О. Н. Ринейская, К. Г. Бурдашкина, Н. И. Губкина

БИООРГАНИЧЕСКАЯ ХИМИЯ:
практический курс для студентов-стоматологов

BIOORGANIC CHEMISTRY:
practical course for dental students

Минск БГМУ 2012
УДК 577.1(811.111)-054.6(076.5) (075.8)
ББК 28.072(81.2 Англ-923)
P51

Рекомендовано Научно-методическим советом университета в качестве практикума 30.05.2012 г., протокол № 8

Рецензенты: д-р мед. наук, проф. А. Д. Таганович; д-р биол. наук, проф. Е. В. Барковский

Перевод с русского языка О. Н. Ринейской, К. Г. Бурдашкиной, Н. И. Губкиной

Ринейская, О. Н.


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

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

Учебное издание

Ринейская Ольга Николаевна
Бурдашка Кристина Григорьевна
Губкина Нина Ивановна

БИООРГАНИЧЕСКАЯ ХИМИЯ:
практический курс для студентов-стоматологов

BIOORGANIC CHEMISTRY: practical course for dental students

Практикум на английском языке

Ответственная за выпуск О. Н. Ринейская
В авторской редакции
Компьютерный набор О. Н. Ринейской

Подписано в печать 31.05.12. Формат 60х84/8. Бумага писчая «Снегурочка».
Печать ризографическая. Гарнитура «Times».
Усл. печ. л. 10,23. Уч.-изд. л. 2,88. Тираж 30 экз. Заказ 474.

Издатель и полиграфическое исполнение:
учреждение образования «Белорусский государственный медицинский университет».
ЛИ № 02330/0494330 от 16.03.2009.
ЛП № 02330/0150484 от 25.02.2009.
Ул. Ленинградская, 6, 220006, Минск.

## REGISTRATION FORM

<table>
<thead>
<tr>
<th>№</th>
<th>Theme</th>
<th>Date</th>
<th>Mark</th>
<th>Signature of teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Labwork # 1 Classification and nomenclature of organic compounds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Labwork # 2 Stereoisomerism, its role for biological activity demonstration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Labwork # 3 Chemical bond structure and atom effects in the organic molecules</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Labwork # 4 Acid-base properties of organic compounds. Oxidation reactions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Labwork # 5 Classification and mechanisms of reactions in organic chemistry. Reactions of radical substitution (S$_E$). Electrophilic addition reactions (A$_E$). Electrophilic substitution reactions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Labwork # 6 Biologically important reactions reaction of aldehydes and ketones</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Labwork # 7 Carboxylic acid and their derivatives</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Labwork # 8 Concluding test “Theoretical fundamentals of basic classes of organic compound structure and reactivity”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Labwork # 9 Heterofunctional compounds of aliphatic, benzene and heterocyclic series. Metabolites and bioregulators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Labwork # 10 Lipids. Structure, properties. Lipid peroxidation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Labwork # 11 Carbohydrates. Monosaccharides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Labwork # 12 Oligo- and polysaccharides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Labwork # 13 Structure and reactivity of amino acids acting as heterofunctional compounds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Labwork # 14 Peptides. their structure, reactivity and importance. The levels of protein organization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Labwork # 16 Concluding test “Biopolimers and their structural componens”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Labwork # 17 Polymer materials, using in stomatology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Labwork # 18 Concluding test</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Safety rules during the work in the chemical laboratory

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

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

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

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

Work with alcohol lamps. Precautions

Careless work with an alcohol lamp can result in a fire, that is why it is necessary to follow the below requirements:
- the wick of an alcohol lamp should tightly enter the aperture of a metal bush; the topping should be put forward for 1 cm and fluffed up;
- the bush should close the aperture of a alcohol lamp tightly; the alcohol lamp should be filled with alcohol no more than 2/3 of the volume;
- the lighting of an alcohol lamp should be carried only by matches, it is strictly forbidden to light an alcohol lamp from another alcohol lamp, because the bush can stoop and coming out steams of alcohol can be fired;
- to blow out an alcohol lamp only by covering it with bell-glass;
- when heating up substances in chemical glassware it is necessary to heat them at the top or mid-range flame, not touching a wick, because a wick is always cool, and when hot glass contacts with it, glass may burst.

**Work with chemical glassware. Precautions**

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

**Work with chemical reagents. Precautions**

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

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

Work with acids and alkalis. Precautions

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

Work with toxicants. Precautions

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

First-aid treatment in case of accidents:
- in case of hands are cut with glass first of all it is necessary to remove all the splinters out of the wound, then to treat the wound with an alcohol solution of iodine and to put a bandage;
- in case of thermal burns happen it is necessary to treat the burnt place with the 70 % solution of ethanol;
- in case of burns are caused by solutions of acids or alkalis it is necessary to wash up the burnt site with water quickly and to put an aseptic bandage;
- in case of acids or alkalis hit the eyes it is necessary wash them with water carefully and to refer the victim to the outpatient clinic;
- in case of skin burns caused by bromine it is necessary quickly to wash the injured place off with ethanol and to put anti-burn emulsion;
- in case of burns caused by hot organic liquids it is necessary to wash out the injured place with ethanol;
- in case of burns caused by liquid phenol it is necessary to massage the emerged sites of white skin with a glycerine until normal skin color is restored then to wash with water and to put the gauze bandage moistened with a glycerine solution;
- after providing the first-aid treatment it necessary to address to the health center of the university or to the outpatient clinic.
LABWORK # 1

Theme: CLASSIFICATION AND NOMENCLATURE OF ORGANIC COMPOUNDS

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

Recommended literature:

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

Exercises
1. Give the IUPAC names for the following compounds:
   a) lactic acid
   b) oxaloacetic acid
   c) serine
   d) salicylic acid

\[
\begin{align*}
\text{lactic acid} & : \quad \text{H}_3\text{C} - \text{CH} - \text{COOH} \\
\text{oxaloacetic acid} & : \quad \text{HOOC} - \text{CH}_2 - \text{C} - \text{COOH} \\
\text{serine} & : \quad \text{H}_2\text{C} - \text{CH} - \text{COOH} \\
\text{salicylic acid} & : \quad \text{C}_6\text{H}_4\text{COOH}
\end{align*}
\]
2. Write a structural formula for each of the following compounds:
   a) 3-hydroxy-3-carboxypentanedioic acid (citric acid)

   b) 1,1,2-trichloroethene

   c) 2-amino-4-methylthiobutanoic acid

   d) 4-methylpentanol-2

   e) 4-aminobenzoic acid

   a) 2,6-diaminohexanoic acid

**Test control**

1. Give the IUPAC name for the following amino acid:
   a) 2-aminobutanedioic acid
   b) 2-aminopropanoic acid
   c) 2-aminopentanoic acid
   d) 2-aminopentanedioic acid
2. Indicate a heterocyclic compound:
   a) [image of a cyclic compound with a sulfur atom]
   b) [image of a cyclic compound with an amine group]
   c) [image of a cyclic compound with a hydroxyl group]
   d) [image of a cyclic compound without any shown functional groups]

3. Give the IUPAC name for the following compound CH₃-CHCl-CH₂-CHBr-CH₃:
   a) 2-chloro-4-bromobutane
   b) 2-bromo-4-chlorobutane
   c) 2-chloro-4-bromopentane
   d) 2-bromo-4-chloropentane

4. Select compounds containing hydroxyl group:
   a) ethanol   b) phenol        c) ethanol        d) 2-hydroxypropanoic acid

5. Indicate methylpropylether:
   a) CH₃-O-CH₂-CH₃
   b) CH₃-CH₂-CH₂-O-CH₃
   c) CH₃-CH₂-O-CH₂-CH₃
   d) CH₃-CH₂-CH₂-O-CH₂-CH₃

6. Select the unsaturated compounds:
   a) cyclohexane b) propenal          c) pentane         d) butadiene-1,3

LABWORK #2

**Theme:** STEREOISOMERISM, ITS ROLE FOR BIOLOGICAL ACTIVITY DEMONSTRATION

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

**Recommended literature:**
Problems for discussion:
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.

Exercises
1. Write all possible conformations by means of Newman projections for the following compounds.
   a) ethanthiol

   b) butane

   c) butanedioic acid
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 following compounds:
   a) 2-methylcyclohexanol
   
   b) 1,3-dichlorocyclohexane

5. Write D- and L-isomers by means of Fisher projections for the following compounds:
   a) 2-aminopropanoic acid
   
   b) 2-hydroxybutanedioic acid
   
   c) 2-amino-3-hydroxybutanoic acid (2 chiral centers)

6. Write R- and S-isomers for the following compounds:
   a) 2-hydroxypropanoic acid
Test control

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

   a) \[
   \begin{array}{c}
   \text{Cl} \\
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{H}
   \end{array}
   \]

   b) \[
   \begin{array}{c}
   \text{H} \\
   \text{Cl} \\
   \text{H} \\
   \text{H} \\
   \text{H}
   \end{array}
   \]

   c) \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{Cl} \\
   \text{Cl} \\
   \text{H}
   \end{array}
   \]

   d) \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{Cl} \\
   \text{Cl}
   \end{array}
   \]

2. Indicate the most stable butanoic acid conformation:

   a) \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{COOH}
   \end{array}
   \]

   b) \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{CH}_3
   \end{array}
   \]

   c) \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{COOH}
   \end{array}
   \]

   d) \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{COOH}
   \end{array}
   \]

3. Select the most stable methylecyclohexane conformation:

   a) \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{CH}_3
   \end{array}
   \]

   b) \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{CH}_3
   \end{array}
   \]

   c) \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{CH}_3
   \end{array}
   \]

   d) \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{CH}_3
   \end{array}
   \]

4. Chiral molecules are:

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

5. Enantiomers are:

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

\[
\begin{array}{cccc}
  & a) & b) & c) \\
\text{HO} & \text{C} & \text{H} & \text{CH}_3 \\
\text{CH}_3 & & & \\
\text{H} & \text{C} & \text{OH} & \text{CH}_3 \\
\text{CH}_3 & & & \\
\end{array}
\]

\[
\begin{array}{cccc}
  & a) & b) & c) \\
\text{HO} & \text{C} & \text{H} & \text{CH}_3 \\
\text{CH}_3 & & & \\
\text{H} & \text{C} & \text{OH} & \text{CH}_3 \\
\text{CH}_3 & & & \\
\end{array}
\]

\[
\begin{array}{cccc}
  & a) & b) & c) \\
\text{HO} & \text{C} & \text{H} & \text{CH}_3 \\
\text{CH}_3 & & & \\
\text{H} & \text{C} & \text{OH} & \text{CH}_3 \\
\text{CH}_3 & & & \\
\end{array}
\]

7. What statements concerning racemic mixtures are true:

a) at mixture equimolar quantities D-and L-stereoisomers the inactive mixes named racemic are formed optically
b) racemic substances are formed at chemical synthesis without observance of special conditions
c) racemic substances can be divided on optically active enantiomers by means of only physical methods
d) from racemic substances can be evolved enantiomers by means of microbiological (biochemical), chemical methods and by an affyne chromatography

8. Select the compounds containing two chiral centers:

\[
\begin{array}{cccc}
  & a) & b) & c) \\
\text{H}_2\text{N} & \text{C} & \text{H} & \text{CH}_3 \\
\text{H} & \text{C} & \text{OH} & \text{CH}_3 \\
\text{H}_2\text{N} & \text{C} & \text{NH}_2 & \text{CH}_2 \\
\text{CH}_3 & & & \\
\end{array}
\]

\[
\begin{array}{cccc}
  & a) & b) & c) \\
\text{H}_2\text{N} & \text{C} & \text{H} & \text{CH}_3 \\
\text{H} & \text{C} & \text{OH} & \text{CH}_3 \\
\text{H}_2\text{N} & \text{C} & \text{NH}_2 & \text{CH}_2 \\
\text{CH}_3 & & & \\
\end{array}
\]

\[
\begin{array}{cccc}
  & a) & b) & c) \\
\text{H}_2\text{N} & \text{C} & \text{H} & \text{CH}_3 \\
\text{H} & \text{C} & \text{OH} & \text{CH}_3 \\
\text{H}_2\text{N} & \text{C} & \text{NH}_2 & \text{CH}_2 \\
\text{CH}_3 & & & \\
\end{array}
\]

\[
\begin{array}{cccc}
  & a) & b) & c) \\
\text{H}_2\text{N} & \text{C} & \text{H} & \text{CH}_3 \\
\text{H} & \text{C} & \text{OH} & \text{CH}_3 \\
\text{H}_2\text{N} & \text{C} & \text{NH}_2 & \text{CH}_2 \\
\text{CH}_3 & & & \\
\end{array}
\]

\[
\begin{array}{cccc}
  & a) & b) & c) \\
\text{H}_2\text{N} & \text{C} & \text{H} & \text{CH}_3 \\
\text{H} & \text{C} & \text{OH} & \text{CH}_3 \\
\text{H}_2\text{N} & \text{C} & \text{NH}_2 & \text{CH}_2 \\
\text{CH}_3 & & & \\
\end{array}
\]
LABWORK # 3

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

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

Recommended literature:

Problems for discussion:
1. An electronic and dimensional structure of sp²-hybridized carbon atom.
2. Conjugated systems. Conjugation energy.
4. Aromaticity of heterocyclic systems (pyrrole, pyridine).
5. Inductive effect.
6. Mesomeric (or resonance) effect.
7. Electron donating and electron withdrawing substituents.

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

<table>
<thead>
<tr>
<th>Compound</th>
<th>Structure/Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>butadiene-1,3</td>
<td>propenoic acid</td>
</tr>
<tr>
<td>propenal</td>
<td>pyrrole</td>
</tr>
<tr>
<td>2-methylbutadiene-1,3</td>
<td>pyridine</td>
</tr>
</tbody>
</table>
2. Define aromaticity by the means of Huckel’s rule for the compounds:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Molecular Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>benzene</td>
<td>[chair conformation]</td>
</tr>
<tr>
<td>pyridine</td>
<td>(draw the electronic structure of pyridine nitrogen)</td>
</tr>
<tr>
<td>phenanthrene</td>
<td></td>
</tr>
<tr>
<td>pyrrole</td>
<td>(draw the electronic structure of pyrrole nitrogen)</td>
</tr>
<tr>
<td>pyrimidine</td>
<td></td>
</tr>
<tr>
<td>purine</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Compound</th>
<th>Molecular Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-chlorbutane</td>
<td></td>
</tr>
<tr>
<td>benzoic acid</td>
<td></td>
</tr>
<tr>
<td>propanal</td>
<td></td>
</tr>
<tr>
<td>toluene</td>
<td></td>
</tr>
<tr>
<td>benzylamine</td>
<td></td>
</tr>
<tr>
<td>phenol</td>
<td></td>
</tr>
</tbody>
</table>

**Test control**

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

a) ![Conjugated Double Bond](image)

b) \( CH_2 \equiv CH - CH \equiv CH_2 \)

c) \( CH_2 \equiv CH - CH_2 - CH\equiv CH_2 \)
2. Select the compounds with $\pi$-$\pi$-conjugation:

a) $\text{CH}_2 = \text{CH} + \text{CH} = \text{CH}_2$

b) $\text{CH}_2 = \text{CH} - \text{C} = \text{O}$

c) $\text{CH}_2 = \text{CH} - \text{CH}_2$

d) [Image of a compound with a nitrogen atom and two double bonds]

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

a) low thermodynamic stability

b) addition reactions are more feature than substitution reactions

c) substitution reactions are more feature than addition reactions

d) high stability of compounds to oxidant and temperature action

4. Which of the following compounds are aromatic?

a) [Image of a 5-membered ring with a hydrogen atom]

b) [Image of a benzene ring]

c) [Image of a 5-membered ring with a nitrogen atom]

d) [Image of a 5-membered ring with a double bond and oxygen atom]

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

a) $\text{COOH}$

b) $\text{CH}_3$

c) $\text{OH}$

d) $\text{Br}$

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

a) $+I$

b) $+I$, $+M$

c) $-I$, $+M$

d) $-I$

e) $-I$, $-M$

LABWORK # 4

**Theme:** ACID-BASE PROPERTIES OF ORGANIC COMPOUNDS.

**OXIDATION REACTIONS**

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

**Problems for discussion:**
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.

**Exercises:**
1. Compare acidity of compound in the following groups:
   a) ethanol and ethanthiol
   b) propanol-1 and propantriol-1,2,3 (glycerine)
   c) acetic and monochloracetic acids
   d) ethanoic and ethanedioic acids
   e) phenol and 4-aminophenol
f) propanoic and 2-oxopropanoic acids

g) propanoic and propenoic acid

3. Write the conjugate acid of the following bases:
   a) $\text{CH}_3\text{-NH}_2$
   b) $\text{H}_2\text{O}$
   c) $\text{OH}^-$
   d) $\text{CH}_3\text{COO}^-$
   e) $\text{NH}_2$
   f) $\text{H}_2\text{NNCO}\text{-NH}_2$

4. Compare basicity of compound in the following groups:
   a) dimethyl ether, dimethylamine, dimethylsulfide

   b) ethylamine and aniline

   c) ethylamine and diethylamine

   d) 2-aminoethanol and ethylamine

5. Write the ethanol oxidation reaction in vivo.

6. Write the 2-amino-3-mercaptopropionic acid oxidation reaction scheme.
8. Designate all basic sites in the novocaine structure and define the most strong basic site:

\[
\text{H}_2\text{N} \begin{array}{c}
\text{O} \\
\text{C}_2\text{H}_5
\end{array} \text{O} \begin{array}{c}
\text{CH}_2\text{CH}_2\text{N} \\
\text{C}_2\text{H}_5
\end{array}
\]

Write the reaction of novocaine with hydrochloric acid.

**Test control**

1. With regard to anion stability indicate which of the following acids are stronger than acetic acid:
   a) 2-chloracetic acid  
   b) trichloroacetic acid  
   c) carbonic acid  
   d) formic acid

2. Select the formula of amine with the strongest basic properties:

   a)  
   b)  
   c)  
   d)  

3. Select the methylphenylamine chloride:

   a)  
   b)  
   c)  
   d)  

4. Indicate the strongest CH-acid:

   a)  
   b)  
   c)  
   d)  

5. Indicate the correct statements:

   a) the dimethylamine basic properties are stronger than ammonia has  
   b) the trimethylamine basic properties are stronger than dimethylamine has  
   c) the methylamine basic properties are stronger than aniline has
d) the ammonia basic properties are stronger than aniline has

6. With regard to anion stability indicate the strongest acid:
   a) 4-aminobenzoic acid  b) benzoic acid
   c) 4-nitrobenzoic acid  d) phenol

**Practical part**

1. **Oxidation of primary alcohols**

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

\[
3\text{CH}_3\text{CH}_2\text{OH} + \text{K}_2\text{Cr}_2\text{O}_7 + 4\text{H}_2\text{SO}_4 \xrightarrow{\text{t}} \text{H}_3\text{C} = \text{C} + \text{K}_2\text{SO}_4 + \text{Cr}_2(\text{SO}_4)_3 + 7\text{H}_2\text{O}
\]

**Accomplishment:** add 5 drops of \(\text{H}_2\text{SO}_4\) (23) dilute solution and 3 drops of \(\text{C}_2\text{H}_5\text{OH}\) to 5 drops of \(\text{K}_2\text{Cr}_2\text{O}_7\) (24). Carefully mix and heat.

*Notice: reagents marked with asterisk (*) are in the draft.

**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:

\[
\begin{align*}
\text{H}_2\text{C} - \text{OH} + \text{H}_3\text{O}^- & \xrightarrow{\text{NaOH}} \left[ \begin{array}{c}
\text{H}_2\text{C} - \text{O} - \text{Cu} - \text{O} - \text{OH} \\
\text{H}_2\text{C} - \text{OH} - \text{OH} - \text{CH}_2 \\
\text{H}_2\text{C} - \text{OH} - \text{OH} - \text{CH}_2
\end{array} \right]^{-2-}
\end{align*}
\]
**Accomplishment:** to 5 drops of NaOH (21) solution add 1-2 drops of solution CuSO₄ (26), shake, add 2 drops of glycerine (4), shake.

**Observed changes:** ________________________________________________________________

**Conclusion:** ______________________________________________________________________

__________________________________________________________________________________

3. Sodium phenoxide production and its decomposition

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

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

\[
\text{C}_6\text{H}_5\text{ONa} + \text{H}_2\text{SO}_4 \rightarrow \text{C}_6\text{H}_5\text{OH} + \text{NaHSO}_4
\]

**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 H₂SO₄ (23), and again emulsia is formed.

**Observed changes:** ________________________________________________________________

**Conclusion:** ______________________________________________________________________

__________________________________________________________________________________

4. Qualitative test on phenol

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

Phenol as an acid reacts with ion Fe³⁺ forming the complex compound.

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

**Observed changes:** __________________________________________________________________________
5. Comparison of the methyl amine and aniline basic properties

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

\[ \text{CH}_3 \rightarrow \text{NH}_2 + \text{H}_2\text{O} \quad \text{CH}_3\text{NH}_3 + \text{OH} \]

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

\[ \text{Accomplishment:} \quad \text{one litmus band is moistened with water solution of methylamine* and another is with water solution of aniline*}. \]

\[ \text{Observed changes:} \]

\[ \text{Conclusi-} \]

\[ \text{si-} \]

\[ \text{on:} \]
LABWORK # 5

Theme: CLASSIFICATION AND MECHANISMS OF REACTIONS IN ORGANIC CHEMISTRY

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

Recommended literature:

Problems for discussion:
2. Organic reactions classification according to the direction and result of reaction.
4. Electrophilic addition ($A_E$) to alkenes: hydrogenation, halogenation, hydrohalogenation and hydration reactions. The Markovnikov’s rule.
5. Mechanism of electrophilic substitution reactions ($S_E$) in aromatic compounds. I and II sort directing substituents.

Exercises:
1. Describe the mechanism of the following free radical reactions:
   a) bromination of propane
   b) chlorination of cyclohexane
2. Describe the reaction mechanism of interaction of the following compounds:
   a) ethene and HCl
   b) propene and HCl
   c) ethene and H₂O
   d) propenoic acid and H₂O
   e) butene-2-oic acid and H₂O

1. Write the mechanism of the following reactions:
   a) chlorination of benzene (AlCl₃ as catalyst)
   b) nitration of benzene
   c) alkylation of toluene with CH₃Cl (AlCl₃ as catalyst)

Test control
1. What particles are formed as a result of covalent bond heterolytic cleavage:
   a) two radicals
   b) electrophile and nucleophile
   c) two electroneutral particles
   d) positively and negatively charged ions

2. Select chain termination steps in the chlorination reactions of alkanes:
3. Which of the following reagents react with ethylene according to the A_E mechanism:
   a) bromine water       c) KMnO_4 weak solution
   b) oxygen             d) water at concentrated solution of H_2 SO_4 presence

4. Which of the following compounds is mainly formed as a result of acrylic acid hydrochlorination reaction:
   a) 2-chloropropanic acid       c) 3-chlorproanoic acid
   b) chloranhydride of propanoic acid       d) α-chlorproanoic acid

5. Select the nucleophilic reagents:
   a) H^+   b) H_2 O   c) C_2 H_5 OH       d) OH^-

6. Select the electrophilic reagents:
   a) CH_3-NH_2   b) H^+   c) CH_3-OH       d) ^+CH_3

7. The following factors may result in homolysis:
   a) acid catalysis   b) base catalysis
   c) ultraviolet radiation   d) heating   e) using of peroxides

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

<table>
<thead>
<tr>
<th>Column I</th>
<th>Column II</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) butane</td>
<td>1) A_E</td>
</tr>
<tr>
<td>b) cyclohexane</td>
<td>2) A_R</td>
</tr>
<tr>
<td>c) 2-methyl propene</td>
<td>3) S_R</td>
</tr>
<tr>
<td>d) cyclopropane</td>
<td></td>
</tr>
<tr>
<td>e) chloroethene</td>
<td></td>
</tr>
</tbody>
</table>
Practical part

1. Qualitative test on the alkenes with bromine water.

\[
\begin{align*}
\text{CH}_3 & \quad + \text{Br}_2 \\
\text{\(\alpha\)-pinene} & \quad \rightarrow \\
\text{H} & \quad \text{Br} \\
\text{Br} & \quad \text{CH}_3
\end{align*}
\]

1,2-dibrompinane

**Accomplishment:** to 4 drops of bromine water* add 2 drops of \(\alpha\)-pinene* and shake.

**Observed changes:**

**Conclusion:**

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

2. Qualitative test on the alkenes with potassium permanganate.

\[
\begin{align*}
\text{CH}_3 & \quad + \text{O} \\
\text{\(\alpha\)-pinene} & \quad \rightarrow \\
\text{HO} & \quad \text{HO} \\
\text{HO} & \quad \text{CH}_3
\end{align*}
\]

pinenglycol

**Accomplishment:** to 6 drops of \(\text{KMnO}_4\) (14) solution add 1 drop of \(\alpha\)-pinene* and shake.

**Observed changes:**

**Conclusion:**

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

3. Toluene oxidation

Oxidation stability is one of the main properties of aromatic systems. Toluene oxidation reaction goes in a side chain but the aromatic kernel is stored:
Accomplishment: to 10 drops of KMnO₄ water solution (14) add 10 drops of dilute solution of H₂SO₄ (23) and 5 drops of toluene*, carefully heat and shake.

Observed changes:___________________________________________________

Conclusion:_________________________________________________________
____________________________________________________________________
____________________________________________________________________

LABWORK # 6

Theme: BIOLOGICALLY IMPORTANT REACTIONS REACTION OF ALDEHIDES AND KETONES

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

Recommended literature:

Problems for discussion:
1. An electronic structure of a carbonyl group. The reactionary centers in aldehydes and ketones.

4. Oxidation reactions are qualitative tests on aldehyde group. Oxidation reactions of ketones. Disproportionation reactions.


**Exercises:**

1. Write reaction schemas of ethanal reduction *in vivo* and *in vitro*.

2. Write down the reduction reaction of 2-oxopropanoic acid with NADH-H⁺.

3. Describe the mechanism of acetalization reaction:
   a) ethanal with methanol

   b) methanal with propanol-2

4. Describe the mechanism of intramolecular acetalization reaction to form cyclic hemiacetal:
   a) 5-hydroxyhexanal

   b) 4-hydroxypentanal
5. Describe the mechanism of interaction of ethanal and methylamine.

6. Write the schema of aldol condensation reaction on an example of 2-methylpropanal.

7. Describe the mechanism of disproportionation reaction for the formaldehyde.

Test control
1. Select reagents by means of which it is possible to find out presence of aldehydic group:
   a) Shiff’s reagent
   b) Cu (II) hydroxide when heated
   c) Cu (II) hydroxide at room temperature
   d) I₂ + NaOH
2. As a result of reaction of reduction in vivo acetic aldehyde are formed:
   a) ethanol and NADH + H⁺
   b) ethanol and NAD⁺
   c) ethanal and NAD⁺
   d) methanol and NAD⁺
3. Which compounds are formed as a result of secondary alcohol oxidation:
   a)  C₃H₇—C—O—CH₃
   b)  C₃H₇—O—C—CH₃
   c)  CH₁—CH₂—C—CH—CH₃
   d)  CH₃—CH—C=O
4. What reaction leads to acetal formation:
   a) 1 mol of methanal + 1 mol of propanal
b) 1 mol of propanal + 1 mol of methanol
c) 1 mol of ethanol + 2 mol of methanol
d) 1 mol of propanal + 2 mol of ethanol

5. Indicate the reagents used to obtain Schiff’s bases:
a) propanal and benzaldehyde   
b) acetaldehyde and ethanol
c) propanal and aniline       
d) ethylamine and benzaldehyde

6. Indicate the reaction used to obtain acetal:
a) propanal and benzaldehyde   
b) acetaldehyde and ethanol
c) propanal and aniline       
d) methylamine and benzaldehyde

7. Indicate the reaction used to obtain hemiacetal:
a) propanal and aniline       
b) acetaldehyde and ethanol (1:2)
c) methanal and propanol-1 (1:1)  
d) methylamine and acetaldehyde

**Practical part**

1. **Formaldehyde oxidation with Cu(OH)₂ in alkaline medium**

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

\[ \text{CuSO}_4 + 2 \text{NaOH} \rightarrow \text{Cu(OH)}_2 + \text{Na}_2 \text{SO}_4 \]

\[ \text{R} - \text{CHO} + 2 \text{Cu(OH)}_2 \xrightarrow{\text{OH}^-} \text{R} - \text{COOH} + \text{H}_2\text{O} + 2\text{CuOH} \]

\[ 2\text{CuOH} \rightarrow \text{Cu}_2\text{O} + \text{H}_2\text{O} \]

**Accomplishment:** to 1-3 drops of formaline (32) add 10 drops of NaOH solution (21) and 1-2 drops of CuSO₄ (26). Mixture is heated to boiling point.

**Observed changes:**____________________________________________________
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 3-4 drops of the Shiff’s reagent* add 1 drop of formaldehyde solution (32).

**Observed changes:**

**Conclusions:**

3. Disproportionation reaction of formaldehyde

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

$$
\begin{align*}
2 \text{H}_2\text{C} = \text{O} \text{H} + \text{H}_2\text{O} & \rightarrow \text{H}_2\text{C} = \text{O} \text{H} + \text{C}_2\text{H}_5\text{OH} \\
\text{formic acid} & \text{methanol}
\end{align*}
$$

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

**Observed changes:**

**Conclusions:**
4. Acetone detection by transformation to iodoform (iodoform reaction)
Iodoform reaction is connected with ability of carbonyl containing compounds to substitute hydrogen atom at \(\alpha\)-carbon atom on halogen and the following cleavage of carbon-carbon bond with iodoform (CHI\(_3\)) formation.

\[
\begin{align*}
I_2 + NaOH & \quad \rightarrow \quad HIO + NaI \\
CH_3 - C - CH_3 & \quad + \quad 3HIO \quad \rightarrow \quad Cl_3 - C - CH_3 & \quad + \quad 3H_2O \\
Cl_3 - C - CH_3 & \quad + \quad NaOH \quad \rightarrow \quad CH_3↓ & \quad + \quad CH_3-C \quad ONa
\end{align*}
\]

Accomplishment: to 6-8 drops of Lugol (47) solution (I\(_2\) in KI solution) add NaOH solution (21) to disappearing of color, then pour 1-2 acetone drops*.

Observed changes:______________________________________________

Conclusion:__________________________________________________________________

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

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

Observed changes:___________________________________________
LABWORK # 7

Theme: CARBOXYLIC ACID AND THEIR DERIVATIVES

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

Recommended literature

Problems for discussion
1. Reactions sites of carboxylic acids and derivatives.
2. Acidic properties of carboxylic acids.
5. Amides, acyl chlorides, anhydrides. Their hydrolysis.

Exercises
1. Compare the acidity of ethanoic and ethanedioic acids. Write the reaction of salt formation of the stronger acid with Ca(OH)$_2$. 
2. Write down the decarboxylation reaction of the following compounds:
   a) malonic acid
   b) 2-aminopentanedioc acid

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

4. Write down the hydrolysis reaction of methyl ethanoate:
   a) acidic hydrolysis
   b) alkaline hydrolysis (with NaOH)

6. What products would be obtained from the hydrolysis of each of the following amides:
   a) ![amide structure](image)
   b) ![amide structure](image)

   **Test control**
   1. Indicate the dicarboxylic aliphatic acids:
      a) butyric  b) oxalic  c) malonic  d) succinic
   2. When heated in the acidic medium butandioic acid can give the following products:  a) H₂O  b) CO₂  c) propanoic acid  d) succinic anhydride
   3. Which of the following compounds reacts with acetic acid to form thioester?
      a) ethanol  b) ethanthiol  c) NH₃  d) socl₂
   4. Indicate the compounds that can easily undergo the decarboxylation reaction:
5. Arrange in order of decreasing reactivity in $S_N$ reactions of the following compounds:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>2)</td>
<td>3)</td>
<td>4)</td>
</tr>
<tr>
<td></td>
<td>$\text{H}_3C\text{C}=\text{O}\text{Cl}$</td>
<td>$\text{H}_3C\text{C}=\text{O}\text{CH}_3$</td>
<td>$\text{H}_3C\text{C}=\text{O}\text{CH}_3\text{NH}_2$</td>
</tr>
<tr>
<td>a)</td>
<td>1&gt;3&gt;2&gt;4</td>
<td>b) 2&gt;3&gt;4&gt;1</td>
<td>c) 3&gt;1&gt;2&gt;4</td>
</tr>
</tbody>
</table>

6. Decarboxylation reaction of 2-amino-3-hydroxypropanoic acid leads to the formation:

- a) 3-hydroxypropanoic acid
- b) 2-aminoethanal
- c) 2-aminopropanol
- d) 2-aminoethanol

**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 nucleophilic substitution mechanism ($S_N$).

$$\text{CH}_3\text{C}=\text{O}\text{Na} + \text{H}_2\text{SO}_4 \rightarrow \text{CH}_3\text{COOH} + \text{NaHSO}_4$$

$$\text{CH}_3\text{C}=\text{O}\text{OH} + \text{C}_2\text{H}_5\text{OH} \quad \text{H}^+, t' \quad \text{CH}_3\text{C}=\text{O}\text{OC}_2\text{H}_5 + \text{H}_2\text{O}$$

**Accomplishment:** to 5 drops of ethanol* add 5 drops of $\text{H}_2\text{SO}_4$ concentrated solution* and waterless $\text{CH}_3\text{COONa}$ (42), heat. Pour solution to another test-tube with water.

**Observed changes:** ________________________________

**Conclusi-**
2. Oxalic acid decarboxylation

Result of the oxalic acid decarboxylation is carbon dioxide which forms CaCO₃ when mixed with the lime water (solution of Ca(OH)₂)

\[
\text{HOOC} \rightarrow \text{CO}^+ \text{H}_2 \text{O}
\]

\[
\text{HOC} \rightarrow \text{CO}_2 + \text{HCOOH}
\]

\[
\text{CO}_2 + \text{Ca(OH)}_2 \rightarrow \text{CaCO}_3 \downarrow + \text{H}_2 \text{O}
\]

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 (2).

Observed changes: ________________________________

Conclusion: ____________________________________________________________________________

_____________________________________________________________________________________

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


6. Electronic effects in organic molecules (inductive and mesomeric), their role in the reactivity centers in the molecule. Electron donors and withdrawers.

7. Conjugation ($\pi,\pi$- and $\pi,p,\pi$- conjugations). Conjugated systems with open chain (butadiene-1,3).

8. Conjugated systems with close chain. Aromaticity, criteria of aromaticity, Huchel’s rule (benzene, naphtalene, phenantrene).

9. Heterocyclic aromatic compounds (pyrrol, pyridine). Pyrrol and pyridine nitrogen atoms. $\pi$-Excess and $\pi$-deficient aromatic systems.

10. Acidity and basicity of organic compounds: Brensted and Lewis theories.


12. Basic properties of organic compounds (alcohols, ethers, thioesters, amines). Comparing of basic properties of aliphatic and aromatic amines; salt formation.

13. Classification of organic reactions (substitution, addition, elimination, isomerisation, red-ox, acid-basic interaction).


15. Oxidation reactions of organic compounds (alcohols, thiols, phenols). Antioxidants (2,3-dimercaptopropanol, ascorbic acid, phenols and others).

19. Alkylation reactions of aromatic compounds.
20. Electronic and spatial structure of the carbonyl group. Comparative reactivity of aldehydes and ketones.
22. Nucleophilic addition reactions of aldehydes and ketones; addition of water and alcohols.
23. Addition of amines to carbonyl compounds, mechanism. Schiff’s bases.

LABWORK # 9

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

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

Recommended literature
Problems for discussion
1. Polyfunctional compounds: classification, chemical properties.
2. Heterofunctional compounds: classification, a role in biological processes.
3. Aminoalcohols: their biological role.
9. Salicylic acid, its derivatives.

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

<table>
<thead>
<tr>
<th>a) glycerol</th>
<th>b) ethylene glycol</th>
</tr>
</thead>
<tbody>
<tr>
<td>c) choline</td>
<td>d) fumaric acid</td>
</tr>
<tr>
<td>e) colamine</td>
<td>f) malic acid</td>
</tr>
<tr>
<td>g) maleic acid</td>
<td>h) oxalic acid</td>
</tr>
<tr>
<td>i) lactic acid</td>
<td>j) citric acid</td>
</tr>
<tr>
<td>k) malonic acid</td>
<td>l) pyruvic acid</td>
</tr>
</tbody>
</table>
2. Write schema of oxidation reaction in vivo of:
   a) lactic acid
   b) malic acid

3. Write the equations of interaction of lactic acid and:
   a) NaOH
   c) C₂H₅OH
   c) CH₃COCl

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

5. Write down the tautomeric forms of oxaloacetic acid

6. Write down the formulas of ketone bodies.

7. Write the schemas of acetylsalicylic acid formation reaction.

<table>
<thead>
<tr>
<th>m) oxaloacetic acid</th>
<th>n) α-oxoglutaric acid</th>
</tr>
</thead>
</table>
8. Write the structures of
a) para-aminobenzoic acid

b) anestesine

c) novocaine

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

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

b) ultracaine

c) lidocaine

Test control
1. What substances does lactic acid react with:
   a) acetylchloride  c) ammonia
   b) ethanol  d) potassium hydroxide

2. Which of the following hydroxyacids at oxidation in vivo with coenzyme NAD$^+$ participation turns to an oxalacetic acid:
   a) lactic acid  c) citric acid
   b) malic acid  d) pyruvic acid

3. Which of the following compounds are ketone bodies:
   a) $\alpha$-hydroxybutaric acid  c) $\beta$-hydroxybutaric acid
   b) acacetocetic acid  d) acetone

4. Which products are formed at interaction of salicylic acid with acetic anhydride:
   a) acetic acid  c) aspirin
   b) acetylsalycilic acid  d) CO$_2$
5. High quality of aspirin is determined with reagent:
   a) bromine water   c) \( \text{FeCl}_3 \)
   b) \( \text{Cu(OH)}_2 \)   d) \( \text{Ag}_2\text{O} \)

6. Para-aminobenzoic acid possesses amphoteric properties in the reactions with:
   a) \( \text{C}_2\text{H}_5\text{OH} \)  b) HCl  c) \( \text{PCl}_3 \)  d) NaOH

**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.

![Chemical reactions image]

**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 \( \text{Cu(OH)}_2 \) and forms copper (II) alcoholate (chelate).

![Chemical reactions image]
Copper alchoholate 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 ortho-hydroxybenzoic acid is formed which with Fe (III) chloride forms complex compound.

**Accomplishment:** Place some grains of aspirin* and 5 - 6 drops of water in a test tube, shake it. Divide the test tube contents into 2 parts. To one part add 1 drop of FeCl$_3$ (8), another part boil for half a minute and then add 1 drop of FeCl$_3$.

**Observed changes:**

**Conclusion:**
Objective: to develop knowledge about the saponifiable lipids.

Recommended literature:

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.

Exercises
1. Write a structural formulas of the following triglycerides:
   a) 1-linoleoyl 2-palmitoyl 3-stearoylglycerol

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

3. Draw the structural formulas of the following compounds:
   a) 1-stearoyl-2-oleoylphosphatidylserine
   b) 1-stearoyl-2-linoleoylphosphatidylcholine
   c) 1-palmitoyl-2-arachidonoylphosphatidylethanolamine

Show hydrophobic and hydrophilic parts of these structures.

Test control
1. Which of the following statements are correct for unsaturated fatty acids:
   a) they have a nonbranched structure
   b) they contain one or a few \( \pi \)-bonds
c) they always have trans-configuration
d) they contain the even number of the carbon atoms

2. Indicate the correct fat name having the following structure:
   d) 1-stearoyl-2-palmitoyl-3-linolenoylglycerol
e) 1-linolenoyl-2-palmitoyl-3-linoleoylglycerol
f) 1-oleoyl-2-stearoyl-3-arachydoylglycerol
g) 1-stearoyl-2-linolenoyl-3-linoleoylglycerol

3. What compounds belong to saponified lipids:
   a) cholesterol
   b) phospholipids
c) glycolipids
d) waxes

4. Which is the mechanism of fat hydrolysis in the acidic medium:
   a) $A_E$
   b) $A_N$
   c) $A_R$
   d) $S_N$

5. Which compounds can react with phosphatidylethanolamine containing residues of palmitic and oleic acids:
   a) water
   b) aqueous solution KOH
c) potassium permanganate solution
d) bromine water

6. Which of the following compounds are formed as a result of the lipid peroxidation:
   a) malonic dialdehyde
   b) aldehydic acid
   c) dienic conjugates
d) amino acids
e) oxoacids

**Practical part**

1. **Qualitative reactions on the unsaturated acids which form fats**
A reaction with bromine water.
Accomplishment: to 1 drop of fat* add some drops of bromine water *. Shake the test-tube.

Observed changes:__________________________________________________________

Conclusion:_________________________________________________________________

____________________________________________________________________

2. Oxidation reaction with potassium permanganate

Oxidation occurs in the double bond location.

Accomplishment: to 1 drop of fat* pour 10 drops of KMnO₄ solution (14) and 2 drops of Na₂CO₃ (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 addiction mechanism.
Accomplishment: in a test-tube #1 pour 10 drops of a fresh sunflower-seed oil* solution, in a test-tube #2 pour 10 drops long time stored on the light (in conditions of oxygen access) sunflower-seed oil, in a test-tube #3 pour 10 drops of margarine* solution (oils and margarine are dissolved in heptane-chloroform mixture in the volume ratio 1:1). Then in each of the test-tubes add on 10 drops of the TBA - reagent (0,8 % solution of thiobarbituric acid in an ice acetic acid)*. Test-tubes with a reaction mixture shake up, close with foil, place into boiling water bath. In 15 minutes take out the test-tubes and visually estimate color intensity of solutions.

Observed changes:____________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
Conclusion:_________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
LABWORK #11

Theme: CARBOHYDRATES. MONOSACCHARIDES

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

Recommended literature

Problems for discussion
1. Carbohydrates: definition, biological role.
7. Monosaccharide reduction. Xylitol and sorbitol.
8. Aminosugars. Their structure, properties and a biological role.
9. Ascorbic acid (vitamin C) as water-soluble antioxidant.

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

   a)  
   b)  
   c)  
   d)  

   Show the chiral centers.

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

3. Show the chair conformations of the following monoses:

   1. α, D-glucopyranose

   2. β, D-glucopyranose

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

5. Write the schemas of the following reactions:
   a) oxidation of D-galactose with bromine water

   b) oxidation of D-glucose with HNO₃
6. Write down the structures of glucose-6-phosphate, fructose-1,6-diphosphate.

7. Write the formulas of 2-deoxy-2-amino-β-D-glucopyranose.

Test control
1. What monosaccharides fall into to hexoses:
   a) glucose  c) galactose
   b) ribose  d) fructose

2. Select differences between ribose and deoxyribose:
   a) value of molar weight
   b) number of oxygen atoms in a molecule
   c) only ribose forms the cyclic form
   d) a number of hydroxyl groups

3. What compound is formed as a result of monosaccharide with alcohol reaction at HCl presence:
   a) ether  c) ester
   b) acetal  d) glycoside

4. Which medium are glycosides hydrolyzed:
   a) acidic  b) neutral  c) alkaline

5. Considering the stability of α- and β- anomeric forms of glucose in water solution:
   a) the α-form is steadier
b) the stability of α-and β-forms is identical

c) the β-form is steadier

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

a) phosphates  

b) nitrates  

c) sulphates  

d) acetates

**Practical part**

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

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

\[
\text{CuSO}_4 + 2\text{NaOH} \rightarrow \text{Cu(OH)}_2 \downarrow + \text{Na}_2\text{SO}_4
\]

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

**Observed changes:**

**Conclusion:**

________________________________________________________________________

________________________________________________________________________

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

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

\[
2\text{Cu(OH)}_2 \rightarrow [O] + \text{H}_2\text{O} + 2\text{CuOH}
\]

\[
2\text{CuOH} \rightarrow \text{H}_2\text{O} + \text{Cu}_2\text{O}
\]
Oxygen molecule oxidizes glucose and monosaccharide molecules are completely broken up into acids and oxoacids. The first intermediate of glucose oxidation is gluconic acid.

\[
\text{CH}_2\text{OH}-(\text{CHOH})_4\text{C}^\equiv\text{O} + [\text{O}] \rightarrow \text{CH}_2\text{OH}-(\text{CHOH})_4\text{C}^\equiv\text{O} \text{OH}
\]

gluconic acid

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

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

**Observed changes:**___________________________________________________

**Conclusion:**_________________________________________________________

____________________________________________________________________

____________________________________________________________________

3. **Comparison of reactions of glucose and formalin with 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 as much a solution of glucose (54) and add in everyone on 3 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.
Accomplishment: to 10 drops of fructose (56) solution add 10 drops of HCl* concentrated solution and 1 spatula of resorcinol* crystals. Heat up.

Observed changes:___________________________________________________
__________________________________________________________________
Conclusion:_________________________________________________________
____________________________________________________________________
___________________________________________________________________

LABWORK #12
Theme: 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

Problems for discussion
1. Classification of polysaccharides.
2. Disaccharides: maltose, cellobiose, lactose, lactulose, sucrose. Their structures and properties.
5. Dextrane as a source to obtain plasma substitutes.
6. Heteropolysaccharides.

**Exercises**

1. Write down the acidic hydrolysis reaction of:
   a) $\alpha$-maltose
   b) $\beta$-lactulose
   c) sucrose
   d) $\beta$-lactose

2. Show the structure of disaccharide, fragment of amilose.

3. Show the amylopectin fragment containing $\alpha(1\rightarrow4)$ and $\alpha(1\rightarrow6)$ glycosidic bonds.
4. Explain why cellulose can provide structural function in the plant organisms? Show the fragment of cellulose structure.

5. Write down the fragment of dextrane. Designate the types of bonds.

Test control
1. Which disaccharide hasn’t reducing properties?
   a) maltose c) lactose
   b) sucrose d) cellobiose

2. Starch has the types of glycoside bond:
   a) $\alpha (1 \rightarrow 4)$ c) $\beta (1 \rightarrow 4)$
   b) $\alpha (1 \rightarrow 6)$ d) $\beta (1 \rightarrow 3)$

3. Glycogen possesses the types of glycoside bond:
   a) $\beta (1 \rightarrow 4)$ c) $\alpha (1 \rightarrow 4)$
   b) $\alpha (1 \rightarrow 6)$ d) $\alpha (1 \rightarrow 3)$

4. Select the homopolysaccharides:
   a) heparin c) dextrane
   b) cellulose d) chondroitin sulfate

5. Select the heteropolysaccharides:
   a) starch c) glycogen
   b) heparin d) hyaluronic acid
6. Select the monosaccharides which are formed as a result of an acidic hydrolysis of hyaluronic acid:
   a) N-acetylglucosamine       b) N-acetylgalactosamine
   c) D-glucuronic acid          d) D-galacturonic acid

7. Select the monosaccharides which are formed as a result of an acidic hydrolysis of chondroitin sulfate:
   a) D-glucuronic acid          b) D-galacturonic acid
   c) N-acetyl-D-mannosamine     d) N-acetyl-D-galactosamine

8. Cellulose has the following bond types:
   a) glycoside bonds            b) disulfide bonds
   c) hydrogen bonds             d) peptide bonds

**Practical part**

1. **The Fehling’s reaction with sucrose and lactose**

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

   ![Chemical structures of lactose and sucrose](image)

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

   **Observed changes:** _________________________________________________________
   _________________________________________________________________________
   _________________________________________________________________________
   _________________________________________________________________________
   _________________________________________________________________________

   **Conclusion:** _____________________________________________________________
   _________________________________________________________________________
   _________________________________________________________________________
   _________________________________________________________________________
   _________________________________________________________________________
2. The qualitative test on the starch

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

Observed changes: ____________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
Conclusion: ________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

LABWORK #13

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

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

Recommended literature

Problems for discussion
2. Amphoteric properties of amino acids.
3. Reactions of amino acids on the carboxylic group.
4. Reactions of amino acids on the amino group.
5. Biologically important reactions of amino acids: deamination, transamination, decarboxylation, hydroxylation reactions.

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

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a) L-glutamic acid</td>
<td>b) L-threonine</td>
</tr>
<tr>
<td>c) L-tyrosine</td>
<td>d) D-isoleucine</td>
</tr>
<tr>
<td>e) L-isoleucine</td>
<td>f) L-tryptophan</td>
</tr>
</tbody>
</table>

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

3. **Write the structures of amino acids at the pH = 7.4:**

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

4. **Write the oxidation reaction of cysteine.**

5. **Write down the schemas of biologically important reactions:**

   a) pyruvic acid with Glu

   b) decarboxylation of His
c) decarboxylation of Glu

d) hydroxylation of Phe

Test control

1. Select the hydrophilic amino acids:
   a) Met   b) Asp   c) Asn   d) Ser
2. Select the hydrophobic amino acids:
   a) Met   b) Ile   c) Thr   d) Phe
3. Select essential amino acids:
   a) Arg   b) Met   c) Phe   d) Pro
4. Select amino acids with two chiral centers:
   a) Leu   b) Ile   c) Thr   d) Ser
5. Select the ionogenic amino acids:
   a) Lys   b) His   c) Ala   d) Asp   e) Gln   f) Arg
6. Which of the following tests are used to detect amino acids:
   1) xanthoproteinic test   2) Trommer’s test
   3) ninhydrin reaction   4) Schiff’s test
7. Which of the following amino acids can be detected with concentrated solution of nitric acid?
   a) Ala   b) Tyr   c) Phe   d) Trp
Practical part

1. Reactions of amino acids with copper salts

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

\[
2 \text{R-CH-CHOH} \quad \text{CuSO}_4 \quad \text{RCH-NH}_2 \quad \text{Cu} \quad \text{O-C} \\
\text{NH}_2 \quad \text{OH} \quad \text{O} \quad \text{O} \\
\text{α-amino acid} \quad \text{chelated salt of Cu (II)} \quad \text{with α-amino acid}
\]

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

Observed changes:____________________________________________________
____________________________________________________________________
____________________________________________________________________
Conclusion:__________________________________________________________
____________________________________________________________________
____________________________________________________________________

2. Glycine has neutral medium

\[
\text{H}_2\text{N-CH}_2\text{-C-} + \text{H}_2\text{O} \quad \text{H}_2\text{N-CH}_2\text{-C-} \\
\text{OH} \quad \text{OH} \quad \text{O}
\]

Accomplishment: add 1 drop of 0,2 % methyl red indicator* solution to 3 drops of 0,2 % glycine (1) 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.

\[
\begin{align*}
R - CH - NH_2 + H - C - H + H_2O & \rightarrow R - CH \equiv CH_2 \\
& \text{COOH} \\
\end{align*}
\]

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

**Accomplishment:** add 1 drop of 0.2 % methyl red indicator* solution to 3 drops of 40 % of formaldehyde solution (32). Add (carefully) 2N NaOH* solution to neutral medium of solution (fix color change). Then add 3 drops of 0.2 N glycine (1) solution (fix color change again).

**Observed changes:**

**Conclusion:**

---

4. Ninhydrin reaction

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

\[
\begin{align*}
\text{ninhydrin} & \quad + \text{H}_2\text{N} - \text{CH} - \text{COOH} & \text{100°C} & \Rightarrow \text{reaction product} \\
\end{align*}
\]

**Accomplishment:** add 1 drop of 0.03% ninhydrin* solution to 1 ml of 1% glycine (1) solution. Heat the mixture to boil.

**Observed changes:**
LABWORK #14

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

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

Recommended literature

Problems for discussion
1. Peptides: structure and functions. Gluthathion, aspartam, insulin.
2. Peptide bond.
4. Artificial peptide synthesis.
5. Secondary structure of proteins.
7. Denaturation of proteins.

Exercises
1. Describe the formation reaction of peptide alanyllysine.
2. Describe the acidic hydrolysis reaction of dipeptide Thr-Phe.

3. Write down the schema of hydrolysis reaction of the following peptides:
   a) Pro-Gln
   b) Asp-His

4. Show the following peptides in the ionized form:
   a) Gln-Asp-Ile
   b) Met-Pro-Glu

5. Write the gluthathione structure and its oxidation reaction.

---

**Test control**

1. What charge do peptide Arg-Val have at pH=7,4?
   a) positive  b) negative  c) hasn’t charge

2. Select the correct statements about peptide bond:
   a) carbon, nitrogen and oxygen atoms are sp²-hybridized
   b) peptide bond has p-π-conjugation
   c) rotation along C-N bond is possible
   d) rotation along C-N bond isn’t possible
3. Primary structure of proteins is formed with:
   a) disulfide bonds  b) ionic bonds   c) hydrogen bonds   d) peptide bonds
4. Secondary structure of proteins is formed with:
   a) hydrogen bonds   b) peptide bonds   c) hydrophobic interactions   d) ionic bonds
5. Tertiary structure of proteins is formed with:
   a) hydrogen bonds   
   b) peptide bonds   
   c) hydrophobic interactions   
   d) ionic bonds
6. Peptide bonds are found with:
   a) xantoproteinic reaction   
   b) biuretic test   
   c) ninhydrin reaction   
   d) lead acetate

Practical part
1. Xantoproteinic reaction proves the presence of aromatic and heterocyclic α-amino acids such as tryptophane, phenylalanine, tyrosine, histidine in protein structure. When reacted HNO₃ concentrated solution with protein solution nitro-compound is formed. When alkali is added to protein solution the ionization of phenol OH-group occurs.

\[
\begin{align*}
\text{tyrosine} & \xrightarrow{\text{HNO}_3} \text{yellow} \\
\text{NaO} & \xrightarrow{\text{+2NaOH}} \text{orange}
\end{align*}
\]
**Accomplishment:** to 1 ml of protein solution (28) add drop by drop concentrated solution of HNO₃* 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.

\[
\text{H}_2\text{N} - \text{CH} - C - \text{N} - \text{CH} \ldots \text{R} \ldots \text{COOH} \quad \xrightarrow{+2\text{NaOH}, \text{CuSO}_4} \quad \text{H}_2\text{N} - \text{CH} - \overset{\text{C} = \text{N}}{\text{C}} - \text{N} - \text{CH} \ldots \text{R} \ldots \text{COOH}
\]

Biuretic reaction proceeds in such way:
Accomplishment: to 1 ml of protein solution (28) add 1 ml of NaOH (21) concentrated solution and then by degrees on the test-tube side pour 1-2 drops of 0,5% solution of CuSO₄ (26).

Observed changes:___________________________________________________
____________________________________________________________________

Conclusion:__________________________________________________________________
____________________________________________________________________

3. Precipitation of proteins with sulfosalicylic acid

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

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

Observed changes:___________________________________________________
____________________________________________________________________

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, (NH₄)₂SO₄, MgSO₄) or denaturants (alcohol, acetone). Hydration of protein polar group decreases and
charge disappearance leads to aggregation and precipitation of proteins. Obtained precipitate can be dissolved with dilution or dialysis that’s why it is the reversible precipitation.

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

**Observed changes:** ____________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

**Conclusion:** _________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

LABWORK #15

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

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

**Recommended literature**


**Problems for discussion**

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

**Exercises**

1. Write down the heterocyclic bases: uracil, thymine, guanine, adenine, cytosine. What types of tautomerism are characterized for each of them? Write tautomeric forms?

2. Write the structural formulas showing the hydrogen bonds in complementary base pairs of DNA and RNA:
   a) uracil – adenine
   b) cytosine – guanine
   c) thymine – adenine

3. Write the formulas of the following nucleosides:
   a) guanosine
b) thymidine

c) deoxyadenosine

4. Write the hydrolysis reaction of 2′-deoxycytidine-5′-monophosphate in the cases of:
   a) pH=4  b) pH=1  c) pH=9

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

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

\[
\begin{array}{c}
\text{N} \\
\text{R} \\
\text{C} \\
\text{O} \\
\text{NH}_2
\end{array}
\]

**Test control**

1. Heterocyclic bases are formed as a result of DNA hydrolysis:
   a) Thymine  b) adenine  c) uracil  d) guanine

2. Nucleic acids contain the following components:
   a) sulfate  b) phosphate  c) heterocyclic bases  d) ribose

3. The types of bond are found in the nucleic acids:
a) peptide  b) disulfide  c) glycosidic  d) 3′, 5′-phosphodiesteric
4. The products are formed as a result of an alkaline hydrolysis of cytidine-5′-monophosphate:
   a) ribose  b) cytidine  c) cytosine  d) phosphate
5. Which nucleotide sequence of the one chain of DNA chain accords to GTTACTG:
   a) CATTGAC  b) GAATCAG  c) CAATGAC  d) CTTAGTC
6. The end products of an acidic hydrolysis of 2′-deoxyadenosine-5′-monophosphate are:
   a) 2-deoxyribose  b) phosphate  c) adenosine  d) adenine

Practical part
To investigate chemical composition of nucleotides baker's yeast hydrolyzate is used.
1. Phosphoric acid detection in products of nucleoprotein hydrolysis (hydrolyzates)

   \[
   \text{H}_3\text{PO}_4 + 12 (\text{NH}_4)_2\text{MoO}_4 + 21\text{HNO}_3 \rightarrow (\text{NH}_4)_3\text{PO}_4 \cdot 12 \text{MoO}_3 + 21\text{NH}_4\text{NO}_3 + 12\text{H}_2\text{O}
   \]

   ammonium phosphomolybdic

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

   Observed changes:__________________________________________________

   Conclusion:__________________________________________________________________
   ______________________________________________________________________
   ______________________________________________________________
2. **Pentose detection in products of nucleoprotein hydrolysis** (the Bial’s test)

When reacted with H$_2$SO$_4$ concentrated solution or dilute HCl pentoses are dehydrated to form furfural which is condensed with orcinol.

![Chemical Reaction](image)

**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**

![Chemical Reaction](image)

**Accomplishment:** add 1 drop of concentrated solution of ammonia and 5 drops of 1% solution of AgNO$_3$* to 10 drops of yeast hydrolyzate*. Leave the test-tube for 3–5 minutes without mixing.

**Observed changes:**

**Conclusion:**

____________________________________________________________________

____________________________________________________________________

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

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

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

Questions to the test control
1. Oxidation reactions of hydroxy acids in vivo.
2. Reduction reactions of oxo acids in vivo.
4. Decomposition reaction of citric acid at heating.
5. Formation reaction of citric acid from oxaloacetic acid and acetyl coenzyme A.
6. Dehydration reaction of citric acid in vivo.
7. \( \pi \)-Diastereomers of butenedioic acid. Hydration reaction of fumaric acid.
8. Specific reactions of \( \alpha \)-, \( \beta \)-, \( \gamma \)- hydroxy and amino acids.
10. Ketone bodies, their biological role.
11. Formation of acetylsalicylic acid.
12. \( p \)-Aminobenzoic acid, their derivatives. Modern anesthetics.
18. Ascorbic acid as water soluble antioxidant.
20. Polysaccharides: structure, biological role.
22. Biologically important reactions of α-amino acids: deamination, hydroxylation, decarboxylation, transamination reactions.
27. ATP, cyclo-AMP.

It is necessary to know formulas of the following compounds:

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

Theme: POLYMER MATERIALS, USING IN STOMATOLOGY

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

Recommended literature

Problems for discussion
2. Classification of polymers: 
   - according to ways of receipt 
   - according to chemical composition of fundamental macromolecule chain 
   - according to structure of macromolecules 
   - according to composition of principal chain 
   - according to behaviour during heating 
   - according to ways of combination elementary links (groups) 
   - according to dimensional organisation of linkage (space isomerisation) of linkage. 
3. Ways of receipt polymers (polymerization, polycondensation, chemical modification of natural polymers).
4. Mechanism free radicae polymerization of acrylic acid ester’s.
8. Low-molecular components, using in adhesive systems for improvement for sticking of material filling to tissue of tooth.


**Exercises**

1. Write schemas (steps) of reactions generation
   a) methyl methacrilates
   b) ethylmethacrilates
   c) butylmethacrylate

2. Make up equation of reaction polymerisation ethylmethacrylate. Describe the mechanism of free radical polymerisation with participation initiator (benzoyl’s peroxide).

3. How material of filling does contact with dentine. Make comments with scheme of collaboration correspond functional groups.
Practical part

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

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

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

**Observed changes:**

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

*Write the schem of reaction polymerization methylmethacrylate.*

**Conclusion:**

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

2. Depolymerisation of polymethylmethacrilate and evidence unsaturatide of monomer.

**Accomplishment:** In test-tube put small bits of polymer, fixe small test-tube with holder approximatly horisontaly (with small angle in side of aperture) carefully heart sprit-lamp resulting fume of monomer like white smoke (harder then open air) carefully transfuse in second test-tube with 3-5 drops Br₂-water and shake.

**Observed changes:**

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

*Write schemas of additional reaction bromine to methylmethacrylate.*
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:
2. Cyclohexane conformations.
6. Electronic effects in organic molecules (inductive and mesomeric), their role in the reactivity centers in the molecule. Electron donors and withdrawers.
7. Conjugation (π,π- and p,π- conjugations). Conjugated systems with open chain (butadiene-1,3).
8. Conjugated systems with close chain. Aromaticity, criteries of aromaticity, Huchel’s rule (benzene, naphtaline, phenantrene).

10. Acidity and basicity of organic compounds; Brensted and Lewis theories.


12. Basic properties of organic compounds (alcohols, ethers, thioesters, amines). Comparing of basic properties of aliphatic and aromatic amines; salt formation.

13. Classification of organic reactions (substitution, addition, elimination, isomerisation, red-ox, acid-basic interaction).


15. Oxidation reactions of organic compounds (alcohols, thiols). Antioxidants (2,3-dimercaptopropanol, ascorbic acid, phenols and others).


18. Electrophilic substitution reactions of aromatic hydrocarbons.


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

21. Addition of amines to carbonyl compounds, mechanism. Schiff’s bases.


27. Heterofunctional compounds and their characteristics. Intramolecular and intermolecular reactions of nucleophilic substitution in the amino acids and hydroxy acids. Elimination reactions.
28. Citric acid (2-hydroxypropane-1,2,3-tricarboxylic acid). Decomposition reactions. Citrates.
29. Oxo acids (pyruvic acid, acetoacetic acid, oxaloacetic acid, \( \alpha \)-ketoglutaric acid). Transamination reactions of \( \alpha \)-oxo acids.
31. \( \beta \)-Hydroxy butyric acid, \( \beta \)-oxo butyric acid, acetone as representatives of ketone bodies, their biological and diagnostic significance (visual tests on the acetone).
33. Salicylic acid, acetylsalicylic acid.
34. Properties of fatty acids. Saturated and unsaturated fatty acids.
36. Phospholipids as amphiphilic molecules.
39. Ring-chain tautomerism of fructose. Furanoses and pyranoses; \( \alpha \)- and \( \beta \)-anomers.
40. Structure and tautomeric forms of important representatives of pentoses (ribose and deoxyribose). Their biological role.
41. Nucleophilic substitution at the anomeric centre in the cyclic forms of mono-
42. Oxidation of monosaccharides. Biological role of glycuronic acids.
43. Ascorbic acid as water soluble antioxidant.
44. Reducing disaccharides (maltose, lactose, cellobiose). Structure, ring-chain
 tautomerism.
Role of oligosaccharides of lactose group in the nonpathogenic intestinal flora neces-
sary for normal digestion. Lactulose.
46. Sucrose as representative of nonreducing disaccharides (the Haworth formula).
Hydrolysis of sucrose. Invert sugar.
47. Starch. Structure (amylose and amyllopectin), properties, hydrolysis reactions.
Biological role.
48. Cellulose. Structure, properties, application, role in nutrition.
49. Glycogen is reserve homopolysaccharide of animals and human (the Haworth
structure). Biological significance of branched structure of glycogen.
50. Dextran as representative of bacterial origin homopolysaccharides. The Ha-
worth structure. Partial hydrolysis products of dextran and their medical application.
51. Proteinogenic amino acids. Structure, nomenclature, acid-basic properties, bi-
polar structure. Stereoisomerism of natural α-amino acids with one and two chiral
centres.
52. Biologically important reactions of α-amino acids. Deamination reactions (oxi-
dative and non-oxidative). Hydroxylation reactions (phenylalanine – tyrosine, trypto-
phane – 5-hydroxytryptophane).
53. Decarboxylation reaction of α-amino acids – way to formation of biogenic
amines and bioregulators (colamine, histamine, γ-amino butyric acid).
55. Representatives of peptides and their biological significance (glutathione, neu-
ropetides, insulin).
56. Proteins. Organization levels of protein molecules and types of interactions in the stabilization. Primary, secondary ($\alpha$-helix and $\beta$-conformation) and tertiary protein structures.

57. Pyridine and purine heterocyclic bases, their aromaticity as reason of high stability.


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

61. Classification of polymers.

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

63. Mechanism free radicae polymerization of acrylic acid ester’s.


65. Modern restore materials photo- and chemical hardening.


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

68. Impressional materials on the basis of alginate acids.
<table>
<thead>
<tr>
<th>Labwork #</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Classification and nomenclature of organic compounds. Spatial structure of organic molecules. Configuration and conformations</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Stereoisomerism, its role for biological activity demonstration</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Chemical bond structure and atom effects in the organic molecules</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>Acid-base properties of organic compounds. Oxidation reactions</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>Classification and mechanisms of reactions in organic chemistry. Reactions of radical substitution. Electrophilic addition reactions. Electrophilic substitution reactions</td>
<td>23</td>
</tr>
<tr>
<td>6</td>
<td>Biologically important reactions reaction of aldehydes and ketones</td>
<td>28</td>
</tr>
<tr>
<td>7</td>
<td>Carboxylic acid and their derivatives</td>
<td>33</td>
</tr>
<tr>
<td>8</td>
<td>Concluding test  ‘Theoretical fundamentals of basic classes of organic compound structure and reactivity”</td>
<td>37</td>
</tr>
<tr>
<td>9</td>
<td>Heterofunctional compounds of aliphatic, benzene and heterocyclic series. Metabolites and bioregulators</td>
<td>39</td>
</tr>
<tr>
<td>10</td>
<td>Lipids. Structure, properties. Lipid peroxidation.</td>
<td>44</td>
</tr>
<tr>
<td>11</td>
<td>Carbohydrates. Monosaccharides</td>
<td>49</td>
</tr>
<tr>
<td>12</td>
<td>Oligo- and polysaccharides</td>
<td>56</td>
</tr>
<tr>
<td>13</td>
<td>Structure and reactivity of amino acids acting as heterofunctional compounds</td>
<td>61</td>
</tr>
<tr>
<td>14</td>
<td>Peptides. their structure, reactivity and importance. The levels of protein organization</td>
<td>66</td>
</tr>
<tr>
<td>16</td>
<td>Concluding test “Biopolimers and their structural componens”</td>
<td>76</td>
</tr>
<tr>
<td>17</td>
<td>Polymer materials, using in stomatology</td>
<td>78</td>
</tr>
<tr>
<td>18</td>
<td>Concluding test</td>
<td>82</td>
</tr>
</tbody>
</table>