O. N. RYNEISKAYA, E. M. ERMOLENKO

BIOORGANIC CHEMISTRY

Manual for dental students

Minsk BSMU 2018

МИНИСТЕРСТВО ЗДРАВООХРАНЕНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ
БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ
КАФЕДРА БИООРГАНИЧЕСКОЙ ХИМИИ

О. Н. Ринейская, Е. М. Ермоленко

БИООРГАНИЧЕСКАЯ ХИМИЯ

BIOORGANIC CHEMISTRY

Практикум для студентов-стоматологов

4-е издание, исправленное

Минск БГМУ 2018

УДК 577.1(076.5)(075.8)-054.6
ББК 28.072я73
Р51

Рекомендовано Научно-методическим советом университета в качестве практикума 16.05.2018 г., протокол № 9

Р е ц е н з е н т ы: канд. мед. наук, доц. И. Л. Котович; канд. мед. наук, доц. Т. В. Латушко

Ринейская, О. Н.

Р51 Биоорганическая химия = Bioorganic chemistry : практикум для студентов-стоматологов / О. Н. Ринейская, Е. М. Ермоленко. – 4-е изд., испр. – Минск : БГМУ, 2018. – 84 с.

ISBN 978-985-21-0032-8.

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. Первое издание вышло в 2015 году.

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

УДК 577.1(076.5)(075.8)-054.6
ББК 28.072я73

ISBN 978-985-21- 0032-8

REGISTRATION FORM

Student name_____

№	Theme	Date	Mark	Signature of teacher
1.	Classification and nomenclature of organic compounds			
2.	Chemical bond structure and atom effects in the organic molecules			
3.	Stereoisomerism, its role for biological activity demonstration			
4.	Hydrocarbons			
5.	Monofunctional hydrocarbon derivatives			
6.	Biologically important reactions of aldehydes and ketones			
7.	Carboxylic acids and their derivatives			
8.	Concluding test «Theoretical fundamentals of basic classes of organic compound structure and reactivity»			
9.	Poly-and heterofunctional compounds			
10.	Organic compounds using in dentistry			
11.	Carbohydrates. Monosaccharides			
12.	Oligo- and polysaccharides			
13.	Structure and reactivity of amino acids			
14.	Peptides. The levels of protein organization			
15.	Nucleosides. Nucleotides. Nucleic acids			
16.	Lipids. Structure, properties. Lipid peroxidation			
17.	Concluding test “Biopolymers and their structural components”			
18.	Exam test			

LABORATORY SAFETY RULES

1. Dress appropriately for the lab. Wear white lab coat. Tie back long hair.
2. Know what safety equipment is available and how to use it. This includes eyewash place, fire blanket, fire extinguisher and sand.
3. Know the dangers of the chemicals in use, and read labels carefully. Do not taste or sniff chemicals.
4. Dispose of chemicals according to instruction. Use designated disposal sites, and follow the rules. Never return unneeded chemicals to the original containers.
5. Always add acids and bases to water slowly to avoid splattering. This is especially important when using strong acids and bases that can generate significant heat, form steam, and splash out of the container.
6. Never point test tubes at yourself or others. Be aware of reactions that are occurring so that you can remove them from the heat if necessary.
7. Do not eat or drink in the lab! It is too easy to take in some dangerous substance accidentally.
8. Follow all directions. Never occasionally mix chemicals. Pay attention to the order in which chemicals are to be added to each other, and do not deviate!
9. 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 the laboratory room;

– student on duty should leave the laboratory the last, after receiving permition from the lab assistant.

I agree _____ 20___ year _____
(date) (signature)

PRECAUTIONS

Work with alcohol lamps

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 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

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, splasing 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 it 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 (45º), so that splashes will hit walls of a glassware and will not be thrown outside. 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.

Work with inflammable liquids (IL)

IL (diethyl ether, alcohol, toluene, acetone, acetoacetic ether) are kept always in a fume hood. 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

Concentrated solutions of nitric, sulfuric, hydrochloric acids, nitrosulfuric acid are kept in a fume hood. All experiments with concentrated acids and alkalis are carried out only in the fume hood. It is necessary to cover carelessly spilt on the floor acids and alkalis by sand and after that to clean up.

Work with toxicants

Toxic organic substances — aniline, methyl amine, toluene, picric acid are kept in a fume hood. 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 glycerin until normal skin color is restored then to wash with water and to put the gauze bandage moistened with a glycerin 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
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 / S. E. Zurabyan. 2006. P. 19–32.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 27–39.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 3–7.

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.

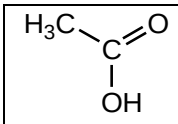
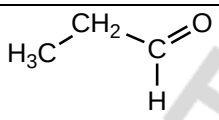
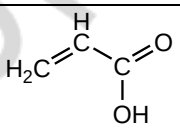
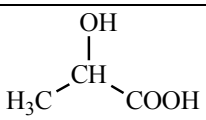
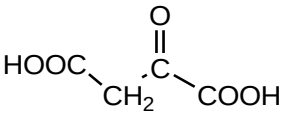
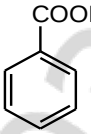
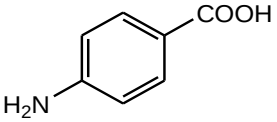
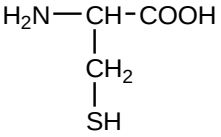
Exercises

1. Write the formulas of the following compounds:

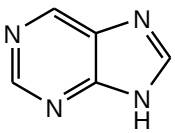
methane	ethane	propane
butane	ethene	propene
but-1-ene	but-2-ene	2-methylpropene
ethanol	pentan-1-ol	propan-2-ol
butan-2-ol	propanone	ethanethiol

methanoic acid	propanoic acid	benzene
phenol	benzoic acid	toluene
ethanedioic acid	butanedioic acid	butenedioic acid
2-aminopropanoic acid	2-oxopentanedioic acid	

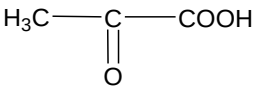
2. Give the IUPAC names for the following compounds:

TEST CONTROL

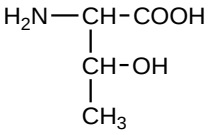
1. Give the name for the heterocycle: 

1) pyrrole; 2) purine; 3) pyridine; 4) pyrimidine.

2. Give the IUPAC name for the following compound 

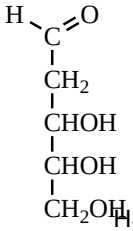
1) α-ketopropionoic acid; 3) pyruvic acid;
2) 2-oxopropanoic acid; 4) oxaloacetic acid.

3. Choose the IUPAC name of the amino acid (threonine)



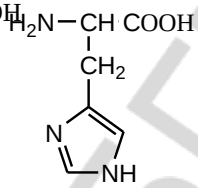
1) 2-hydroxypentanoic acid;
2) 2-aminobutanoic acid;
3) 2-amino-3-aminopropanoic acid;
4) 2-amino-3-hydroxybutanoic acid.

4. Choose the IUPAC name of the deoxyribose



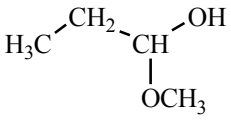
1) 1,3,4,5,6-pentahydroxyhexanone-2;
2) 2,3,4,5,6-pentahydroxyhexanal;
3) 2,3,4,5-tetrahydroxypentanal;
4) 3,4,5-trihydroxypentanal.

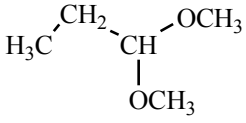
5. Choose the IUPAC name of the following compound

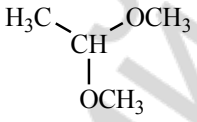


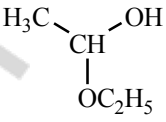
1) 2-amino-3-imidazolylpropanoic acid;
2) 2-amino-3-indolylpropanoic acid;
3) 2-amino-4-imidazolylpropanoic acid;
4) 2-hydroxy-3-imidazolylpropanoic acid.

6. Select the structural formula of the 1-methoxypropanol:

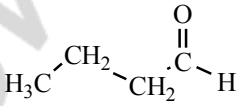
1) 

2) 

3) 

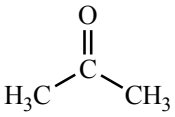
4) 

7. Choose the name of the following compound:



1) propanoic acid;
2) propanal;
3) butanal;
4) butanoic acid.

8. Select the IUPAC name of the following compound:

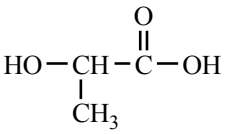


1) acetone;
2) propanone;
3) propanal;
4) propanoic acid.

9. Select unsaturated compound(s):

1) but-2-ene; 2) ethane; 3) cyclohexene; 4) benzene.

10. Select the trivial name of the compound:



1) 2-hydroxypropanoic acid;
2) alanine;
3) lactic acid;
4) malic acid.

PRACTICAL PART

1. Antioxidant activity of ascorbic acid.

Take the two test tubes. In both tubes, place 2 drops of ethanol[1]*. To one of them add a few crystals of ascorbic acid* with a glass spatula. Then add 1 drop of $KMnO_4$ solution (14) and 2 drops of H_2SO_4 solution (23) to each tube, and shake. Heat each tube to the boil and discoloration of the solution. Note the appearance of apples smell in one of the test tubes.

Observed changes: _____

_____

[1] Notice: reagents marked with (*) are in the fume hood.

Write a scheme of the reaction:

Conclusion: _____

_____

Signature of teacher:

LABWORK № 2
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 / S. E. Zurabyan. 2006. P. 5–17, 33–44.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 13–25, 40–49.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 7–16.

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. Mesomeric effect.
6. Electron donating and electron withdrawing substituents.

Exercises:

Write the formulas of the following compounds. Indicate compounds with conjugated system.

buta-1,3-diene	hexa-2,4-diene
penta-1,4-diene	but-2-ene

2. Determine the type of conjugated system:

2-methylbut-1,3-diene	propanoic acid
propenal	pyrrole
propenoic acid	pyridine

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

benzene	pyridine
pyrrole	imidazole
pyrimidine	purine

4. ***Electronic effects*** — …

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

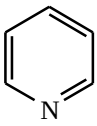
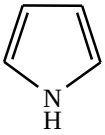
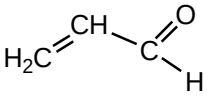
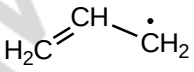
1-chlorobutane	propanal

benzaldehyde	propenal
ethanol	phenol

TEST CONTROL

1. Indicate formulas of compounds with conjugated double bonds:
1) ethene; 3) cycloheptatrienyl cation;
2) pent-1,3-diene; 4) propenoic acid.

2. Indicate formulas of compounds with conjugated p-π double bonds:

1)  2)  3)  4) 

3. Compounds with conjugated p-π double bonds are following:
1) benzene; 2) naphthalene; 3) cyclopentadienyl anion; 4) vinylamine.

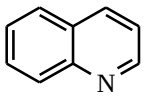
4. Indicate correct statements about pyridine: 1) everyone atom are in the sp^2-hybridization; 2) nitrogen gives in the conjudated system 2 electrons; 3) is π-deficient aromatic system; 4) nitrogen gives in the conjudated system 1 electron; 5) is π-excessive aromatic system.
1) 1, 4, 5; 2) 1, 2, 3; 3) 1, 3, 4; 4) 1, 2, 5.

5. What electronic effect(s) does hydroxyl group possess in propanol:
1) +I, –M; 2) –I; 3) –I, +M; 4) –I, –M.

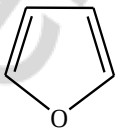
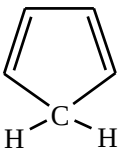
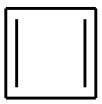
6. Which substitutions possess electron donor properties towards benzene:
1) – COOH; 2) $–CH_3$; 3) – OH; 4) $–NHCH_3$.

7. What electronic effect(s) does hydroxyl group possess in phenol:
1) +I, –M; 2) –I; 3) –I, +M; 4) – I, –M.

8. How many electrons are in cyclic conjugated system of quinoline:
1) 14; 2) 8; 3) 12; 4) 10.



9. Which of the following compounds are aromatic:

1)  2)  3)  4) 

10. Indicate electronic effects of functional groups in the following compound:
A) benzyl alcohol; 1) –I, –M;
B) phenol; 2) –I < +M;
C) ethanol; 3) –I;
D) chlorobenzene. 4) –I > +M.

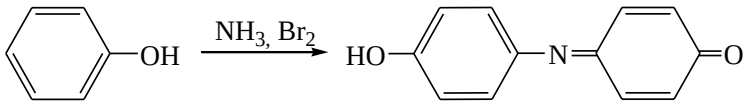
PRACTICAL PART

1. Indophenol test.

In a test tube, place 1 drop water emulsion of phenol*, 3 drops of ammonia solution* and 3 drops of a saturated solution of bromine water*. Note the appearance of the characteristic staining.

Observed changes: _____

_____



indophenol

Conclusion: _____

_____

Signature of teacher:

LABWORK № 3
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 / S. E. Zurabyan. 2006. P. 61–81.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 76–81, 149–161.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 16–27.

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. Buthane 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. Fischer'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. Cys-, trans-isomerism. Stereoisomers of butenedioic and oleic acids.

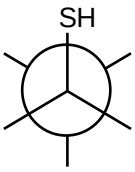
Exercises

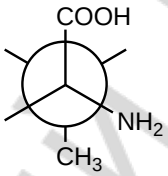
1. Write all possible conformations by means of Newman projections for the following compounds.

a) ethane

b) butane

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

a) 

b) 

3. Draw the possible chair conformations of the cyclohexanol.

4. Draw the preferred conformation of the 2-methylcyclohexanol.

5. Write Fisher projections for the following compounds. Indicate pairs of enantiomers and diastereomers:

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 2-hydroxypropanoic acid.

TEST CONTROL

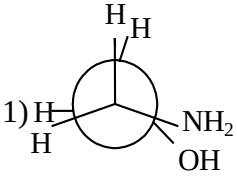
1. Repulsive interaction between electron clouds in the C-H bond is called:
1) Van der Waals strain; 2) angle strain; 3) Baeyer strain; 4) torsion strain.

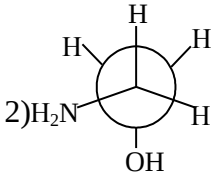
2. Indicate compounds with chiral centers:
1) 2,3-dihydroxybutanedioic acid; 3) 2-aminobutanoic acid;
2) methanol; 4) butanol-2.

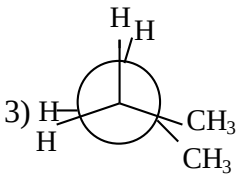
3. Various spatial arrangement of the atoms in molecular that differ only after rotation about C-C single bonds are:
1) enantiomers; 2) configuration; 3) diastereomers; 4) conformation.

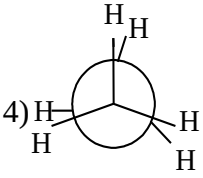
4. Less stable butane conformation —is:
1) stagged; 2) eclipsed; 3) skew; 4) zigzag.

5. Select conformations with the maximal Van der Waals strain:

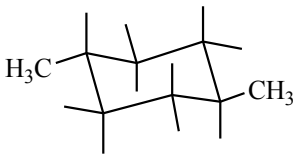


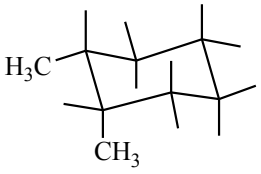


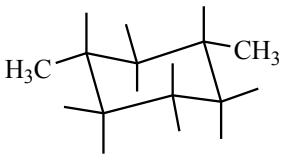


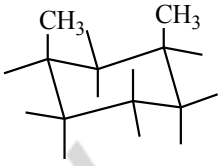


6. Less stable 1,3-dimethylcyclohexane conformation is:

1) 

2) 

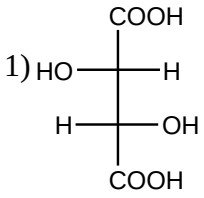
3) 

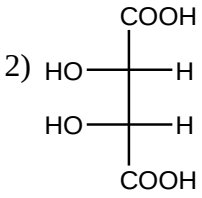
4) 

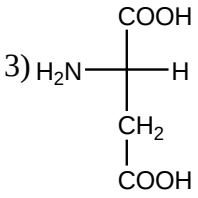
7. Select compounds with 2 chiral centrals:

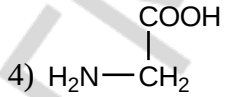
1) 2-amino-3-methylpentanoic acid;
2) 2,3-dihydroxybutandioc acid;
3) 2-amino-3-methylbutanoic acid;
4) 2-hydroxyethanoic acid.

8. Select L-stereoisomers:

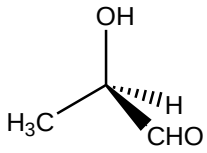
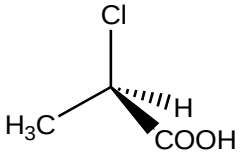
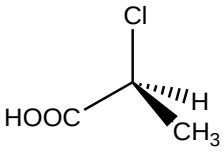
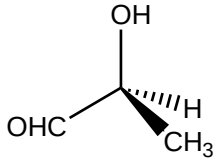
1) 

2) 

3) 

4) 

9. Select names for the corresponded structures:

A) 	1) R-2-chloropropanoic acid
B) 	2) R-2-hydroxypropanal
C) 	3) S-2-hydroxypropanal
D) 	4) S-2-chloropropanoic acid

10. Diastereoisomers — are:

1) pairs of stereoisomers which concern to each other as a subject and its display in an ideal plane mirror, possess in achiral surrounding identical chemical and physical properties, except for a sign on optical rotation;
2) pairs of stereoisomers of the same substance not being a mirror image of one another and possessing various chemical and physical properties;
3) pairs of stereoisomers of the same substance not being a mirror image of one another and possessing the same chemical and physical properties;
4) pairs of stereoisomers which consist in migration of some groups within a molecule and is an accompanied by redistribution of electron density.

Signature of teacher:

LABWORK № 4
HYDROCARBONS

Objective: to develop knowledge about classification and mechanisms of organic reactions; 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 / S. E. Zurabyan. 2006. P. 94–110.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 52–57, 75, 82–96.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 27–28, 30–35.

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 substitutients.

Exercises:

1. Indicate the type of reagent:

$^{+}CH_3$	HOH	$^{\cdot}CH_3$	CH_3–Cl	CH_3 – OH

2. Write the scheme of chlorination reaction of propane. Indicate mechanism.

3. Write the schemes of polymerization reaction of:
a) ethene

b) propenoic acid

c) 2-methylpropenoic acid

4. Write the schemes of addition reaction:
a) HCl to propene

b) HBr to propenoic acid

c) HOH to butenedioic acid

5. Describe the reaction mechanism of:
a) chlorination of benzene ($AlCl_3$ as catalyst)

b) alkylation of toluene with $CH_3 – CH_2 – Cl$ ($AlCl_3$ as catalyst)

TEST CONTROL

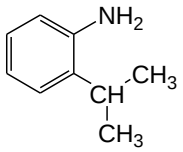
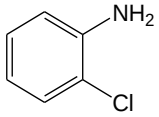
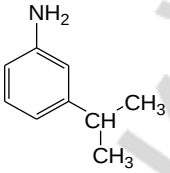
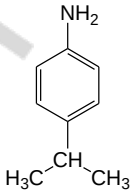
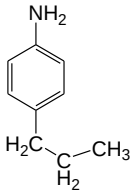
1. Nucleophile reagents are:
1) H^-; 2) HOH; 3) C_2H_5OH; 4) H^+; 5) CH_3NH_2.

2. Select properties of free radicals reactions:
1) molecular contain polar covalent bond;
2) covalent bonds breaks as a result of hemolysis;
3) acids and bases catalyze these reactions;
4) require violent conditions (high t°, pressure, irradiation).

3. Electrophilic addition reaction usually takes place in:
1) cyclohexene;
2) but-2-enoic acid;
3) ethane;
4) 3-methyl-1-chlorobutane.

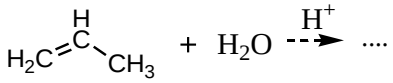
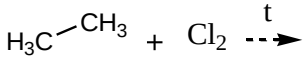
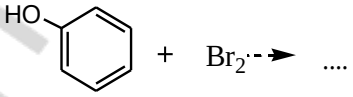
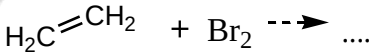
4. The following product is mainly formed as a result of interaction of 2-methylpenten-1 and HCl:
1) 4-methyl-3-chloropentane;
2) 4-methyl-2-chloropentane;
3) 2-methyl-2-chloropentane;
4) 2-methyl-1-chloropentane.

5. The following product is mainly formed as a result of interaction of 2-chloropropaneand aniline with catalyst:

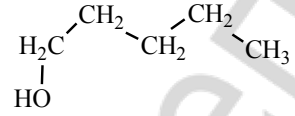
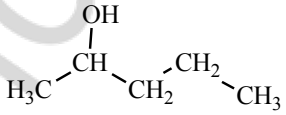
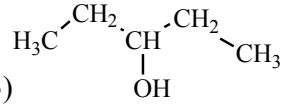
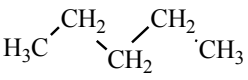
1) 
2) 
3) 
4) 
5) 

6. Hydration reaction is:
1) hydrogen addition;
2) water addition;
3) hydrogen elimination;
4) water elimination.

7. Select scheme(s) of electrophilic addition reaction(s):

1) 
2) 
3) 
4) 

8. Indicate product of following reaction: пентен-1 + HOH $\xrightarrow{H^+}$

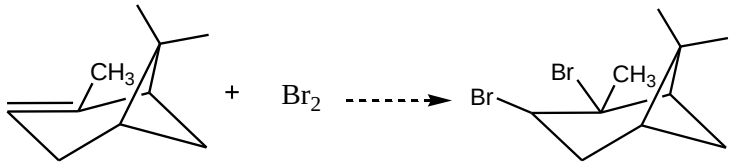
1) 
2) 
3) 
4) 

9. Select reactions which goes according Marcovnicov rules:
1) ethane hydration;
2) propenoic acid hydration;
3) propene hydration;
4) butene-2 hydrohalogenation;
5) butene-1 hydrohalogenation.

10. Indicate compound possessing strongest reaction ability in the S_E mechanism:
1) benzene;
2) toluene;
3) benzoic acid;
4) pyridine.

PRACTICAL PART

1. Qualitative test on the alkenes with bromine water.

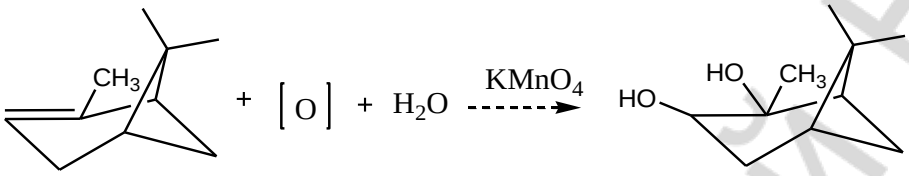


Accomplishment: to 4 drops of bromine water* add 2 drops of α-pinene* and shake.

Observed changes: _____

Conclusion: _____

2. Qualitative test on the alkenes with potassium permanganate.



α-pinene α-pinenglycol

Accomplishment: to 3 drops of $KMnO_4$ (14) solution add 1 drop of α-pinene* and shake.

Observed changes: _____

Conclusion: _____

_____

Signature of teacher:

LABWORK № 5
MONOFUNCTIONAL HYDROCARBON DERIVATIVES

Objective: to study structure and properties of monofunctional hydrocarbon derivatives; acidity and basicity of organic compounds; to generate skills for qualitative determination of organic compound acidity and basicity.

Recommended literature:

1. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2006. P. 47–59, 112–131.

2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 61–73, 101–119.

3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 28–30, 35–41.

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.
6. Nucleophilic substitution reaction at sp^3-hybrid carbon atom. Elimination reaction.

Exercises

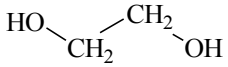
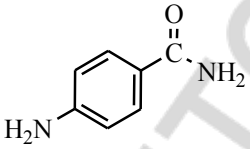
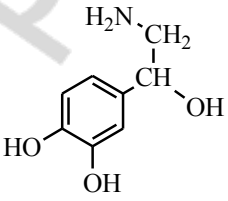
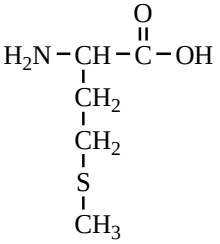
1. ***Brensted acid*** — …

Brensted base — …

Lewis acid — …

Lewis base — …

2. Indicate acidic and basic centers at the following compounds:

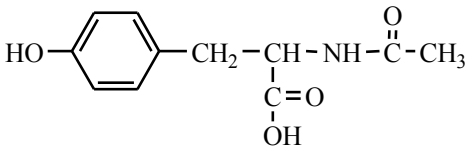
			

3. Compare acidity of compounds in the following groups:

a) ethanol and ethanthiol

b) ethanoic and ethanedioic acids

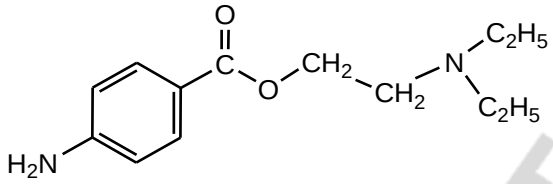
4. Indicate the acidic centers at the N-acetyltyrosine



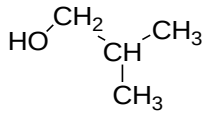
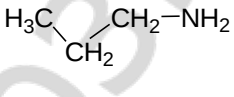
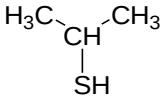
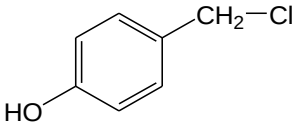
5. Compare basicity of compounds in the following groups:
a) ethylamine and aniline

b) methylamine and dimethylamine

6. Show the strongest basic center at the procaine molecule. Write the reaction of procaine with hydrochloric acid.



7. Indicate reactive sites in the following molecules:

8. Write the schemes of interaction reactions of:
a) 1-chloropropane and NAOH solution

b) propan-1-ol and HBr

c) 2-bromo-2-methylpropane and alcoholic solution of NAOH.

9. Write the scheme of dehydration reactions of 2-hydroxybutanedioic acid *in vivo.*

10. Write the ethanol oxidation reaction *in vitro* and *in vivo.*

11. Write the scheme of oxidation reaction:
a) methanethiol

b) 2-amino-3-mercaptopropanoic acid

TEST CONTROL

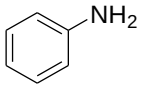
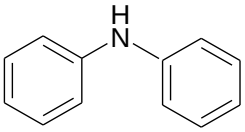
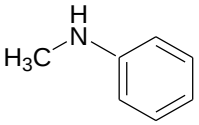
1. Acidity increases in the following row of acids:
1) acetic acid, oxalic acid, malonic acid;
2) acetic acid, malonic acid, oxalic acid;
3) oxalic acid, malonic acid, acetic acid;
4) malonic acid, acetic acid, oxalic acid.

2. Basicity according to the Bransted theory is ability of molecular or ion:
1) accept electrons; 2) donate electrons; 3) donate proton; 4) accept proton.

3. Indicate the correct statement about acidity comparison:
1) conjugation stabilizes anion and increase acidity;
2) electron donors increase acidity;
3) electron withdrawers increase acidity;
4) solvation effect influence on anion stability and acidity.

4. Select substances which are capable to link heavy metals:
1) 2-amino-3-mercaptopropanoic acid;
2) propan-2-ol;
3) 2,3-dimercaptopropan-1-ol;
4) diethyl disulfide.

5. Basicity decreases in the following row of amines:

1)  2)  3) CH_3NH_2 4) 

6. Acidity according to the Lewis theory is the ability of molecule or ion:

1) to accept proton; 2) to accept electrons; 3) to donate electrons; 4) to donate proton.

7. Indicate the factors which influence on the basicity:

1) polarizability of the basic site elements is in the same period of the periodic table;
2) electronegativity of the basic site elements is in the same period of the periodic table;
3) electronegativity of the basic site elements is in the same group of the periodic table;
4) polarizability of the basic site elements is in the same group of the periodic table.

8. Give characteristics for interaction reaction between butene-2 and H_2O (in acidic medium):

1) S_N mechanism; 3) S_E mechanism;
2) water is electrophile; 4) A_E mechanism.

9. Give characteristics for interaction reaction between benzene and isopropyl chloride (with $AlCl_3$presence):

1) Cl^+ is electrophile; 3) S_E mechanism;
2) alkylation of benzene is result of this reaction; 4) S_N mechanism.

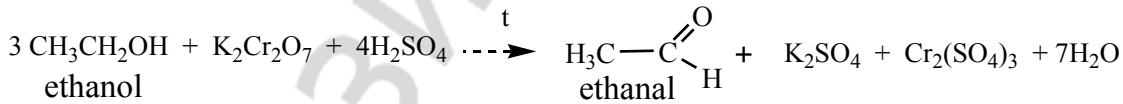
10. Find the accordance between scheme of the reaction and typical reaction mechanism:

A) toluene + CH_3Br ($FeBr_3$); 1) S_R;
B) propene + HCl; 2) A_E;
C) ethane + Cl_2 (light); 3) S_E;
D) *tert*-butyl alcohol+ HBr $_{(conc.)}$. 4) S_N.

PRACTICAL PART

1. Oxidation of primary alcohols

Alcohol oxidation reaction is carried out in narrow term. Primary alcohols are oxidized to aldehydes.



Accomplishment: add 2 drops of H_2SO_4 (23) dilute solution and 3 drops of C_2H_5OH* to 3 drops of $K_2Cr_2O_7$ (24). Carefully mix and heat.

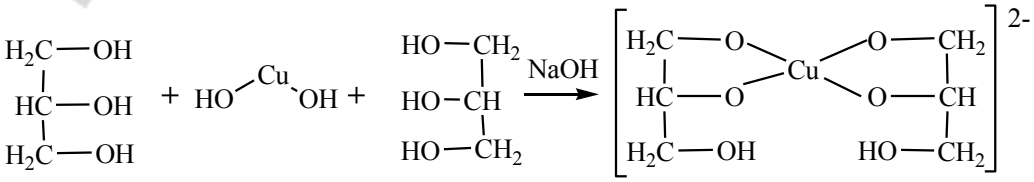
Observed changes: _____

Conclusion: _____

_____

2. Qualitative test on polyols.

Unlike primary alcohols polyols react not only with alkali metals but with some metal hydroxides. In reaction of glycerine with copper (II) hydroxide complex compound is formed:



Accomplishment: to 2 drops of NaOH (21) solution add 2 drops of solution $CuSO_4$ (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 alcohols are capable to react with alkalis. Water-soluble sodium phenoxide is formed. Mineral acids replace phenol from phenoxides.

$$C_6H_5OH + NaOH \rightarrow C_6H_5ONa + H_2O$$

$$C_6H_5ONa + H_2SO_4 \rightarrow C_6H_5OH + NaHSO_4$$

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 H_2SO_4 (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. Phenol as an acid reacts with ion Fe^{3+} forming the complex compound.

Accomplishment: to 10 drops of phenol water emulsia* add 1–2 drops of solution of $FeCl_3$ (8), shake.

Observed changes: _____

Conclusion: _____

_____

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 NH_3.

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: _____

Conclusion: _____

_____

Signature of teacher:

LABWORK № 6
BIOLOGICALLY IMPORTANT REACTIONS OF ALDEHYDES AND KETONES

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

Recommended literature:

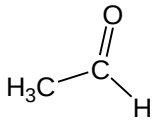
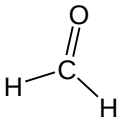
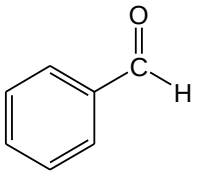
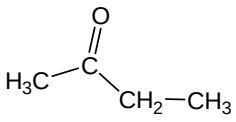
1. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2006. P. 133–147.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 121–133.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 41–46.

Problems for discussion:

1. An electronic structure of a carbonyl group. The reactive 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. Indicate reactive centers in the carbonyl compound molecules:

2. Write down the equation reaction acetalization: interaction ethanal with 2 mol methanol.

3. Describe the mechanism of intramolecular acetalization reaction to form cyclic hemiacetal of 5-hydroxyhexanal.

4. Write the interaction reaction of ethanal and methylamine.

5. Write reaction schemes of ethanal reduction *in vivo* and *in vitro.*

Write the scheme of aldol condensation reaction of 2-methylpropanal.

7. Write the scheme of oxidation reaction of ethanal.

8. Describe the mechanism of dismutation reaction for the formaldehyde.

TEST CONTROL

1. Indicate reaction sites in the 2,2-dimethylpropanal molecule:
1) CH-acidic site on α-carbon atom;
2) basic site on the oxygen atom;
3) electrophilic site on the carbonyl carbon atom;
4) nucleophile site on the carbonyl carbon atom.

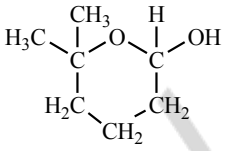
2. Find the accordance between the carbonyl compounds and its reduction product:

A) 2-methylpropanal;	1) 2-hydroxybutandioic acid;
B) 2-oxopropanoic acid;	2) 2-methylpropan-1-ol;
C) 2-oxobutandioic acid;	3) propan-1-ol;
D) propanal.	4) 2-hydroxypropanoic acid.

3. Select the product of methanal and ethanol (1:2) interaction in acidic medium:

1) 2-methoxyethanol; 3) ethoxymethanol;
2) diethoxymethane; 4) 1,1-dimethoxyethane.

4. Select the hydrolysis product of the represented hemiacetal:



1) 4-hydroxy-5-methylhexanal; 3) 5-hydroxy-5-methylhexanal;
2) 5-hydroxyhexanal; 4) 5-hydroxy-5-methylheptanal.

5. Schiff's bases forms as a result of interaction between:

1) methylamine and ethanal; 3) propanaland ethylamine;
2) methylamine and benzoic acid; 4) methylamine and ethylamine.

6. In aldol condensation reaction could undergo:

1) 2-methylpropanal; 2) propanal; 3) benzaldehyde; 4) 2,2-dimethylpropanal.

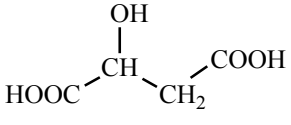
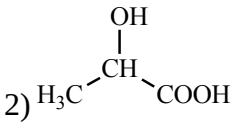
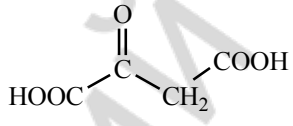
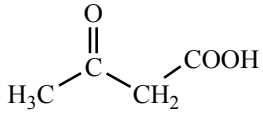
7. For qualitative detection of the aldehyde group are used:

1) Shiffs reagent; 2) $FeCl_3$; 3) $Cu(OH)_2$, heating; 4) Ag_2O in ammonia solution.

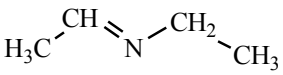
8. Choose carbonyl compound with the highest reactive ability in A_N reactions:

1) propanone; 2) butan-2-one; 3) ethanal; 4) methanal.

9. Select the product of 2-oxopropanoic acid reduction:

1) 
2) 
3) 
4) 

10. Represented substance forms as a result of interaction between:



1) methylamine and ethanal; 3) ethylamine and methanol;
2) ethylamine and ethanal; 4) ethylamine and methylamine.

PRACTICAL PART

1. Formaldehyde oxidation with $Cu(OH)_2$ in alkaline medium

Qualitative tests on aldehydes are connected with easy oxidizability of aldehyde 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.

$$CuSO_4 + 2\ NaOH \rightarrow Cu(OH)_2 + Na_2SO_4$$

$$R - CHO + 2Cu(OH)_2 \xrightarrow{OH^-,t} R - COOH + 2CuOH + H_2O$$

$$2\ CuOH \longrightarrow Cu_2O + H_2O$$

Accomplishment: to 3 drops of formaline (32) add 5 drops of NaOH solution (21) and 1–2 drops of $CuSO_4$ (26). Mixture is heated to boiling point.

Observed changes: _____

Conclusion: _____

_____

2. Reaction of formaldehyde with Shiff's reagent

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

Accomplishment: to 2 drops of the Shiff's reagent* add 3 drop of formaldehyde solution (32).

Observed changes: _____

Conclusion: _____

_____

3. Disproportiation 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.

$$2\ HCHO \rightarrow HCOOH + CH_3OH$$

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

Observed changes: _____

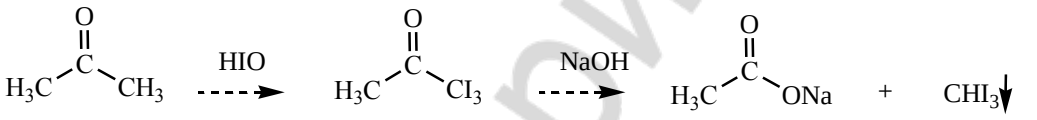
Conclusion: _____

_____

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.

$$I_2 + NaOH \longleftrightarrow HIO + NaI$$



triiodoacetone iodoform

Accomplishment: to 3 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: _____

Conclusion: _____

_____

5. Colored reaction on the acetone with sodium nitroprusside.

Reaction with sodium nitroprussiate $Na_2[Fe(CN)_5NO]$ 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 3dropsacetone* add 2 drops of sodium nitroprussiate $Na_2[Fe(CN)_5NO]$ (35) and 2 drops of NaOH (21) solution. In 2–3 minutes add 2 drops of acetic acid (36).

Observed changes: _____

Conclusion: _____

_____

Signature of teacher:

LABWORK № 7
CARBOXYLIC ACIDS AND THEIR DERIVATIVES

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

Recommended literature:

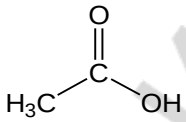
1. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2006. P. 149–159.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 135–135.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 47–52.

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. Indicate reactive sites at the carboxylic acid molecule:



2. Compare the acidity of ethanoic and ethanedioic acids. Write the reaction of salt formation of the stronger acid with $Ca(OH)_2$.

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

a) propanedioic acid (malonic)

b) 2-aminopentanedioic acid

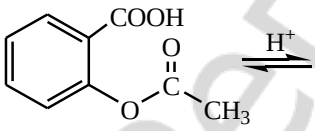
4. Write the dehydration reaction of pentanedioic acid.

5. Write the formulas of the functional derivatives of carboxylic acids:

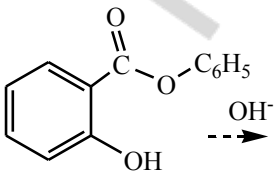
anhydride of acetic acid	acetyl chloride
ethylethanoate	ammonia acetate
full amide of oxalic acid	full amide of carbonic acid

6. Write the esterification reactions of the methanoic acid with ethanol.

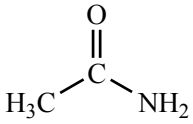
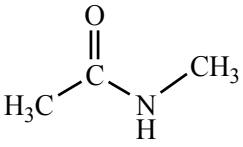
7. Write down the acidic hydrolysis reaction of the following compound:



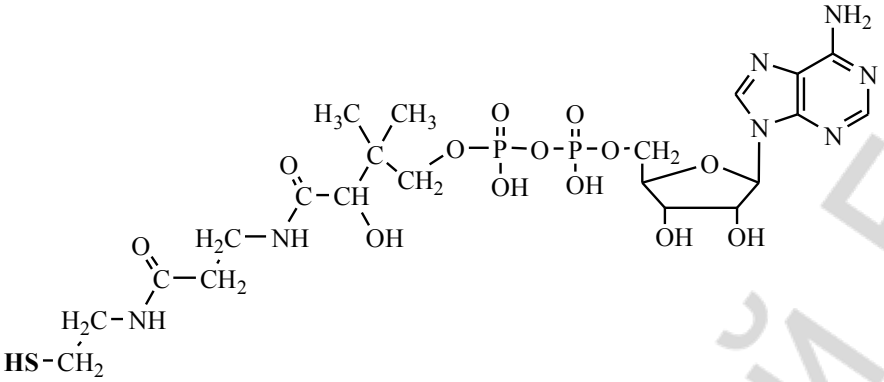
8. Write down the alkaline hydrolysis reaction of the following compound:



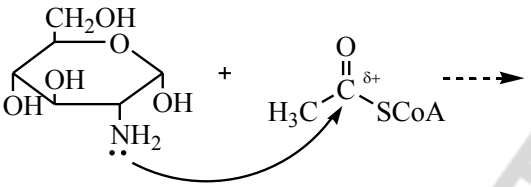
9. What products would be obtained from the hydrolysis of each of the following amides:

10. Mark the ester, amide, anhydride bonds at the coenzyme A molecule. Write the scheme of acetyl coenzyme A formation (using short formula for coenzyme A — CoA-SH).

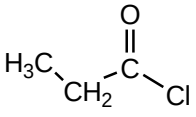
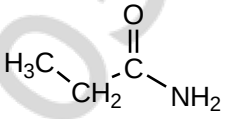
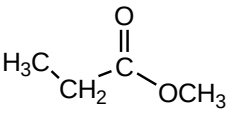
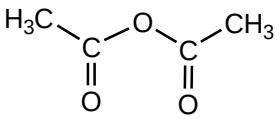


11. Write the scheme of acylation reaction:



TEST CONTROL

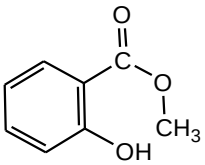
1. Arrange in order of decreasing of reactivity in S_N reactions of the following compounds:

1) 
2) 
3) 
4) 

2. Find accordance between compound and its decarboxylation products:

A) ethandioic acid;	1) propanone;
B) 2-amino-3-hydroxypropanoic acid;	2) 2-aminoethanol;
C) propandioic acid;	3) ethanoic acid;
D) 3-oxobutanoic acid.	4) methanoic acid.

3. Methyl salicylate forms as a result of acidic hydrolysis of:



1) methanol and *o*-hydroxybenzoic acid;
2) *o*-hydroxybenzoic acid and methanoic acid;
3) *p*-hydroxybenzoic acid and methanol;
4) *o*-hydroxybenzoic acid and phenol.

4. Choose correct statement(s):
1) RS-group possess less +M effect than RO-group;
2) RS-ions more stable than RO-ions and are more easily leaving group;
3) RO-ions more stable than RS-ions and are more easily leaving group;
4) partial positive charge on carbonyl carbon atom in thioesters is higher than its in esters.

5. Electron density distribution in propanoic acid molecule is characterized by presence:
1) O – H acidic site in the carboxyl group;
2) nucleophile site on the carbon atom of carboxylic group;
3) C – H acidic site in the alkyl group;
4) basic site on the oxygen atom in the carboxyl group;
5) electrophilic site on the carbon atom of carboxylic group.

6. Indicate type of the following reaction$CH_3COCl + CH_3OH \rightarrow CH_3COOCH_3 + HCl$:
1) elimination; 3) electrophilic substitution;
2) nucleophilic substitution; 4) nucleophilic addition.

7. Indicate acids which are stronger than acetic acid?
1) 2-chloroacetic acid; 2) hydrochloric acid; 3) propanoic acid; 4) formic acid.

8. To increase reactive ability of carboxylic acids we should:
1) conduct reaction in alkaline medium;
2) conduct reaction in acidic medium;
3) enter more strong electron withdrawer in aside chain;
4) enter more strong electron withdrawer in a carboxyl group.

9. Select functional derivatives of carboxylic acids:
1) ethanoic acid; 2) ethyl chloride; 3) acetic anhydride; 4) methyl benzoate.

10. Choose products of the butandioic acid heating in acidic medium:
1) H_2O; 2) CO_2; 3) propanoic acid; 4) succinic anhydride.

PRACTICAL PART

1. Ethyl acetate formation

To detect the carboxylic acids the esters production reaction can be used if esters have specific smell. The reaction is carried out according to the nucleofilic substitution mechanism (S_N).

$$CH_3COONa + H_2SO_4 \rightarrow CH_3COOH + NaHSO_4$$

$$CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_5 + H_2O$$

Accomplishment: to 3 drops of ethanol* add 5 drops of H_2SO_4 concentrated solution*and waterless CH_3COONa (42), heat. Pour solution to another test-tube with water.

Observed changes: _____

Conclusion: _____

_____

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 $Ca(OH)_2$).

$$HOOC - COOH \xrightarrow{t} CO_2 + HCOOH$$

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3\downarrow + H_2O$$

Accomplishment: in dry test-tube add crystal oxalic acid* (mass ≈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 ($Ca(OH)_2$) (2).

Observed changes: _____

Conclusion: _____

_____

Signature of teacher:

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

13. Electrophilic substitution reactions of aromatic hydrocarbons. Substituent effects in the aromatic ring on the reactivity of aromatic hydrocarbons. Alkylation reactions of aromatic compounds.

14. Electronic and spatial structure of the carbonyl group. Comparative reactivity of aldehydes and ketones.

15. 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.

16. Nucleophilic addition reactions of aldehydes and ketones; addition of water and alcohols.

17. Addition of amines to carbonyl compounds, mechanism. Schiff's bases.

18. Electronic and spatial structure of the carboxylic group. Acidic properties of the carboxylic acids: mono-, dicarboxylic, aliphatic saturated, aliphatic unsaturated, aromatic carboxylic acids.

19. Nucleophilic substitution at sp^2-hybridized carbon atom in the carboxylic group: esterification reaction. Properties of esters, hydrolysis.

LABWORK № 9
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 / S. E. Zurabyan. 2006. P. 161–171.

2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 163–172.

3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 52–61.

Problems for discussion:

1. Polyfunctional compounds: classification, chemical properties.
2. Heterofunctional compounds: classification, a role in biological processes.
3. Amino alcohols: their biological role.
4. Hydroxy acids. 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.
11. Sulfanylamides.

Exercises

1. Write the structural formulas of the following polyfunctional compounds:

glycerol	ethylene glycol

inositol	catechol
hydroquinone	resorcinol
oxalic acid	malonic acid
succinic acid	glutaric acid
fumaric acid	maleic acid

2. Write the structural formulas of the amino alkohols:

2-aminoethanol	choline

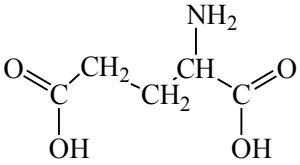
3. Write the structural formulas of the hydroxy acids:

lactic acid salts — …	malic acid salts — …
citric acid salts — …	

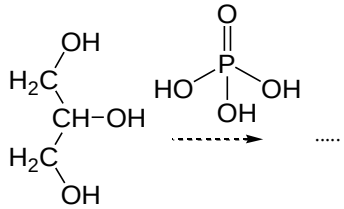
4. Write the structural formulas of the oxo acids:

pyruvic acid	oxaloacetic acid	α-oxoglutaric acid

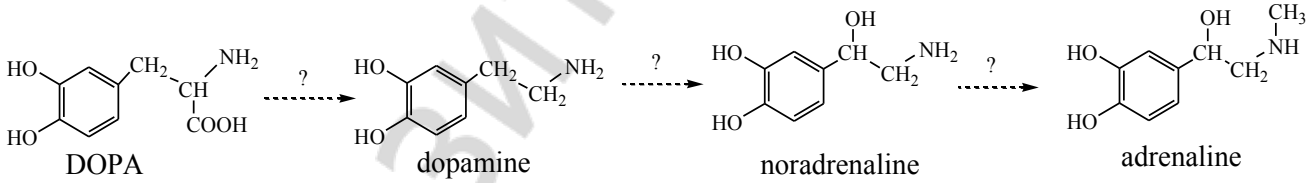
5. Indicate the acidic and basic centers in the following molecules and write its ionic forms:



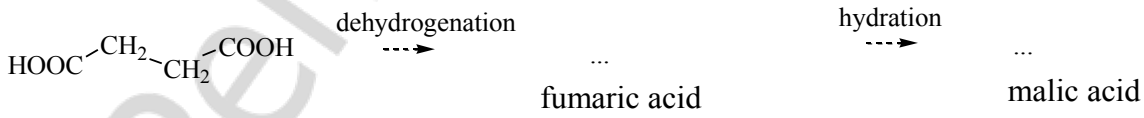
6. Fill in the scheme of the α-glycerophosphate formation:



7. Show the catechol at the catecholamine molecules and its precursor DOPA (3,4-dihydroxyphenylalanine). Write the name of the reactions occurring during the synthesis of catecholamines *in vivo* (alkylation, decarboxylation, hydroxylation). Mark the chiral centers in molecules.



8. Complete the scheme of the reactions *in vivo*:

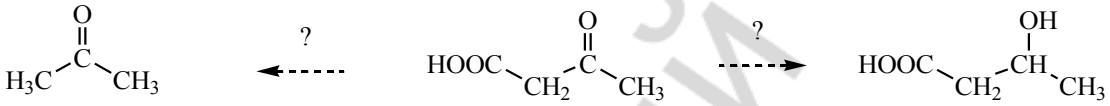


9. Write scheme of the oxidation reaction *in vivo* of malic acid.

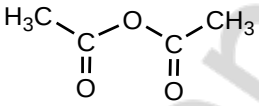
10. Write scheme of the reduction reaction *in vivo* of pyruvic acid.

11. Write down the tautomeric forms of oxaloacetic acid:

12. Write the names of the ketone bodies formation according to the following scheme:



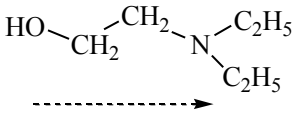
13. Fill in the scheme of the acetylsalicylic acid formation reaction.



salicylic acid

acetylsalicylic acid

14. Fill in the scheme of the *p*-aminobenzoic acid derivatives formation reaction:

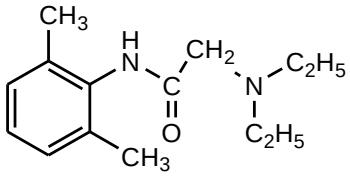


benzocaine

p-aminobenzoic acid

procaine

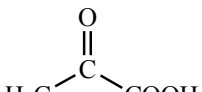
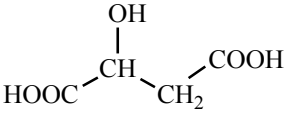
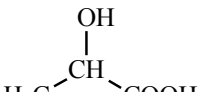
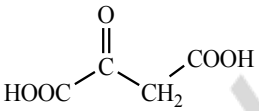
15. Explain the structure peculiarities of the modern anesthetic remedies such as lidocaine.



lidocaine

TEST CONTROL

1. Indicate the product of malic acid oxidation *in vivo*:

1) 
2) 
3) 
4) 

2. Salicylic acid is stronger than benzoic acid because of:
1) both functional groups are acidic;
2) mesomeric effect of phenol OH-group decrease anion stability;
3) formation of intermolecular hydrogen bond between ionized carboxyl group and phenol hydroxyl group;
4) mesomeric effect of phenol OH-group increase anion stability.

3. Novocain possess less long-term anesthetic action in comparison with ultracaine because of:
1) it has ethers bonds;
2) it is Shiff"s base which hydrolyzes easy;
3) it has esters bond which hydrolyze easier then amide bond;
4) it has glycoside bond.

4. As a result of decarboxylation of 2-amino-3-hydroxypropanoic acid decarboxylation forms CO_2 and:
1) propanon;
2) 2-aminoethanol;
3) ethanoic acid;
4) methanoic acid.

5. Indicate correct statements about oxaloacetic acid:
1) refer to ketoacids;
2) posseses optical activity;
3) exist in toutomeric forms in solution;
4) undergo in nucleophilic substitution reaction.

6. Choose the carbonic acid derivatives:
1) carbamic acid;
2) carbamide;
3) uric acid;
4) urea.

7. As result of interaction of salicylic acid and acetic anhydride forms:
1) acetylsalicylic acid;
2) phenyl salicylate;
3) methyl salicylate;
4) ethyl salicylate.

8. Indicate correct statements about urea:
1) gives acidic properties of medium;
2) possess basic properties;
3) is the final product of nitrogen metabolism in human body;
4) oxygen is protonated after interaction with acid;
5) nitrogen is protonated after interaction with acid.

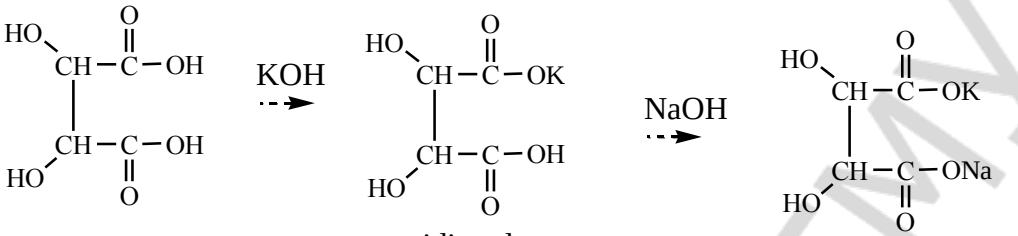
9. Which acids undergo elimination reaction:
1) 4-hydroxypentanoic acid;
2) 2-hydroxy-3-methylbutanoic acid;
3) 3-hydroxybutanoic acid;
4) 3-aminopentanoic acid.

10. Which one of the following compounds forms gamma-lactone under heating:
1) 4-hydroxy-2-methylbutanoic acid;
2) 2-hydroxybutanoic acid;
3) 3-hydroxybutanoic acid;
4) 5-hydroxypentanoic acid.

PRACTICAL PART

1. Evidense of two carboxyl groups in tartaric acid structure

Tartaric acid as dioic forms two salts — acid salt and neutral [normal] salt which differ with water solubility.



acidic salt — normal salt

Accomplishment: to 3 drops of tartaric acid (50) add 2–3 drops of KOH solution (51), intensively intermix rubbing with glass rod against walls of a test tube. There is a crystal deposit. Add 2–3 drops of NaOH solution into a test tube to form the solution of **segnetic salt** (sodium and potassium tartrate). Save this solution for next experiment.

Observed changes: _____

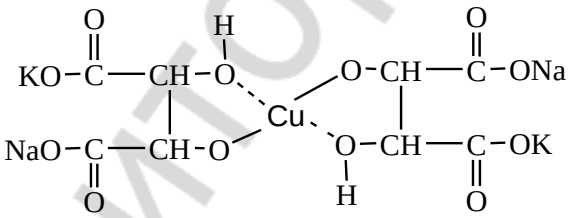
Conclusion: _____

_____

2. Evidense of two hydroxyl groups in tartaric acid structure

Qualitative test on polyols is used. Tartaric acid reacts with $Cu(OH)_2$ and forms copper (II) alcoholate (chelate).

$$CuSO_4 + 2NaOH \rightarrow Cu(OH)_2 + Na_2SO_4$$



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.

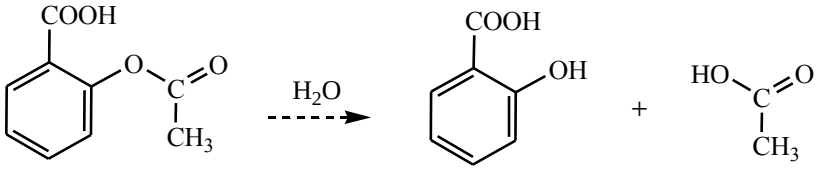
Observed changes: _____

Conclusion: _____

_____

3. Test on the high quality of aspirin

At hydrolysis of aspirin *o*-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: _____

Conclusion: _____

_____

Signature of teacher:

LABWORK № 10
POLYMER MATERIALS USING IN DENTISTRY

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

Recommended literature:

1. *Solomons, T. W.* Fundamentals of Organic Chemistry / T. W. Solomons. 1994. P. 951–961.
2. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 69–76.

Problems for discussion:

1. General characteristic of high-molecular compounds (AMC): monomer elementary groups, degree of polymerisation. Oligo- and polymers, subpolymers, compositional polymers.
2. Classification of polymers.
3. Ways of receipt polymers.
4. Mechanism of free radical 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 of composite materials. Reaction of bilding Bis-GMa (bis-phenol-A-glycidylmethacrylate). TEG-GMA (triethylene glycoldimethacrylate).
8. Low-molecular components, using in the adhesive systems for improvement for stiking of material filling to tissue of tooth.

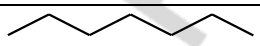
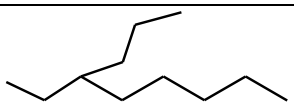
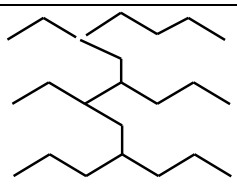
Exercises

1. Classify the polymers:

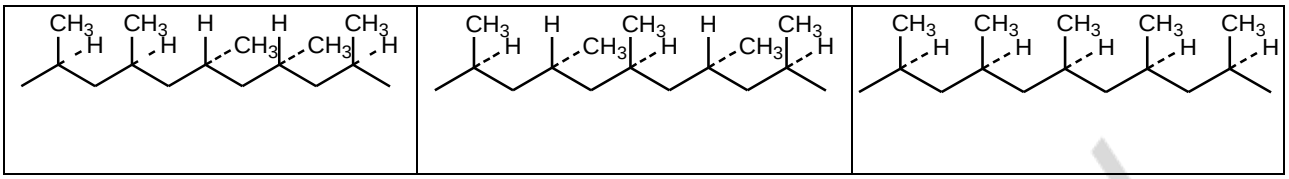
according to the origin (natural or synthetic)

polysterene	starch	polyethylene	polyethyleneglycol

according to the structure of macromolecule (linear, branched, spatial)

according to the spatial isomerism chain (isotactic, syndiotactic, atactic)



2. ***The main methods of polymer formation*****:** …

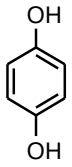
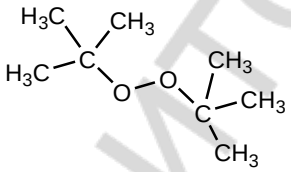
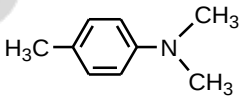
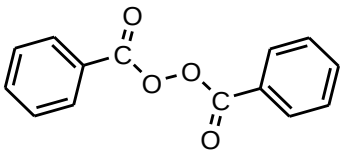
3. ***Radical polymerization may be initiated with***…

4. ***Initiators***…

Activators …

Inhibitors…

Select initiators, activators and inhibitors:

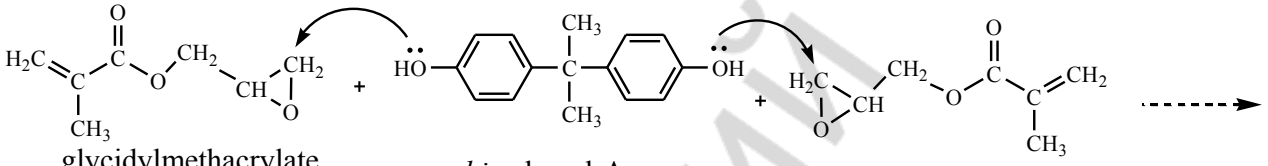
$FeSO_4$				

5. Write schemes of the formation reactions of....
a) polymethylmethacrylate

b) polyethylmethacrylate

6. Describe the mechanism of free radical polymerization of ethylmethacrylate with participation of initiator (benzoyl peroxide).

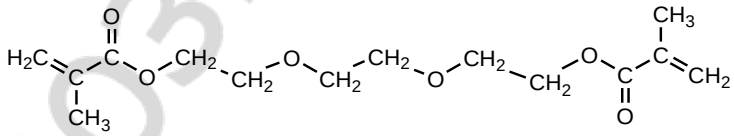
7. Modern restore materials photo- and chemical cured contain Bis-GMA (bis-phenol-A-glycidylmethacrylate). Analyze compounds, from which Bis-GMA forms and complete the scheme.



glycidylmethacrylate *bis*-phenol-A glycidylmethacrylate

.....

Triethylene glycoldimethacrylate add to composition materials to reduce viscosity. Select familiar fragments at the molecule of triethylene glycoldimethacrylate.

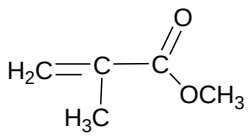
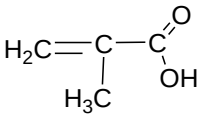
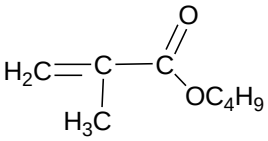
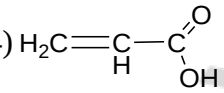


triethylene glycoldimethacrylate

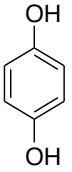
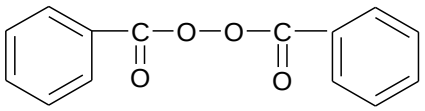
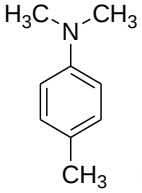
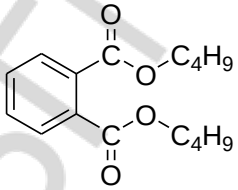
8. Dimethacrylate of glycerophosphate acid uses as component of adhesive systems. Write down the formula of dimethacrylate of glycerophosphate acid.

TEST CONTROL

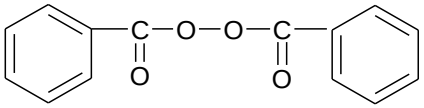
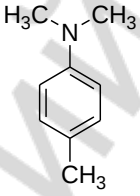
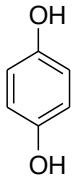
1. Indicate structural formula of polymethacrylate monomer:

1)  2)  3)  4) 

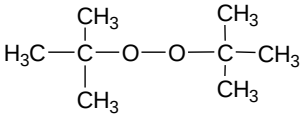
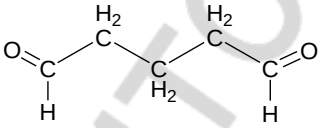
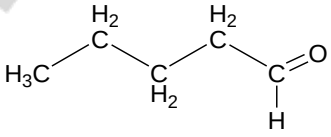
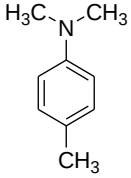
2. Indicate structural formula of free radical reaction activator:

1)  2)  3)  4) 

3. Indicate structural formula of free radical reaction inhibitor:

1) $FeSO_4$ 2)  3)  4) 

4. Indicate compound which may provide a tooth tissue binding with restoration material:

1)  2)  3)  4) 

5. Gutta-percha represented by:

1) *cis*-polybutadiene;
2) *trans*-polybutadiene;
3) *cis*-polyisoprene;
4) *trans*-polyisoprene.

6. Find the reasons of including gypsum in alginate impression materials:

1) to decrease thermal stability;
2) to increase elasticity and rigidity of material;
3) using as a preserving agent;
4) using as a indifferent.

7. Polyethylene glycol is … polymer:

1) carbo chained; 2) hetero chained; 3) linear; 4) branched.

8. Natural rubber represented by:

1) *cis*-polybutadiene;
2) *trans*-polybutadiene;
3) *cis*-polyisoprene;
4) *trans*-polyisoprene.

9. To slow down the aging processes of polymer are used:

1) peroxides; 2) aromatic amines; 3) phenols; 4) carboxylic acid.

10. Find the reasons of using dimethacrylate of glycerophosphic acid in adhesive systems:

1) presence of double bonds in hydrophobic part;
2) capability to undergo nucleophilic addition reactions;
3) presence of free phosphoric acid residual;

4) it has biphilic properties.

PRACTICAL PART

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

Accomplishment: in a porcelain crucible place a small amount of powder (ACR-7 or ACR-15) and 3–4 drops of monomer. Mix using a glass stick. Cover and leave to swell for 15–20 minutes. Mass is considered to ready if it loses stickiness. Form the object (tooth) the desired shape and put the object in boiling water for complete hardening (5–10 min.)

Conclusion: _____

_____

2. Depolymerisation of polymethylmethacrilate and evidence of monomer unsaturation.

Accomplishment: in the test tube put small pieces of polymer, fix the tube almost horizontally and heated on a spirit lamp, carefully pour monomer vapors in the form of white smoke into a another tube with 3–5 drops of bromine water, shake.

Observed changes: _____

Conclusion: _____

_____

Signature of teacher:

LABWORK № 11
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:

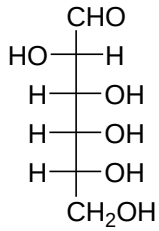
1. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2006. P. 189–199.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 195–207.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 76–85.

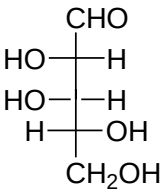
Problems for discussion:

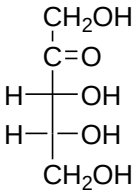
1. Carbohydrates: definition, biological role.
2. Monosaccharides, definition, classification, stereoisomerism. Epimers.
3. Monosaccharide tautomerism. Anomers. Tautomeric forms of D-glucose, D-galactose, D-fructose, D-ribose, 2-deoxy-D-ribose. Fisher and Haworth formulas. Conformations of cyclic forms.
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. Amino sugars. Their structure, properties and a biological role.
9. Ascorbic acid (vitamin C) as water-soluble antioxidant.

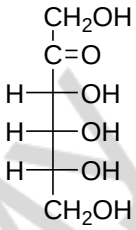
Exercises

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







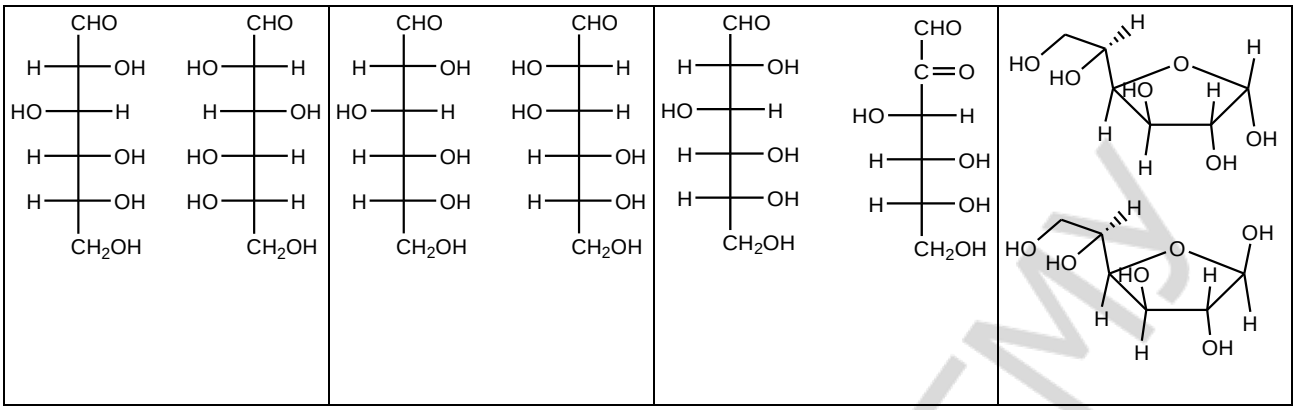


2. Write the all tautomeric forms of D-glucose (according to Fisher and Haworth).

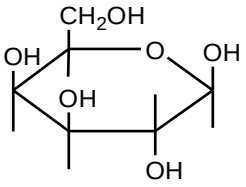
3. Write the formulas of β-D-ribofuranose and β-D-deoxyribofuranose.

4. Write the all tautomeric forms of D-fructose.

5. Call the pairs of isomers *(epymers, anomers, functional isomers, enantiomers).*

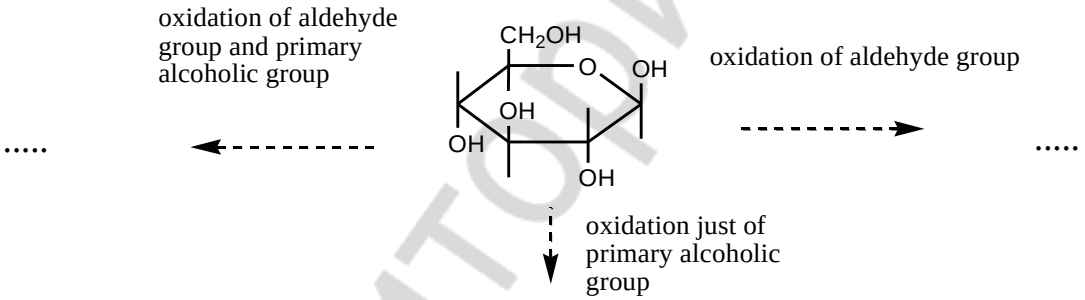


6. Complete the scheme of the reaction:



C_2H_5OH, H^+ ⇢ .....

7. Write down the formulas of product reactions.

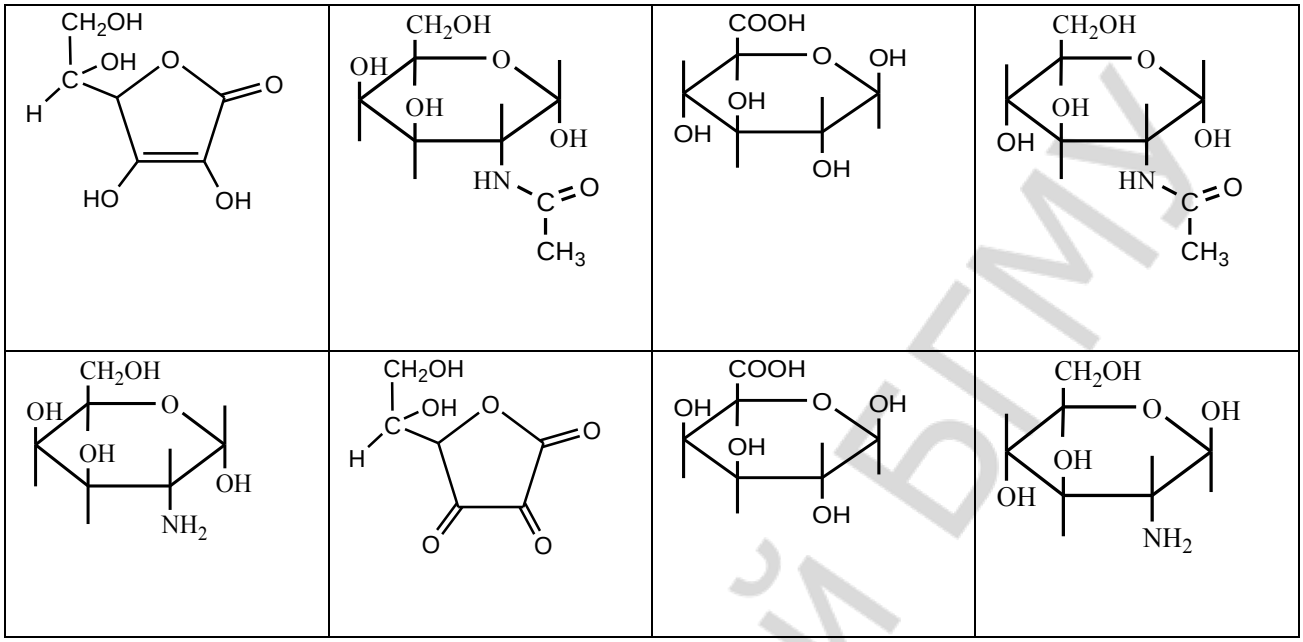


8. Write down the formulas of reduction products of monoses.

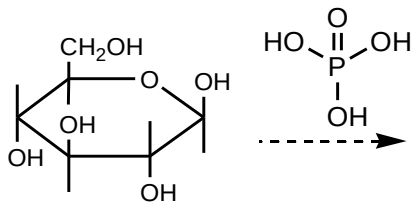
D-xylose $\xrightarrow{H_2,\ Pd}$ .....

D-glucose $\xrightarrow{H_2,\ Pd}$ .....

9. From the formulas raw select the following compounds: 2-deoxy-2-amino-β-D-glucopyranose, 2-deoxy-2-amino-α-D-galactopyranose, N-acetylgalactosamine, N-acetylglucosamine, glucuronic acid, galacturonic acid, reduce form of ascorbic acid, oxidized form of ascorbic acid.

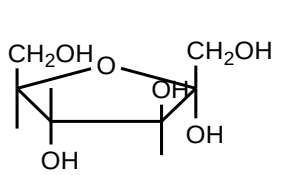


10. Phosphorylation is the way of formation of metabolic active forms of compound. Write down the products of phosphorylation reactions.



.....

6 - phosphate-D - glucopyranose



.....

1,6 - diphosphate-D - fructofuranose

TEST CONTROL

1. Select monosaccharaides which refer to aldohexoses:
1) mannose; 2) galactose; 3) xylose; 4) glucose; 5) fructose.

2. Find characteristics for D-glucose:
1) refer to hexose; 2) is aldose; 3) refer to pentose; 4) is ketoses.

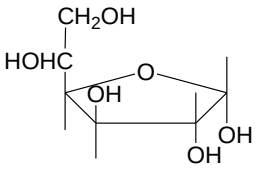
3. Choose a type of glucose fermentation where hydrogen liberate?
1) lactic-acid; 2) alcoholic; 3) butyric-acid; 4) citric-acid.

4. How many chiral carbon atoms in cyclic glucose form?

1) 4; 2) 5; 3) 3; 4) 6; 5) 2.

5. Give the name of the following compound:

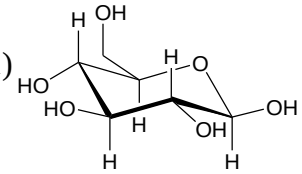
1) α-D-galactopyranose; 3) α-D-fructofuranose;
2) α-D-glucofuranose; 4) β-D-glucopyranose.

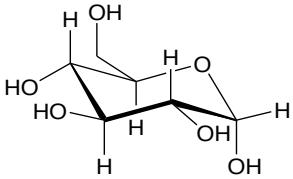


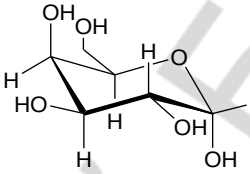
6. D-glucose and D-mannose are stereoisomers which are called:

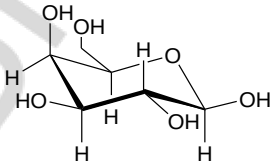
1) enantiomers; 2) epimers; 3) functional isomers; 4) anomers.

7. Find β-D-galactopyranose:

1) 

2) 

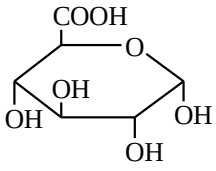
3) 

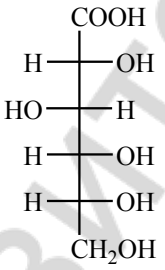
4) 

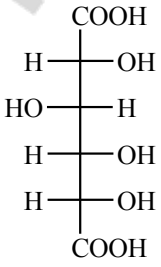
8. Point out the product of interaction between α-D-glucopyranose and methanol (with HCl presence):

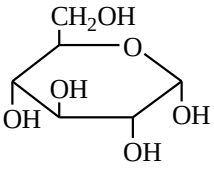
1) 2,3,4,6-tetramethyl-D-glucopyranose;
2) 2,3,4,6-tetramethyl-O-methyl-D-glucopyranoside;
3) methyl-α-D-glucopyranoside;
4) methyl-β-D-glucopyranoside.

9. Point out glucuronic acid:

1) 

2) 

3) 

4) 

10. Select correct statements about transformation acyclic form of monosaccharide in cyclic form:

1) acetal is cyclic form of monosaccharide;
2) carbon atom pass into sp^3-hybridization from sp^2-hybridization and becomes asymmetric;
3) anomer forms of monosaccharide are created;
4) acetal is acyclic form of monosaccharide.

PRACTICAL PART

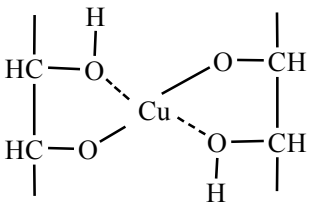
1. A qualitative test on the hydroxyl groups in the glucose molecule.

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

$$CuSO_4 + 2NaOH \longrightarrow Cu(OH)_2\downarrow + Na_2SO_4$$

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

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



Accomplishment: to 5 drops of glucose (54) solution add 2 drops of NaOH (21) and 2 drops of $CuSO_4$ (26).

Observed changes: _____

Conclusion: _____

_____

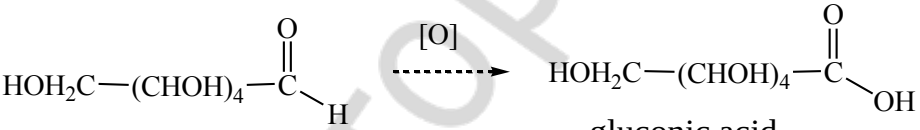
2. A qualitative test on the aldehyde group in the glucose molecule.

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 $Cu(OH)_2$oxidizes glucose.

$$2Cu(OH)_2 \longrightarrow [O] + H_2O + 2CuOH$$

$$2CuOH \longrightarrow H_2O + Cu_2O$$

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 3 drops of the Fehling's reagent (55) and heat up.

Observed changes: _____

Conclusion: _____

_____

3. Comparison of reactions of glucose and formalin with Shiff'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 one — 5–7 drops of glucose solution (54) and add in everyone on 2 drops Shiff's reagent (33). In a test tube with formalin — red violet color with glucose this reaction is negative.

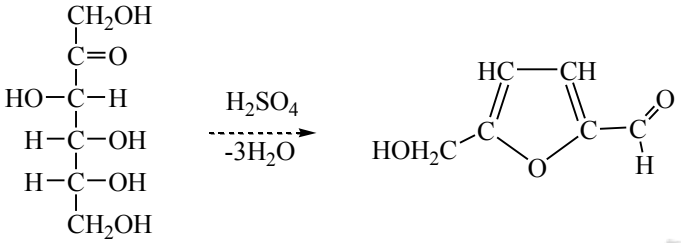
Observed changes: _____

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.



D-fructose oxymethylfurfural

Accomplishment: to 10 drops of fructose (56) solution add 2 drops of HCl* concentrated solution and 1 spatula of resorcinol* crystals. Heat up.

Observed changes: _____

Conclusion: _____

_____

Signature of teacher:

LABWORK № 12
OLIGO- AND POLYSACCHARIDES

Objective: to develop knowledge of a structure, consider important chemical properties of homo- and heteropolysaccharides in view of their biological properties.

Recommended literature:

1. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2006. P. 199–208.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 207–216.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 85–91.

Problems for discussion:

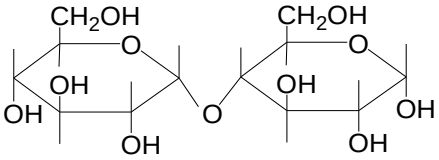
1. Classification of polysaccharides.
2. Disaccharides: maltose, cellobiose, lactose, lactulose, sucrose. Their structures and properties.
3. Starch: structure, biological role. Glycogen.
4. Cellulose: structure, biological role.
5. Dextrane as a source to obtain plasma substitutes.
6. Heteropolysaccharides. Impressional materials on the basis of alginate acids.

Exercises

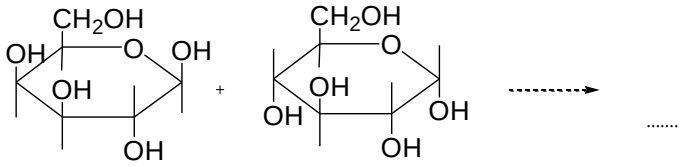
1. Classify the polysaccharides (reducing disaccharide, non-reducing disaccharide, homopolysaccharide, heteropolysaccharide):

sucrose	cellulose	starch	maltose	lactose
dextrane		chondroitin sulfate		hyaluronic acid

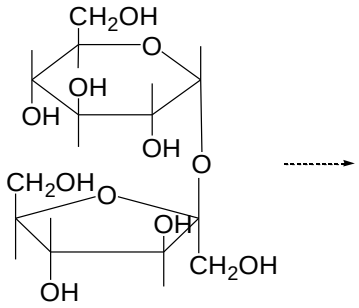
2. Indicate the monosaccharide residuals of disaccharide. Call this disaccharide and type of glycoside bond.



3. Write the reaction of lactose formation.

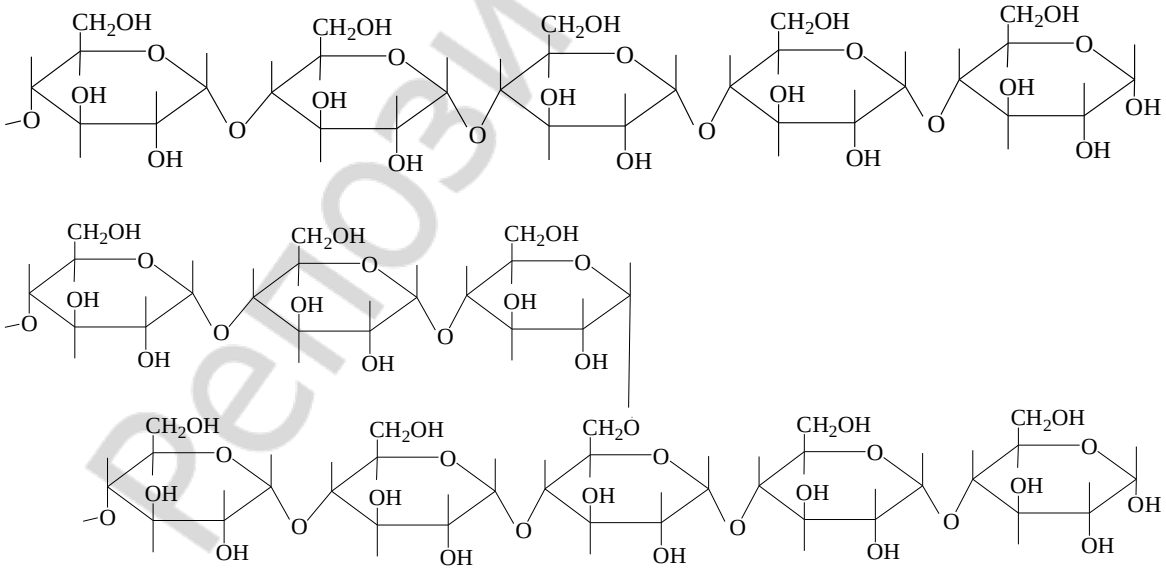


4. Complete the reaction of sucrose hydrolysis:



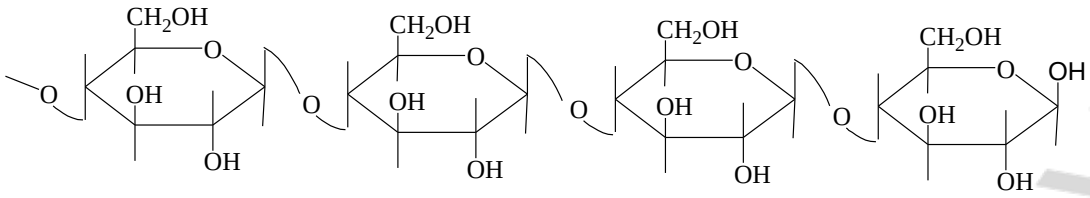
5. Starch consists of the following fractions:

At the amylose and amylopectine fragments, indicate monomer, bond types between monosaccharide residuals.



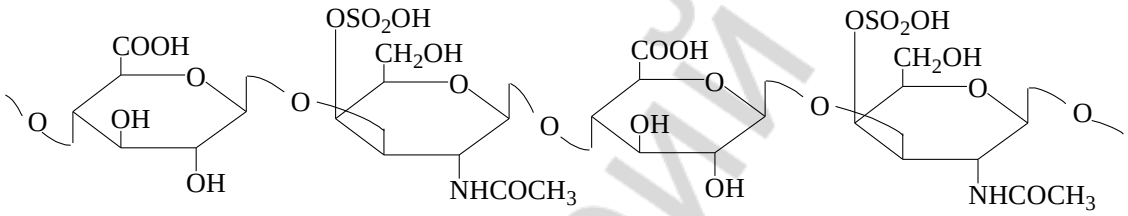
The end hydrolysis product of starch is …

6. Call mentioned below fragment of polysaccharide. Indicate monomer and bond types between monosaccharide residuals.

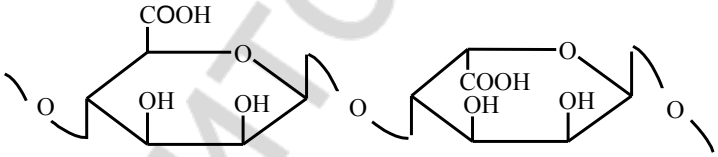


7. Write the fragment of hyaluronic acid (min. 4 monosaccharide residuals) consisting of disaccharide fragment — D-glucuronic acid and N-acetyl-D-glucosamine bonded β (1-3) glycoside linkage. Between disaccharide fragments — β (1-4) glycoside bond.

8. Call the residuals of monosaccharide at the chondroitin sulfate structure.



9. Mark the residuals of monosaccharide derivatives at the alginic acid fragment and indicate the type of glycosidic bond.



TEST CONTROL

1. Point out functional groups participated in bond formation between monosaccharide residues in nonreducing disaccharide:

1) two alcoholic OH-groups;
2) hemiacetal and alcoholic OH-groups;
3) two hemiacetal OH-groups;
4) aldehyde and alcoholic OH-group.

2. Which disaccharides could undergo mutarotation?

1) lactulose; 2) cellobiose; 3) sucrose; 4) lactose.

3. As a result of sucrose hydrolyses forms:

1) glucose and mannose;
2) galactose and glucose;
3) galactose and fructose;
4) glucose and fructose.

4. Point out characteristics and properties of dextran:

1) main type of glycoside bond between monosaccharide residue is α (1→6);
2) hydrolysis yield glucose;
3) bacterial metabolic product;
4) has plant origin.

5. Choose disaccharide(s) acid-catalyzed hydrolysis of which yields only glucose
1) lactose; 2) lactulose; 3) maltose; 4) cellobiose; 5) sucrose.

6. Select sugar which refer to homopolysuccharides:
1) heparin; 2) starch; 3) dextran; 4) cellulose; 5) hyaluronic acid.

7. Invert sugar is hydrolysis product of:
1) cellobiose; 2) maltose; 3) lactose; 4) sucrose.

8. Chose the type of glycoside bond in lactose:
1) α (1-4); 2) α,β (1-2); 3) β (1-4); 4) α (1-3).

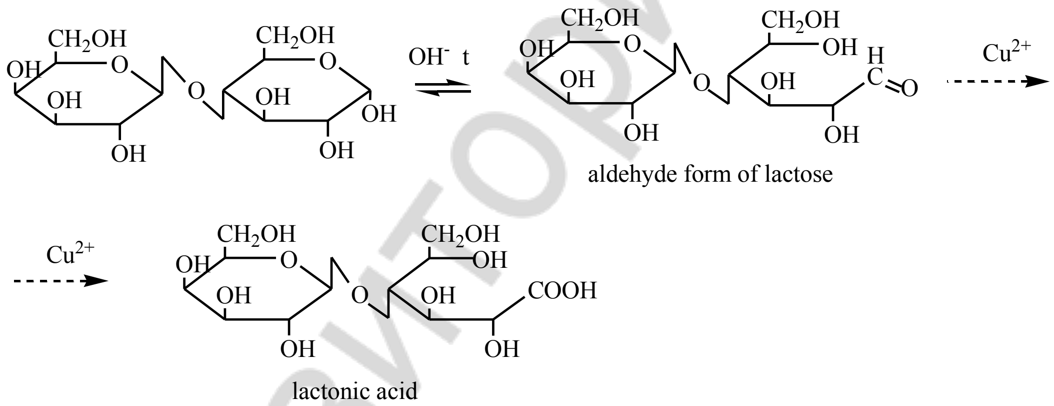
9. Chose the type of glycoside bond in lactulose:
1) α,β (1-2); 2) α (1-4); 3) β (1-4); 4) α (1-6).

10. Find characteristics and properties of cellulose:
1) monosuccharide residues link by α (1-4) glycoside bond;
2) hydrolysis yield glucose molecules;
3) monosuccharide residues link by β (1-4) glycoside bond;
4) produced by plants.

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: ____________________

____

Signature of teacher:

LABWORK № 13
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 / S. E. Zurabyan. 2006. P. 211–217.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 217–224.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 92–98.

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 proteinogenic amino acids at the mentioned below table with three letter code.

Hydrophobic AA (8)	**Hydrophilic AA**		
	With inionized radical (7)	*With negative ionized radical(2)*	*With positive ionized radical(3)*

Aliphatic AA (5)	
Hydroxy amino acids (2)	
Dicarbonic (acidic) AA (2)	
Amides of dicarbonic AA (2)	
Diaminomonocarbonic acids (2)	
S-containing AA (2)	
Aromatic AA (2)	
Heterocyclic AA (3)	

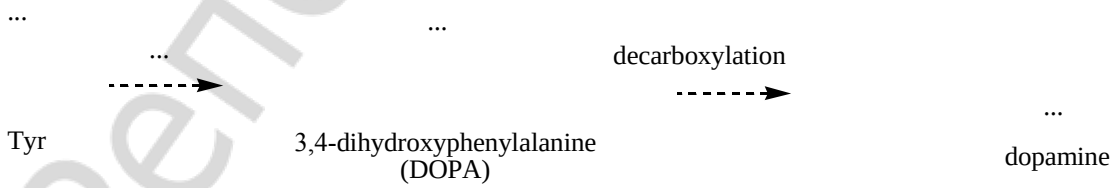
Designate(*) essential AA at the table.

2. Write down the formulas of aliphatic amino acids, designate chiral centers.

3. Write Fischer projections of L-valine.

4. Write down the formulas of aromatic amino acids.

Complete the scheme.



5. Write the structures of hydroxyl containing amino acids.

Write down the serine decarboxylation reaction. Call vitamin, which participates at that reaction as coenzyme.

6. Write the structures of S-containing amino acids.

Write the oxidation reaction of cysteine *in vivo*.

7. Write down the hydrophilic amino acids with negative ionized radical.

Write down the reaction of decarboxylation of Glu. Indicate the biological role of reaction product.

8. Write down the hydrophilic AA with positive ionized radical.

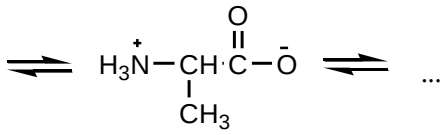
Write down the reaction of decarboxylation of His. Indicate the biological role of reaction product.

9. Write down the tryptophan formula. Indicate heterocycle in this AA.

10. Write down the hydrophilic AA containing amide group.

11. Complete the scheme:

pH 1,0 pH6,0 pH 12,0

....  ...

12. Write down the formula of proline and fill in the scheme. Indicate the coenzyme of this reaction.

hydroxylation

... ---> ...

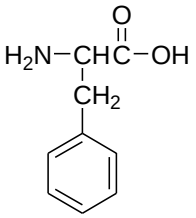
proline 4-hydroxyproline

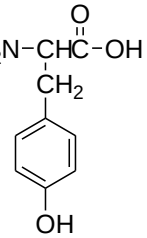
13. Write the reaction of transamination between L-alanine and α-oxoglutaric acid. Indicate the coenzyme of this reaction.

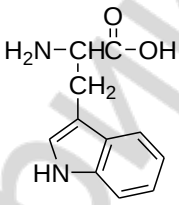
14. Write the scheme of oxidative deamination reaction of Glu *in vivo.*

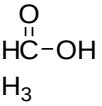
TEST CONTROL

1. Choose structural formulas of essential amino acids:

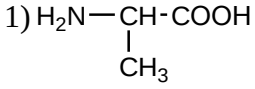
1) 

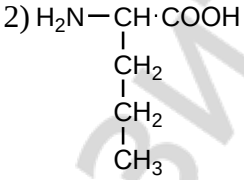
2) 

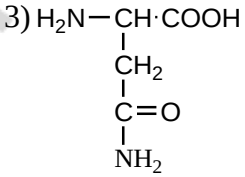
3) 

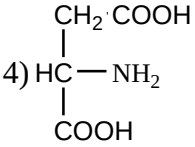
4) 

2. Choose structural formulas of proteinogenic amino acids:

1) 

2) 

3) 

4) 

3. Choose aromatic cycle containing amino acids:
1) Tyr; 2) Pro; 3) Thr; 4) His; 5) Trp.

4. Point out amino acids with ionogenic radical:
1) Asn; 2) Asp; 3) Arg; 4) Glu; 5) His.

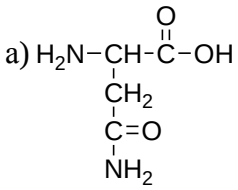
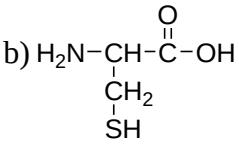
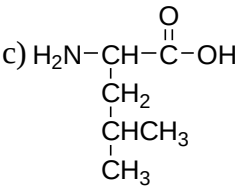
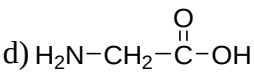
5. Choose amino acids which exist in the form of four stereoisomers:
1) isoleucine; 2) threonine; 3) 4-hydroxyproline; 4) arginine.

6. Choose amino acids with two carboxylic group:
1) Gln; 2) Ala; 3) Glu; 4) Asn; 5) Asp.

7. Which vitamin participate in reactions of prolin and lysine hydroxylation for connective tissue synthesis:
1) B_6; 2) C; 3) PP; 4) D.

8. As a result of posttranslational modification is formed:
1) cysteine; 2) 4-hydroxyproline; 3) 5-hydroxylysine; 4) threonine.

9. Choose amino acids structures in following sequence: leucine, asparagine, cysteine, glycine:

a)  b)  c)  d) 

1) c, a, b, d; 2) a, c, d, b; 3) a, b, c, d; 4) d, a, b, c.

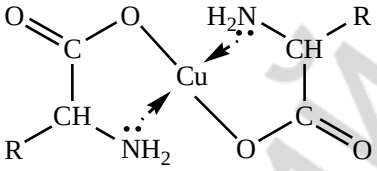
10. Select transamination reaction products of pyruvic acid and Glu:

1) Ala and 2-oxobutanedioic acid; 3) Ala and 2-oxopentanedioic;
2) Gly and 2-oxopentanedioic; 4) Asp and 2-oxopentanedioic.

PRACTICAL PART

1. Reactions of amino acids with copper salts

Amino acids as the amphoteric compounds form water soluble chelated compounds with copper ions.



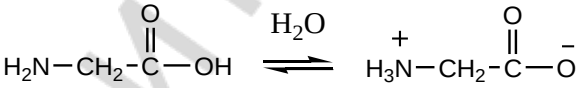
Accomplishment: add 1 copper (II) sulfate crystal (3) and 1 sodium acetate crystal (42) to 10 drops of 1 % glycine (6) solution. Shake the test-tube.

Observed changes: _____

Conclusion: _____

_____

2. Glycine has neutral medium



Accomplishment: add 1 drop of 0.2 % methyl red indicator* solution to 5 drops of 1 % glycine (6) solution.

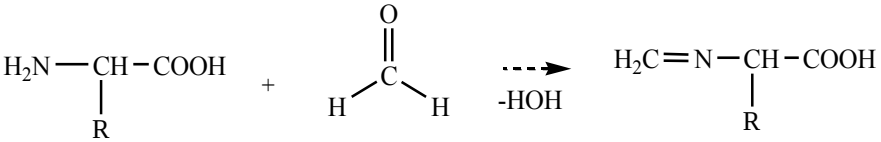
Observed changes: _____

Conclusion: _____

_____

3. Reactions of amino acid with formaldehyde

Formaldehyde is able to react in the A_N reaction (nucleophilic addition with the following water elimination) with amines and amino acids. At the same time the amino group of amino acid transforms into the methylenamino group (substituted imine). A 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 5 drops of 40 % formaldehyde solution (32). Carefully add (with glass stick) NaOH solution (21) to neutral medium of solution (fix color change). Then add 3 drops of 1 % glycine (6) solution (fix color change again).

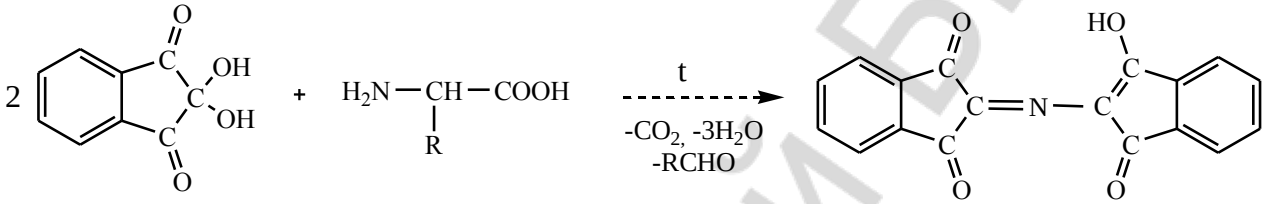
Observed changes: _____

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.



ninhydrine reaction product

Accomplishment: add 2 drop of 0.1 % ninhydrin* solution to 5 drops of 1 % glycine (6) solution. Heat the mixture to boil.

Observed changes: _____

Conclusion: _____

_____

Signature of teacher:

LABWORK № 14
PEPTIDES. 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:

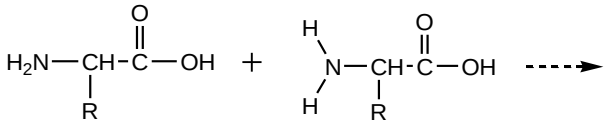
1. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2006. P. 211–224.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 224–228.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 99–103.

Problems for discussion:

1. Peptides: structure and functions. Glutathione, 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. Write down the reaction of dipeptide formation.



2. Describe the formation reaction of the following peptides and indicate their charge:
   a) Ala-Thr

b) Glu-His

c) Asp-Tyr-Met

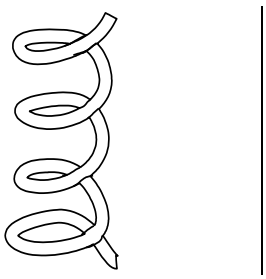
d) aspartyl asparaginyl leucine

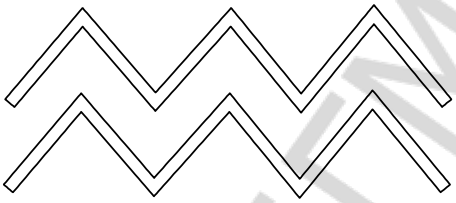
3. Write down the formula of glutathione.

4. Call the type of the secondary protein structure:

They are stabilized with …

Complete the pictures with bonds stabilizing secondary protein structure.





5. Tertiary structure is stabilized with …

Indicate the type of interaction between AA at the polypeptide chain.

Phe and Ala	Arg and Glu	Ile and Val	Cys and Cys
Ser and Gln	Tyr and Thr	Asp and Lys	His and Ser
Trp and Leu	Glu and His	Asn and Ser	Met and Ala

6. ***Denaturation*** is …

TEST CONTROL

1. Indicate amino acids which participate in ion bonds formation in tertiary structure of protein:
1) Asn; 2) Arg; 3) Cys; 4) Asp; 5) Glu.

2. Indicate amino acids which participate in hydrophobic interactions in tertiary structure of protein:
1) arginine; 2) isoleucine; 3) phenylalanine; 4) thryptophan; 5) asparaginic acid.

3. Choose correct statements:
1) proteins are polymers of proteinogenic amino acids;
2) secondary protein structure is stabilized by ionic bonds;
3) N-end and C-end presents in polypeptide chains;
4) proteins-shaperones participates in tertiary protein structure formation.

4. Indicate amino acids which participate in hydrogen bonds formation in tertiary structure of protein:
1) glutamine; 2) phenylalanine; 3) tyrosine; 4) proline; 5) serine.

5. In physiological conditionals positive charge has:
1) His-Val; 2) Thr-Lys; 3) Arg-Ser; 4) Ile-Tyr; 5) Cys-Arg.

6. Aspartameis dipeptide consisting of asparaginic acid and residue of methyl ether of:
1) glycine; 2) phenylalanine; 3) glutamine; 4) tyrosine.

7. Point out correct statement(s) about peptide bond:
1) carbon, nitrogen and oxygen atoms are in sp^2-hybridisation;
2) a lone pair of electrons enter in conjugation with p-electrons of double bond;
3) rotation is capable around peptide bind;
4) carbon, nitrogen and oxygen atoms are in the same plane.

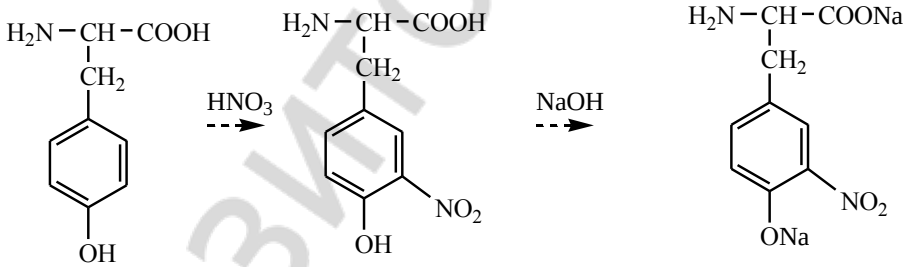
8. Peptide bonds in proteins and peptides are detected by reaction:
1) biuretic; 2) xanthoproteinic; 3) decarboxylation; 4) deamination.

9. In physiological conditionals negative charge has:
1) Asp-Phe; 2) Gln-Trp; 3) Glu-Thr; 4) Ile-Asp; 5) Asn-Pro.

10. C-end amino acid of glutathione is:
1) Glu; 2) Gly; 3) Cys; 4) Gln; 5) Ser.

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 10 drops of protein solution* add drop by drop concentrated solution of HNO_3* to form sediment (of what color?). Then heat carefully this test-tube (fix the change of color). Add some NaOH (21) solution (fix the change of color again).

Observed changes: _____

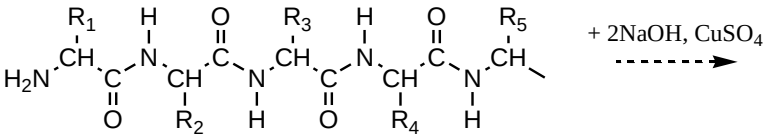
_____

Conclusion: _____

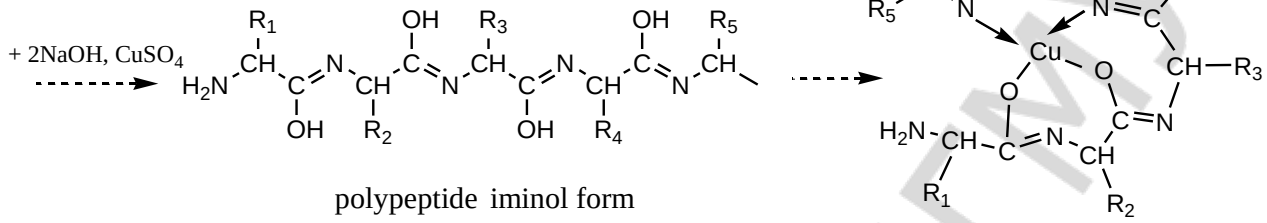
_____

2. Biuretic reaction determines the peptide bond in the solution of analysed compound. Complex compound of Cu with protein peptide group is formed as a result of biuretic reaction. Commonly peptide bond is presented in amide (or keto-form) in peptides and protein, but in alkaline medium it turns to iminol (enol) form.

Biuretic reaction proceeds in such way:



polypeptide



polypeptide iminol form

Biuretic chelate

Accomplishment: to 5 drops of protein solution* add 5 drops of NaOH (21) concentrated solution and then by degrees on the test-tube side pour 2–3 drops of 2 % solution of $CuSO_4$ (26).

Observed changes: _____

Conclusion: _____

_____

3. Precipitation of proteins with sulfosalicylic acid.

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

Accomplishment: pour 5 drops of 20 % sulfosalicylic acid* solution to 10 drops of protein solution*. Solution turbidity occurs.

Observed changes: _____

Conclusion: _____

_____

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, $(NH_4)_2SO_4$, $MgSO_4$) 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 precepitation.

Accomplishment: to 10 drops of protein* solution pour 5 drop of acetone*. Solution turbidity occurs.

Observed changes: _____

Conclusion: _____

_____

Signature of teacher:

LABWORK № 15
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 carreing out of qualititative reactions on structural components of nucleotides.

Recommended literature:

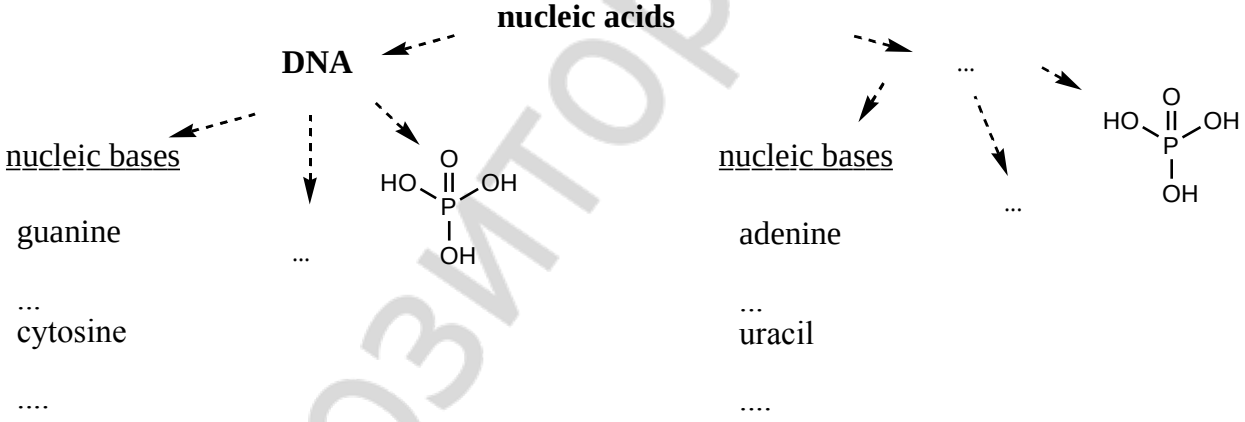
1. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2006. P. 225–237.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 246–256.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 103–108.

Problems for discussion:

1. Structural components of nucleic acids.
2. Heterocyclic bases: pyrimidine bases and purine bases.
3. Tautomeric forms of heterocyclic bases.
4. Pentoses of nucleic bases.
5. Nucleosides.
6. Nucleotides.
7. Primary structure of DNA and RNA.
8. Secondary structure of DNA.
9. Nucleotide derivatives: cyclic AMP, cyclic GMP, ATP.NAD^+ coenzyme.

Exercises:

1. Complete the table.



2. Write down the pyrimidine, number its atoms. Then write uracil, thymine and cytosine at the lactam and lactim tautomeric forms.

pyrimidine	uracil	thymine	cytosine

3. Write down the purine, number its atoms. Then write adenine and guanine at the lactam and lactim tautomeric forms.

purine	adenine	guanine

4. Write the structural formulas showing the hydrogen bonds in complementary base pairs of DNA:

a) thymine – adenine

b) cytosine – guanine

5. Write the formulas of the following nucleosides:

a) guanosine

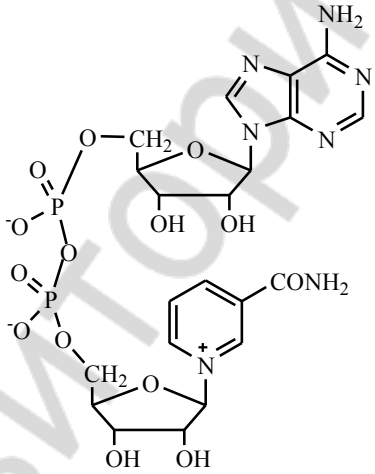
b) thymidine

6. Write the formulas of the following nucleotides:

adenosine- 5′-monophosphate	deoxycytidine-5′-monophosphate

7. Draw ATP molecule, indicate the bond types.

8. Analyze the formula of NAD^+. Mark the structural components of this molecule. Indicate its biological role.



TEST CONTROL

1. Point out types of tautomerism which characterize cytosine:
1) lactim-lactam; 3) amino-imine;
2) keto-enol; 4) cyclo-oxo.

2. Select products of deoxyadenosine-5'-monophosphate alkaline hydrolysis:
1) deoxyribose; 3) phosphate;
2) adenine; 4) deoxyadenosine.

3. Choose nitrogen bases included in RNA:
1) 2-amino-6-hydroxypurine;
2) 2,4-dihydroxy-5-methylpyrimidine;
3) 6-aminopurine;
4) 4-amino-2-hydroxypyrimidine;
5) 2,4-dihydroxypyrimidine.

4. Which type of bond take place between amide of nicotine acid and ribose residue in coenzyme NAD^+:

1) anhydride bond; 3) O-glycoside bond;
2) N-glycoside bond; 4) amide bond.

5. Select products of thymidine-5'-monophosphate acidic hydrolyses (pH 1):

1) thymine; 2) ribose; 3) deoxyribose; 4) thymidine; 5) phosphoric acid.

6. How many ester bonds in adenosine-3',5'-cyclophosphate:

1) 1; 2) 2; 3) 3; 4) 4.

7. Point out type of tautomerism which characterize adenine:

1) keto-enol; 2) cyclo-oxo; 3) amino-imine; 4) lactim-lactam.

8. Which type of bonds presents in nucleotide structure:

1) ester and anhydride; 3) anhydride and ether;
2) ester and N-glycoside; 4) phosphodiester and N-glycoside.

9. How many high-energy bonds in adenosine-5'-triphosphate:

1) 3; 2) 2; 3) 1; 4) 4.

10. Which type of bonds presents in GTP molecule between second and third phosphoric acid residues:

1) anhydride; 2) ester; 3) thioester; 4) hydrogen.

PRACTICAL PART

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.

$$H_3PO_4 + 12\ (NH_4)_2MoO_4 + 21\ HNO_3 \rightarrow (NH_4)_3PO_4 \cdot 12MoO_3 + 21NH_4NO_3 + 12\ H_2O$$

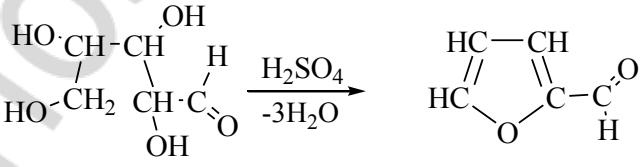
Observed changes: _____

Conclusion: _____

_____

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

When reacted with H_2SO_4 concentrated solution or dilute HCl pentoses are dehydrated to form furfural which is condensed with orcinol.



pentose furfural

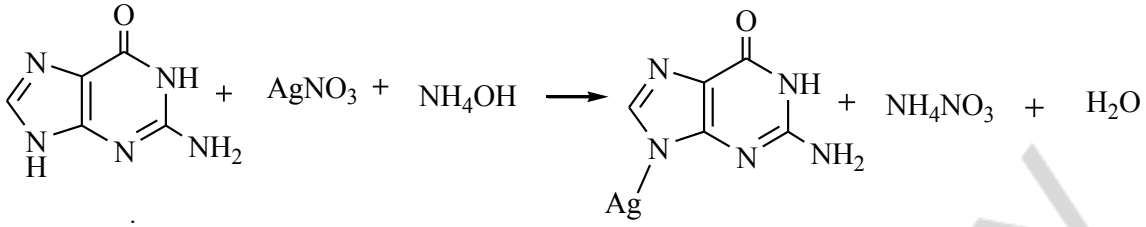
Accomplishment: add 10 drops of the Bial's reagent* (orcinol solution in HCl with $FeCl_3$) to 10 drops of yeast hydrolyzate* and boil 1–2 minutes.

Observed changes: _____

Conclusion: _____

_____

3. Purine base detection in products of nucleoprotein hydrolysis



guanine

Accomplishment: add 1 drop of concentrated solution of ammonia and 5 drops of 1 % solution of $AgNO_3$* to 5 drops of yeast hydrolyzate*. Leave the test-tube for 3–5 minutes without mixing.

Observed changes: _____

Conclusion: _____

_____

Signature of teacher:

LABWORK № 16
LIPIDS. LIPID PEROXIDATION

Objective: to develop knowledge about the saponifiable lipids.

Recommended literature:

1. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2006. P. 238–247.
2. *Zurabyan, S. E.* Fundamentals of Bioorganic Chemistry / S. E. Zurabyan. 2012. P. 173–182.
3. *Ryneiskaya, O. N.* Bioorganic chemistry. Course of lecture / O. N. Ryneiskaya, I. V. Ramanouski. 2015. P. 108–116.

Problems for discussion:

1. Classification of lipids, their biological role.
2. Fatty acids, their structure, properties and nomenclature. Alcohols which form fats and lipids.
3. Waxes, their composition and role.
4. Triacylglycerols, their structure, nomenclature, properties.
5. Phospholipids, their structure, nomenclature, physicochemical properties.
6. Sphingolipids, biological role.
7. The lipid peroxidation of cell membranes. Antioxidants.

Exercises

1. Write the molecular and stick formulas of fatty acids. Give their names according to ω-nomenclature.

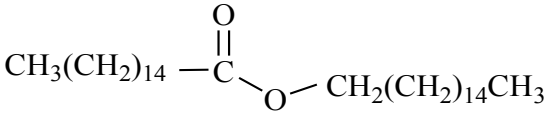
Stearic acid

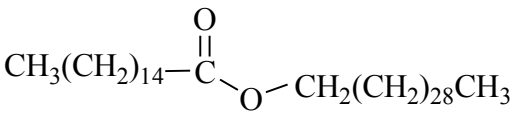
Palmitic acid
Oleic acid
Linoleic acid
Linolenic acid
Arachidonic acid

2. Write the formulas of the following hydroxyl containing compounds.

glycerol	ethanolamine
serine	choline

3. Analyze the mentioned below formulas of waxes.



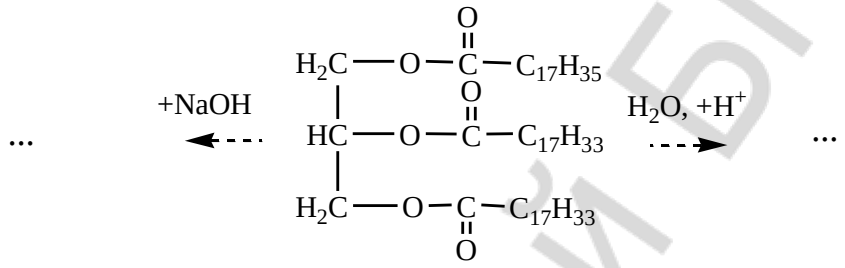


4. Write a structural formulas of the following triacylglycerol:

1-linoleoyl 2-palmitoyl 3-stearoylglycerol

1,3-dioleoyl-2-linoleoylglycerol

5. Write the hydrolysis reactions of fat. What is the soaps?



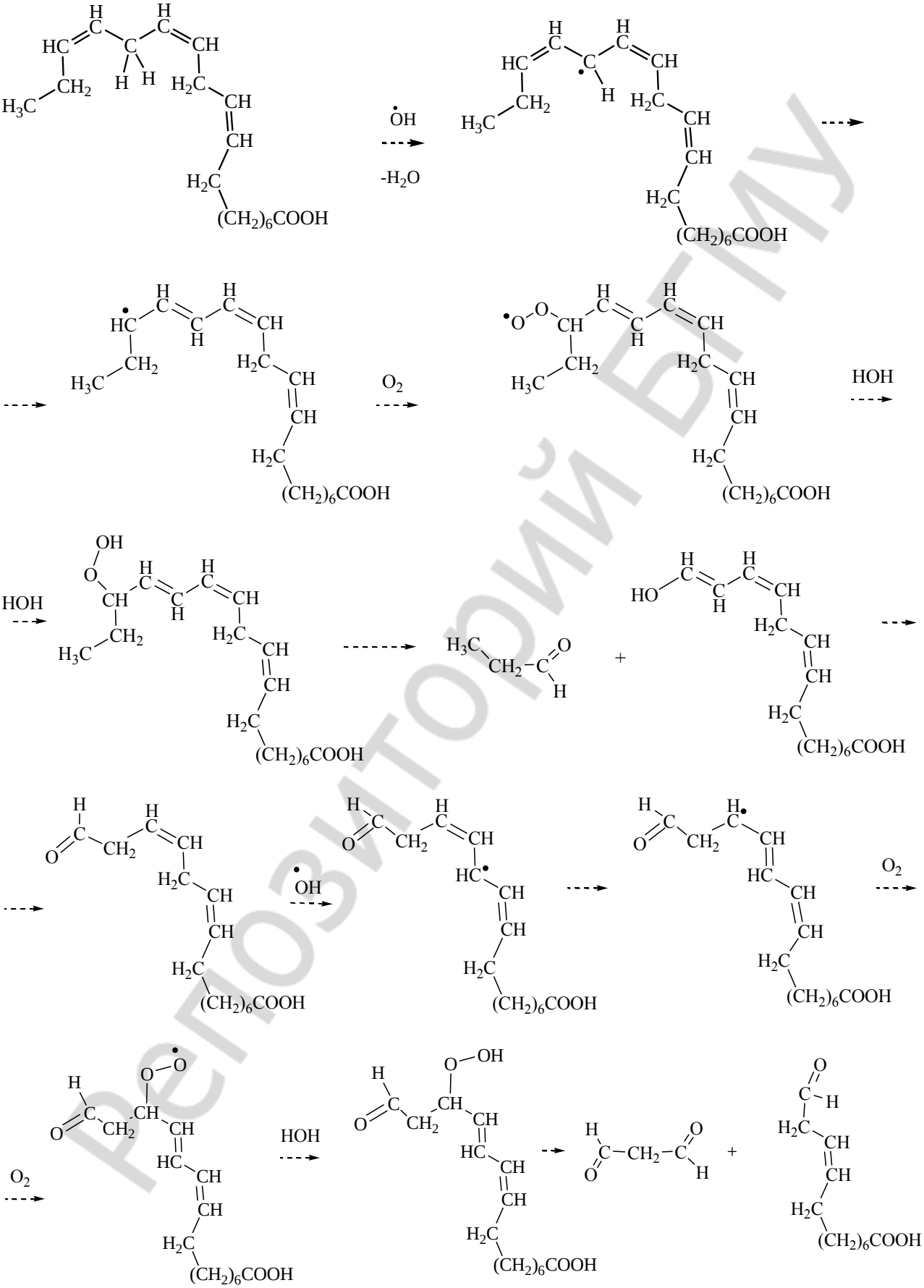
6. Draw the structural formulas of the following compounds. Mark the hydrophobic tails and hydrophilic head.

a) 1-stearoyl-2-oleoylphosphatidylserine

b) 1-stearoyl-2-linoleoylphosphatidylcholine

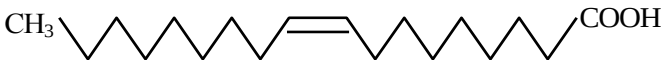
c) 1-palmitoyl-2-arachidonoylphosphatidylethanolamine

7. Analyse the mentioned below scheme peroxidation of linolenic acid.



TEST CONTROL

1. Indicate name of the following structure:



1) linoleic acid; 3) oleic acid;
2) arachidonic acid; 4) stearic acid.

2. Choose simple lipid:
1) myricylpalmitate; 3) 1-palmytoil-2-oleoylphospatidylcholine;
2) trioleoylglycerol; 4) dipalmitoylphosphatidylserine.

3. Point out correct statements about unsaturated fatty acids including in lipids structure:
1) has conjugated double bonds; 4) has branched carbon chain;
2) even number of atoms; 5) it is usually cis-isomeres.
3) it is monocarboxylic acids;

4. ω-Nomenclature name of linoleic acid is:
1) 20:4 **ω** 6; 2) 18:3 **ω** 3; 3) 18:1 **ω** 9; 4) 18:2 **ω** 6.

5. Choose complex lipid:
1) myricylpalmitate;
3) 1-palmitoyl-2-oleoylphosphatidylcholine;
2) 1-srearoyl-2-oleoylphosphatidylinositol;
4) tristearoylglycerol.

6. Select alcohols which are a part of lipids composition:
1) propantriol-1,2,3; 3) 2-aminooctadecen-4-diol-1,3;
2) ethanol; 4) inositol.

7. Vitamin E is native antioxidant because of presence in its structure …
1) amino group; 3) phenol hydroxyl;
2) alcoholic hydroxyl; 4) thiol group.

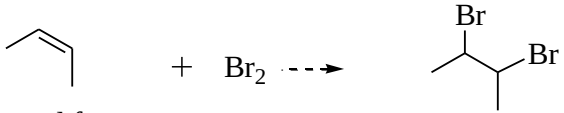
8. ω-Nomenclature name of arachidonic acidis:
1) 20:4 **ω**6; 2) 20:4 **ω** 3; 3) 18:1 **ω** 6; 4) 18:2 **ω** 6.

9. Choose reserve lipids:
1) 1,2-dioleoyl-3-linolenoylglycerol;
2) 1-oleoyl-2-steariylphosphatidylcholine;
3) 1-oleoyl-2-stearoylphosphatidylinositol;
4) 1,3- dioleoyl-2-stearoylglycerol.

10. Point out type of chemical bond in phosphatidylserine between phospatidic acid and serine?
1) ester bond; 2) anhydride bond; 3) O-glycoside bond; 4) amid bond.

PRACTICAL PART

1. Qualitative reactions on the unsaturated acids which form fats.



unsaturated fragment of fatty acid

product of addition reaction

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.

unsaturated fragment of fatty acid — product of oxidation reaction

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.

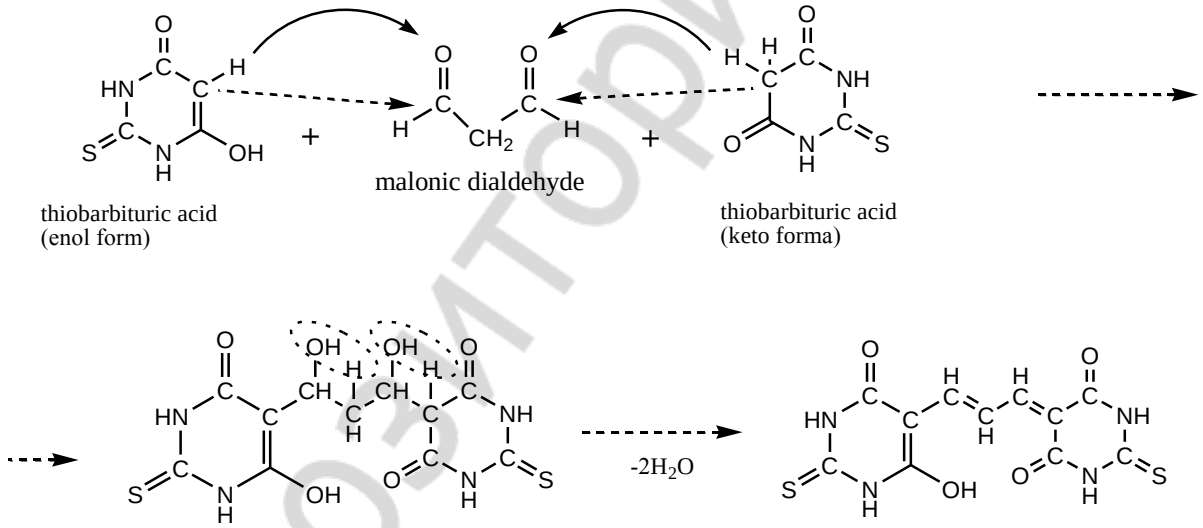
Observed changes: _____

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 nucleofilic addition mechanism.



thiobarbituric acid (enol form) — thiobarbituric acid (keto forma) — trimethin complex

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: _____

_____

Signature of teacher:

LABWORK № 17
CONCLUDING TEST "BIOPOLYMERS AND THEIR STRUCTURAL COMPONENTS"

Remind the program material from the theme № 9 to № 16.

Recommended literature:
Study the literature from the theme № 9 to № 15.

Questions to the test control:

1. Oxidation reactions of hydroxy acids *in vivo*. Reduction reactions of oxo acids *in vivo*.
2. Decarboxylation reactions of hydroxyl andoxo acids *in vivo*. Biogenic amines.
3. Formation reaction of citric acid from oxaloacetic acid and acetyl coenzyme A.
4. Dehydration reaction of citric acid *in vivo*.
5. π-Diastereomers of butenedioic acid. Hydration reaction of fumaric acid.
6. Tautomerism. Keto-enol and lactim-lactam tautomerism.
7. Ketone bodies, their biological role.
8. Formation of acetylsalicylic acid.
9. p-Aminobenzoic acid, their derivatives. Modern anesthetics.
10. Fatty acids. Conformational structure. ω-Nomenclature of unsaturated fatty acids.
11. Triacylglycerols: structures, nomenclature, biological role. Hydrolysis of triacylglycerols.
12. Phospholipids as amphiphilic molecules. Structures, nomenclature, biological role. Hydrolysis of phospholipids.
13. Cyclo-oxo tautomerism of monosaccharides. The Fischer projection formulas and Haworth formulas of glucose and galactose. Conformations of monosaccharide cyclic forms. Glycosides.
14. Oxidation of monosaccharides. Biological role of glycuronic acids.
15. Ascorbic acid as water soluble antioxidant.
16. Reducing and nonreducing disaccharides. Structure, biological role.
17. Polysaccharides: structure, biological role.
18. Proteinogenic amino acids. Structure, nomenclature, acid-basic properties, bipolar structure. Stereoisomerism. Biologically important reactions of α-amino acids: deamination, hydroxylation, decarboxylation, transamination reactions.
19. Peptides: structures, nomenclature, biological role. Representatives of peptides and their biological significance (glutathione, neuropeptides, insulin).
20. Nucleic bases: structures, tautomeric forms, biological role. Complementary pairs of nucleic bases. Hydrogen bonds. Nucleosides, nucleotides. Structure, biological role. Hydrolysis. ATP, cyclo-AMP.
21. Classification of polymers. Free radical polymerization. Initiators, activators, inhibitors of free radical reactions.

It is necessary to know formulas of the following compounds:

1. glycerol 2. pyruvic acid 3. oxaloacetic acid 4. lactic acid 5. malic acid 6. acetyl coenzyme A 7. citric acid 8. fumaric acid 9. maleic acid 10. β-hydroxybutyric acid 11. β-oxobutyric acid 12. barbituric acid 13. phenobarbital 14. urea	15. uric acid 16. hypoxanthine 17. xanthine 18. acetylsalicylic acid 19. novocaine 20. ultracaine 21. lidocaine 22. palmitic acid 23. oleic acid 24. linoleic acid 25. linolenic acid 26. arachidonic acid 27. choline 28. inositol	29. ethanolamine 30. D-glucose 31. D-ribose 32. D-deoxyribose 33. D-fructose 34. D-galatose 35. ascorbic acid 36. sucrose 37. maltose 38. lactose 39. lactulose 40. starch 41. glycogen 42. cellulose	43. dextran 44. uracil 45. thymine 46. cytosine 47. adenine 48. guanine 49. fatty acids 50. proteinogenic amino acids (20), their names and three letter codes

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. Conjugation (π,π- and p,π-conjugations). Conjugated systems with open chain. Conjugated systems with close chain. Aromaticity.
2. Electronic effects in organic molecules (inductive and mesomeric), their role in the reactivity centers in the molecule. Electron donors and withdrawers.
3. Chirality. Chiral molecules. Relationship of the spatial structure of the compound with its biological activity. Complementarity.
4. Asymmetric carbon atom. Enantiomerism. Optical activity. Relative D-L-system of stereochemical nomenclature. Fisher's formulas. The concept of the R-S nomenclature.
5. Stereoisomerism of molecules with one, two or more centers of chirality: enantiomerism and σ-diastereomerism.
6. Racemic mixture. Methods for the separation of racemic mixtures. π-Diastereomerium of unsaturated compounds.
7. Conformations. Newman formulas. Types of strain. Energetic characteristic of eclipsed, gauche and staggered conformations. Conformational structure of hydrocarbon radicals of fatty acids.
8. Conformations of cyclohexane. Conformations of cyclohexane derivatives.
9. Acidity and basicity of organic compounds; the theory of Bronsted and Lewis. General regularities in the change of acidic or basic properties, which depend on the nature of atoms in the acid or basic center, the electronic effects of substituents at these centers, and solvation effects.
10. Toxicity of organic acids and bases. Amphoteric properties. Hydrogen bond. Hydrogen bonds in the structure of biopolymers.
11. Classification of organic reactions. Electronic and spatial structure of free radicals, carbocations and carboanions. Factors determining their relative stability.
12. Mechanism of the reaction of free-radical substitution in sp^3-hybridized carbon atom. Initiators and inhibitors of radical reactions.
13. Reactions of electrophilic addition in alkenes. Hydration reactions of alkenes. Acid catalysis. The influence of static and dynamic factors on regioselectivity of addition reactions (Markovnikov's rule).
14. Features of electrophilic addition to conjugate systems. Hydration of α-β-unsaturated carboxylic acids.
15. Reactions of electrophilic substitution in aromatic compounds. Effect of substituents in the aromatic cycle on the reactivity. Orientans I and II.
16. The mechanism of alkylation reactions of aromatic compounds.
17. Reaction centers in molecules of alcohols, phenols, thiols, amines. Reactions of nucleophilic substitution at sp^3-hybridized carbon atom in monofunctional hydrocarbon derivatives. Competitive reactions of nucleophilic substitution and elimination in the alkyl halides and alcohols.
18. Oxidation reactions of organic compounds (alcohols, thiols, phenols). Compounds containing thiol group, phenolic hydroxyl group as antioxidants.
19. Electronic and spatial structure of the carbonyl group. Comparative reactivity of aldehydes and ketones.
20. Reactions of oxidation and reduction of carbonyl compounds. Qualitative reactions to the aldehyde group. Reduction of carbonyl compounds *in vivo*.
21. Reactions of nucleophilic addition to the carbonyl group in aldehydes and ketones.

22. Reactions of the interaction of carbonyl compounds with amines, their mechanism. Schiff's bases.

23. Reactions of aldol condensation. The reaction of dismutation (oxidation-reduction).

24. Use of aldehydes as disinfectants, means for sterilization; for preserving of anatomical preparations (formalin).

25. Electronic and spatial structure of the carboxyl group. Acidic properties of carboxylic acids.

26. Mechanism of the reaction of nucleophilic substitution in the sp^2-hybridized carbon atom of a carboxyl group. Functional derivatives of carboxylic acids: esters, anhydrides, amides, thioesters. Properties of esters, their hydrolysis.

27. Acylation reactions. Comparative characteristics of the acylating ability of esters and thioesters of carboxylic acids; their biological significance. Biologically important reactions of acylation with the participation of acyl phosphates. The concept of phosphorylation reactions.

28. Amides of carboxylic acids. Features of the structure of the amide group. Acid-base properties of amides. Functional derivatives of carbonic acid; their acid-base properties, biological significance. Carbamic acid, urea.

29. Classification of poly- and heterofunctional compounds. Acid-base properties. Typical reactivity of poly- and heterofunctional compounds.

30. Specific properties due to the mutual influence of the groups: chelation of polyols, α-aminoalcohols, α-amino acids, as well as intramolecular (in γ- and δ-hydroxyaldehydes, γ- and δ-hydroxy- and amino acids, dicarboxylic acids with number carbon atoms 4 or 5) and intermolecular (for α-hydroxy- and amino acids) cyclization. Cyclic hemiacetals, cyclic anhydrides. Decarboxylation reactions. Elimination reactions of β-hydroxy and β-amino acids.

31. Tautomerism: keto-enol and lactim-lactam.

32. Polyols. Esters of polyols with inorganic acids and fatty acids. Qualitative reaction on the diol fragment.

33. Diatomic phenols. Oxidation of diatomic phenols. Participation of the hydroquinone-quinone system in the processes of biological oxidation. Phenols are antioxidants. Tocopherols.

34. Dibasic carboxylic acids. Decarboxylation reactions and the formation of anhydrides.

35. π-Diastereomerism of biologically important unsaturated carboxylic acids.

36. Biologically important aminoalcohols. Catecholamines.

37. Biologically important hydroxy acids. Acidic properties and reactivity. Reactions of oxidation of hydroxy acids with the participation of coenzyme NAD^+. The participation of citric acid in the Krebs cycle.

38. Biologically important oxo acids. Acidic properties and reactivity of keto acids. Reactions of transamination of α-keto acids. Keto-enol tautomerism.

39. Ketone bodies: their medico-biological significance.

40. Salicylic acid and its derivatives, their use in medicine.

41. *p*-Aminobenzoic acid as a structural component of folic acid. The derivatives of *p*-aminobenzoic acid, which have an anesthetic effect. Modern anesthetics.

42. Sulfanilic acid and its amide. Sulfanilamide preparations. The concept of antimetabolites.

43. Hydroxypurines: hypoxanthine, xanthine, uric acid, their tautomeric forms. Salts of uric acid.

44. Biogenic amino acids. Proteinogenic amino acids. Non-proteinogenic amino acids.

45. Classification of proteinogenic amino acids. Essential amino acids. Structure, nomenclature, chemical properties.

46. Stereoisomerism of natural α-amino acids with one and two centers of chirality.

47. Biologically important reactions of amino acids: transamination, deamination (nonoxidative and oxidative), hydroxylation, decarboxylation, phosphorylation, methylation, carboxylation, oxidation of cysteine. Biogenic amines. The concept of neurotransmitters.

48. Peptides. Electronic and spatial structure of peptide bond. Acidic and alkaline hydrolysis of peptides. Biological significance of representatives of peptides (glutathione, neuropeptides, insulin).

49. Artificial synthesis of peptides. The strategy of activation and protection of the functional groups of amino acids in the artificial synthesis of peptides.

50. Proteins. The levels of organization of protein molecules and the types of interactions involved in their stabilization. Primary, secondary and tertiary structure of the protein. The concept of complex proteins. Quaternary structure of hemoglobin.

51. Denaturation of protein. Denaturing effect of alcohols, aldehydes, surfactants.

52. Carbohydrates: classification, biological role.

53. Monosaccharides: classification, the importance of monosaccharides. Stereoisomerism. Epimers.

54. Cyclo-oxo-tautomerism of monosaccharides. The mechanism of the reaction of formation of the cyclic form of a monosaccharide. Anomers. The formulas of Fisher and Haworth. Conformations of cyclic forms of monosaccharides on the example of glucose and galactose.

55. Glycosides: structure, biological significance. Hydrolysis of glycosides. Esters of monosaccharides. Phosphates of D-glucose and D-fructose.

56. Oxidation of monosaccharides. Aldonic, aldaric and uronic acids. The biological role of uronic acids.

57. Reactions of fermentation of carbohydrates.

58. Structure, properties, biological significance of aminosugars.

59. Structure, properties, biological significance of ascorbic acid. The participation of vitamin C in oxidation-reduction processes, as well as in hydroxylation reactions.

60. Polysaccharides: classification, biological significance.

61. Disaccharides possessing reducing properties. Structure, tautomerism. Non-reducing disaccharides. Hydrolysis. Biological significance.

62. Starch: structure, properties, biological role. Use of starch for the manufacture of plasma-substituting drugs.

63. Cellulose: structure, properties, application, role in nutrition.

64. Glycogen. Biological significance of the branched structure of glycogen.

65. Dextran: structure, properties, application of products of partial hydrolysis for the manufacture of plasma-substituting drugs.

66. Heteropolysaccharides. The concept of the structure of heteropolysaccharides of connective tissue. Their role in providing tissue turgor. The concept of mixed biopolymers (proteoglycans, glycoproteins, glycolipids).

67. Nucleic bases: structure, acid-base properties, aromaticity.

68. Nucleosides: structure, nomenclature. Nucleotides. Structure, nomenclature, hydrolysis.

69. Nucleoside mono- and polyphosphates. Biological significance of ATP and other nucleoside polyphosphates. Nucleoside cyclophosphates as secondary mediators in the regulation of cell metabolism.

70. The concept of coenzymes. The structure of nicotinamide adenine dinucleotide oxidized (NAD^+). The system NAD^+ – NADH; hydride transfer as one of the stages of biological oxidation-reduction reactions involving this system.

71. Primary structure of nucleic acids. Nucleotide composition of RNA and DNA.

72. The concept of the secondary structure of DNA. The role of hydrogen bonds and stacking interactions in the formation of the secondary structure of DNA. Complementarity of heterocyclic bases.

73. Classification, biological significance of individual groups of lipids. The concept of the structure of waxes. Triacylglycerols. The main natural fatty acids, which are part of lipids. Features of unsaturated higher fatty acids, ω-nomenclature. The role of free fatty acids in energy supply and thermoregulation.

74. Anionic and cationic soaps. The detergent and disinfectant effect of surfactants.

75. Phospholipids. Phosphatidyl ethanolamines and phosphatidyl serines, phosphatidyl cholines (lecithins), phosphatidyl inositols are structural components of cell membranes. The concept of the composition and role of surfactant. Sphingolipids and glycolipids, their role in the myelination of nerve fibers.

76. Lipid peroxidation of unsaturated fatty acids in cell membranes, its mechanism and biological role.

77. General characteristic of polymers: monomer, elementary groups, degree of polymerization. Oligo- and polymers, copolymers, compositional polymers.

78. Classification of polymers. Ways of receipt polymers (chain polymerization, step polymerization, chemical modification of natural polymers). Mechanism of free radical polymerization of acrylic acid ester's.

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

80. Modern restore materials photo- and chemical hardening. Main components compositions materials.

81. Low-molecular components, using in adhesive systems for improvement for sticking of material filling to tissue of tooth.

82. Impressional materials on the basis of alginate acids.

It is necessary to be able to write down and recognize the formulas of the following compounds:

1) benzoyl peroxide, hydroquinone, ethyleneglycol dimethacrylate (EGDMA), triethyleneglycol dimethacrylate (TEGDMA), fragments of polyacrylate, polymethylacrylate, polymethylmethacrylate, polyethylmethacrylate, polybutylmethacrylate; fragment of glass ionomeric cements (copolymers of acrylic, maleic, itaconic acids)

2) formaldehyde, acetaldehyde, malonic aldehyde, glutaraldehyde, acetone

3) formic acid, acetic acid, propionic acid, butyric acid, benzoic acid, acrylic acid, methyl methacrylic acid, acetylcoenzyme A, urea

4) ethylene glycol, glycerol, inositol; cathechol, resorcinol, hydroquinone

5) oxalic acid, malonic acid, succinic acid, glutaric acid, fumaric acid, maleic acid

6) ethanolamine, choline, acetylcholine, dopamine, epinephrine, norepinephrine

7) lactic acid, malic acid, citric acid, *cis*-aconitic acid, isocitric acid

8) pyruvic acid, oxaloacetic acid, α-ketoglutaric acid, acetoacetic acid, β-ketobutyric acid

9) salicylic acid, acetylsalicylic acid, *p*-aminobenzoic acid, anesthesin, novocaine, the general formula of sulfonamides, uric acid, nicotinamide

10) 20 proteinogenic amino acids (with three-letter code), dioxyphenylalanine (DOPA), γ-aminobutyric acid (GABA), histamine, serotonin; peptides constructed from proteinogenic amino acids; glutathione

11) tautomeric forms of D-glucose, D-galactose, D-mannose, D-fructose, D-ribose, 2-deoxy-D-ribose; derivatives of the indicated monosaccharides formed upon the substitution of a hemiacetal hydroxyl, by substitution of an alcohol hydroxyl on amino group, by oxidation of the primary alcohol group, an aldehyde group or two groups simultaneously; ascorbic acid

12) sucrose, maltose, lactose, lactulose

13) fragments of the formulas of the following polymers: amylose, amylopectin, glycogen, cellulose, dextran

14) thymine, uracil, cytosine, adenine, guanine, adenosine, with the participation of the above-mentioned nucleobases — mono- and polyphosphates of nucleosides, fragments of polynucleotides, coenzyme NAD^+ and its reduced form

15) palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, arachidonic acid; triacylglycerols, glycerophospholipids

It is necessary to recognize and analyze the structure of the following compounds:

hydroquinone methyl ether (MEHQ); butylated hydroxytoluene (BHT); N,N,-dimethyl-*p*-toluidine; *bis*-GMA; UDMA; *bis*-EMA; spiroorthocarbonates (SOC); epoxy based resins; camphoroquinone; dimethylaminoethyl methacrylate (DMAEMA); propanedione (PPD); benzil (BZ); Lucirin TPO; Irgacure 819; 3-methacryloxypropyl trimethoxysilane; dimethacrylate of glycerophosphoric acid, 2-hydroxyethyl methacrylate; N-(p-tolyl)-glycine-2-hydroxypropyl methacrylate (NTG-GMA); anhydride 4-acrylhydroxyethyl of pyromellitic acid (4-AETA); anhydride 4-methacrylhydroxyethyl of pyromellitic acid (4-META); vitamin E; vitamin A; β-carotene; inositol triphosphate; sphingophospholipids; glycolipids; heme; lidocaine; ultracaine.

ANSWERS TO TESTS

Labwork № 1. Classification and nomenclature of organic compounds

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
2	2	4	4	1	1	3	2	1, 3, 4	3

Labwork № 2. Chemical bond structure and atom effects in the organic molecules

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
2, 3, 4	2, 4	3, 4	3	2	2, 3, 4	3	4	1, 2	A3 B2 C3 D4

Labwork № 3. Stereoisomerism, its role for biological activity demonstration

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
4	1, 3, 4	4	2	1, 3	4	1, 2	1, 3	A2 B1 C4 D3	2

Labwork № 4. Hydrocarbons

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
1, 2, 3, 5	2, 4	1, 2	3	1, 4	2	1, 4	2	3, 5	2

Labwork № 5. Monofunctional hydrocarbon derivatives

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
2	4	1, 3, 4	1,3	3, 4, 1, 2	2	2, 4	4	2	A3 B2 C1 D4

Labwork № 6. Biologically important reactions of aldehydes and ketones

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
2, 3	A2 B4 C1 D3	2	3	1, 3	1, 2	1, 3, 4	4	2	2

Labwork № 7. Carboxylic acid and their derivatives

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
1, 4, 3, 2	A4 B2 C3 D1	1	1, 2, 4	1, 3, 4, 5	2	1, 2, 4	2, 3	3, 4	1, 4

Labwork № 9. Poly- and heterofunctional compounds

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
4	3	3	2	1, 3, 4	1, 2, 4	1	2, 3, 4	3, 4	1

Labwork № 10. Organic compounds using in stomatology

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
2	3	4	2	4	2	2, 3	3	2, 3	1, 3, 4

Labwork № 11. Carbohydrates. Monosaccharides

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
1, 2, 4	1, 2	3	2	2	2	4	3, 4	1	1, 2, 3

Labwork № 12. Oligo- and polysaccharides

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
3	1, 2, 4	4	1, 2, 3	3, 4	2, 3, 4	4	3	3	2, 3, 4

Labwork № 13. Structure and reactivity of amino acids

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
1, 3	1, 3, 4	1, 4, 5	2, 3, 4, 5	1, 2, 3	3, 5	2	2, 3, 4	1	3

Labwork № 14. Peptides. The levels of protein organization

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
2, 4, 5	2, 3, 4	1, 3, 4	1, 3, 5	1, 2, 3, 5	2	1, 2, 4	1	1, 3, 4	2

Labwork № 15. Nucleosides. Nucleotides. Nucleic acids

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
1, 3	3, 4	1, 3, 4	2	1, 3, 5	2	3	2	2	1

Labwork № 16. Lipids. Structure, properties. Lipid peroxidation

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
3	1, 2	2, 3, 5	4	2, 3	1, 3, 4	3	1	1, 4	1

Учебное издание

Ринейская Ольга Николаевна
Ермоленко Елена Михайловна

БИООРГАНИЧЕСКАЯ ХИМИЯ

BIOORGANIC CHEMISTRY

Практикум для студентов-стоматологов

На английском языке

4-е издание, исправленное

Ответственная за выпуск О. Н. Ринейская
Переводчики О. Н. Ринейская, Е. М. Ермоленко, Н. И. Губкина
Компьютерная верстка Н. М. Федорцовой

Подписано в печать 04.06.18. Формат 60×84/8. Бумага «Discovery».
Ризография. Гарнитура «Times».
Усл. печ. л. 9,76. Уч.-изд. л. 3,46. Тираж 141 экз. Заказ 359.

Издатель и полиграфическое исполнение: учреждение образования
«Белорусский государственный медицинский университет».
Свидетельство о государственной регистрации издателя, изготовителя,
распространителя печатных изданий № 1/187 от 18.02.2014.
Ул. Ленинградская, 6,220006, Минск.