystal oxalic acid* (mass $\approx 0,5$ g). Test-tube is closed by flatus tube and heat. The end of flatus tube put into test-tube with 15 drops of lime water (2).

Observed changes: _____

Conclusi-

si-

on: _____

LABWORK # 8

CONCLUDING TEST "THEORETICAL FUNDAMENTALS OF BASIC CLASSES OF ORGANIC COMPOUND STRUCTURE AND REACTIVITY"

Remind the program material from the theme # 1 to # 7.

Recommended literature: Study the literature from the theme # 1 to # 7.

QUESTIONS TO THE CONCLUDING TEST

1. Conformations. Newman projections. Types of strains. Energetic characteristic of eclipsed, gauche and staggered conformations (butane). Conformational structure of hydrocarbon radicals of fatty acids (palmitic and stearic acids).

2. Cyclohexane conformations. Types of strains (angle, torsion, Van-der-Waals). Inversion of cycle. 1,3-diaxial interaction.
3. Configuration of organic compounds. Stereoisomerism. Fischer projections. Relative configuration and D, L-convention. Glyceraldehyde as the configurational standard.
4. Stereoisomerism of molecules with one chiral centre (lactic acid as an example). Enantiomers. Optic activity. Racemic mixtures.
5. Absolute configuration of stereoisomers. R, S-convention. Relationship of spatial structure with biological activity.
6. Electronic effects in organic molecules (inductive and mesomeric), their role in the reactivity centers in the molecule. Electron donors and withdrawers.
7. Conjugation (π,π - and p,π - conjugations). Conjugated systems with open chain (butadiene-1,3).
8. Conjugated systems with close chain. Aromaticity, criteria of aromaticity, Hückel's rule (benzene, naphthalene, phenanthrene).
9. Heterocyclic aromatic compounds (pyrrole, pyridine). Pyrrole and pyridine nitrogen atoms. π -Excess and π -deficient aromatic systems.
10. Acidity and basicity of organic compounds; Brønsted and Lewis theories.
11. Acidic properties of organic compounds (alcohols, phenols, thiols, carboxylic acids, amides). Factors of anion stability.
12. Basic properties of organic compounds (alcohols, ethers, thioesters, amines). Comparing of basic properties of aliphatic and aromatic amines; salt formation.
13. Classification of organic reactions (substitution, addition, elimination, isomerisation, red-ox, acid-basic interaction).
14. Classification of organic reactions on the mechanism of covalent bond cleavage (radical and ionic). Electronic and spatial structure of free radicals, carbocations and carbanions.
15. Oxidation reactions of organic compounds (alcohols, thiols, phenols). Antioxidants (2,3-dimercaptopropanol, ascorbic acid, phenols and others).
16. Radical substitution reactions. Propane chlorination as an example of free radical substitution. Initiators of radical reactions. Antioxidants.

17. Electrophilic addition reactions of alkenes. Hydration reactions of alkenes. Acidic catalysis. Markovnikov's rule.
18. Electrophilic substitution reactions of aromatic hydrocarbons. Substituent effects in the aromatic ring on the reactivity of aromatic hydrocarbons.
19. Alkylation reactions of aromatic compounds.
20. Electronic and spatial structure of the carbonyl group. Comparative reactivity of aldehydes and ketones.
21. Oxidation and reduction reactions of carbonyl compounds. Visual tests on the aldehyde group (silver mirror test, Trommer test). Reduction reactions *in vivo*, NADH as a hydride ion donor.
22. Nucleophilic addition reactions of aldehydes and ketones; addition of water and alcohols.
23. Addition of amines to carbonyl compounds, mechanism. Schiff's bases.
24. Electronic and spatial structure of the carboxylic group. Acidic properties of the carboxylic acids: mono-, dicarboxylic, aliphatic saturated, aliphatic unsaturated, aromatic carboxylic acids.
25. Nucleophilic substitution at sp^2 -hybridized carbon atom in the carboxylic group: esterification reaction. Properties of esters, hydrolysis.

LABWORK # 9

Theme: HETEROFUNCTIONAL COMPOUNDS OF ALIPHATIC, BENZENE AND HETEROCYCLIC SERIES, METABOLITES AND BIOREGULATORS

Objective: to develop skills to predict chemical properties biologically important heterofunctional compounds taking into account a structure and interference of various functional groups.

Recommended literature

1. Zurabyan S.E. Fundamentals of Bioorganic Chemistry. Textbook for medical students, 2006 P. 161-171, 175-177, 178-179, 236

2. T. W. Solomons. Fundamentals of Organic Chemistry. John Willey&sons, 1994. p. 805-807, 808, 827-837, 869-870, 782-783, 849-850, 782-783.

Problems for discussion

1. Polyfunctional compounds: classification, chemical properties.
2. Heterofunctional compounds: classification, a role in biological processes.
3. Aminoalcohols: their biological role.
4. Hydroxyacids. A structure, typical and specific properties of α -, β -, γ - hydroxy and amino acids.
5. A citric acid: a structure, properties. Citrates.
6. Oxoacids. Acid properties and reactivity. Ketone bodies.
7. Keto-enol tautomerism.
8. Amides of carbonic acid. Urea.
9. Salicylic acid, its derivatives.
10. Para-aminobenzoic acid, its derivatives.

Exercises

1. Write the structural formulas of the following compounds:

a) glycerol	b) ethylene glycol
c) choline	d) fumaric acid
e) colamine	f) malic acid
g) maleic acid	h) oxalic acid
i) lactic acid	j) citric acid
k) malonic acid	l) pyruvic acid

m) oxaloacetic acid	n) α -oxoglutaric acid

2. Write schema of oxidation reaction *in vivo* of:

a) lactic acid

b) malic acid

3. Write the equations of interaction of lactic acid and:

a) NaOH

c) C₂H₅OH

c) CH₃COCl

4. Write down schema of the reduction reaction of pyruvic acid *in vivo*.

5. Write down the tautomeric forms of oxaloacetic acid

6. Write down the formulas of ketone bodies.

7. Write the schemas of acetylsalicylic acid formation reaction.

8. Write the structures of
a) para-aminobenzoic acid

b) anesthesine

c) novocaine

9. Describe the acid-catalysed hydrolysis reaction of novocaine.

10. Write down the salt formation reaction of HCl with:

a) novocaine

b) ultracaine

c) lidocaine

Test control

1. What substances does lactic acid react with:

a) acetylchloride

c) ammonia

b) ethanol

d) potassium hydroxide

2. Which of the following hydroxyacids at oxidation in vivo with coenzyme NAD⁺ participation turns to an oxalacetic acid:

a) lactic acid

c) citric acid

b) malic acid

d) pyruvic acid

3. Which of the following compounds are ketone bodies:

a) α -hydroxybutaric acid

c) β -hydroxybutaric acid

b) acetocetic acid

d) acetone

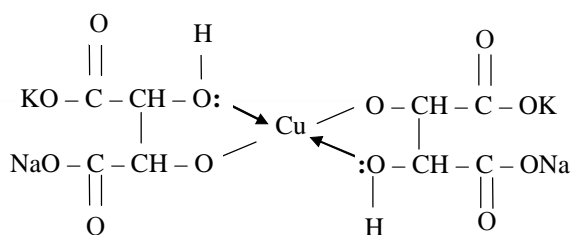
4. Which products are formed at interaction of salicylic acid with acetic anhydride:

a) acetic acid

c) aspirin

b) acetylsalicylic acid

d) CO₂



The Fehling's reagent

Copper alcoholate of sodium and potassium tartrate is called the Fehling's reagent and is used for qualitative and quantitative definition of carbohydrates.

Accomplishment: Pour 2 drops of 5% solution of CuSO_4 (26) and 2 drops of 10 % solution of NaOH (21) in the test tube. Then to the formed mixture add the solution of segnetic salt, received at the last experiment.

Observed changes: _____

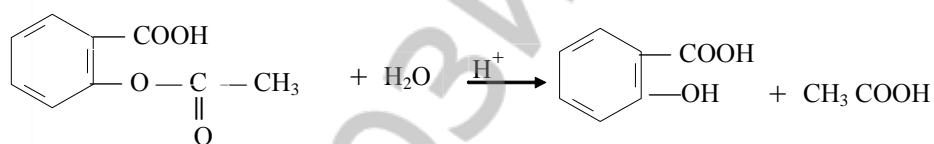
Conclusi-

si-

on: _____

3. Test on the high quality of aspirin

At hydrolysis of aspirin ortho-hydroxybenzoic acid is formed which with Fe (III) chloride forms complex compound.



Accomplishment: place some grains of aspirin* and 5 - 6 drops of water in a test tube, shake it. Divide the test tube contents into 2 parts. To one part add 1 drop of FeCl_3 (8), another part boil for half a minute and then add 1 drop of FeCl_3 .

Observed changes: _____

Conclusi-

si-

on: _____

2. Write the alkaline hydrolysis (saponification) reaction of 1-lynolenoyl-2-arachidonoyl-3-stearoylglycerol. What is the soaps?

3. Draw the structural formulas of the following compounds:

a) 1-stearoyl-2-oleoylphosphatidylserine

b) 1-stearoyl-2-linoleoylphosphatidylcholine

c) 1-palmitoyl-2-arachidonoylphosphatidylethanolamine

Show hydrophobic and hydrophilic parts of these structures.

Test control

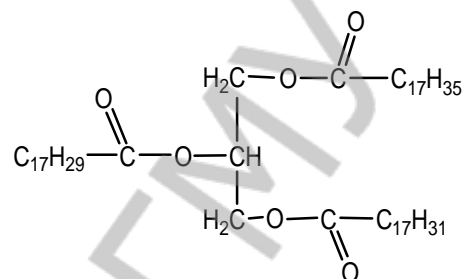
1. Which of the following statements are correct for unsaturated fatty acids:

- a) they have a nonbranched structure
- b) they contain one or a few π -bonds

- c) they always have trans - configuration
- d) they contain the even number of the carbon atoms

2. Indicate the correct fat name having the following structure:

- d) 1-stearoyl-2-palmitoyl-3-linolenoylglycerol
- e) 1-linolenoyl-2-palmitoyl-3-linoleoylglycerol
- f) 1-oleoyl-2-stearoyl-3-arahydroyl glycerol
- g) 1-stearoyl-2-linolenoyl-3-linoleoylglycerol



3. What compounds belong to saponified lipids:

- a) cholesterol
- b) phospholipids
- c) glycolipids
- d) waxes

4. Which is the mechanism of fat hydrolysis in the acidic medium:

- a) A_E
- b) A_N
- c) A_R
- d) S_N

5. Which compounds can react with phosphatidylethylamine containing residues of palmitic and oleic acids:

- a) water
- b) aqueous solution KOH
- c) potassium permanganate solution
- d) bromine water

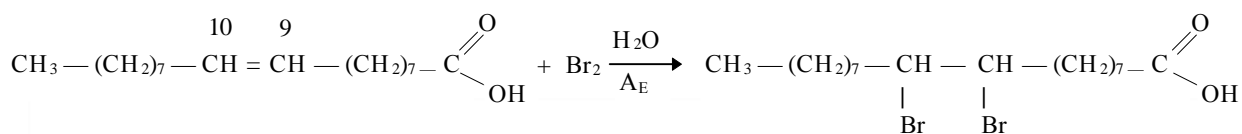
6. Which of the following compounds are formed as a result of the lipid peroxidation:

- a) malonic dialdehyde
- b) aldehydic acid
- c) dienic conjugates
- d) amino acids
- e) oxoacids

Practical part

1. Qualitative reactions on the unsaturated acids which form fats

A reaction with bromine water.



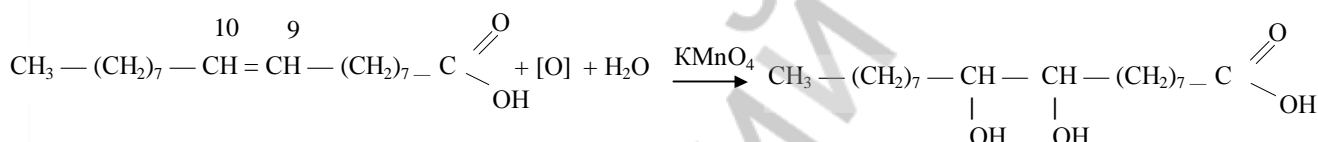
Accomplishment: to 1 drop of fat* add some drops of bromine water *. Shake the test-tube.

Observed changes: _____

Conclusion: _____

2. Oxidation reaction with potassium permanganate

Oxidation occurs in the double bond location.



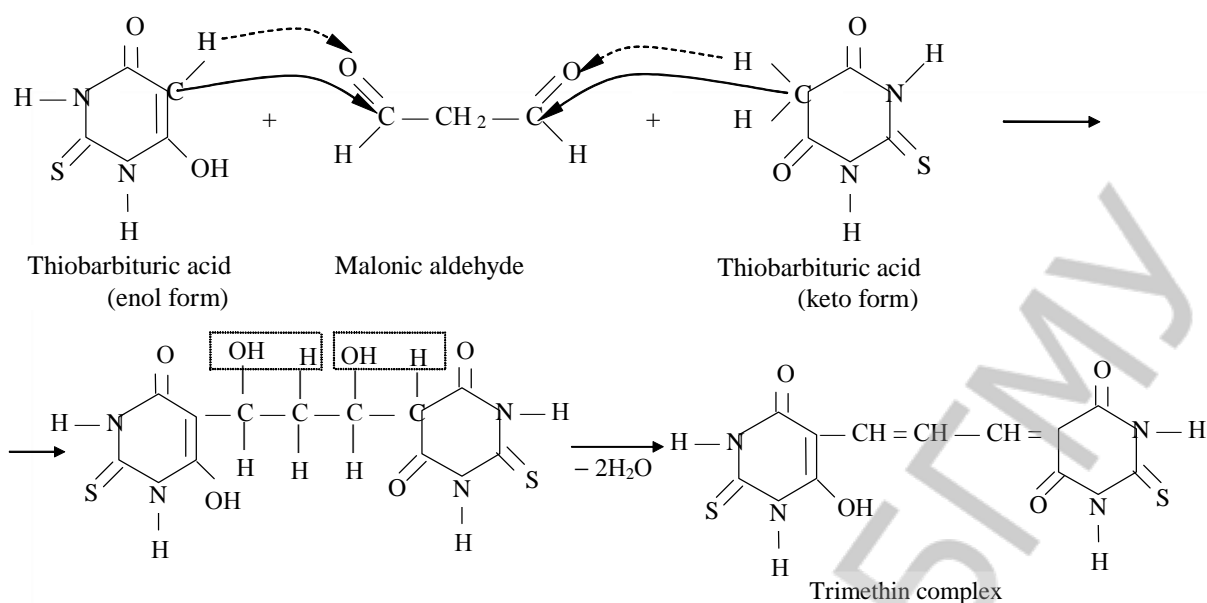
Accomplishment: to 1 drop of fat* pour 10 drops of KMnO_4 solution (14) and 2 drops of Na_2CO_3 (43). Shake the test-tube.

Observed changes: _____

Conclusion: _____

3. Malonic dialdehyde detection in the vegetable oil peroxidation products

The model of lipid peroxidation is rancidification. One of the lipid peroxidation products is malonic dialdehyde which can be formed from ω -3 unsaturated fatty acid hydroperoxides. To detect the malonic dialdehyde the reaction with thiobarbituric acid is used which goes according to the nucleophilic addition mechanism.



Accomplishment: in a test-tube #1 pour 10 drops of a fresh sunflower-seed oil* solution, in a test-tube #2 pour 10 drops long time stored on the light (in conditions of oxygen access) sunflower-seed oil, in a test-tube #3 pour 10 drops of margarine* solution (oils and margarine are dissolved in heptane-chloroform mixture in the volume ratio 1:1). Then in each of the test-tubes add on 10 drops of the TBA - reagent (0,8 % solution of thiobarbituric acid in an ice acetic acid)*. Test-tubes with a reaction mixture shake up, close with foil, place into boiling water bath. In 15 minutes take out the test-tubes and visually estimate color intensity of solutions.

Observed changes: _____

Conclusion: _____

LABWORK #11

Theme: CARBOHYDRATES. MONOSACCHARIDES

Objective: to develop knowledge of a stereochemical structure, consider important properties of monosaccharides and gain skills to carry out qualitative reactions on monosaccharides.

Recommended literature

1. Zurabyan S.E. *Fundamentals of Bioorganic Chemistry. Textbook for medical students, 2006 p 189-199.*
2. T. W. Solomons. *Fundamentals of Organic Chemistry. John Wiley&sons, 1994. p. 891-920*

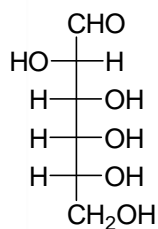
Problems for discussion

1. Carbohydrates: definition, biological role.
2. Monosaccharides, definition, classification, stereoisomerism. Epimers.
3. Monosaccharide tautomerism. Anomers. Tautomeric forms of D-glucose, D-galactose, D-fructose, D-ribose, 2-deoxy-D-ribose. Fisher and Haworth formulas. Conformations of cyclic forms.
4. Chemical properties of monosaccharides. Glycosides (O- and N-glycosides).
5. Monosaccharide esters. A biological role of monosaccharide phosphates.
6. Monosaccharide oxidation: aldonic, aldaric and uronic acids.
7. Monosaccharide reduction. Xylitol and sorbitol.
8. Aminosugars. Their structure, properties and a biological role.
9. Ascorbic acid (vitamin C) as water-soluble antioxidant.

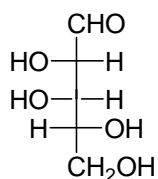
Exercises

1. Classify the following monoses according to the type of carbonyl group and the number of carbon atoms:

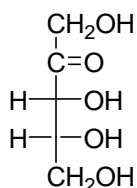
a)



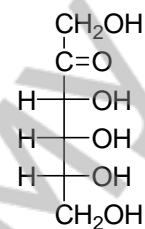
b)



c)



d)



Show

the

chiral

cen-

ters.

2. Write the all tautomeric

forms of D-

glu-

cose (according to Fisher and Haworth).

3. Show the chair conformations of the following monoses:

1. α , D-glucopyranose

2. β , D-glucopyranose

4. Write the interaction reaction between β , D-glucopyranose and ethanol at HCl presence.

5. Write the schemas of the following reactions:

a) oxidation of D-galactose with bromine water

b) oxidation of D-glucose with HNO_3

b) the stability of α - and β -forms is identical

c) the β -form is steadier

6. What esters of D-glucose and D-fructose are a part of vegetative and animal organisms?

a) phosphates

c) sulphates

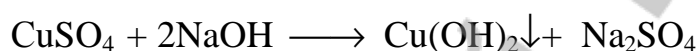
b) nitrates

d) acetates

Practical part

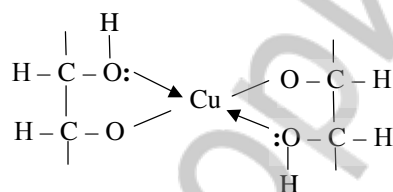
1. A qualitative test on the hydroxyl groups in the glucose molecule

Definition of some hydroxyl groups in the monosaccharide composition is carried out with $\text{Cu}(\text{OH})_2$. This reaction is the same that on the polyatomic alcohols.



First forming sediment $\text{Cu}(\text{OH})_2$ is dissolved when polyatomic alcohol is added.

This is the evidence of some hydroxyl group presence in the compound.



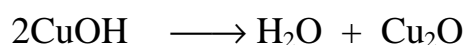
Accomplishment: to 10-12 drops of glucose (54) solution add 4-5 drops of NaOH (21) and drop by drop of CuSO_4 (26).

Observed changes: _____

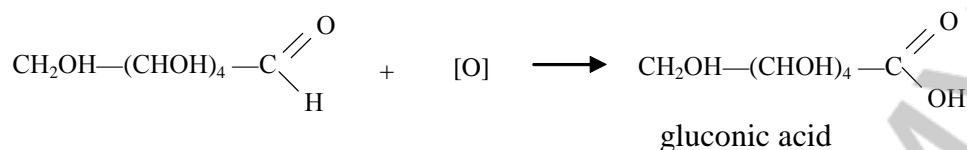
Conclusion: _____

2. A qualitative test on the aldehyde group in the glucose molecule

This reaction is carried out with the Fehling's reagent which is an alkaline solution of Cu^{2+} alcoholate with K-, Na - tartrates. Obtained chelate is stable and when heated the color doesn't change. However if it is heated at the aldose presence alcoholate will be hydrolyzed. And obtained $\text{Cu}(\text{OH})_2$ oxidizes glucose.



Oxygen molecule oxidizes glucose and monosaccharide molecules are completely broken up into acids and oxoacids. The first intermediate of glucose oxidation is gluconic acid.



The Fehling's reaction is used to discover glucose in urine.

Accomplishment: pour 10-12 drops of glucose (54) solution in the test-tube and add 2 drops of the Fehling's reagent (55) and heat up.

Observed changes: _____

Conclusion: _____

3. Comparison of reactions of glucose and formalin with Schiff's reagent

This qualitative test is negative for monosaccharides because of cyclic hemiacetal structure that hasn't aldehyde group.

Accomplishment: in one test tube pour 5-7 drops of formalin (32), in another as much a solution of glucose (54) and add in everyone on 3 drops Schiff's reagent (33). In a test tube with formalin - red violet color with glucose this reaction is negative.

Observed changes: _____

Conclusion: _____

4. The qualitative test on ketohexoses (the Selivanov's test)

The test is predicated on the oxymethylfurfural formation which is condensed with resorcinol forming complex compound of characteristic color.

4. Cellulose: structure, biological role.
5. Dextrane as a source to obtain plasma substitutes.
6. Heteropolysaccharides.

Exercises

1. Write down the acidic hydrolysis reaction of:
 - a) α -maltose
 - b) β -lactulose
 - c) sucrose
 - d) β -lactose
2. Show the structure of disaccharide, fragment of amilose.
3. Show the amylopectin fragment containing $\alpha(1\rightarrow4)$ and $\alpha(1\rightarrow6)$ glycosidic bonds.

4. Explain why cellulose can provide structural function in the plant organisms? Show the fragment of cellulose structure.
5. Write down the fragment of dextrane. Designate the types of bonds.

Test control

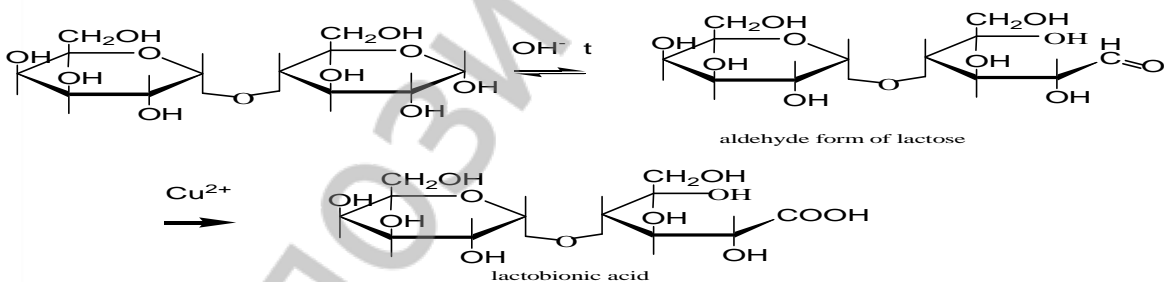
1. Which disaccharide hasn't reducing properties?
- a) maltose c) lactose
b) sucrose d) cellobiose
2. Starch has the types of glycoside bond:
- a) α (1→4) c) β (1→4)
b) α (1→6) d) β (1→3)
3. Glycogen possesses the types of glycoside bond:
- a) β (1→4) c) α (1→4)
b) α (1→6) d) α (1→3)
4. Select the homopolysaccharides:
- a) heparin c) dextrane
b) cellulose d) chondroitin sulfate
5. Select the heteropolysaccharides:
- a) starch c) glycogen
b) heparin d) hyaluronic acid

6. Select the monosaccharides which are formed as a result of an acidic hydrolysis of hyaluronic acid:
- a) N-acetylglucosamine b) N-acetylgalactosamine
 c) D-glucuronic acid d) D-galacturonic acid
7. Select the monosaccharides which are formed as a result of an acidic hydrolysis of chondroitin sulfate:
- a) D-glucuronic acid b) D-galacturonic acid
 c) N-acetyl-D-mannosamine d) N-acetyl-D-galactosamine
8. Cellulose has the following bond types:
- a) glycoside bonds b) disulfide bonds
 c) hydrogen bonds d) peptide bonds

Practical part

1. The Fehling's reaction with sucrose and lactose

Lactose has free hemiacetal hydroxyl group and in alkaline medium when heated it can turn into tautomeric forms containing aldehyde groups that possess reducing properties. Unlike lactose (and maltose) sucrose hasn't free hemiacetal hydroxyl group and belong to unreducing disaccharides.



Accomplishment: take 2 test-tubes. In the one test-tube pour 10 drops of sucrose solution (57), in another pour the same quantity of the lactose solution (58), add to each test-tube 3 - 4 drops of the Fehling's reagent (55) and carefully heat up.

Observed changes: _____

Conclusion: _____

2. The qualitative test on the starch

Accomplishment: to 10 - 12 drops of gelatinized starch add 1 drop of the Lugol's solution (47). Fix the color change, heat up the solution and fix the changes.

Observed changes: _____

Conclusion: _____

LABWORK #13

Theme: STRUCTURE AND REACTIVITY OF AMINO ACIDS ACTING AS HETEROFUNCTIONAL COMPOUNDS

Objective: to discuss characteristics of amino acids as heterofunctional compounds acting as structural components of peptides and proteins; to form skills for carrying out qualitative reactions on the amino acids.

Recommended literature

1. Zurabyan S.E. *Fundamentals of Bioorganic Chemistry. Textbook for Medical Students, 2006. P. 211-217.*
2. T. W. Solomons. *Fundamentals of Organic Chemistry. John Willey&sons, 1994. p. 972-979.*

Problems for discussion

1. Biogenic amino acids. Proteinogenic amino acids: classification, structures, stereochemistry.
2. Amphoteric properties of amino acids.
3. Reactions of amino acids on the carboxylic group.
4. Reactions of amino acids on the amino group.
5. Biologically important reactions of amino acids: deamination, transamination, decarboxylation, hydroxylation reactions.

Exercises

1. Write down the Fischer projections for the following compounds:

a) L-glutamic acid	b) L-threonine
c) L-tyrosine	d) D-isoleucine
e) L-isoleucine	f) L-tryptophan

2. Show the structure of alanine according to the R, S-nomenclature.

3. Write the structures of amino acids at the **pH = 7,4**:

a) Ala b) Glu c) Asn d) His e) Arg

4. Write the oxidation reaction of cysteine.

5. Write down the schemas of biologically important reactions:

a) pyruvic acid with Glu

b) decarboxylation of His

c) decarboxylation of Glu

d) hydroxylation of Phe

Test control

1. Select the hydrophilic amino acids:

a)Met b)Asp c)Asn d)Ser

2. Select the hydrophobic amino acids:

a) Met b) Ile c) Thr d) Phe

3. Select essential amino acids:

a) Arg b) Met c) Phe d) Pro

4. Select amino acids with two chiral centers:

a)Leu b)Ile c)Thr d)Ser

5. Select the ionogenic amino acids:

a) Lys b)His c)Ala d)Asp e)Gln f)Arg

6. Which of the following tests are used to detect amino acids:

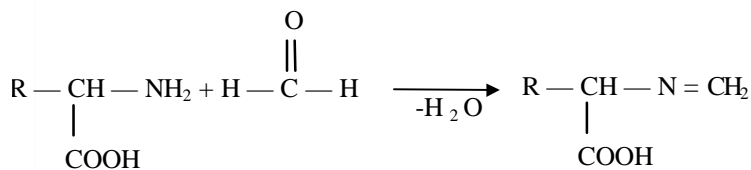
1)xanthoproteinic test 2) Trommer's test

3) ninhydrin reaction 4) Schiff's test

7. Which of the following amino acids can be detected with concentrated solution of nitric acid?

a)Ala b)Tyr c) Phe d) Trp

free carboxylic group of the methylenamino acid causes pH medium change (the medium becomes acidic). It may be proved by the indicator color change.



This reaction is the basis of amino acid quantitative detection in the biological substrates (formalin titration with alkali according to the Serensen method).

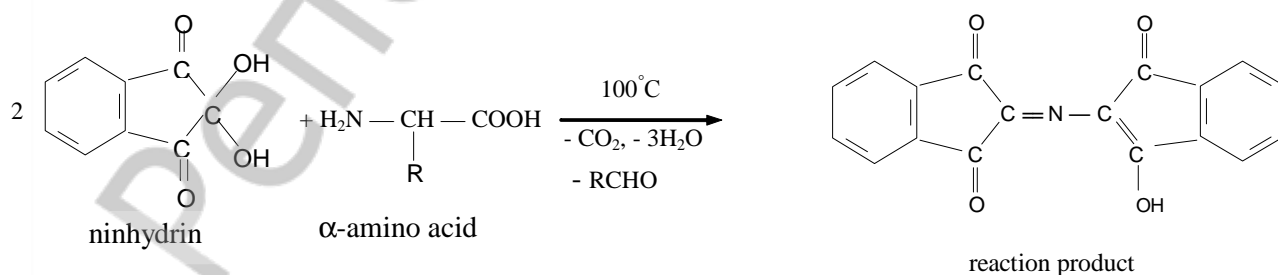
Accomplishment: add 1 drop of 0,2 % methyl red indicator* solution to 3 drops of 40 % of formaldehyde solution (32). Add (carefully) 2N NaOH* solution to neutral medium of solution (fix color change). Then add 3 drops of 0,2 N glycine (1) solution (fix color change again).

Observed changes: _____

Conclusion: _____

4. Ninhydrin reaction

This reaction is characterized for amino groups of free amino acids and α -amino groups of amino acids that are the part of peptide and protein structure. A ninhydrin reaction is used for α -amino acid detection in the biological liquids under consideration.



Accomplishment: add 1 drop of 0,03% ninhydrin* solution to 1 ml of 1% glycine (1) solution. Heat the mixture to boil.

Observed changes: _____

Conclusion: _____

LABWORK #14

Theme: PEPTIDES. THEIR STRUCTURE, REACTIVITY AND IMPORTANCE.
THE LEVELS OF PROTEIN ORGANIZATION

Objective: to form knowledge about organization levels of protein molecules, stereochemical features of peptide bond and types of interactions in protein molecule formation.

Recommended literature

1. Zurabyan S.E. *Fundamentals of Bioorganic Chemistry. Textbook for Medical Students, 2006. p. 211-224.*
2. T. W. Solomons. *Fundamentals of Organic Chemistry. John Willey&sons, 1994. p. 986-1005.*

Problems for discussion

1. Peptides: structure and functions. Gluthathion, aspartam, insulin.
2. Peptide bond.
3. Proteins. Primary structure of peptides and proteins.
4. Artificial peptide synthesis.
5. Secondary structure of proteins.
6. Tertiary and quaternary structures of proteins. Hemoglobin.
7. Denaturation of proteins.

Exercises

1. Describe the formation reaction of peptide alanyllysine.

2. Describe the acidic hydrolysis reaction of dipeptide Thr-Phe.

3. Write down the schema of hydrolysis reaction of the following peptides:

a) Pro-Gln

b) Asp-His

4. Show the following peptides in the ionized form:

a) Gln-Asp-Ile

b) Met-Pro-Glu

5. Write the glutathione structure and its oxidation reaction.

Test control

1. What charge do peptide Arg-Val have at pH=7,4?

a) positive b) negative c) has't charge

2. Select the correct statements about peptide bond:

a) carbon, nitrogen and oxygen atoms are sp^2 -hybridized

b) peptide bond has p- π -conjugation

c) rotation along C-N bond is possible

d) rotation along C-N bond isn't possible

3. Primary structure of proteins is formed with:

- a) disulfide bonds b) ionic bonds c) hydrogen bonds d) peptide bonds

4. Secondary structure of proteins is formed with:

- a) hydrogen bonds b) peptide bonds c) hydrophobic interactions d) ionic bonds

5. Tertiary structure of proteins is formed with:

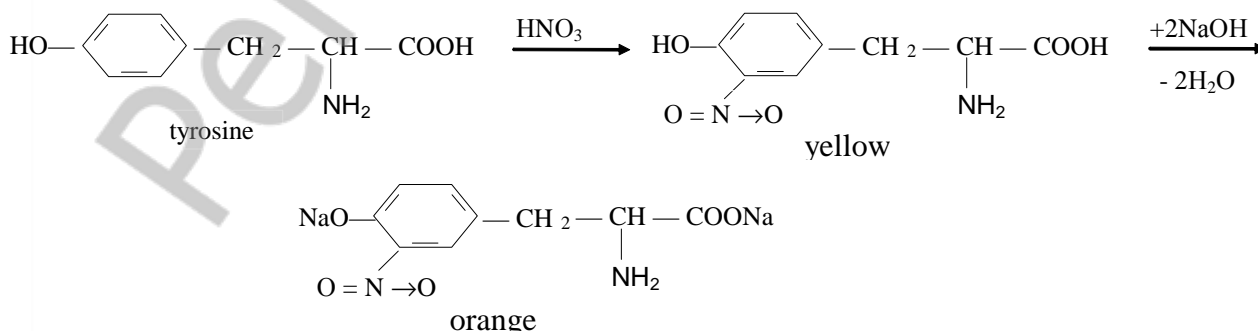
- a) hydrogen bonds
b) peptide bonds
c) hydrophobic interactions
d) ionic bonds

6. Peptide bonds are found with:

- a) xantoproteinic reaction
b) biuretic test
c) ninhydrin reaction
d) lead acetate

Practical part

1. Xantoproteinic reaction proves the presence of aromatic and heterocyclic α -amino acids such as tryptophane, phenylalanine, tyrosine, histidine in protein structure. When reacted HNO_3 concentrated solution with protein solution nitro-compound is formed. When alkali is added to protein solution the ionization of phenol OH-group occurs.



Accomplishment: to 1 ml of protein solution (28) add 1 ml of NaOH (21) concentrated solution and then by degrees on the test-tube side pour 1-2 drops of 0,5% solution of CuSO_4 (26).

Observed changes: _____

Conclusi-

si-

on: _____

3. Precipitation of proteins with sulfosalicylic acid

It is the example of irreversible protein precipitation. Proteins can not be soluble in the same solvent. Irreversible reactions are protein precipitation reactions with heavy metals, mineral (inorganic) and organic acids, alkaloid reagents and when boiled.

Accomplishment: pour 10 drops of 20% sulfosalicylic acid* solution to 0,5 ml of protein solution (28). Solution turbidity occurs.

Observed changes: _____

Conclusi-

si-

on: _____

4. Precipitation of proteins with dehydrating agents (alcohol or acetone)

It is the example of reversible protein precipitation. It's called graining that means precipitation process with the concentrated salt solutions (NaCl , $(\text{NH}_4)_2\text{SO}_4$, MgSO_4) or denaturants (alcohol, acetone). Hydration of protein polar group decreases and

charge disappearance leads to aggregation and precipitation of proteins. Obtained precipitate can be dissolved with dilution or dialysis that's why it is the reversible precipitation.

Accomplishment: to 0,5 ml of protein (28) solution pour 1 drop of acetone*. Solution turbidity occurs.

Observed changes: _____

Conclusi-

si-

on: _____

LABWORK #15

Theme: PURINE AND PYRIMIDINE BASES. NUCLEOSIDES. NUCLEOTIDES.
NUCLEIC ACIDS

Objective: to form knowledge about structure and properties of purine and pyrimidine bases, nucleosides and nucleotides, nucleic acids; to develop skills to carrying out of qualitative reactions on structural components of nucleotides.

Recommended literature

1. Zurabyan S.E. *Fundamentals of Bioorganic Chemistry. Textbook for Medical Students*, 2006. p. 225-237.
2. T. W. Solomons. *Fundamentals of Organic Chemistry*. John Willey&sons, 1994. p. 1017-1039.

Problems for discussion

1. Structural components of nucleic acids: heterocyclic bases, pentoses.

2. Nucleosides, nucleotides: their structure and properties.
3. Primary structure of DNA and RNA.
4. Secondary structure of DNA.
5. Nucleotide derivatives: cyclic AMP, cyclic GMP, ATP.
6. NAD⁺ coenzyme.

Exercises

1. Write down the heterocyclic bases: uracil, thymine, guanine, adenine, cytosine. What types of tautomerism are characterized for each of them? Write tautomeric forms?
2. Write the structural formulas showing the hydrogen bonds in complementary base pairs of DNA and RNA:
 - a) uracil – adenine
 - b) cytosine – guanine
 - c) thymine – adenine
3. Write the formulas of the following nucleosides:
 - a) guanosine

b) thymidine

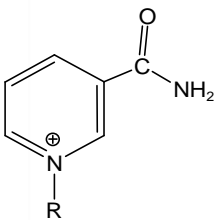
c) deoxyadenosine

4. Write the hydrolysis reaction of 2'-deoxycytidine-5'-monophosphate in the cases of:

a) pH=4 b) pH=1 c) pH=9

5. Write the alkaline hydrolysis reaction of ATP to obtain ADP.

6. Write the oxidation reaction of lactic acid with NAD^+ . Use the following short form of NAD^+ .



Test control

1. Heterocyclic bases are formed as a result of DNA hydrolysis:

a) Thymine b) adenine c) uracil d) guanine

2. Nucleic acids contain the following components:

a) sulfate b) phosphate c) heterocyclic bases d) ribose

3. The types of bond are found in the nucleic acids:

a) peptide b) disulfide c) glycosidic d) 3', 5'-phosphodiesteric

4. The products are formed as a result of an alkaline hydrolysis of cytidine-5'-monophosphate:

a) ribose b) cytidine c) cytosine d) phosphate

5. Which nucleotide sequence of the one chain of DNA chain accords to GTTACTG:

a) CATTGAC b) GAATCAG c) CAATGAC d) CTTAGTC

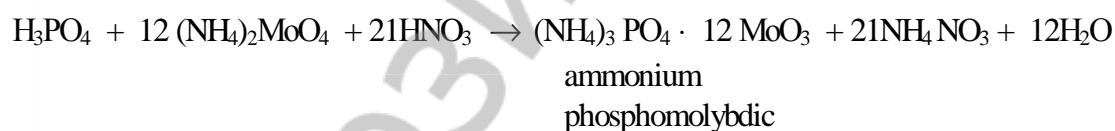
6. The end products of an acidic hydrolysis of 2'-deoxyadenosine-5'-monophosphate are:

a) 2-deoxyribose b) phosphate c) adenosine d) adenine

Practical part

To investigate chemical composition of nucleotides baker's yeast hydrolyzate is used.

1. Phosphoric acid detection in products of nucleoprotein hydrolysis (hydrolyzates)



Accomplishment: add 5 drops of molybdenic reagent* to 3–5 drops of yeast hydrolyzate* and boil some minutes.

Observed changes: _____

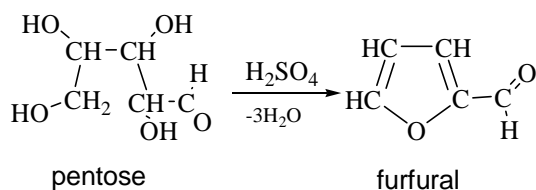
Conclusi-

si-

on: _____

2. Pentose detection in products of nucleoprotein hydrolysis (the Bial's test)

When reacted with H₂SO₄ concentrated solution or dilute HCl pentoses are dehydrated to form furfural which is condensed with orcinol.



Accomplishment: add 10 drops of the Bial's reagent* (orcinol solution in HCl with FeCl₃) to 10 drops of yeast hydrolyzate* and boil 1-2 minutes.

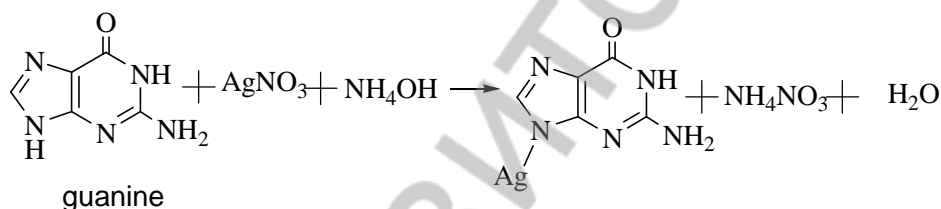
Observed changes: _____

Conclusi-

si-

on: _____

3. Purine base detection in products of nucleoprotein hydrolysis



Accomplishment: add 1 drop of concentrated solution of ammonia and 5 drops of 1 % solution of AgNO₃* to 10 drops of yeast hydrolyzate*. Leave the test-tube for 3–5 minutes without mixing.

Observed changes: _____

Conclusi-

si-

on: _____

LABWORK # 16
CONCLUDING TEST
“BIOPOLIMERS AND THEIR STRUCTURAL COMPONENTS”

Remind the program material from the theme # 9 to # 15.

Recommended literature

Study the literature from the theme # 9 to # 15.

Questions to the test control

1. Oxidation reactions of hydroxy acids *in vivo*.
2. Reduction reactions of oxo acids *in vivo*.
3. Decarboxylation reactions of hydroxyl and oxo acids *in vivo*. Biogenic amines.
4. Decomposition reaction of citric acid at heating.
5. Formation reaction of citric acid from oxaloacetic acid and acetyl coenzyme A.
6. Dehydration reaction of citric acid *in vivo*.
7. π -Diastereomers of butenedioic acid. Hydration reaction of fumaric acid.
8. Specific reactions of α -, β -, γ - hydroxy and amino acids.
9. Tautomerism. Keto- enol and lactim- lactam tautomerism.
10. Ketone bodies, their biological role.
11. Formation of acetylsalicylic acid.
12. *p*-Aminobenzoic acid, their derivatives. Modern anesthetics.
13. Fatty acids. Conformational structure. ω -Nomenclature of unsaturated fatty acids.
14. Triacylglycerols: structures, nomenclature, biological role. Hydrolysis of triacylglycerols.
15. Phospholipids as amphiphilic molecules. Structures, nomenclature, biological role. Hydrolysis of phospholipids.
16. Cyclo- oxo tautomerism of monosaccharides. The Fischer projection formulas and Haworth formulas of glucose and galactose. Conformations of monosaccharide cyclic forms. Glycosides.
17. Oxidation of monosaccharides. Biological role of glycuronic acids.

18. Ascorbic acid as water soluble antioxidant.
19. Reducing and nonreducing disaccharides. Structure, biological role.
20. Polysaccharides: structure, biological role.
21. Proteinogenic amino acids. Structure, nomenclature, acid-basic properties, bipolar structure. Stereoisomerism.
22. Biologically important reactions of α -amino acids: deamination, hydroxylation, decarboxylation, transamination reactions.
23. Peptides: structures, nomenclature, biological role. Representatives of peptides and their biological significance (glutathione, neuropeptides, insulin).
24. Nucleic bases: structures, tautomeric forms, biological role.
25. Complementary pairs of nucleic bases. Hydrogen bonds.
26. Nucleosides, nucleotides. Structure, biological role. Hydrolysis.
27. ATP, cyclo-AMP.

It is necessary to know formulas of the following compounds:

1. glycerol	22. D-glucose
2. pyruvic acid (pyruvate)	23. D-ribose
3. oxaloacetic acid (oxaloacetate)	24. D-deoxyribose
4. lactic acid (lactate)	25. D-fructose
5. malic acid (malate)	26. D-galactose
6. acetyl coenzyme A	27. ascorbic acid
7. citric acid	28. sucrose
8. fumaric acid	29. maltose
9. β -hydroxy butyric acid	30. lactose
10. β -oxo butyric acid	31. starch
11. acetylsalicylic acid	32. glycogen
12. novocaine	33. cellulose
13. ultracaine	34. dextran
14. lidocaine	35. proteinogenic amino acids (20), their names and three letter codes
15. palmitic acid	36. uracil
16. oleic acid	37. thymine
17. linoleic acid	38. cytosine
18. linolenic acid	39. adenine
19. arachidonic acid	40. guanine
20. choline	
21. ethanolamine (colamine)	

LABWORK #17

Theme: POLYMER MATERIALS, USING IN STOMATOLOGY

Objective: to develop knowledge about composition and properties of polymer materials using in stomatology.

Recommended literature

1. T. W. Solomons. Fundamentals of Organic Chemistry. John Willey&sons, 1994. p. 951-961.

Problems for discussion

1. General characteristic high-molecular compounds (AMC): monomer elementary groups, degree of polymerisation. Oligo- and polymers, subpolymers, compositional polymers.

2. Classification of polymers:

- according to ways of receipt

- according to chemical composition of fundamental macromoleculaz chain

- according to structure of macromoleculs

- according to composition of principal chain

- according to leHAVIour during heating

- according to ways of comblination elementary links (groups)

- according to dimensional organisation of linkage (space isomerisation) of linkage.

3. Ways of receipt polymers (polymerization, polycondensation, chemical modification of natural polymers).

4. Mechanism free radicae polymerization of acrylic acid ester's.

5. Generation of free radicals. Initiators of process polymerization. Activators. Inhibitors of free radical reaction.

6. Modern restore materials photo- and Chemical hardening.

7. Main components compositions materials. Reaction of bilding Bis-GMa(bis-phenol-A-glycidymethacrylate). TEG-GMA(triethylene glycoldimethacrylate).

8. Low-molecular components, using in adhesive systems for improvement for sticking of material filling to tissue of tooth.
9. Impressional materials on the basis of alginate acids.

Exercises

1. Write schemas (steps) of reactions generation
 - a) methyl methacrilates
 - b) ethylmethacrilates
 - c) butylmethacrylate
2. Make up equation of reaction polymerisation ethylmethacrylate. Describe the mechanism of free radical polymerisation with participation initiator (benzoyl's peroxide).
3. How material of filling does contact with dentine. Make comments with scheme of collaboration correspond functional groups.

Practical part

1. Prepare and consolidation (hardening) forming mass, using for preparation dentures.

Into porcelain (china) small crucible put several close pulver (ACR-7 or ACR-15) and several drops of monomer (to full wetting of the pulver).

Accomplishment: Contents of small crucible mixing glass stick, close fiber cover and leave for swelling during 15-20 minutes. This mass consider to ready just after components lose adhesive effects and simple remove from wall of small crucible and stick. From receiving mass model subject required form and make subpolymerisation (sewing together oligomers), for what production place into glass with water, heat to boiling and boil to full hardening (10-15 min).

Observed changes: _____

Write the scheme of reaction polymerization methylmethacrylate.

Conclusion: _____

2. Depolymerisation of polymethylmethacrylate and evidence unsaturation of monomer.

Accomplishment: In test-tube put small bits of polymer, fix small test-tube with holder approximately horizontally (with small angle in side of aperture) carefully heat spirit-lamp resulting fume of monomer like white smoke (harder than open air) carefully transfuse in second test-tube with 3-5 drops Br_2 -water and shake.

Observed changes: _____

Write schemas of additional reaction bromine to methylmethacrylate.

**Conclusi-
si-
on:** _____

LABWORK # 18

CONCLUDING TEST "BIOORGANIC CHEMISTRY"

Remind the program material from the theme # 1 to # 17.

Recommended literature

Study the literature from the theme # 1 to # 17.

Questions to the bioorganic chemistry concluding test:

1. Conformations. Newman projections. Types of strains. Energetic characteristic of eclipsed, gauche and staggered conformations (butane). Conformational structure of hydrocarbon radicals of fatty acids (palmitic and stearic acids).
2. Cyclohexane conformations.
3. Configuration of organic compounds. Stereoisomerism. Fischer projections. Relative configuration and D, L-convention. Glyceraldehyde as the configurational standart.
4. Stereoisomerism of molecules with one chiral centre (lactic acid as an example). Enantiomers. Optic activity. Racemic mixtures.
5. Absolute configuration of stereoisomers. R, S-convention. Relationship of spatial structure with biological activity.
6. Electronic effects in organic molecules (inductive and mesomeric), their role in the reactivity centers in the molecule. Electron donors and withdrawers.
7. Conjugation (π,π - and p,π - conjugations). Conjugated systems with open chain (butadiene-1,3).
8. Conjugated systems with close chain. Aromaticity, criteries of aromaticity, Huchel's rule (benzene, naphtaline, phenantrene).

9. Heterocyclic aromatic compounds (pyrrol, pyridine). Pyrrol and pyridine nitrogen atoms.
10. Acidity and basicity of organic compounds; Brønsted and Lewis theories.
11. Acidic properties of organic compounds (alcohols, phenols, thiols, carboxylic acids, amides). Factors of anion stability.
12. Basic properties of organic compounds (alcohols, ethers, thioesters, amines). Comparing of basic properties of aliphatic and aromatic amines; salt formation.
13. Classification of organic reactions (substitution, addition, elimination, isomerisation, red-ox, acid-basic interaction).
14. Classification of organic reactions on the mechanism of covalent bond cleavage (radical and ionic). Electronic and spatial structure of free radicals, carbocations and carboanions.
15. Oxidation reactions of organic compounds (alcohols, thiols). Antioxidants (2,3-dimercaptopropanol, ascorbic acid, phenols and others).
16. Radical substitution reactions. Propane chlorination as an example of free radical substitution. Initiators of radical reactions. Antioxidants.
17. Electrophilic addition reactions of alkenes. Hydration reactions of alkenes.
18. Electrophilic substitution reactions of aromatic hydrocarbons.
19. Oxidation and reduction reactions of carbonyl compounds. Visual tests on the aldehyde group (silver mirror test, Trommer test). Reduction reactions *in vivo*.
20. Nucleophilic addition reactions of aldehydes and ketones; addition of water and alcohols.
21. Addition of amines to carbonyl compounds, mechanism. Schiff's bases.
22. Electronic and spatial structure of the carboxylic group. Acidic properties of the carboxylic acids: mono-, dicarboxylic, aliphatic saturated, aliphatic unsaturated, aromatic carboxylic acids.
23. Nucleophilic substitution at sp^2 -hybridized carbon atom in the carboxylic group: esterification reaction. Properties of esters, hydrolysis.
24. Polyfunctional compounds and their characteristics. Polyols: ethylene glycol, glycerol, inositol, xylitol, sorbitol. Visual test on the diol fragment.

25. Dicarboxylic acids and their properties. Decarboxylation reactions and anhydride formation.
26. Diatomic phenols: hydroquinone, resorcinol, catechol. Oxidation of diatomic phenols. Phenols as antioxidants. Adrenaline.
27. Heterofunctional compounds and their characteristics. Intramolecular and intermolecular reactions of nucleophilic substitution in the amino acids and hydroxy acids. Elimination reactions.
28. Citric acid (2-hydroxypropane-1,2,3-tricarboxylic acid). Decomposition reactions. Citrates.
29. Oxo acids (pyruvic acid, acetoacetic acid, oxaloacetic acid, α -ketoglutaric acid). Transamination reactions of α -oxo acids.
30. Keto-enol tautomerism. Reactions on the enol fragment.
31. β -Hydroxy butyric acid, β -oxo butyric acid, acetone as representatives of *ketone bodies*, their biological and diagnostic significance (visual tests on the acetone).
32. Anesthesin and novocain as ester of p-aminobenzoic acid. Novocain chloride. Modern anesthetics: lidocaine, ultracaine.
33. Salicylic acid, acetylsalicylic acid.
34. Properties of fatty acids. Saturated and unsaturated fatty acids.
35. Lipids. Properties. Triacylglycerols: structures, biological role.
36. Phospholipids as amphiphilic molecules.
37. Carbohydrates. Classification, biological properties. Monosaccharides. D, L-stereochemical rows.
38. Tautomeric forms of monosaccharides: open chain and cyclic forms. The Fischer projection formulas and Haworth formulas of glucose and galactose. Conformations of cyclic forms of glucose.
39. Ring-chain tautomerism of fructose. Furanoses and pyranoses; α - and β -anomers.
40. Structure and tautomeric forms of important representatives of pentoses (ribose and deoxyribose). Their biological role.

41. Nucleophilic substitution at the anomeric centre in the cyclic forms of monosaccharides. O- and N-glycosides. Hydrolysis of glycosides.
42. Oxidation of monosaccharides. Biological role of glycuronic acids.
43. Ascorbic acid as water soluble antioxidant.
44. Reducing disaccharides (maltose, lactose, cellobiose). Structure, ring-chain tautomerism.
45. Lactose: structure, ring-chain tautomerism. Reducing properties. Hydrolysis. Role of oligosaccharides of lactose group in the nonpathogenic intestinal flora necessary for normal digestion. Lactulose.
46. Sucrose as representative of nonreducing disaccharides (the Haworth formula). Hydrolysis of sucrose. Invert sugar.
47. Starch. Structure (amylose and amylopectin), properties, hydrolysis reactions. Biological role.
48. Cellulose. Structure, properties, application, role in nutrition.
49. Glycogen is reserve homopolysaccharide of animals and human (the Haworth structure). Biological significance of branched structure of glycogen.
50. Dextran as representative of bacterial origin homopolysaccharides. The Haworth structure. Partial hydrolysis products of dextran and their medical application.
51. Proteinogenic amino acids. Structure, nomenclature, acid-basic properties, bipolar structure. Stereoisomerism of natural α -amino acids with one and two chiral centres.
52. Biologically important reactions of α -amino acids. Deamination reactions (oxidative and non-oxidative). Hydroxylation reactions (phenylalanine – tyrosine, tryptophane – 5-hydroxytryptophane).
53. Decarboxylation reaction of α -amino acids – way to formation of biogenic amines and bioregulators (colamine, histamine, γ -amino butyric acid).
54. Peptides. Electronic and spatial structure of peptide bond.
55. Representatives of peptides and their biological significance (glutathione, neuropeptides, insulin).

56. Proteins. Organization levels of protein molecules and types of interactions in the stabilization. Primary, secondary (α -helix and β -conformation) and tertiary protein structures.
57. Pyridine and purine heterocyclic bases, their aromaticity as reason of high stability.
58. Nucleotides. Structure of mononucleotides forming nucleic acids. Nomenclature. Hydrolysis of nucleotides.
59. Primary structure of nucleic acids. Phosphodiester bond. Ribonucleic and deoxyribonucleic acid. Nucleotide composition of RNA and DNA. Hydrolysis of nucleic acids.
60. General characteristic high-molecular compounds (AMC): monomer elementary groups, degree of polymerisation. Oligo- and polymers, subpolymers, compositional polymers.
61. Classification of polymers.
62. Ways of receipt polymers (polymerization, polycondensation, chemical modification of natural polymers).
63. Mechanism free radical polymerization of acrylic acid ester's.
64. Generation of free radicals. Initiators of process polymerization. Activators. Inhibitors of free radical reaction.
65. Modern restore materials photo- and chemical hardening.
66. Main components compositions materials. Reaction of bilding Bis-GMa. TEG-GMA (triethylene glycoldimethacrylate).
67. Low-molecular components, using in adhesive systems for improvement for stiking of material filling to tissue of tooth.
68. Impressional materials on the basis of alginate acids.

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