MINISTRY OF PUBLIC HEALTH
ZAPOROZHYE STATE MEDICAL UNIVERSITY

DEPARTMENT OF ORGANIC AND BIOORGANIC CHEMISTRY

GUIDELINES AND LABORATORY PROTOCOLS OF BIOORGANIC CHEMISTRY

for medical students
specialty 7.110101 "medicine"

1st-year student of ___.group

_____

name

Zaporozhye
2013

GUIDELINES AND LABORATORY PROTOCOLS OF BIOORGANIC CHEMISTRY FOR MEDICAL STUDENTS OF SPECIALTY 7.110101 "MEDICINE"

Authors board:

Kovalenko S.I. – Doctor, professor.
Priymenko B.A. – Doctor, professor.
Gnatov N.I. – PhD., associate professor.
Kandybey K.I. - PhD., associate professor.
Voskoboynik A.Yu. – PhD., assistant professor.
Antipenko L.N. – PhD., assistant professor.
Kazunin M.S. – Assistant.
Vasylyev D.A. – Senior laboratory assistant.

Under the general editorship of the Head of Organic and Bioorganic Chemistry Department, doctor, professor **Kovalenko S.I.**

Reviewers:

The Head of the Biological Chemistry and Laboratory Diagnosis Department, doctor, associate professor **Alexandrova. E.V.**

The Head of the Department of Toxicology and Inorganic Chemistry, doctor, professor **Panasenko A.I.**

PLAN OF
THE LABORATORY AND PRACTICAL TRAINING OF
BIOORGANIC CHEMISTRY

№	Theme	Hours
1	The spatial structure of organic molecules. Principles of nomenclature.	2
2	The electronic structure of the chemical bonds and mutual influence of atoms in organic molecules.	2
3	Investigation of the reactivity of hydrocarbons.	2
4	Investigation of the acidic and basic properties of organic compounds. Oxidation reactions. Nucleophilic substitution at the saturated carbon atom.	2
5	**Practical skills and solution of situational problems of "Theoretical basis of the structure and reactivity of organic compounds".**	**2**
6	Biologically important reactions of carbonyl compounds.	2
7	Investigation of the chemical properties of the carboxylic acids and their functional derivatives. Lipids.	2
8	The heterofunctional organic compounds involved in the life processes of living organisms.	2
9	The biologically active heterofunctional derivatives of benzene and heterocyclic series.	2
10	**Practical skills and solution of situational problems of "Heterofunctional organic compounds, metabolites, and precursors of the most important groups of drugs. Carboxylic acids and their functional derivatives. Lipids»**	**2**
11	Investigation of the monosaccharides chemical properties.	2
12	Investigation of the structure, chemical properties and biological functions of the disaccharides and polysaccharides.	2
13	The α-amino acids, peptides and proteins.	2
14	The primary and secondary structure of the nucleic acids. The nucleosides and nucleotides.	2
15	**Final module test: “Biologically important classes of bioorganic compounds. Biopolymers and their structural components”**	**2**
	TOTAL	**30**

EVALUATION CRITERIA OF STUDENT ACADEMIC PROGRESS

Every lesson student gets mark: "excellent" - 5 points, "good" - 4 points, "satisfactory" - 3 points, "unsatisfactory" - 0 points.

The student is allowed to take the final module control if he scores no less than 42 mark points (14 × 5 = 42) for 14 lessons, which corresponds to 60 rate points.

The final module is counted finished if the student scores no less than 50 rate points.

Characteristics	The minimum score	The maximum score
Total score for submodules.	**60**	**110**
Individual student self-work: Preparation the scientific literature review on the selected topic.	**–**	**10**
The score for final module test.	**50**	**80**
TOTAL	**110**	**200**

CHEMISTRY LABORATORY SAFETY RULES

One often forgets that chemistry is a potentially dangerous enterprise; a careless attitude often results in disastrous consequences. Therefore, extreme caution should be exercised at all time, especially when one handles chemical reactions that are exothermic or when dealing with toxic, reactive chemicals, carcinogens using any glassware.

You are expected to learn and adhere to the following general safety guidelines to ensure a safe laboratory environment both for yourself and people you are working with. Additional safety precautions will be announced in class prior to experiments if there is potential danger. Students who are failed to follow all the safety rules have to leave the laboratory and obtain 0 points for the lesson.

PERSONAL PROTECTION

- Laboratory coats and caps provide an important barrier for your clothes and, more important, your skin from chemicals. The laboratory coat should fit comfortably, have long sleeves, and should be clean.
- Laboratory gloves are an essential part of safe laboratory practice and must be worn while handling chemicals.
- Closed toe shoes and long pants must be worn in the lab. Sandals and shorts are not allowed.
- The coats, backpacks, etc., should not be left on the lab benches and table. Beware that lab chemicals can destroy personal possessions.
- Eating, drinking, and smoking are strictly prohibited in the laboratory.
- The most common forms of eye protection include safety glasses (with side shields), goggles, and face shields. Prescription eye glasses are acceptable provided that the lenses are impact resistant and they are equipped with side shields. Contact lenses are not allowed. Even when worn under the safety goggles, various fumes may accumulate under the lens and cause serious injuries or blindness.
- Long hair must be tied back when using open flames.
- Learn where the safety and first-aid equipment is located. This includes fire extinguishers, fire blankets, and eye-wash stations.
- Always wash your hands before leaving the lab.
- Inform the teacher immediately in case of an accident.

PROPER HANDLING OF CHEMICALS AND EQUIPMENT

- Consider all chemicals to be hazardous unless you are instructed otherwise. Material Safety Data Sheets (MSDS) are available in lab for all chemicals in

use. These will inform you of any hazards and precautions of which you should be aware.

- Know what chemicals you are use. Carefully read the label twice before taking anything from a bottle. Learn how to interpret hazardous materials labels.
- Never taste chemicals.
- No unauthorized experiments are to be performed. Every experimental procedure must be consulted with your teacher.
- Never directly smell the source of any vapor or gas. You should waft a small sample of scent air to your nose with cupped hand. Do not inhale these vapors but detect if the odor is observed.
- The excess of reagents are never to be returned to their bottles. If you take too much, dispose of the excess.
- Many common reagents, for example, alcohols and acetone, are highly flammable. Do not use them near working burner.
- Never leave the burners unattended. Turn them off whenever you leave your workstation. Be sure that the gas is shut off at the bench rack when you leave the lab.
- Never point a test tube or any vessel that you are heating at yourself or your neighbor - it may erupt like a geyser.
- Always pour acids into water. If you pour water into acid, the appearing exothermic reaction causes water transformation into steam with powerful acid splattering.
- Clean up all broken glassware immediately and dispose of it properly.
- Contact the stockroom for special bottle for mercury spills.

FIRST AID IN THE LABORATORY

THE OCCURRENCE OF AN ACCIDENT OF ANY KIND IN THE LABORATORY SHOULD BE REPORTED IMMEDIATELY TO YOUR TEACHER, EVEN IF IT SEEMS RELATIVELY MINOR!

Thermal burns. In the case of a burn, apply cold water and/or ice immediately to the burned area until the pain subsides. Wrap the burned area to protect from infection. It is best to avoid oils and ointments in first aid treatment since these frequently complicate the physician's job.

Chemical burns. Areas of the skin with which corrosive chemicals have come in contact should be immediately and thoroughly washed with soap and warm

water. Acid or minor bromine burns may then be treated with 5% sodium carbonate solution. Alkali burns can be washed with 5% acetic acid solution or saturated boric acid solution. If the burns are minor, apply burn ointment; for treatment of more serious burns, see a physician. If chemicals, in particular corrosive or hot reagents, come in contact with the eyes, immediately flood the eyes with water from the nearest outlet. A specially designed eyewash fountain is useful if available in the laboratory. Do not touch the eye. The eyelid as well as the eyeball should be washed with water for several minutes. In all instances where sensitive eye tissue is involved in such an accident, consult an ophthalmologist as soon as possible.

Fire. Your first consideration is to remove yourself from any danger, not to extinguish the fire. If *it is possible to do so without endangering yourself*, turn off any burners and remove containers of flammable solvents from the immediate area to prevent the fire from spreading. For the most effective use of a fire extinguisher, direct its nozzle toward the base of the flames. If your clothing is on fire, DO NOT RUN; rapid movement will only fan the flames. Roll on the floor to smother the fire and to help keep the flames away from your head. Your neighbors can help to extinguish the flames by using fire blankets, laboratory coats, or other items that are immediately available. Do not hestitate to aid your neighbor if he or she is involved in such an emergency; a few seconds delay may result in serious injury. If burns are minor, apply a burn ointment. In the case of serious burns, do not apply any ointment; seek professional medical treatment at once.

Minor bleeding. Allow the blood to flow a few moments. Flush the wound thoroughly with water. Apply an antiseptic and bandage to the wound to prevent contamination. Minor cuts may be treated by ordinary first-aid procedures; seek professional medical attention for serious cuts. If severe bleeding indicates that an artery has been severed, attempt to stop the bleeding with compresses and pressure; a tourniquet should be applied only by those who have received first-aid training. Arrange for emergency room treatment at once. A person who is injured severely enough to require a physician’s treatment should be accompanied to the doctor’s office, or infirmary, even if he or she claims to be all right. Persons in shock, particularly after suffering burns, are often more seriously injured than they appear to be.

Toxic fumes. If there are complaints of a headache or dizziness in the laboratory in which the odors of such toxic gases are, you should go immediately to a fresh air outside.

Read and Agree with the Safety Rules _____

Name Signature

Lesson №1

Subject: THE SPATIAL STRUCTURE OF ORGANIC MOLECULES. PRINCIPLES OF NOMENCLATURE

Subject motivation: The rapid development of Pure and Applied Organic Chemistry has created serious problems for the development of the huge flow of new information and theoretical understanding of factual material. In this regard, the assimilation of chemical language, nomenclature rules, the formation of ideas about the unity of structure, configuration, conformation of organic molecules are of much importance for the successful study and exchange of chemical information, understanding the link "structure - biological activity."

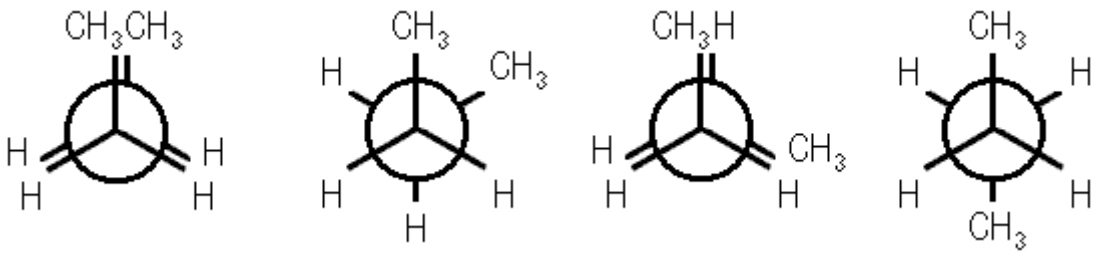
Learning goal: To study the basic principles of chemical nomenclature, classification, the spatial structure of organic compounds, and to determine the class of drugs by the main functional group.

THEORETICAL QUESTIONS

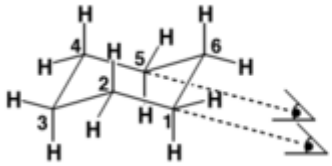
1. The theory of the chemical structure of organic compounds by A.M. Butlerov. The functional groups of organic compounds.
2. The spatial structure of methane, ethylene, acetylene. Representation of the structure in three-dimensional, ball-and-stick or space-filling model, and expanded structural formulas.
3. The International Union of Pure and Applied Chemistry (IUPAC) nomenclature of organic compounds.
4. The conformations of ethane and their potential energies. The Newman projections: eclipsed (30°) and staggered (60°, anti and gauche).
5. The cyclohexane and methylcyclohexane conformations.

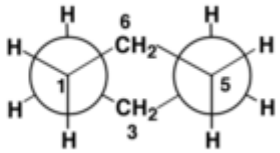
CHALLENGE QUESTIONS

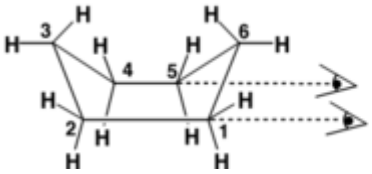
1. How is the tetrahedral shape maintained in a molecule with two carbon atoms?
2. Name the Newman projections of the butane.

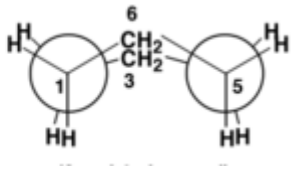


3. Name and choose the most preferred conformation of the cyclohexane.

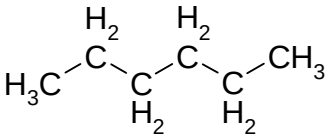


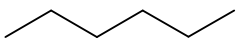


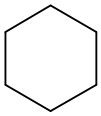


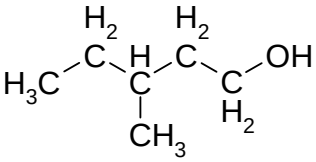


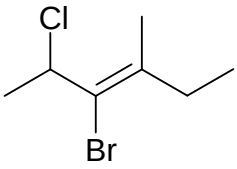
Give the IUPAC name for each of the following substances:

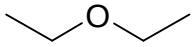


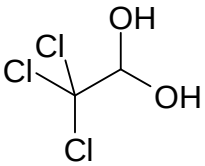


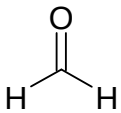


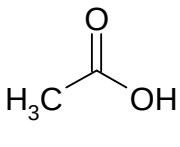


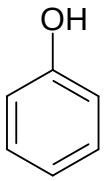


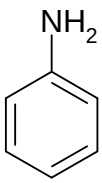


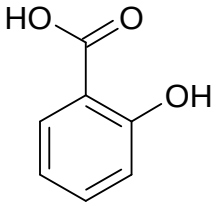


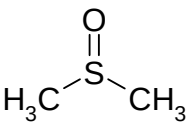


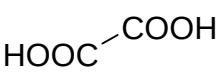


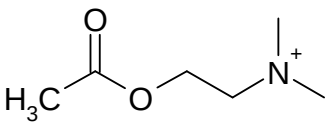










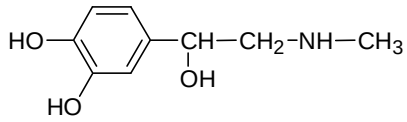


ADDITIONAL PROBLEMS

1. Indicate which class of organic compounds aniline can be referred:

A. primary
B. aliphatic amine
C. primary aromatic amine
D. secondary aromatic amine
E. tertiary aromatic amine

2. Specify the functional group which is absent in the molecule of adrenaline:

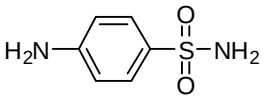


A. the primary alcoholic hydroxyl
B. secondary alcoholic hydroxyl
C. secondary amine
D. phenolic hydroxyl
E. aromatic ring

3. Specify the number of asymmetric carbon atoms in the molecule of noradrenaline:

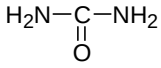
A. 0
B. 1
C. 2
D. 3
E. 4

4. Determine which class of organic compounds streptocid is referred to:



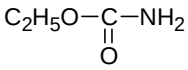
A. aromatic amine
B. carbocyclic amine
C. aromatic acid
D. aromatic sulfonic acid
E. amide of the aromatic sulfonic acid

5. Indicate which class of organic compounds urea can be referred:



A. amino acid
B. diamide of the carboxylic acid
C. ketone
D. aldehyde
E. diamino carboxylic acid

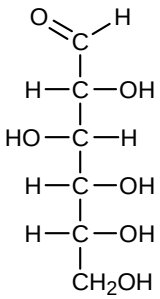
6. Specify the senior functional group in the molecule of urethane:



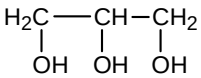
A. amino group
B. ketone group
C. amide group
D. ester group
E. ether group

7. Specify the number of asymmetric carbon atoms in the aldehyde form of glucose:

A. 1
B. 2
C. 3
D. 4
E. 5



8. Glycerin is triatomic alcohol, which is the part of fats. Specify it's number of asymmetric carbon atoms (chiral centers):



A. 0
B. 1
C. 2
D. 3
E. 4

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 74–92, 51-54, 74-92, 94-101, 108-129.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 323–340, 356-370.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 283–307.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 17-25, 29-41, 61-91.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 106–111, 290-320.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 93–108, 111-125.
7. Lectures.

Lesson №2

Subject: THE ELECTRONIC STRUCTURE OF CHEMICAL BONDS AND MUTUAL INFLUENCE OF ATOMS IN ORGANIC MOLECULES

Subject motivation: The knowledge about electronic structure of atomic orbitals and their hybridization, the covalent bond, the conjugation, the electronic effects, their mutual influence is very important part of the organic chemistry study, that helps to understand reactivity of the biologically important organic compounds, qualitatively compare thermodynamic stability of the compounds, to interpret the mechanisms of biochemical reactions.

Learning goal: To form knowledge about the structure of chemical bonds, electron effects of substituents; the structure of molecules with conjugated bonds as a thermodynamically stable systems, which are used in the construction of biologically important compounds.

THEORETICAL QUESTIONS

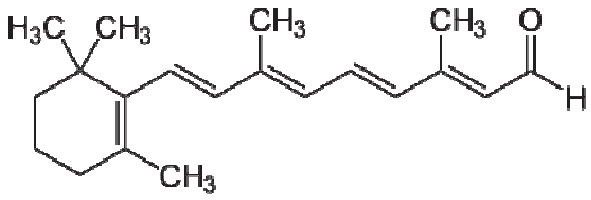
1. The bonding in organic chemistry.
2. The sp^3, sp^2, sp hybrid orbitals.
3. The hydrogen-bonding.
4. Conjugated compounds, conjugation energy, $\pi - \pi$ and π-p conjugation.
5. Polar covalent bonds. Inductive and resonance effects. Substituent's effects in aromatic rings.

CHALLENGE QUESTIONS

1. Determine the hybridization of carbon atoms in the molecule of the following compounds: 1-penten-3-in, pentadiene-2,3, naphthalene, pyrrole, furan, pyridine.

2. Compare the electron density in the molecule of heptadiene-2,4-oic acid and butadiene-1,3.

3. Retinal, also called retinaldehyde or vitamin A aldehyde, is one of the many forms of vitamin A., is a polyene chromophore, and bound to proteins called opsins, is the chemical basis of animal vision. Mark the conjugate chain, and specify the form and sign the electronic effects of the aldehyde group.



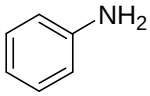
ADDITIONAL PROBLEMS

1. Determine the influence of the chlorine atom in the molecule of vinyl chloride:

$H_2C=CH-Cl$

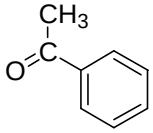
A. σ-electrons acceptor
B. π-electrons acceptor
C. σ- and π-electrons acceptor
D. σ- and π-electrons donor
E. σ-electrons donor and π-electrons acceptor

2. Specify the type and charge of the electronic effects of the nitrogen atom in the molecule of the aniline



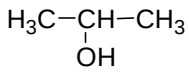
A. -I
B. -I; -M
C. -I; +M
D. +I
E. +I; +M

3. Specify the type and charge of the electronic effects of the oxygen atom of the carbonyl group in the molecule of acetophenone:



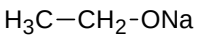
A. -I
B. -I; -M
C. -I; +M
D. +I
E. +I; +M

4. Specify the type and charge of the electronic effect of the oxygen in the molecule of 2-propanol:



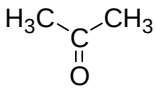
A. -I
B. +I
C. -M
D. +M
E. -I; +M

5. Specify the type and charge of the electronic effect of the oxygen atom in a molecule of sodium ethoxide:



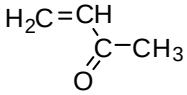
A. -I
B. +I
C. -M
D. +M
E. -I; +M

6. Specify the type and charge of the electronic effect of the oxygen atom in a molecule of acetone:



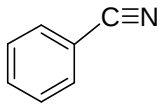
A. -I
B. -M
C. +I
D. +M
E. -I; -M

7. Specify the type and charge of the electronic effects of the oxygen atom in the molecule butenone:



A. +I
B. +M
C. -I
D. -I; +M
E. -I; -M

8. Specify the type and charge of the electronic effect of the nitrogen atom in the molecule of benzonitrile:



A. -I; -M
B. -I
C. -I; +M
D. -M
E. +M

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 1-21, 34-48, 61-62, 580-591.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 95-97, 340-343, 421, 510.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 69, 86-87, 112-113, 94-98, 356, 537.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 7-11, 25-27, 41-53.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 75-79, 81-84, 153-155, 383.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 77-79, 103-110, 478.
7. Lectures.

Lesson №3

Subject: INVESTIGATION OF THE REACTIVITY OF HYDROCARBONS

Subject motivation: The hydrocarbons are the most broadly used organic known compounds. The greatest amounts of hydrocarbons are used as fuel for combustion, particularly in heating and motor fuel applications. In medicine the mineral hydrocarbons used as adjutants for vaccines, bases for ointments, emollients, ingredients in antiparasiticides, and slow release devices.

Learning goal: To gain skills to predict the ability of hydrocarbons to polar or nonpolar reactions due to electronic structure of the carbon atoms and electronic effects of the substituents or heteroatoms introduced into the aromatic ring.

THEORETICAL QUESTIONS

1. Radical substitution reactions (S_R) of alkanes and cycloalkanes.
2. Electrophilic addition reactions (A_E) of alkenes, alkadienes and alkynes.
3. The structure of arenes.
4. Electrophilic substitution reactions (S_E) of arenes and heteroaromatic compounds.
5. Oxidation of hydrocarbons.

LABORATORY PRACTICE

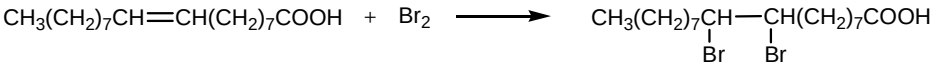
Protocol № 3 Date_____

Experiment № 1

Bromination of unsaturated compounds

Place 3-4 drops of oleic acid in the test tube, and dissolve it in 1 ml of carbon tetrachloride (CCl_4). Then add 4-5 drops of 5% solution of bromine in carbon tetrachloride. Note the observed changes.

The chemistry of the reaction:



Observations:

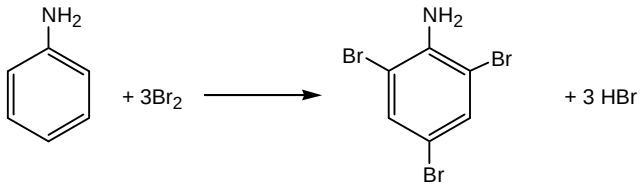
Conclusions:

Experiment № 2

The formation of tribromaniline

Place one drop of aniline and 5-6 drops of water in the test tube, shake well and add a few drops of bromine water until a white precipitate of 2,4,6-tribromaniline is formed. The bromination proceeds quantitatively. And this reaction is used in pharmaceutical analysis for the discovery of aniline and some of its derivatives.

The chemistry of the reaction:



Observations:

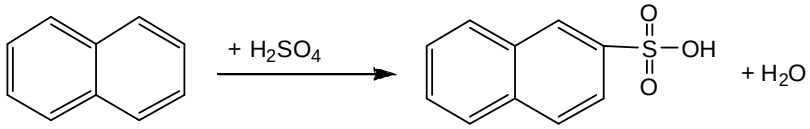
Conclusions:

Experiment № 3

Sulfonation of naphthalene.

Place a bit of naphthalene in a dry test tube. Heat the tube till the naphthalene is melt. Then let it cool and add 10 drops of concentrated sulfuric acid (**you should add it in a fume hood**!). Gently heat the test tube in the burner flame, shaking constantly until formation of the completely homogeneous mixture. Then let the mixture cool, and add 10 drops of water. Heat the mixture slightly again. Crystals obtained after the cooling are the *β*-naphthalenesulfonic acid.

The chemistry of the reaction:



Observations:

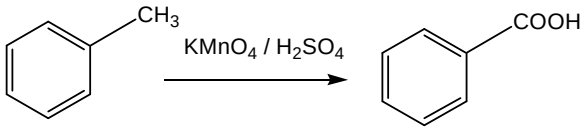
Conclusions:

Experiment № 4

Oxidation of the side chains of benzene homologues.

Place 5 drops of water, 3 drops of 2% potassium permanganate solution, and 1 drop of 10% sulfuric acid solution in the test tube. Add 1-2 drops of toluene and vigorously shake the tube. Then heat the mixture in the burner flame. Note how the solution changes its color. Regardless of its length, each side chain of benzene eventually forms a carboxyl group in the result of oxidation. Thus, using the oxidation reaction, it is possible to establish the presence of side chains in aromatic hydrocarbons.

The chemistry of the reaction:



Observations:

Conclusions:

CHALLENGE QUESTIONS

1. Write the reaction of acetylene hydration (Kucherov's reaction). Name the product of the reaction.
2. When ethylbenzene is brominated the substitution could happen as in the aromatic ring so in the side chain. Write the bromination of ethylbenzene in each of these directions and name the reaction products. Specify the conditions and mechanisms of these reactions.
3. Write the formulas of furan, thiophene, pyrrol, pyrazole, imidazole, pyridine, pyrimidine, purine. Number the atoms in molecules. Determine the criteria of aromaticity of these compounds.

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 184–200, 237–253, 264–276, 284–287, 296–297, 316–322, 372–397.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 371-372, 392-398, 402-411, 428-430.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 332-336, 340-344, 362-375.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 97-99, 204-262, 269-278, 800-873.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 324-328, 346–355, 357-367.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 183–184, 324-326, 322-323.
7. Lectures.

Lesson 4

Subject: INVESTIGATION OF ACIDIC AND BASIC PROPERTIES OF ORGANIC COMPOUNDS. OXIDATION REACTIONS. NUCLEOPHILIC SUBSTITUTION AT THE SATURATED CARBON ATOM

Subject motivation: The acidity and basicity of organic compounds are among the fundamental concepts, which are necessary for understanding bioorganic chemistry as well as other subjects. Knowledge of these properties are used to correctly predict the reaction mechanism, to understand the acid and base catalysis, to assess the compatibility of drugs, etc.

Learning goal: To form the knowledge of organic compounds acidity and basicity, their relation to oxidation as the most important properties that lead to the many important chemical reactions in living organisms.

THEORETICAL QUESTIONS

1. Bronsted-Lowry acids and bases. Nucleophilicity of the substances.
2. The influence of electronic and structural factors at the strength of acids and bases. “Structure – properties” relationship.
3. The influence of molecular hydrogen bonding at the physical properties of compounds.
4. The oxidation reactions. Oxidizing agents.
5. The nucleophilic substitution reactions (S_N) at the saturated carbon atom.
6. Elimination reactions (E).

LABORATORY PRACTICE

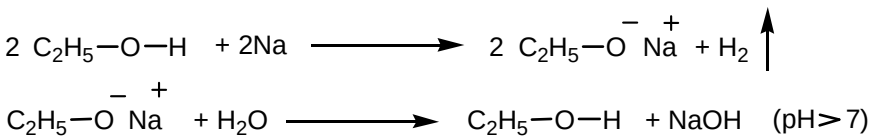
Protocol№ 4 Date _____

Experiment № 1

Preparation of sodium ethoxide and its hydrolysis

Place 3 drops of absolute ethanol in a dry test tube. Squeeze out kerosene from a little piece of sodium (about the size of a match head) with the filter paper. Put sodium in the tube with ethanol. Collect the released hydrogen, closing the tube with a stopper. Then remove the stopper and carefully bring the tube to the burner flame. A mixture of hydrogen and air burns with a characteristic "barking" sound. Dissolve the white precipitate of sodium ethoxide in 2-4 drops of ethanol and add 1 drop of 1% alcoholic solution of phenolphthalein. Add to the tube 1-2 drops of water. Explain the appearance of the crimson color.

The chemistry of the reaction:



Observations:

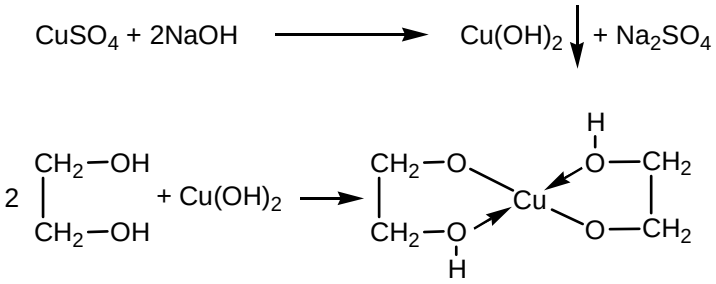
Conclusions:

Experiment № 2

Preparation of the copper(II)-ethyleneglycol.

Add 2 drops of 2% solution of copper(II) sulphate ($CuSO_4$) and 2 drops of 10% solution of sodium hydroxide in the test tube. Note the color of the precipitant. Add to the latter tube a drop of ethylene glycol and shake it. Note the color of the solution. This reaction is used to detect the organic compounds containing the diol fragment (two hydroxyl groups on adjacent carbon atoms) in its structure.

The chemistry of the reaction:



Observations:

Conclusions:

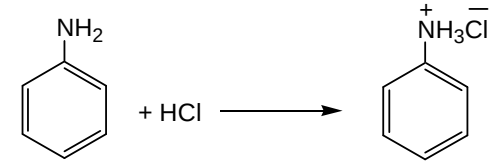
Experiment № 3

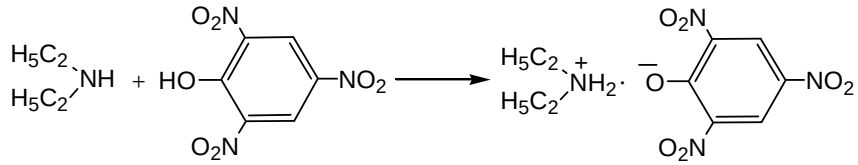
Basicity of aliphatic and aromatic amines.

1. Add 2 drops of water in the two test tubes. Then in the first test tube place 1 drop of aniline ($C_6H_5NH_2$), and in the second - a drop of diethylamine $(C_2H_5)_2NH$ and shake it. Compare the solubility of these amines in water. Put 1 drop of these mixtures on a strip of universal indicator paper. Determine its pH.

2. Add 1 drop of 10% solution of hydrochloric acid to the emulsion of aniline in water. A clear solution is formed. Add 3 drops of a saturated aqueous solution of picric acid to a solution of diethylamine and mix. Put the tube into a glass of cold water. The precipitate of diethylamine picrate is formed in a few minutes.

The chemistry of the reaction:





Observations:

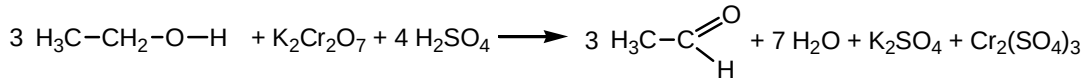
Conclusions:

Experiment № 4

The oxidation of ethyl alcohol by chromic mixture.

Place 2 drops of ethanol, 1 drop of 10% solution of sulfuric acid (H_2SO_4) and 2 drops of 10% solution of potassium dichromate ($K_2Cr_2O_7$) in the test tube. Heat the resulting orange solution in the burner flame till the color changes. Note the change of the color. After a few seconds, the solution becomes blue-green (the color of the resulting chromium (III) sulphate, $Cr_2(SO_4)_3$). At the same time one can smell characteristic odor of acetaldehyde (the smell of rotten apples).

The chemistry of the reaction:



Observations:

Conclusions:

CHALLENGE QUESTIONS

1. Chlorobutanol, or 1,1,1-trichloro-2-methyl-propan-2-ol, is a chemical preservative, sedative hypnotic and weak local anaesthetic similar in nature to chloral hydrate. Compare the acidity of chlorobutanol and n-propyl alcohol. Rate the attitude of these alcohols to oxidation. Write the reactions.

What classes of organic compounds are obtained by the interaction of ethyl bromide with the following reagents:

a) NH_3; b) $C_2H_5NH_2$; c) NaCN; d) C_2H_5ONa

2. Determine the structure of compounds A, B, C, D, and name them.

а) $CH_3\text{-}CH_2\text{-}CH{=}CH_2 \xrightarrow{H_2O,\ H^+} A \xrightarrow{H_2SO_4} B \xrightarrow{H_2O,\ O} C \xrightarrow{Cu(OH)_2} D$

б) $CH_3\text{-}CH_2\text{-}CH_2\text{-}Br \xrightarrow{H_2O,\ KOH} A \xrightarrow{H_2SO_4} B \xrightarrow{H_2O,\ H^+} C \xrightarrow{[O]} D$

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 48-59, 360-361, 372-409, 534-550.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 258-273.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 222-233, 362-365.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 150-156, 327-372, 383-384.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 153-155, 236-237.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 288-290, 322-323.
7. Lectures.

Lesson №5

PRACTICAL SKILLS AND SOLUTION OF SITUATIONAL PROBLEMS OF "THEORETICAL BASIS OF THE STRUCTURE AND REACTIVITY OF ORGANIC COMPOUNDS"

Subject motivation: Knowledge of the nomenclature of organic compounds and their conformational features and configuration, the mutual influence of atoms in the molecules is critical in predicting organic substances physico-chemical properties and reactivity. It contributes the understanding of the radical,

electrophilic mechanisms of reactions *in vivo* and *in vitro*, as well as to form the conception about the pharmacological properties of drugs.

Learning goal: To develop knowledge about the chemical behavior of the major classes of organic compounds depending on their chemical structure.

QUESTIONS AND PROBLEMS

1. Give the definition of "conformers". Draw a Newman projections of the conformations of ethane, ethyl chloride, ethanol, and compare their energy rate. Draw the possible conformations of the open hexagonal chain. What is the reason for the formation of five- and six-membered rings?
2. Draw the "chair" conformation of cyclohexane. Mark the axial and equatorial bonds.
3. What type of stereoisomerism is characteristic for alkenes and cycloalkanes? What π-diastereomers are? Write the *cis* and *trans* isomers for fumaric and cyclohexane-1,4-dicarboxylic acids.
4. Give the electronic structure of C-C bonds in alkanes. What types of reaction mechanism are typical for alkanes? Give the scheme of polar and nonpolar covalent bond breaking. Show the electronic structure of the methyl radical.
5. What are the three steps of a radical reaction? Write bromination of propane, cyclohexane, and describe its mechanism (S_R).
6. Give the electronic structure of ethylene and butadiene-1,3. What types of reaction mechanism are typical for alkenes? What electrophilic reagents are? Write the reaction of electrophilic addition (A_E) of halogen, halides and water (with acid catalyst) to ethylene, propylene, butene-2, and butandiene-1,3. Describe the reaction mechanism.
7. Give the definition of "conjugation" and specify the A_E reactions for conjugated dienes. Could the products of the butadiene-1,3 hydrogenation exist as *cis*-or *trans*-isomers? Explain the Markovnikov's rule.
8. Write the reaction of cyclopropane bromination. Specify its mechanism.
9. Show the electronic structure of benzene. Give a definition of "conjugation energy" and "aromaticity". Specify the criteria of aromaticity (Hückel's rule) for pyrrole, furan, thiophene, imidazole, pyridine, pyrimidine, purine. Compare the energy rate for open and closed conjugation chain for 1,3,5-heptatriene and benzene.
10. Write the reactions of halogenation, sulfonation, alkylation of toluene, aniline, phenol, benzoic acid, naphthalene, furan, thiophene, pyrrole, pyridine. Specify its mechanism. Explain the activating or deactivating influence of the

substituents and heteroatoms in the aromatic rings.

11. Describe oxidation of alkanes, alkenes and arenes by potassium permanganate. Write this reaction for propylene. Why it is used to identify the double bond?

12. What is “acid” and “base” by Brønsted–Lowry.

13. Explain the amphoteric character of alcohols and phenomenon of their intermolecular association. How this phenomenon affects their boiling point and solubility?

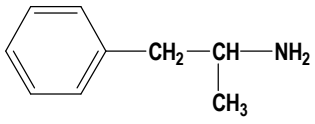
14. Compare the basicity of the next groups of compounds:

A. diethyl ether, diethylsulfide, dimethylalanin;

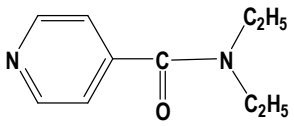
B. diethyl ether, dimethyl sulfide, dimethylalanin,

Write the hydrochloric salt for the most strong bases: What nitrogen atom goes protonation, and why?

C.

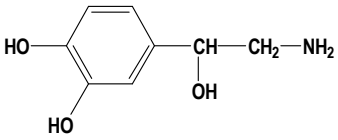


Phemanin

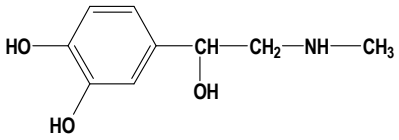


Cordiamin

D.

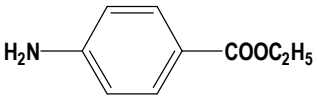


Noradrenalin

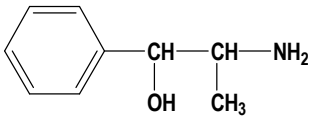


Adrenalin

E.

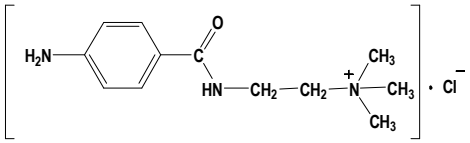


Anaesthesin



Ephedrine

F.



Novocainamide

15. Compare the acidic properties of the next groups of compounds:

A. phenol, *p*-aminophenol;

B. phenol, *p*-hydroxyphenol;

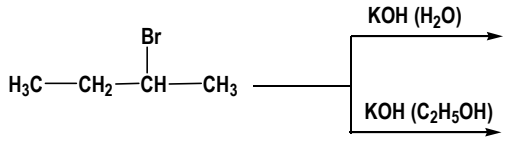
C. *n*-propyl alcohol, 2-chloropropanol-1, 2-mehylpropanol-1;

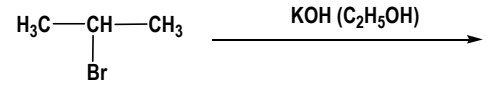
D. ethyl alcohol, ethyl mercaptan, acetic acid;

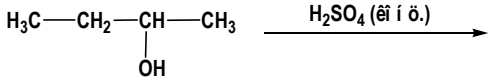
E. *n*-propyl alcohol, glycerol. What is the qualitative reaction for these

alcohols?

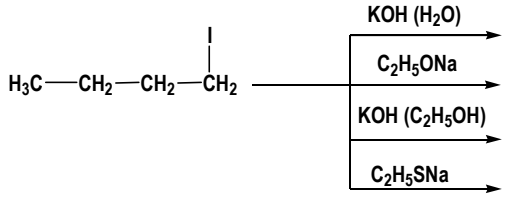
16. Why nucleophilic substitution (S_N) and elimination (E) are possible for alcohols and halogenated compounds? Write chemistry of the next reactions:

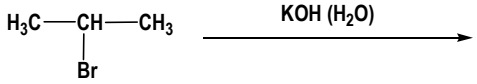
A. 

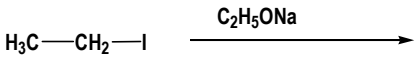
B. 

C. 

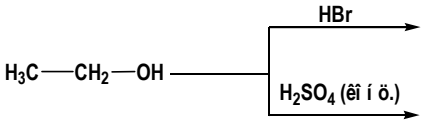
17. Write chemistry of the next reactions. Describe their mechanism. What products could exist as *cis*-, *trans* isomers?

A. 

B. 

C. 

How it is possible to check the quality of the next products?



Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 1-21, 34-62, 74–92, 51-54, 74-92, 94-101, 108-129, 184–200, 237–253, 264–276, 284–287, 296–297, 316–322, 360-361, 372–409, 534-550, 580-591.

2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 95-97, 258-273, 323-343, 356-370, 371-372, 392-398, 402-411, 421, 428-430, 510.

3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 69, 86-87, 112-113, 94-98, 222-233, 283–307, 332-336, 340-344, 362-375, 356, 537.

4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 17-25, 29-41, 61-91, 150-156, 204-262, 269-278, 327-372, 383-384, 800-873.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 75-79, 81-84, 106–111, 153-155, 236-237, 290-320, 324-328, 346–355, 357-367, 383.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 77-79, 93–110, 111-125, 183–184, 288-290, 322-326, 322-323, 478.
7. Lectures.

Lesson №6

Subject: BIOLOGICALLY IMPORTANT REACTIONS OF CARBONYL COMPOUNDS

Subject motivation: The carbonyl group is found in many biologically important compounds in plants and animals (vitamins, hormones, steroids, cardiac glycosides, carbohydrates, etc.). The high reactivity of carbonyl compounds is widely used in fine organic synthesis for obtaining the effective pharmaceuticals. Knowledge of the electronic structure characteristics and chemistry of aldehydes and ketones is the basis for a meaningful understanding and assimilation of biochemical processes, issues of pharmacokinetics, and prediction of the compatibility of drugs.

Learning goal: To generate knowledge about the basic chemical reactions of carbonyl compounds, which are important for biological systems, and be able to conduct qualitative reactions for aldehydes and ketones.

THEORETICAL QUESTIONS

1. The nomenclature of aldehydes and ketones.
2. The structure and reactivity of aldehydes and ketones.
3. The oxidation reaction.
4. Nucleophilic addition reactions (A_N): hydration, cyanohydrin formation, alcohol formation, imine and enamine formation, acetal formatio.
5. Biological reduction. Disproportionation, (dismutation, Cannizzaro reaction).
7. Haloform reaction.

LABORATORY PRACTICE

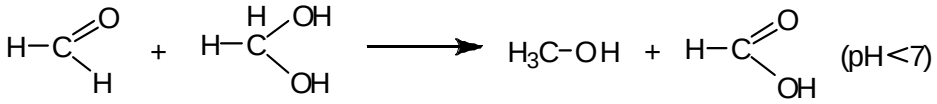
Protocol № 6 Date_____

Experiment 1

Disproportionation of formaldehyde in aqueous solution

Place the tube 2-3 drops of 40% formaldehyde solution. Add 1 drop of 0.2% solution of methyl red indicator. Redness of the solution indicates the acidic medium.

The chemistry of the reaction:



Observations:

Conclusions:

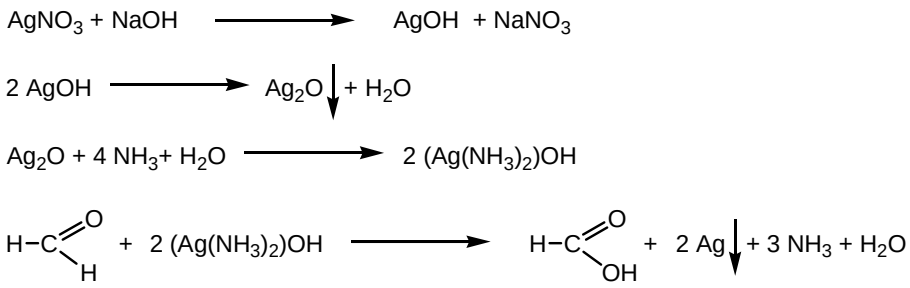
Experiment № 2

Oxidation of the formaldehyde and acetone by alkaline solutions of heavy metal oxides.

1. Oxidation by silver hydroxide (Tollens test, Silver mirror reaction)

Take two test tubes and place in every 1 drop of 5% solution of silver nitrate ($AgNO_3$) and1 drop of 10% solution of sodium hydroxide (NaOH). To the resulting brown precipitate, add dropwisely 10% aqueous ammonia solution to dissolve the precipitate. Then add 2 drops of 40% formaldehyde solution in the first test tube, and in the second - 2 drops of acetone. In the first tube the black precipitate is formed, which after the gentle heating forms the brilliant mirror coating the walls of the tube. There is no precipitate in the second test tube.

The chemistry of the reaction:



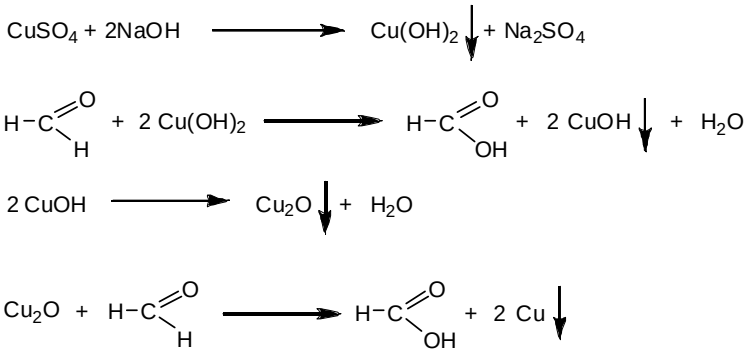
Observations:

Conclusions:

2. Oxidation by copper(II) hydroxide.

Place 5 drops of 10% sodium hydroxide solution and 5 drops of water in a test tube, add 1 drop of 2% solution of copper(II) sulphate ($CuSO_4$). Add 3 drops of 40% formaldehyde solution to the formed copper(II) hydroxide. Gently heat the tube. Firstly the precipitate becomes yellow, then - red and if the tube is clear, metallic copper ("copper mirror") appears on the test tube walls.

The chemistry of the reaction:



Observations:

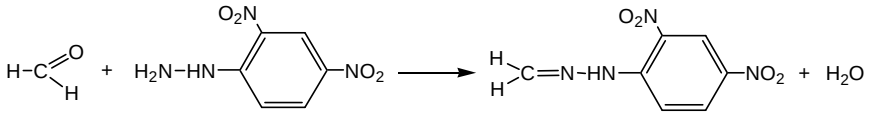
Conclusions:

Experiment № 3

The formation of formaldehyde 2,4-dinitrophenylhydrazone.

Place 5 drops of 2,4-dinitrophenylhydrazine solution in the test tube. Add 1-2 drops of 40% formaldehyde solution until a yellow precipitate formaldehyde 2,4-dinitrophenylhydrazone of is formed.

The chemistry of the reaction:



Observations:

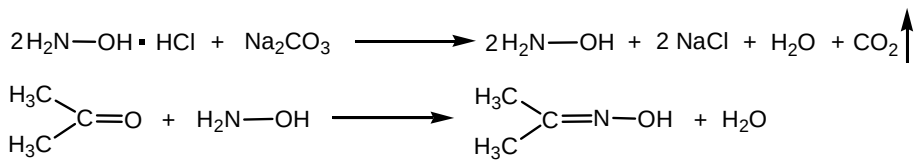
Conclusions:

Experiment № 4

Preparation of acetone's oxime.

Place a bit of hydroxylamine hydrochloride $H_2NOH*HCl$, a bit of crystalline sodium carbonate and 10-25 drops of water in the test tube. After allocating the bulk of carbon dioxide, cool the tube and add, with good stirring, 15 drops of acetone. The mixture is warmed up with formation of white crystals.

The chemistry of the reaction:



Observations:

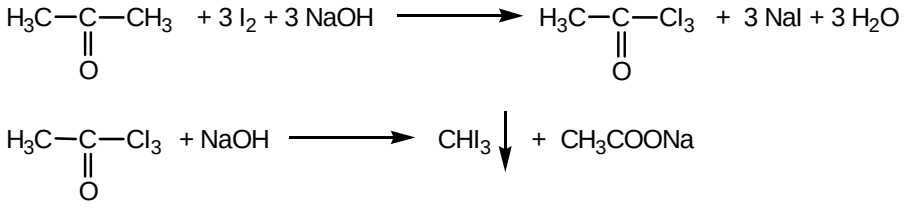
Conclusions:

Experiment № 5

Iodoform test (acetone identifying reaction).

Put 1 drop of iodine solution in potassium iodide and dropwisely 10% sodium hydroxide solution till almost bleaching in the test tube. Then add 1 drop of acetone. At low heat (heat from the hands) the yellowish-white precipitate is formed with a characteristic odor of iodoform. This reaction is used in clinical laboratories and is of practical importance for the diagnosis of diabetes.

The chemistry of the reaction:



Observations:

Conclusions:

CHALLENGE QUESTIONS

1. Describe the mechanism of acetaldehyde transformation in dimethylacetal. What is the role of an acid catalyst in the reaction?

2. The large doses of hydrazine cause the neurological disorders. Describe the chemistry of the interaction of hydrazine (NH_2-NH_2) with coenzyme pyridoxal.

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 712-776.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 473–502.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 367–372.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 566-627.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 408–433.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 373–398.
7. Lectures.

Lesson № 7

Subject: INVESTIGATION OF THE CHEMICAL PROPERTIES OF THE CARBOXYLIC ACIDS AND THEIR FUNCTIONAL DERIVATIVES. LIPIDS.

Subject motivation: The high reactivity of carboxylic acids and their functional derivatives is widely used in organic synthesis and pharmaceuticals industries. Carboxylic acids play a crucial role in the metabolic processes of plants and animals. As intermediates in the oxidation of carbohydrates, fats, proteins, they are involved in the biosynthesis of amino acids, steroids, alkaloids, saponines, etc.

Learning goal: To distinguish the peculiarities of the chemical behavior of carboxylic acids and their functional derivatives, taking place in the metabolic processes.

THEORETICAL QUESTIONS

1. The classification and nomenclature of carboxylic acids.
2. Methods of carboxylic acids preparing.
3. Electronic structure of the carboxyl group and the carboxylate anion.
4. Identification reactions of COOH group.
5. The mechanism of nucleophilic substitution.
6. Decarboxylation.
7. Halogenation.
8. The chemical properties and structure of lipids.

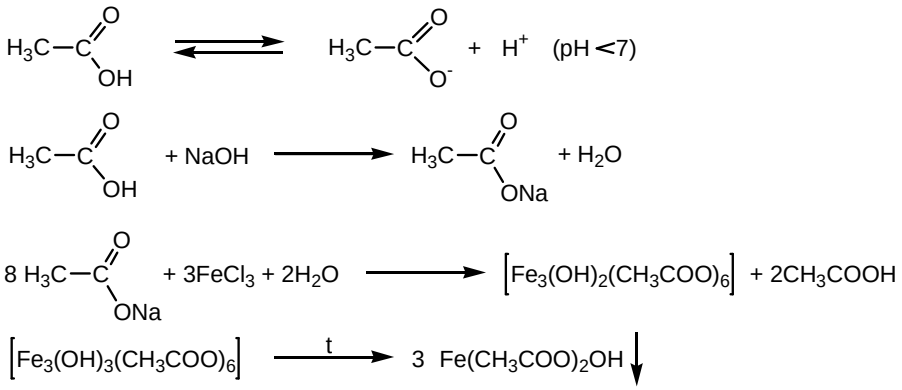
LABORATORY PRACTICE

Protocol № 7 Date_____

Identifying the acetic acid.

Place 3 drops of acetic acid and water in the test tube. Try the pH solution with litmus. Add 2-3 drops of 10% sodium hydroxide solution until complete neutralization of the acetic acid. Then add 2-3 drops of 1% solution of ferric (III) chloride ($FeCl_3$). The iron(III) acetate gives yellowish-red color. Heat the solution. The red-brown precipitate of insoluble in the water hydroxide of the iron diacetate is formed. Solution above the precipitate becomes colorless.

The chemistry of the reaction:



Observations:

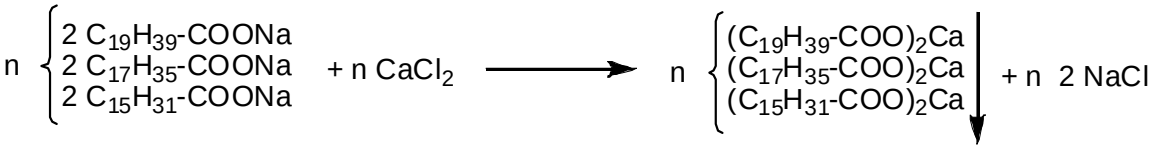
Conclusions:

Experiment № 2

Formation of insoluble fatty acids calcium salts.

Place 5 drops of the soap solution and 1 drop of calcium chloride solution ($CaCl_2$) in the test tube. Shake the tube. A white precipitate is formed.

The chemistry of the reaction:



Observations:

Conclusions:

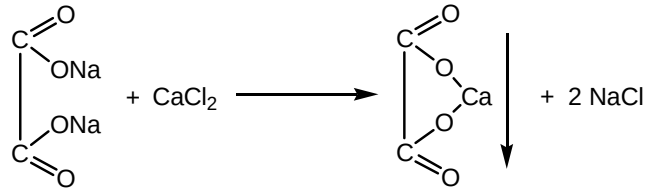
Experiment № 3

Identification calcium salt of oxalic acid.

Place a bit of oxalic acid sodium salt and 4-5 drops of water until salt is dissolved in the test tube. Take one drop of solution with pipette and put on a

glass slide. Add a drop of calcium chloride solution. The crystal precipitate is formed. This reaction is used to determine the oxalates in the urine. The crystals look like envelopes under the microscope.

The chemistry of the reaction:



Observations:

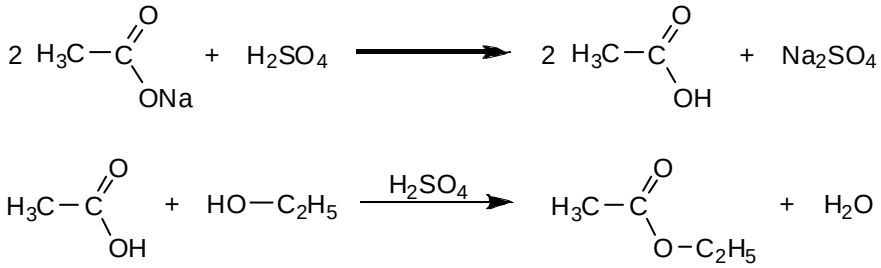
Conclusions:

Experiment № 4

Preparation of ethyl acetate.

Place a powder of anhydrous sodium acetate (height of about 2 mm) and 3 drops of ethyl alcohol in a dry test tube. Add 2 drops of concentrated sulfuric acid (**you should add it in a fume hood**!) and gently heat test tube in a burner flame (**carefully! solution could be splashed**!). After a few seconds appears the pleasant smell of ethyl acetate. The reaction is used to identify the ethanol.

The chemistry of the reaction:



Observations:

Conclusions:

CHALLENGE QUESTIONS

1. Write the chemistry of reaction to synthesize the ethyl acetate, using as a starting compound malonic acid with subsequent hydrolysis and ammonolysis.
2. Olive oil is used for injection. It is composed of oleic acid (80%) and linoleic (7%) acids. Explain the liquid consistency of olive oil (mp -6 °C). What chemical transformation can change the consistency of this oil to butter?
3. Write the formula of the phospholipid based on phosphatidic acid, esterificated by colamine (2-aminoethanol). Name this phospholipid and describe its relation to hydrolysis

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 778–792, 814-847.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 503-539.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 391-426.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 628-716.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 440-465.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 323-332.
7. Lectures.

Lesson № 8

Subject: THE HETEROFUNCTIONAL ORGANIC COMPOUNDS INVOLVED IN THE LIFE PROCESSES OF LIVING ORGANISMS

Subject motivation: The amino, hydroxy, and keto acids are structural components that play the critical role in life processes of biological systems (proteins, nucleic acids, lipids, etc.). Moreover, many organic heterofunctional compounds and their derivatives are used in medicine as drugs (acetylcholine chloride, diphenhydramine, ephedrine, calcium lactate, etc).

Learning goal: To study the stereochemistry and reactivity of amino alcohols, amino, hydroxy and keto acids, taking into account the mutual influence of different functional groups; to perform and explain their qualitative reactions.

THEORETICAL QUESTIONS

1. The amino and keto acids nomenclature and structural isomerism.
2. The spatial structure of heterofunctional acids.
3. The specific properties of heterofunctional acids (transformations of the α-, β-, γ-hydroxy and amino acids when heating).
4. The chemical properties of heterofunctional acids and their derivatives.
5. Preparation and chemical properties of biogenic amines.
6. Tautomerism of keto acids.

LABORATORY PRACTICE

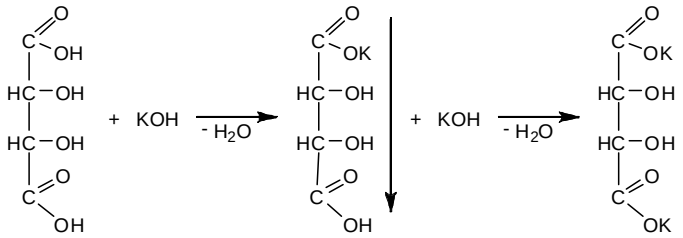
Protocol № 8 Date _____

Experiment №1

The evidence of the two carboxyl groups in tartaric acid.

Place a drop of 15% tartaric acid solution, 2 drops of 5% potassium hydroxide solution in the test tube and shake. Then white crystalline precipitate of potassium salt of tartaric acid (potassium hydrotartrate) gradually starts to form. If the precipitate does not appear, cool the tube under the cold running water and rub the inner wall of the tube with a glass rod. Add to the tube 4-5 drops of potassium hydroxide solution. The crystalline precipitate gradually dissolves, because the water-soluble potassium tartrate is formed. The latter solution of potassium tartrate, save for the next experiment.

The chemistry of the reaction:



Observations:

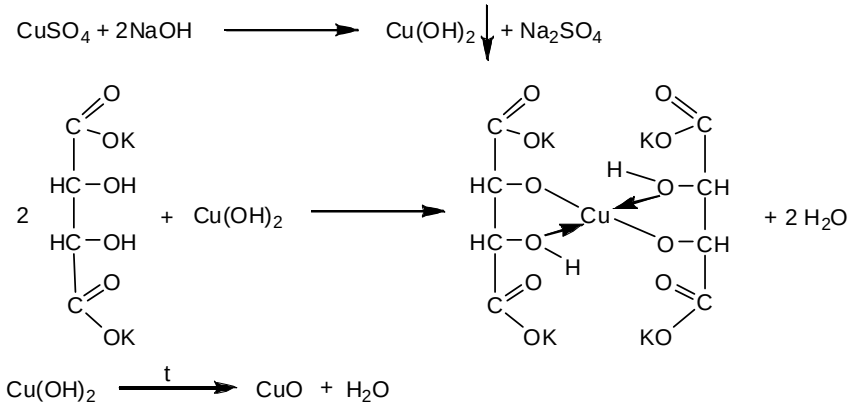
Conclusions:

Experiment № 2

The evidence of the hydroxyl groups in tartaric acid.

Place 2 drops of 2% copper(II) sulphate solution ($CuSO_4$) and 10% sodium hydroxide solution in two test tubes. The blue precipitate of copper(II) hydroxide is formed. Add potassium tartrate solution, obtained in previous studies, in the first test tube. The precipitate of copper(II) hydroxide is dissolved forming a blue solution. Heat both tubes over the burner. The color of the solution does not change in the first test tube, and in the second - a blue precipitate of copper(II) hydroxide is converted into red copper(II) oxide. The bistartratocuprate(II) complex in Fehling's solution is an oxidizing agent. In the process the copper(II) ions of the complex are reduced to copper(I) ions the presence of aldehydes and α-hydroxy-ketones. Red copper(I) oxide then precipitates out of the reaction mixture, which indicates a positive result i.e. that redox has taken place. Thus Fehling's reagent is used to detect glucose in urine, detecting diabetes.

The chemistry of the reaction:



Observations:

Conclusions:

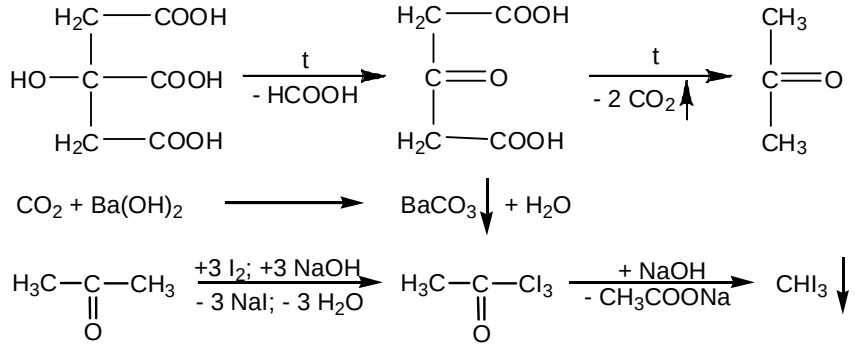
Experiment № 3

Decomposition of the citric acid.

Put a bit of citric acid and 10 drops of concentrated sulfuric acid (**you should add it in a fume hood**!) in a dry test tube equipped with a vapor pipe

and heat it. Put the end of vapor tube into the first test tube containing 5 drops of barium hydroxide solution. When the solution turns turbid, put the vapor tube into the second tube containing 2 drops of iodine solution in potassium iodide, previously decolorized by adding a few drops of 10% sodium hydroxide solution. The pale yellow precipitate of iodoform is formed in the second test tube.

The chemistry of the reaction:



Observations:

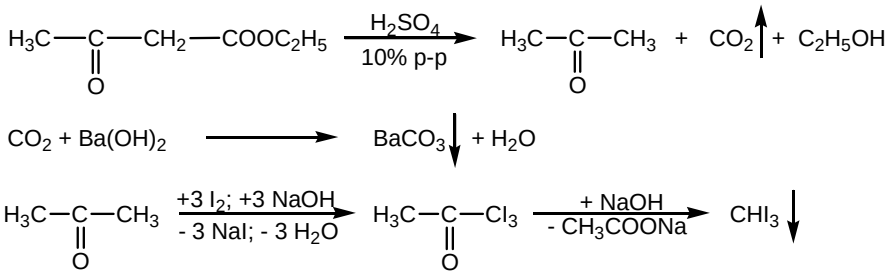
Conclusions:

Experiment№ 4

Decarboxylation of acetoacetic ester.

Put 5 drops of acetoacetic ester and 10 drops of concentrated sulfuric acid (**you should add it in a fume hood**!) in a dry test tube equipped with a vapor pipe and heat it. Put the end of vapor tube into the first test tube containing 5 drops of barium hydroxide solution. When the solution turns turbid, put the vapor tube into the second tube containing 2 drops of iodine solution in potassium iodide, previously decolorized by adding a few drops of 10% sodium hydroxide solution. The pale yellow precipitate of iodoform is formed in the second test tube.

The chemistry of the reaction:



Observations:

Conclusions:

CHALLENGE QUESTIONS

1. The lactic acid which is used in medicine is produced in a 4% aqueous solution. Why further concentration by heated evaporation of solution is not advisable?
2. Write all the possible products which are formed when mixture of α-aminopropionic and α-aminoacetic acid is heated.
3. One of the 2-amino-3-methylpentane acid stereoisomers is part of the protein. Write all the possible formulas of acid stereoisomers and name them.

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 944-979, 1053-1056.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 512-514, 540-568.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 404-419, 494-498.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 661-697.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 471-484, 598-601.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 333–337.
7. Lectures.

Lesson 9

Subject: THE BIOLOGICALLY ACTIVE HETEROFUNCTIONAL DERIVATIVES OF BENZENE AND HETEROCYCLIC SERIES

Subject motivation: Biologically active heterofunctional derivatives of benzene and heterocyclic series play an important role in the course of the natural biochemical processes of living organisms, namely energetic, structure and

plastic functions. Many of the studied compounds are drugs or precursors for their preparation.

Learning goal: To explain the chemical properties of the main representatives of drugs among benzene and heterocyclic series of biologically active compounds.

THEORETICAL QUESTIONS

1. Chemical characterization of *p*-aminophenol.
2. Functional analysis of salicylates.
3. Structure and chemical properties of the *p*-aminobenzoic acid (PABA) and its derivatives.
4. Structure and chemical properties of the sulfanilamides.
5. Structure and chemical properties of the 5-pyrazolone derivatives (amidopyrine, antipyrine, analgin). Lactim-lactam tautomerism.
6. Xanthine and its methylated derivatives.
7. The chemical properties of azine cations and their role in biological processes.
8. The chemical properties of ureides and ureidoacids.

LABORATORY PRACTICE

Protocol № 9 Date_____

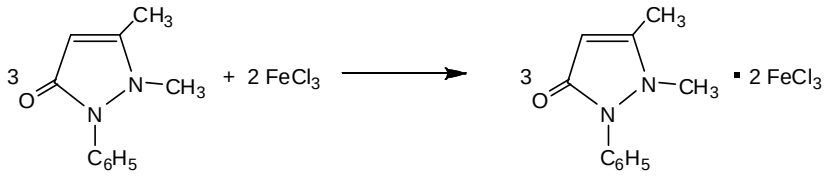
Experiment № 1

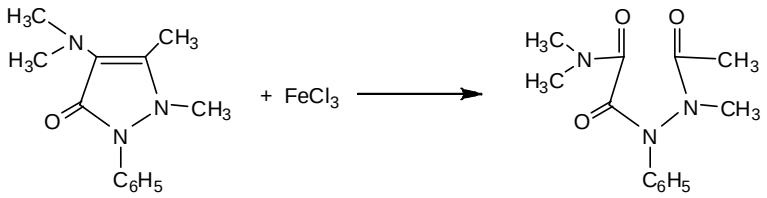
The reactions of antipyrine and amidopyrine with iron(III) chloride.

Put a few crystals of antipyrine, 2 drops of water and a drop of 1% solution of iron(III) chloride in the test tube. An intense orange-red colored complex compound ferropyrine appears and does not disappear on standing.

Put a few crystals of amidopyrine, 2 drops of water and 1 drop of 1% iron(III) chloride solution in another test tube. The violet color oxidation products appear, quickly disappearing. Add more 3 drops of iron(III) chloride. The violet color reappears for longer time, but gradually fades.

The chemistry of the reaction:





Observations:

Conclusions:

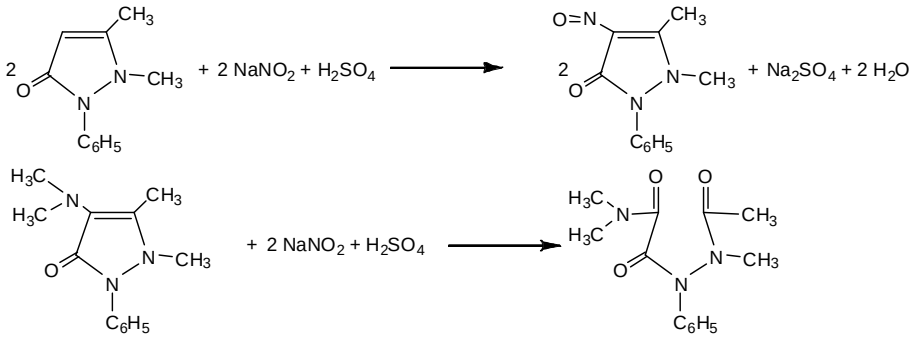
Experiment № 2

Reaction of antipyrine and amidopyrine with nitrous acid.

Place a few crystals of antipyrine, 2 drops of water, 1 drop of 5% sodium nitrite solution in the test tube. The emerald green color appears, gradually fading, especially with an excess of sodium nitrite.

In the second test tube, place a few crystals amidopyrine. Add 2 drops of water, 1 drop of 10% sulfuric acid solution and 1 drop of 5% sodium nitrite solution. The unstable violet color products of amidopyrine oxidation are formed. If the color disappears too quickly, add a little more of amidopyrine. The reaction with nitrous acid is used in pharmaceutical practice to distinguish the antipyrine and amidopyrine.

The chemistry of the reaction:



Observations:

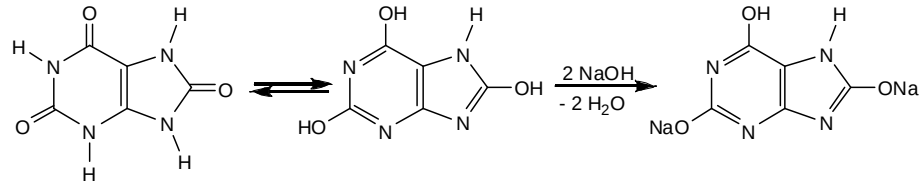
Conclusions:

Experiment№ 3

The solubility of uric acid and its sodium salt in water.

Place a bit of uric acid in the test tube. Add water drop by drop, each time shaking the test tube. Pay attention to the poor solubility of uric acid in the water. In the cold water it almost insoluble: 1 part dissolves in 39,000 parts of water. Add only 1 drop of 10% sodium hydroxide solution - the solution becomes clear immediately because the soluble dibasic uric acid sodium salt is formed. Save the latter solution for the next experiment.

The chemistry of the reaction:



Observations:

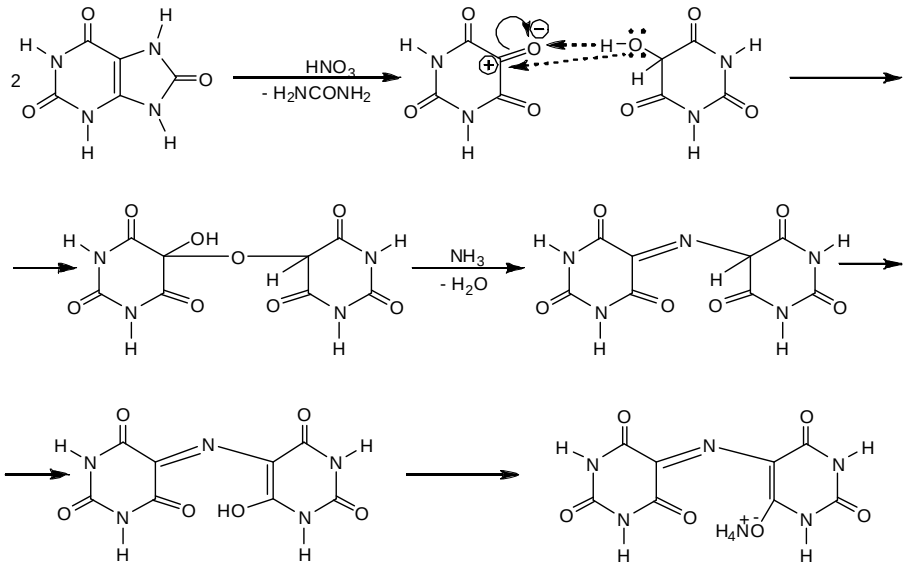
Conclusions:

Experiment № 4

The identification of the uric acid (The murexide test).

Place a drop of uric acid sodium salt solution saved from the previous experiment on a microscope slide. Add one drop of concentrated nitric acid and evaporate gently, holding the glass above the burner flame at some distance (approximately 10 cm). Once the solution is evaporated and the red spots will faint on the former site of the drop, stop heating. When the glass cools place 1 drop of 10% ammonia solution near the red spot. At the contact line the purple-violet stripes (murexide) appear. The murexide test is used in the analysis of urinary stones. This test applies also for identification of caffeine, theobromine and other purine bases.

The chemistry of the reaction:



Observations:

Conclusions:

CHALLENGE QUESTIONS

1. Write to the oxidative and non-oxidative deamination of histidine. Justify the value of this reaction for living organisms.
2. Explain the different solubility of uric acid salts. Which disorders in the body causes the formation of insoluble salts of uric acid.
3. Give the structure of pyridine, pyrimidine, purine. Explain the aromaticity of these compounds, justify their reactivity.

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 534-551.
2. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 800–825, 902-905.
3. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 473-479.
4. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 335–336.
5. Lectures.

Lesson №10

PRACTICAL SKILLS AND SOLUTION OF SITUATIONAL PROBLEMS OF "HETEROFUNCTIONAL ORGANIC COMPOUNDS, METABOLITES, AND PRECURSORS OF THE MOST IMPORTANT GROUPS OF DRUGS. CARBOXYLIC ACIDS AND THEIR FUNCTIONAL DERIVATIVES. LIPIDS»

Subject motivation: The heterofunctional organic compounds are involved in different kinds of tissue, cytosolic and genetic processes, providing a pronounced effect on the vital functions of organism. A lot of them s are potent bioregulators of physiological processes and essential medicines. Lipids are essential structural components of cell membranes.

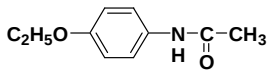
Learning goal: To strengthen knowledge of the structure and chemical properties of the main heterofunctional organic compounds taking into account the mutual influence of their characteristic functional groups as the basis of biochemical processes.

THEORETICAL QUESTIONS

1. The electronic structure of the carboxyl and carbonyl group. Its functional analysis.
2. Nucleophilic substitution reactions.
3. The decarboxylation of carboxylic acids.
4. The specific properties of carboxylic acids.
5. Tautomerism.
6. Chirality.
7. CH and NH-acidity of organic compounds.
8. The principles of aromaticity.
9. Functionally substituted aromatic and heteroaromatic compounds. Their importance for medicine.

ADDITIONAL PROBLEMS

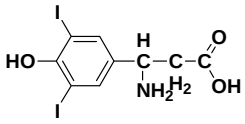
1. Phenacetine is an antipyretic drug.



Determine which class of organic compounds it is referred to:?

A. amine
B. amide
C. aldehyde
D. ester
E. ketone

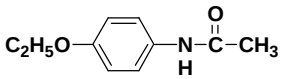
2. Betazine is a synthetic hormone drug:



Specify the senior functional group in the molecule:

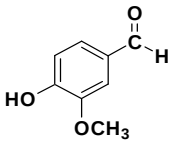
A. –I
B. –OH
C. $–NH_2$
D. –COOH
E. aromatic ring

3. Select the two starting substances for Phenacetin synthesis:



A. *p*-Phenetidin + $(CH_3CO)_2O$
B. Aniline + $(CH_3CO)_2O$
C. *p*-Phenetidin+ C_2H_5OH
D. *p*-Toluidine + $(CH_3CO)_2O$
E. Phenol + CH_3COOH

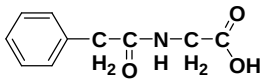
4. Vanilla has a strong smell of aldehyde vanillin:



What is the product of treatment vanillin with $H_2N–NH_2$:

A. the reaction does not go
B. vanillin hydrazine
C. vanillin hydrazone
D. vanillin hydrazide
E. vanillin oxime

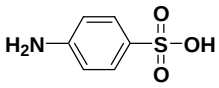
5. Phenaceturic acid is a substance extracted from the urine of animals:



Specify what reagent interacts with phenaceturic acid by COOH-group:

A. C_2H_5Cl ($AlCl_3$)
B. HCl
C. Br_2
D. C_2H_5OH (H^+)
E. $CH_3–O–CH_3$

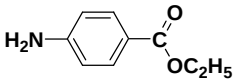
6. Sulfanilic acid is the precursor of sulfanilamides:



Specify the reagent, which interacts only with sulfo-group:

A. CH_3COCl
B. $SOCl_2$
C. Br_2
D. NaOH
E. HCl

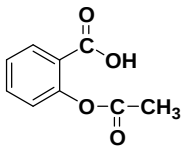
7. Benzocaine is a local anesthetic:



Specify the agent which could qualitatively prove the aromatic amino group in the molecule:

A. $AgNO_3$
B. $NaNO_2$ (HCl)
C. HNO_3 (H_2SO_4)
D. $NaHCO_3$
E. $Cu(OH)_2$

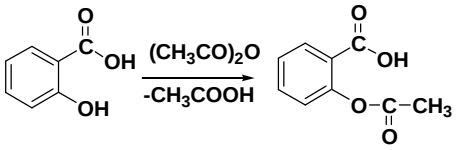
8. Aspirin (acetylsalicylic acid), is an antipyretic and anticoagulant:



Specify the reagent used for the synthesis of aspirin from salicylic acid:

A. C_2H_5OH
B. $H_3C–COOH$
C. $H_3C–COOC_2H_5$
D. $CH_3C(O)NH_2$
E. $(CH_3CO)_2O$

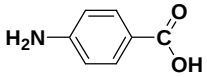
9. Aspirin is generally obtained by acetylating of the salicylic acid:



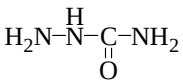
Specify the reagent which could confirm the presence of salicylic acid as an impurity:

A. Br_2
B. NaOH
C. $FeCl_3$
D. $Cu(OH)_2$
E. $Ag(NH_3)_2OH$

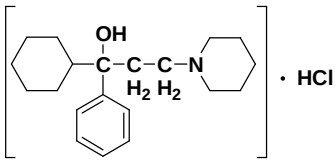
10. PABA (*p*-aminobenzoic acid), is part of the folic acid and paracetamol:



Specify the reagent to get its hydrazide:

A. $H_2N–NH_2$
B. $H_2N–NH–C_6H_5$
C. $H_2N–C_6H_5$
D. $H_2N–OH$
E. 

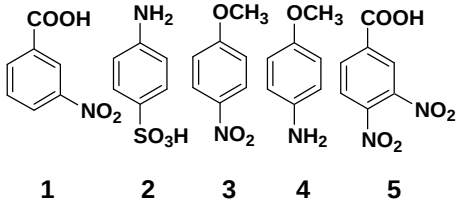
11. Cyclodol is an anticholinergic.



Specify the number of asymmetric carbon atoms in the molecule:

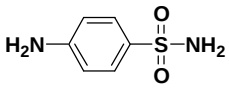
A. 0
B. 1
C. 2
D. 3
E. 4

12. Which of following benzene heterofunctional derivatives is the most active in the S_E:



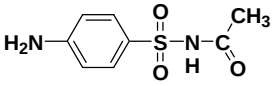
A. 1
B. 2
C. 3
D. 4
E. 5

13. Determine the class of organic compounds of Streptocide:



A. aromatic amine
B. carbocyclic amine
C. aromatic acid
D. aromatic sulfonic acid
E. amide of aromatic sulfonic acid

14. Specify the functional group which is absent in the molecule of Sulfacetamid (Albucid):



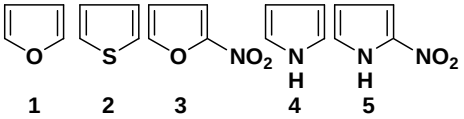
A. aliphatic amino group

B. aromatic amino group
C. aromatic ring
D. acetyl group
E. amide group

15. Indicate the type and sign of electronic effects of the oxygen atom in the molecule of furan:

A. -I
B. +I
C. -M
D. +M
E. -I; +M

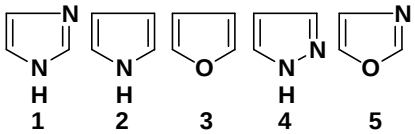
16. There are some five-membered heterocyclic compounds components of the many drugs:



Which of them has the strongest acidic properties.

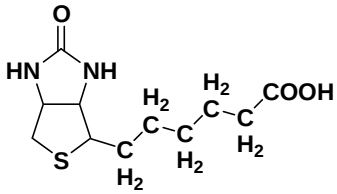
A. 3
B. 5
C. 1
D. 2
E. 4

17. Select the compound with the strongest basic properties among the next compounds:



A. 4
B. 2
C. 3
D. 1
E. 5

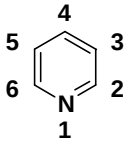
18. Biotin (vit H) has the following structure:



What heterocycles it is consist of ?

A. pyrazole and thiophene
B. hydrogenated pyrazole and thiophene
C. hydrogenated pyrrole and thiazole
D. imidazole and hydrogenated thiophene
E. hydrogenated imidazole and thiophene

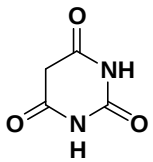
19. Pyridine is a part of many drugs:



Indicate how many monomethyl-substitued pyridines (picolines) could be formed.

A. 1
B. 3
C. 2
D. 4
E. 5

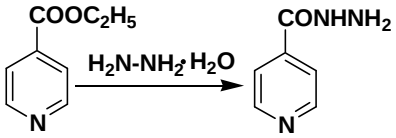
20. Barbituric acid is the basis of many sedatives and anticonvulsants:



Specify the tautomerism which is typical of barbituric acid.

A. lactim-lactam, azole
B. lactim-lactam, keto-enol
C. keto-enol, amine-imine
D. oxo-hydroxy, azole
E. lactamim-lactam, tion-thiol

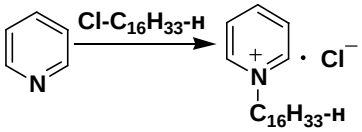
21. Isoniazid is an antituberculosis drug, is obtained according to the next reaction:



Indicate the mechanism of this reaction.

A. S_E
B. S_N1
C. S_R
D. S_N2
E. A_N

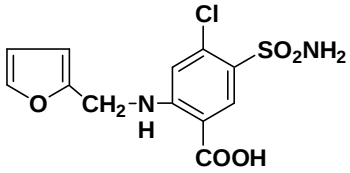
22. Cetylpyridinium chloride (Septolete®) is antibacterial drug is obtained by the next reaction:



What pyridine's property makes possible above reaction.

A. aromaticity.
B. basicity.
C. electrophilicity.
D. nucleophilicity
E. polarity

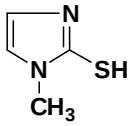
23. Furosemide is a strong diuretic:



Specify its senior functional group.

A. SO_2NH_2
B. furan ring
C. secondary amino group
D. COOH
E. Cl

24. Merkazolil is an antithyroid drug:



Choose its correct IUPAC name.

A. 1-methyl-2-thiopyrazol
B. 1-methyl-1*H*-imidazol-2-thiol
C. 1-methyl-2-thiopyrrol
D. 2-mercapto-3-methylimidazol
E. 1-methyl-2-thiopyrazol

.

CHALLENGE QUESTIONS

1. What compounds give positive Tollence test? ("Silver Mirror")? Is there any redox reactions characteristic for hydroquinone in human body?

2. Show the electronic structure of the oxo group, and explain why nucleophilic addition (A_N) at C=O bond is characteristic for aldehydes and ketones in comparison with the C=C bond. Explain the role of acid catalysis and compare the effect of substituents on the reactivity of the oxo-group of

aldehydes and ketones. Write the reaction of the following aldehydes and ketones: formaldehyde, acetaldehyde, trichloroacetic aldehyde, and acetone with HCN, ethylamine, methyl and ethyl alcohols, water, and lithium aluminum hydride. Describe the mechanism of these reactions and indicate the nucleophiles Justify the acid catalysis in the synthesis of acetals. Write the hydrolysis of acetals. What role plays reaction of aldehydes with alcohols and aminesin the human body? What explains the stability of the hydrated forms of aldehydes? How hydrates of aldehydes are used in medicine?

3. Explain the CH-acidity of the α-carbon atom next to the oxo group. Write the acetal formation with acetic and propionic aldehyde. Could trimethylacetic aldehyde interact in aldol condensation? Write "iodoform test" for acetone and acetaldehyde. Why does this haloform reaction is used in medicine?

4. Write disproportionation (dismutation, Cannizzaro reaction) for formaldehyde and benzaldehyde. What structural features determine the possibility of this reaction for aldehydes?

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 534-551, 712-792, 814-847, 944-979, 1053-1056.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 473–568.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 367–372, 391-426, 494-498.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 566-716, 800–825, 902-905.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 408–433, 440-465, 471-484, 598-601.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 323-337, 373–398.
7. Lectures.

Lesson № 11

Subject: INVESTIGATION OF THE MONOSACCHARIDES CHEMICAL PROPERTIES

Subject motivation: The carbohydrates occupy an important place among the natural compounds. They take part in the construction of vital structures, serve as material for the biosynthesis of various classes of compounds; they play an

important role in bioenergetics of the cells. The carbohydrates are part of the physiologically active glycosides, nucleic acids, polysaccharides, glycolipids and glycoproteins. The immunochemical properties of tissues and specific reactions at external chemical stimuli are depends on carbohydrates. Deep knowledge of the structure and chemistry of carbohydrates are necessary to master the biological chemistry, pharmacology and other medicinal disciplines.

Learning goal: To form deep knowledge about stereomerism, tautomeric equilibrium, and the chemical properties of monosaccharides; to be able to identify the most important monosaccharides.

THEORETICAL QUESTIONS

1. Nomenclature and classification of monosaccharides.
2. The stereoisomers of glucose (dextrose), fructose (levulose), galactose, xylose and ribose.
3. Cyclo-oxo-(ring-chain) tautomerism.
4. The chemical properties of the monosaccharides.
5. Oxidation and reduction reactions.

LABORATORY PRACTICE

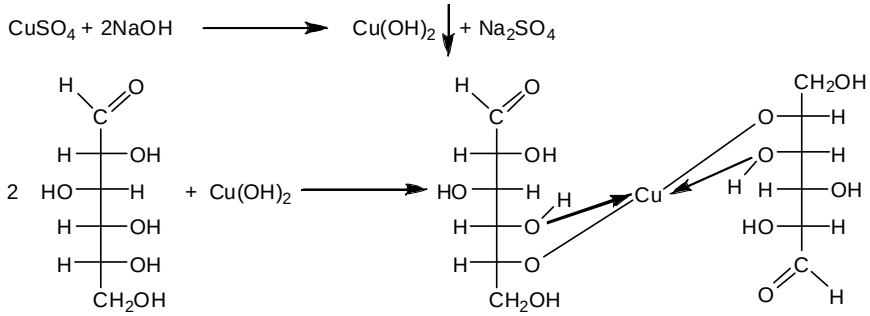
Protocol № 11 Date_____

Experiment № 1

Evidence of the hydroxyl groups in D-glucose.

Place a drop of 0.5% D-glucose solution and 6 drops of 10% sodium hydroxide solution in the test tube. Add 1 drop of 2% copper(II) sulphate solution ($CuSO_4$) to this mixture. The resulting precipitate of copper(II) hydroxide ($Cu(OH)_2$) rapidly dissolves and blue solution turns clear. Save the latter solution for the next experiment.

The chemistry of the reaction:



Observations:

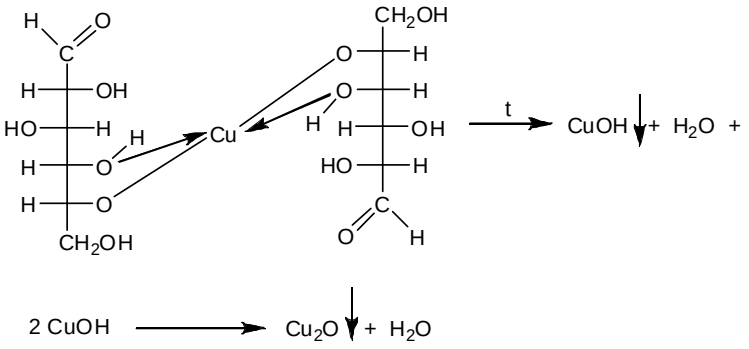
Conclusions:

Experiment № 2

Reduction of the copper(II) hydroxide by glucose in the alkaline medium (Trommer's test).

Put 2 ml of water to the saved solution from the previous experiment. Heat the upper part of the solution over a burner flame only to the boiling point. The color of the upper part of the solution changes from blue to yellow-red because of cuprous oxide formation. This reaction is called Trommer's test and used to identify the glucose in the urine.

The chemistry of the reaction:



Observations:

Conclusions:

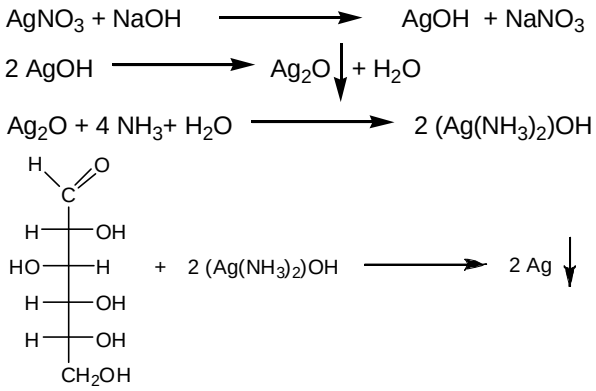
Experiment № 3

Reduction of the ammonia hydroxide solution of silver by glucose.

Place 1 drop of 5% silver nitrate solution ($AgNO_3$), add 2 drops of 10% sodium hydroxide solution in the test tube. Add 3-4 drops of 10% aqueous ammonia solution to dissolve the resulting precipitate of silver hydroxide. The resulting clear solution of ammonium solution of silver hydroxide is a reagent, which oxidizes the glucose (Tollen's reagent). Add to the resulting mixture 1

drop of 0.5% glucose solution and gently heat the test tube over the burner flame till solution turns brown. Then, the reaction proceeds without heating and metallic silver falls either in the form of a black precipitate or precipitates on the walls of the tubes as a mirror film ("Silver Mirror" reaction).

The chemistry of the reaction:



Observations:

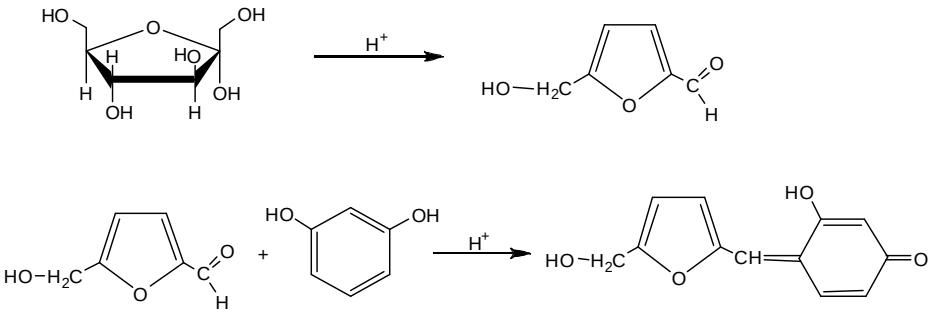
Conclusions:

Experiment № 4

Selivanov's test for fructose.

Place few dry crystals of resorcinol and 2 drops of concentrated hydrochloric acid in the test tube. Add 2 drops of 0.5% fructose solution and heat it. Formation of burgundy-red color after heating indicates the fructose. The reaction is caused by the formation of unstable compound – hydroxymethylfurfural (HMF). In the acidic media (concentrated hydrochloric acid) HMF condenses with resorcinol, giving a colored condensed product.

The chemistry of the reaction:



Observations:

Conclusions:

CHALLENGE QUESTIONS

1. Write the Fischer projection and Haworth perspective formula of *β*-D-galactopyranose. Specify the configuration of an atom that determines the D-series.
2. Write the reaction of galactaric (mucic) acid synthesis. Specify the conditions.
3. Write the reaction of *β*-D-galactopyranose (Haworth formula) with ethanol in the presence of HCl. Name the resulting compound and write its hydrolysis.

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 1000-1025.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 608–626.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 427-441.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 988-1003.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 532-547.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 397-409.
7. Lectures.

Lesson № 12

Subject: INVESTIGATION OF THE STRUCTURE, CHEMICAL PROPERTIES AND BIOLOGICAL FUNCTIONS OF DISACCHARIDES AND POLYSACCHARIDES

Subject motivation: Life processes go along with complex chemical transformations of carbohydrates (carbohydrate metabolism). Carbohydrates occupy a special place in the body dealing with highly specialized functions

(nucleotides – carriers of genetic code, specific polysaccharides – antigens of the immune system; glycoproteins – the specific components of blood etc.). Certain types of carbohydrates are units of plant cells and play a supporting role. Profound knowledge of the structure and chemistry of disaccharides and polysaccharides are necessary for the acquisition of skills in the study of the relevant sections of biological chemistry, pharmacology, therapy and other disciplines.

Learning goal: To form knowledge of the principles and basic structure of the chemical transformations of the most important di- and heteropolysaccharides in relation to their biological functions.

THEORETICAL QUESTIONS

1. Oligosaccharides.
2. Disaccharides (bioses): cellobiose, maltose, lactosa, and sucrose.
3. Reducing and nonreducing disaccharides.
4. Homopolysaccharides: starch, glycogen, chitin, cellulose, insulin.
5. Heteropolysaccharides: hyaluronic acid, chondroitin sulfates, pectin, lignin, glycoproteins, glycolipids, and mucopolysaccharides.

LABORATORY PRACTICE

Protocol № 12 Date _____

Experiment № 1

The absence of the reducing properties of the sucrose.

Place 1 drop of 1% sucrose solution and 6 drops of 10% sodium hydroxide solution in the test tube. Add 10 drops of the water (to height of the liquid layer 15-20mm). Add 1 drop of 2% copper(II) sulphate solution ($CuSO_4$). A clear blue solution of the complex sucrose salt with copper(II) is formed. Warm up gently the test tube in the burner flame heating only the upper part of the solution, and remain the lower part unheated (control). Don’t boil the solution. No change of color is observed.

Remember (***Protocol № 11, Experiment № 2***) that the reducing saccharide *D*-glucose changes color of the upper part of the solution to the yellow-red under the similar conditions.

Observations:

Conclusions:

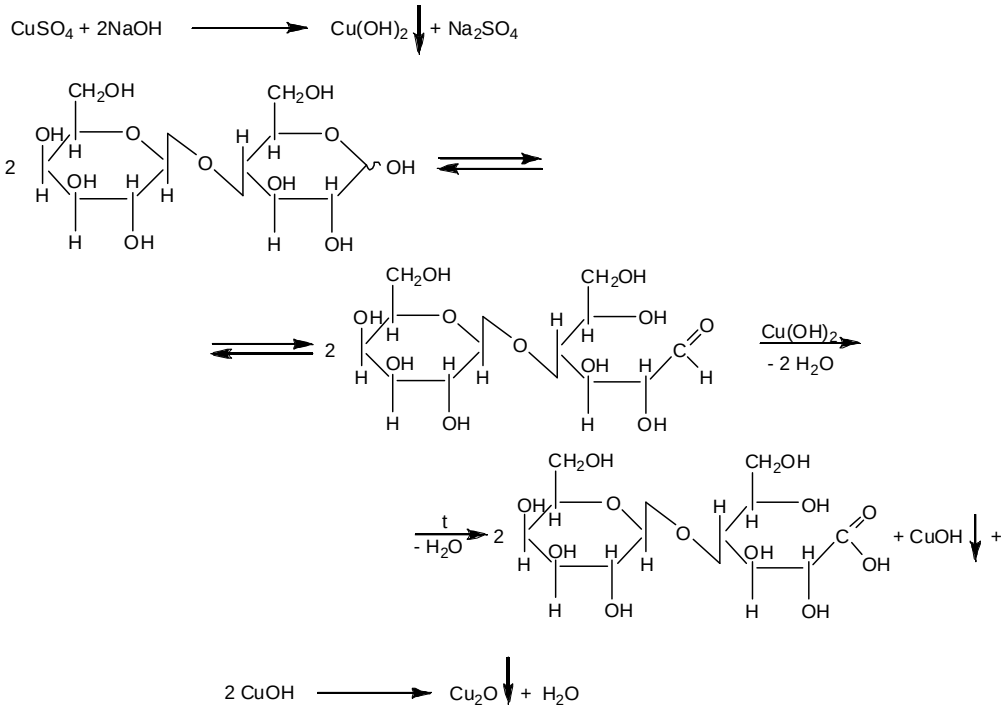
Experiment № 2

Reducing properties of lactose.

Place 1 drop of 1% lactose solution and 4 drops of 10% sodium hydroxide solution in the test tube. Add 1 drop of 2% copper(II) sulfate solution ($CuSO_4$). The resulting blue precipitate of the copper(II) hydroxide dissolves by shaking the tube, forming a blue solution of the complex lactose salt with copper(II). Add 10 drops of water in the test tube. Gently heat only the upper part of the test tube, remaining the bottom without heating (control). Heat to boiling. The color of the upper part of the solution changes to yellow-red during the heating.

Remember (***Protocol № 11, Experiment № 2***) that the reducing saccharide *D*-glucose changes color of the upper part of the solution to the yellow-red under the similar conditions.

The chemistry of the reaction:



Observations:

Conclusions:

Experiment № 3

Starch identification reaction.

Place 5 drops of 0.5% starch and 1 drop of very dilute iodine solution in the test tube. The solution becomes blue (it is supposed that the starch forms with iodine compounds (clathrates), painted in blue color (f_{max} = 620-680 nm) for amylose and red (f_{max} = 520-555 nm) for amylopectin. Amylose coils into a helical secondary structure resembling a tube with a hollow core. The iodine can lodge inside the core. The complex of iodine stuck inside the amylose coil produces a characteristic blue-black color. The starch itself is not altered. Starch-iodine complex becomes unstable at temperatures above 35 °C. This complex in presence of an oxidizing agent the solution turns blue, in the presence of reducing agent, the blue color disappears because triiodide (I_3^-) ions break up into three iodide ions, disassembling the complex. So starch turns into glucose molecules. Therefore the blue black color disappears. However, when it cools down again, then the glucose macromolecules bonded up together again in a long chain, becoming starch. That is why it tested positive for starch and turns back into blue-black color.

Observations:

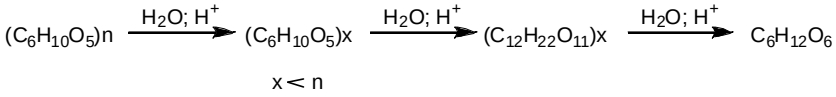
Conclusions:

Experiment № 4

Acid hydrolysis of starch.

Place a drop of 0.5% starch paste in the test tube. Add 2 drops of 10% sulfuric acid solution (H_2SO_4), and place the tube in a boiling water bath. Turbid solution of starch paste becomes clear after 20 minutes. Put 1 drop of the hydrolyzate on a glass slide with pipette and add 1 drop of iodine in potassium iodide dilute solution. If a sample does not give a positive reaction with iodine (blue color), add 8 drops of 10% sodium hydroxide (NaOH) into the tube to achieve an alkaline medium. Then add 1 drop of 2% of copper(II) sulphate solution ($CuSO_4$.). Will the Trommer’s test be positive?

The chemistry of the hydrolysis of starch:



Observations:

Conclusions:

CHALLENGE QUESTIONS

1. Write the structural and conformational formulas of milk sugar (lactose). Give its full name. Write the hydrolysis of lactose.
2. Write the reaction of maltose with an excess of dimethyl sulfate. Name the product and show its hydrolysis. Will the obtained compound have the reducing properties?
3. Write the structural formula of the disaccharide consisting of *D*-glucuronic acid and *N*-acetylglucosamine, which are connected by *β*-1,3-glycosidic bond. What biopolymer this fragment is a part of?

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 1025-1036.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 626-638.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 441-451.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 1003-1014.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 547-560.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 410-433.
7. Lectures.

Lesson №13

Subject: THE α-AMINO ACIDS, PEPTIDES AND PROTEINS

Subject motivation: Life is a way of "protein bodies" being. Natural proteins composed of α-amino acids, is inherent in the implementation of a wide variety of functions characteristic for living organisms: the catalytic function – universal, uncharacteristic to other polymer molecules, nutritious (reserve), transportation, security, contractile, structural, hormonal and others. The amino acids alone are used as effective drugs (methionine, sarcolysin, aminalon, etc.). Knowledge of the structure and chemistry of α-amino acids and peptides is necessary for the successful assimilation of the proteins functions at the molecular level.

Learning goal: To build a knowledge structure and properties of the most important α-amino acids and peptides, as well as their chemical transformations *in vivo* and *in vitro*.

THEORETICAL QUESTIONS

1. Nomenclature and classification of α-amino acids.
2. Methods of preparation.
3. The chemical properties of α-amino acids.
4. The peptides and polypeptides.

LABORATORY PRACTICE

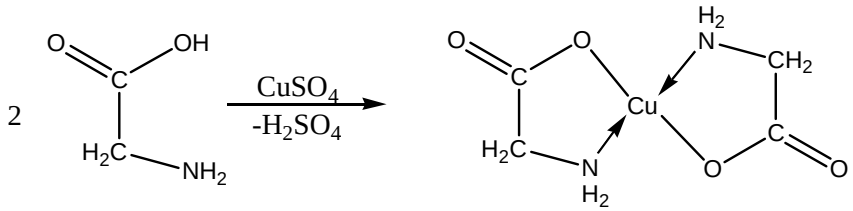
Protocol № 13 Date_____

Experiment 1.

The formation of glycine complex salt with copper(II).

Place 0.5 ml of 2% copper(II) sulfate solution and 0.5 ml of 1% glycine solution in the test tube. The stable blue chelate copper salt of glycine is formed.

The chemistry of the reaction:



Observations:

Conclusions:

Experiment 2.

Precipitation of proteins with concentrated mineral acids.

Put 1 ml of white egg and 1 ml of concentrated nitric acid in the test tube. White flocculent precipitate is formed.

Observations:

Conclusions:

Experiment 3.

Precipitation of proteins by heavy metals salts.

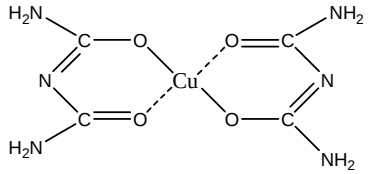
Add 1 ml of white egg, then dropwisely with stirring add 20% copper(II) sulfate solution till precipitate is formed in the first tube. And add the same amount of protein in the second test tube, then dropwisely add 20% aqueous solution of lead(II) acetate. The precipitation is observed in both test tubes.

Observations:

Conclusions:

CHALLENGE QUESTIONS

1. The biuret test requires formation of the next complex compound:



Explain the chemical reaction on the peptide bond.

2. Write a synthesis of the dipeptide alanine-valine (Ala-Val) using the operations "activation" and "protection". Specify the N-and C-ends of the amino acids.

3. What products are formed by oxidative and non- oxidative deamination of tryptophan?

4. What substance is formed by the treatment of nitrous acid with alanine?

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 1044–1079.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 644–681.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 492-523.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 1051-1087.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 596-633.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 433-468.
7. Lectures.

Lesson № 14

Subject: THE PRIMARY AND SECONDARY STRUCTURE OF THE NUCLEIC ACIDS. THE NUCLEOSIDES AND NUCLEOTIDES

Subject motivation: Knowledge of structural and stereochemical features of the nucleosides, nucleotides, and nucleic acids contributes the understanding the protein biosynthesis mechanism, genetic information transfer, coenzyme functioning, as well as the role of ATP as an energy "supplier" in the various biochemical processes.

Learning goal: To form knowledge of the nucleic acids primary, secondary, tertiary, and quaternary structure, that is a necessary prerequisite to understanding of their biosynthesis and biological role.

THEORETICAL QUESTIONS

1. Classification and nomenclature of nucleic bases. Lactim-lactam tautomerism. The complementarity of the bases.
2. The structure of the nucleoside.
3. The structure of the nucleotide.
4. Primary and secondary structure of RNA and DNA.
5. Importance of nucleic acids in the life of plant and animal organisms.

CHALLENGE QUESTIONS

1. Write a scheme of deoxycytidylic acid hydrolytic cleavage in the acidic medium.
2. Write a tautomeric forms of thymine. Which of the tautomers predominates in the equilibrium mixture?
3. Which of the two base pairs UA or TA is the part of the DNA? Write the structure of this pair.
4. Write the structure of the RNA chain subunit GUA, and mark the ester bonds.

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 1000-1036, 1044–1079.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 608–638, 644–681.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 427-451, 492-523.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 988-1014, 1051-1087.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 532-560, 596-633.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 397-468.
7. Lectures.

Lesson № 15

Final module test: "BIOLOGICALLY IMPORTANT CLASSES OF BIOORGANIC COMPOUNDS. BIOPOLYMERS AND THEIR STRUCTURAL COMPONENTS"

1. Bioorganic chemistry as a science: definition, object and tasks, methods of research. Its value for the higher medical education.
2. Classification of organic compounds by the structure of the carbon radical and the nature of functional groups.
3. The structure of the major classes of bioorganic compounds according to the functional groups: alcohols, phenols, thiols, aldehydes, ketones, carboxylic acids, esters, amides, nitro compounds, amines.
4. Nomenclature of organic compounds: trivial, rational, international. Principles of IUPAC nomenclature: substitution, radical-functional.

5. The theory of organic compounds structure. The concept of structural isomers.
6. The nature of chemical bonds in organic compounds: hybridization of orbitals, the electronic structure of carbon compounds.
7. The delocalization of the electrons and conjugate systems. Conjugated systems with open-chain: electronic structure and chemical properties of 1,3-dienes.
8. Conjugate compounds with close chain: the electronic structure of benzene, aromaticity of arenes and heterocyclic compounds.
9. Polar covalent bonds. Inductive and resonance effects. Substituent's effect in aromatic rings.
10. The spatial structure of bioorganic compounds: stereochemical formula, configuration and conformation. Stereoisomers: geometric, optical, rotary (conformers).
11. Geometric isomerism in substituted alkenes, cycloalkanes, unsaturated fatty acids, dicarboxylic acids. *Cis*, *trans* and *E/Z*-nomenclatures.
12. Optical isomerism, chirality of organic molecules. *D*/*L*-, *R*/*S*-stereochemical nomenclature. Enantiomers and diastereomers of bioorganic compounds. Relationship of the spatial structure – physiological activity.
13. Conformational isomers; Newman projection formulas. The energy characteristics of the conformational isomers of the syn-, anti-, and gauche conformations.
14. Conformational isomers of cyclic hydrocarbons. Axial and equatorial bonds in the molecule of cyclohexane. The input of the conformational isomerism for the formation of the spatial structure of biomolecules.
15. Types of reactions: classification by the direction and the reaction mechanism.
16. Characteristics and examples of specific types of reactions in bioorganic chemistry: addition, substitution, elimination, oxidation and reduction.
17. Characteristics and examples of nonpolar (radical) and polar (ionic) reactions in bioorganic chemistry. Electrophilic and nucleophilic reagents.
18. The oxidation-reduction reaction. Free radical reactions of bioorganic compounds, their importance in the normal and pathological conditions.
19. Acidic and basic properties of organic compounds: a proton Bronsted theory, Lewis theory of acids and bases.
20. Structure, properties and biomedical significance of the individual representatives of the alcohols and thiols.

21. Phenols: structure, properties and biomedical significance. Characteristics of the monatomic (phenol, cresol) and diatomic (pyrocatechol, resorcinol, hydroquinone) phenols.
22. Thiols (mercaptans), sulfides and disulfides. Structure and chemical properties.
23. Carbonyl compounds. Chemical properties and biomedical significance of aldehydes and ketones.
24. Carboxylic acids. Structure and chemical properties of functional derivatives of carboxylic acids (anhydrides, amides, esters). The reactions of decarboxylation.
25. Structure and properties of dicarboxylic acids: oxalic, malonic, succinic, glutaric, fumaric acid.
26. Structure and properties of carboxylic acid and its derivatives. Urethane, ureido acids, urea.
27. Carboxylic acids esters: nomenclature, preparation, properties.
28. Amines: nomenclature, properties. Biomedical significance of biogenic amines (adrenaline, noradrenaline, dopamine, tryptamine, serotonin, histamine) and polyamines (spermidine, spermine, putrescine, cadaverine).
29. Aromatic amines: structure, properties. Aniline as a precursor in the synthesis of pharmaceuticals - sulfanilamide, phenacetin, anaesthesin, novocaine.
30. Aminoalcohols: structure, properties. Biomedical significance of ethanolamine (colamin), choline, acetylcholine.
31. Hydroxy acids. Structure and properties of monocarboxylic, dicarboxylic and tricarboxylic hydroxy acids.
32. Amino acids: structure, stereoisomerism, and chemical properties. Biomedical importance of *L*-α-amino acids. Reactions of biochemical transformations of amino acids: deamination, transamination, decarboxylation.
33. Structure and properties of the most common oxo acids: pyruvic, acetoacetic, oxaloacetic, α-ketoglutaric. The concept of ketone bodies.
34. Phenolic acids. Salicylic acid and its anti-inflammatory derivatives (acetylsalicylic acid, methyl salicylate, sodium salicylate) and antimicrobial (phenyl salicylate) compounds.
35. Five-membered heterocycles with one heteroatom (pyrrol, furan, thiophene). Biomedical significance of tetrapyrrole compounds: porphyrin, heme.

36. Indole and its derivatives: Tryptophan and reaction of tryptamine and serotonin. Indoxyl, scatole, scatoxyl value in the process of putrefaction of proteins in the intestine.
37. Five-membered heterocycles with two nitrogen atoms: pyrazole, pyrazolone. The pyrazolone-5 derivatives as drugs (antipyrine, amidopyrine, analgin). Imidazole and its derivatives: histidine and histamine.
38. Five-membered heterocycles with two different heteroatoms: thiazole, oxazole. Thiazole as a structural component of the molecule of thiamine (vitamin B).
39. Six-membered heterocycles with a nitrogen atom: pyridine. Nicotinamide (vitamin PP) as a part of redox pyridine coenzymes. Pyridoxine and molecular forms of the vitamin B_6.
40. Six-membered heterocycles with two nitrogen atoms. Diazine: pyrimidine, pyrazine, pyridazine. Nitrogenous bases - derivatives of pyrimidine (uracil, cytosine, thymine).
41. Pyrimidine derivatives as drugs: 5-fluorouracil, potassium orotate. Barbituric acid. Barbiturates as sedatives and antiepileptic drugs (phenobarbital, barbital).
42. Six-membered heterocycles with different heteroatoms. Phenothiazines (chlorpromazine, etc.) as psychotropic (neuroleptic) drugs.
43. Seven-membered heterocycles with two heteroatoms. Diazepine: benzo-1,4-diazepine as the most common tranquilizer and anxiolytic.
44. Purine and its derivatives. Amino derivatives of purine (adenine, guanine), their tautomeric forms, the biochemical significance in the formation of nucleotides and coenzymes.
45. Hydroxy purine: hypoxanthine, xanthine, uric acid. Methylated xanthine derivatives (caffeine, theophylline, theobromine) as physiologically active compounds with action on the central nervous and cardiovascular systems.
46. Carbohydrates: definition, classification. Sugars (aldose and ketoses; triose, tetroze, pentose, hexose, heptoze), the biomedical significance of the individual representatives.
47. Monosaccharides: pentoses (ribose, 2-deoxyribose, xylose), hexose (glucose, galactose, mannose, fructose) - structure, properties. Identification of the glucose.
48. Structure and properties of amine derivatives of monosaccharides: glucosamine, galactosamine. Uronic acid. *L*-ascorbic acid (vitamin C). Sorbitol, mannitol.

49. Oligosaccharides: structure, properties. Disaccharides (sucrose, lactose, maltose), and their biomedical significance.
50. Polysaccharides. Homopolisaccharides: starch, glycogen, cellulose, dextrans - structure, hydrolysis, biomedical significance. Identification of the starch.
51. Heteropolysaccharides: definition, structure. The structure and biomedical significance of glycosaminoglycans (mucopolysaccharides) - hyaluronic acid, chondroitin sulfates, heparin.
52. Lipids: definition, classification. Fatty acids: palmitic, stearic, oleic, linoleic, linolenic, arachidonic. Lipids. Triacylglycerols (neutral fats): structure, physiologic significance, the hydrolysis.
53. Complex lipids. Phospholipids: phosphatidic acid, phosphatidyl-ethanolamine, phosphatidylcholine, phosphatidylserine. Sphingolipids. Glycolipids. The role of complex lipids in the structure of biological membranes.
54. Steroids as derivatives of sterane. The structure of biologically important representatives of steroids: cholesterol, vitamin D, bile acids, corticosteroids, sex hormones.
55. Amino acids. Classification, nomenclature, chemical properties of L-α-amino acids. Ninhydrine reaction.
56. Proteins and peptides: definition, classification and biological functions. The types of bonds between amino acid residues in protein molecules. Peptide bond: formation, structure: the biuret reaction.
57. Primary, secondary, tertiary, and quaternary structure of proteins. Oligomeric proteins.
58. Physico-chemical properties of proteins and their molecular mass. Denaturation of proteins.
59. Methods for fractionation and analysis of proteins and peptides (sedimentation, chromatography, electrophoresis). Analysis of the primary structure of proteins and peptides: methods Sanger and Edman.
60. Enzymes as biological catalysts of protein nature. The principles of classification and nomenclature of enzymes.
61. Nitrogenous bases of purine and pyrimidine series, which are part of the natural nucleotides. Minor nitrogenous bases.
62. Nucleosides. Nucleotides as phosphorylation derivatives of nucleosides (nucleozidmono-, di-and triphosphates). Nomenclature of nucleosides and nucleotides as components of RNA and DNA.
63. Structure and biochemical functions of the free nucleotides: nucleotid coenzymes, cyclic nucleotides 3',5'-AMP, 3',5'-GMP.

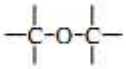
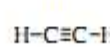
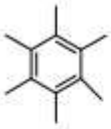
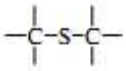
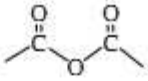
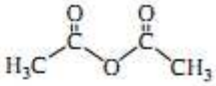
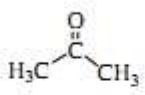
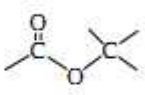
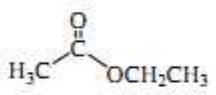
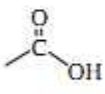
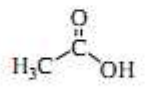
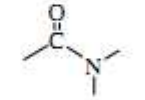
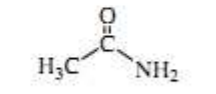
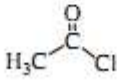
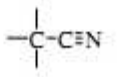
64. Nucleic acids (deoxyribonucleic, ribonucleic) as polynucleotides. The polarity of the polynucleotide chains of DNA and RNA.
65. Structure and properties of DNA nucleotide composition, complementarities of the nitrogenous bases. Primary, secondary and tertiary structure of DNA.
66. RNA: structure, types of RNA and their role in protein biosynthesis.
67. Vitamins: a general overview. The concept of the coenzyme activity of vitamins. Structure and properties of vitamins B_1, B_2, B_6, PP.
68. Hormones: the concept of hormones as bioregulators. General characteristics of hormones of protein-peptide group, amino acid derivatives, steroids and eicosanoids.
69. Alkaloids: definition. The value of the alkaloids as the active drugs (class of pyridine and piperidine, quinoline and isoquinoline, trephine, indole).
70. Antibiotics: a general concept, the characteristic classes of antibiotics: penicillins, cephalosporins, streptomycins.
71. Pesticides: definition, the most common phosphorus and organochlorine pesticides and their toxicological significance.

Literature

1. Organic Chemistry / J. McMurry. – 8th ed. Brooks/Cole. 2012; 534-551, 712-792, 814-847, 944-979, 1000-1036, 1044–1079.
2. General, Organic, and Biological Chemistry / J.G. Smith. – 1st ed. 2010; 473–568, 608–638, 644–681.
3. Principles of general, organic, and biological chemistry / J.G. Smith. – 1st ed. McGraw-Hill. 2012; 367–372, 391-523.
4. Organic Chemistry / W.H. Brown, Ch.S. Foote, B.L. Iverson, E.V. Anslyn. – 5th ed. Brooks/Cole. 2011; 566-716, 800–825, 902-905, 988-1014, 1051-1087.
5. Organic Chemistry / I. Blei, G. Odian – 2nd ed. W. H. Freeman and Company. 2006; 408–433, 440-465, 471-484, 532-560, 596-633.
6. General, Organic, and Biological Chemistry: An Integrated Approach / K.W. Raymond. – 2nd ed. John Wiley & Sons, Inc. 2008; 323-337, 373–468.
7. Lectures.

APPENDIX

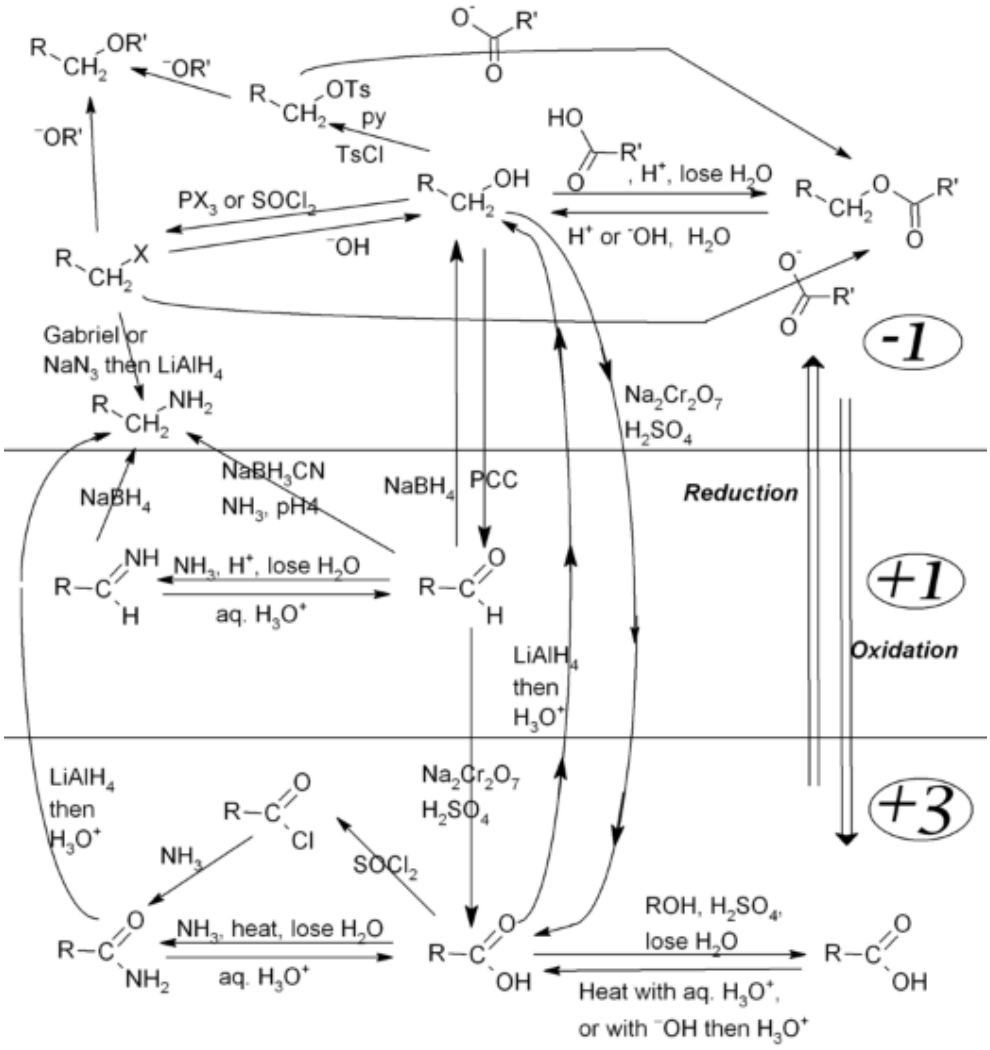
Organic compounds are generally classified based on the reactive parts of their structures, known as **FUNCTIONAL GROUPS**. The remainder of the molecule is usually based upon alkyl chains, which are relatively unreactive. Each functional group has its own characteristic reactions, and it tends to determine many of the chemical and physical properties of the overall compound.

Functional Group – General Structure	Example	Functional Group – General Structure	Example
	CH_3CH_3		CH_3CH_2OH
Alkane	**Ethane**	**Alcohol**	**Ethanol**
	$CH_2{=}CH_2$		$CH_3OCH_2CH_3$
Alkene	**Ethylene**	**Ether**	**Ethyl methyl ether**
			CH_3CH_2SH
Alkyne	**Acetylene**	**Thiol**	**Ethanethiol**
			CH_3SCH_3
Aromatic Ring (Arene)	**Benzene**	**Sulfide**	**Dimethyl sulfide**
 (X = F, Cl, Br, I)	CH_3CH_2Br		$CH_3CH_2NH_2$
Alkyl Halide	**Ethyl bromide**	**Amine**	**Ethylamine**
			
Aldehyde	**Acetaldehyde**	**Acid anhydride**	**Acetic anhydride**
			
Ketone	**Acetone**	**Ester**	**Ethyl acetate**
			
Carboxylic acid	**Acetic acid**	**Amide**	**Acetamide**
			$H_3C{-}C{\equiv}N$
Acid chloride	**Acetyl chloride**	**Nitrile**	**Acetonitrile**

The IUPAC names of the first 10 alkanes

Number of Carbon Atoms	Prefix	Name	Molecular Formula
1	Meth	Methane	CH_4
2	Eth	Ethane	C_2H_6
3	Prop	Propane	C_3H_8
4	But	Butane	C_4H_{10}
5	Pent	Pentane	C_5H_{12}
6	Hex	Hexane	C_6H_{14}
7	Hept	Heptane	C_7H_{16}
8	Oct	Octane	C_8H_{18}
9	Non	Nonane	C_9H_{20}
10	Dec	Decane	$C_{10}H_{22}$

The **REACTION MAP** shown below shows most of the common functional groups, and how to convert between them. The large numbers on the right hand side indicate the oxidation state for the carbon attached to the functional group.[1]



James B. Hendrickson, *J. Chem. Educ.*, **1978**, *55* (4), 216. DOI: 10.1021/ed055p216.