MINISTRY OF HEALTH OF UKRAINE
ZAPORIZHZHIA STATE MEDICAL UNIVERSITY
DEPARTMENT OF ORGANIC AND BIOORGANIC CHEMISTRY

GUIDELINES AND LABORATORY PROTOCOLS OF ORGANIC CHEMISTRY

SEMESTER 1

Basics of the organic compounds structure. Hydrocarbons (alkanes, cycloalkanes, alkenes, alkadienes, alkynes, arenes) and their functional derivatives (halogen-containing, nitrogen-containing, sulfur-containing compounds, hydroxy derivatives of carbohydrates, aldehydes and ketones, carboxylic acids and their derivatives).

For self-training for practical classes in organic chemistry of students of the International Faculty,
specialty 226 «Pharmacy, industrial pharmacy»

Student ___ group 2 course _____ faculty

_____
full name

Zaporizhzhia
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UDC 547(076.5)
G 94

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G94 **Guidelines and Laboratory protocols of Organic chemistry**. Semester 1 : Basics of the organic compounds structure. Hydrocarbons (alkanes, cycloalkanes, alkenes, alkadienes, alkynes, arenes) and their functional derivatives (halogen-containing, nitrogen-containing, sulfur-containing compounds, hydroxy derivatives of carbohydrates, aldehydes and ketones, carboxylic acids and their derivatives) : for self-training for practical classes in organic chemistry of students of the International Faculty, specialty 226 «Pharmacy, industrial pharmacy» / S. I. Kovalenko et al. – Zaporizhzhia : ZSMU, 2021. – 85 p.

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13	Structure and chemical properties of aldehydes and ketones. Nucleophilic addition reactions.	4
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Total		64

CRITERIA FOR EVALUATION OF STUDENT EFFICIENCY

The grade for the discipline is determined by the average score of the student's current performance, which is converted into a 200-point system by the formula:

Score by a 200-point scale = (Average score by a 5-point scale *200)/5

and the results of the final control.

Criteria for assessing of the student's current success.

The current success of students is assessed by a four-point scale by making the following grades:

"5" - the student fully knows, understands and can use in practice the program material, also has extracurricular material related to this topic. The student consistently, logically, reasonably, unmistakably expound the material, skillfully and correctly formulates conclusions and generalizations.

"4" - the student knows, understands and can use in practice the program material, the student consistently, logically, reasonably expound the material making minor mistakes, formulates conclusions and generalizations.

"3" - the student knows and can use in practice the main part of the program material. The student inconsistently learns the material, making significant mistakes, vaguely formulates conclusions and generalizations.

"2" - the student does not possess the program material and therefore is not able to use it in practice, to generalize it and draw conclusions.

CHEMISTRY LABORATORY SAFETY RULES

One often forgets that chemical experiment is a potentially dangerous; a careless attitude often results in disastrous outcomes. 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

_____ _____

Surname, first name Signature

Video materials for practical classes can be found at:

https://www.youtube.com/playlist?list=PL5MKnWeEf-HMgqNjNYfszes_hLaTrUAT6

"Pharmacy" Semester I. Videos for guidelines and laboratory protocols of bioorganic chemistry. "Pharmacy".

LESSON 1

TOPIC: THE SUBJECT OF ORGANIC CHEMISTRY. THE ROLE OF ORGANIC CHEMISTRY IN THE SYSTEM OF PHARMACEUTICAL EDUCATION. CLASSIFICATION AND NOMENCLATURE OF ORGANIC COMPOUNDS. SPATIAL STRUCTURE OF ORGANIC COMPOUNDS. ISOMERISM OF ORGANIC COMPOUNDS.

Subject motivation: extensive usage of modern physicochemical methods, development of new methods of synthesis, change of the strategy of complex organic synthesis have radically changed the face of organic chemistry. These facts require the rapid development of a huge flow of a new information and theoretical understanding of all available material. In this regard, the formation of knowledge of the basic classification features in the nomenclature rules is of a paramount and fundamental importance for the successful study of the chemical properties of organic compounds. Conformational and stereochemical concepts in general have contributed to successes in establishing the structure of molecules of organic compounds, understanding the mechanisms of reactions and developing new methods of the synthesis. The spatial structure of molecules is organically related to their biological activity. The study of stereochemistry of organic compounds enriches biochemistry, pharmacology, pharmaceutical chemistry and creates a theoretical basis for their development at the molecular level.

Objective: To form knowledge of the basic principles of classification, chemical, nomenclature and the ability to use them in solving nomenclature problems and functional analysis of drugs. To form knowledge of the basic principles of stereochemistry of organic compounds as a basis for predicting stereoselectivity, and chemical reactions and understanding of the mechanism of biological activity.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

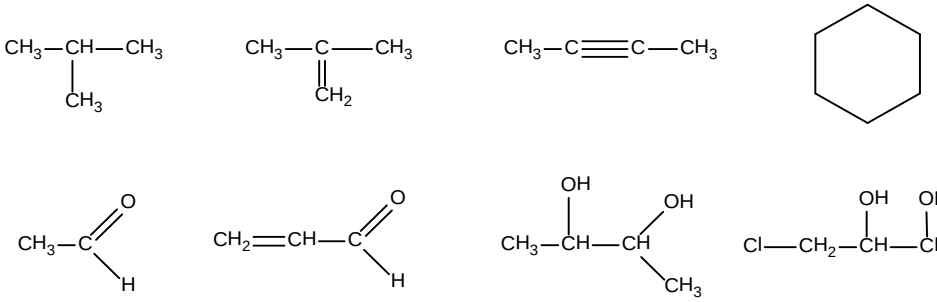
1. History of development of organic chemistry.
2. The theory of types by Gerhardt.
3. Main principles of the theory of the chemical structure of Butlerov.
4. The structure of methane, ethylene, acetylene.
5. Nomenclature of organic compounds.
6. Conformations of alkanes and cycloalkanes.
7. Conformations of carbocyclic and heterocyclic compounds, alkanes, cycloalkanes.
8. *Cis* -, *trans*- isomerism (diastereomers) of alkenes and cycloalkanes.
9. Chirality and achirality of molecules.
10. Enantiomerism.
11. Diastereomerism.
12. Optical isomerism.

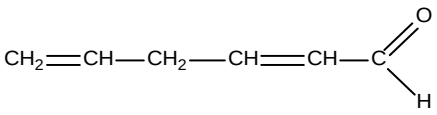
PRACTICAL WORKS PERFORMED IN THE CLASS.

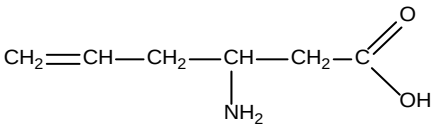
Protocol № 1

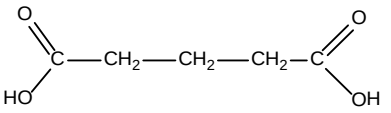
Date_____

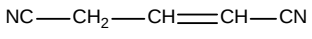
Using nomenclature of organic chemistry (IUPAC), name and write the names of the given formulas of organic substances.

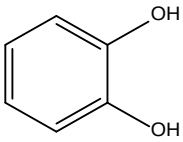


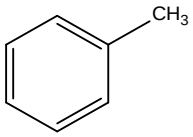


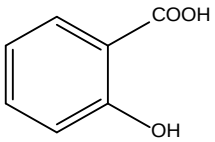


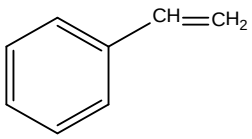




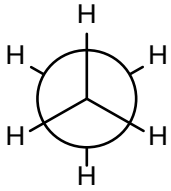


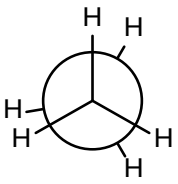




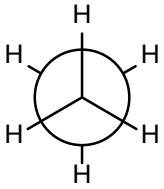


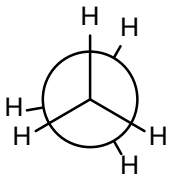
Name the conformations of ethane and explain which of them is more energy efficient and why?

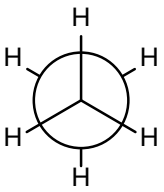


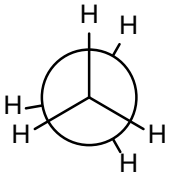


In the following Newman projections, arrange the required number of methyl groups (CH_3) instead of hydrogen atoms (H) to make four possible conformations of butane. Name the obtained conformations.

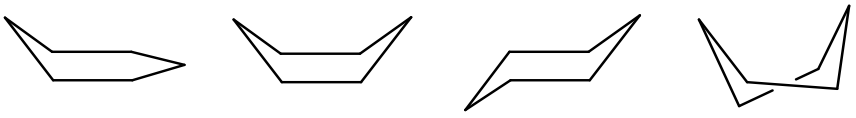








Discuss the following conformations of cyclohexane and write their names.



Which of the following conformations has the lowest energy for methylcyclohexane and why?

CHALLENGE QUESTIONS

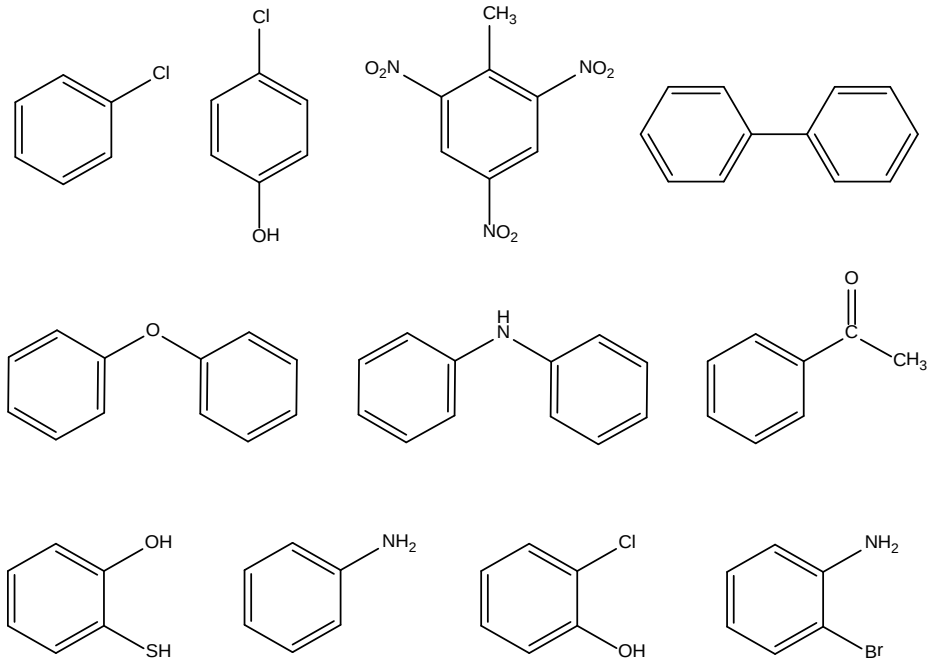
1. Write the structural formulas for each of the following compounds using tetravalent Carbon, divalent Oxygen and monovalent Hydrogen:

a) three isomeric compounds of the molecular formula C_3H_8O;

b) a compound of molecular formula C_5H_{12} in which all hydrogen atoms are in chemically identical positions;

c) 2-bromo-2-chloro-1,1,1-trifluoroethane, propane-1,2,3-triol, propan-2-one, ethanedial.

2. Name the following compounds according to the IUPAC nomenclature.



3. Show which confirmatory position atoms C-2 and C-5 of hexane relative towards to each other occupy in different conformations. Write that, using Newman's projection formulas. Which conformation of the chain has the lowest energy?

4. Write the *E*- and *Z*- forms of 1-chloro-1-fluoro-2-methylbut-1-ene. To what kind of stereoisomers do these compounds belong?

LESSON 2

TOPIC: CHEMICAL BOND AND MUTUAL EFFECTS OF ATOMS IN ORGANIC MOLECULES. ACIDIC AND BASIC PROPERTIES OF ORGANIC COMPOUNDS.

Subject motivation: Electronic structure of atomic orbitals and their hybridization, covalent bonding, conjugation, electronic effects as the main way of transmitting mutual influence are fundamental concepts, are the basis of system knowledge about the reactivity of different classes of organic compounds, allow to make qualitative comparison of stability substances, to interpret the mechanisms of reactions. Equally important for understanding the properties of organic compounds is the knowledge of the acidic and basic properties of organic compounds, which are also among the fundamental concepts needed to study most sections of the course and special disciplines. Knowledge of these properties is used to correctly predict the mechanisms of reactions, to understand the essence of acidic and basic catalysis, to assess the compatibility of drugs and more.

Objective: To form knowledge about the structure of chemical bonds, about the electronic effects of substituents in the molecules of organic compounds, the ability to establish the unity of the structure of substances and their chemical characteristics. To gain knowledge about the acidity and basicity of organic compounds as an important concept that determine their physicochemical and biological properties.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

1. The nature of chemical bonds in organic compounds.
2. Hybridization of atoms. The hybridization of carbon atoms.
3. Electronegativity, the value of electronegativity of the main organogenic elements.
4. Conjugation and conjugated systems.
5. Inductive and mesomeric electronic effects.

6. Proton theory of acids and bases by the Brønsted–Lowry.
7. Lewis concept of acids and bases.
8. Hard and soft acids and bases.
9. Hydrogen bond.

PRACTICAL WORKS PERFORMED IN THE CLASS.

Protocol № 2

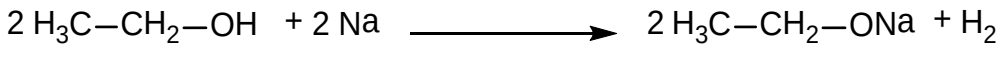
Date_____

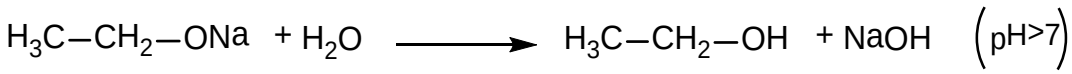
Experiment № 1

Sodium ethoxide preparation and its hydrolysis.

Place 4-5 drops of absolute ethanol in a dry test tube and add a piece of sodium metal (the size of a match head), pre-squeezed from Vaseline oil on a filter paper. Collect the released hydrogen by covering the tube with a stopper. Then the plug is removed the open end of the tube is raised to the flame of the burner. The mixture of hydrogen and air burns with a characteristic «barking» sound. Dissolve the white precipitate of sodium ethylate (sodium ethoxide) in 2-4 drops of ethanol and add 1 drop of 1% alcohol solution of phenolphthalein. Then add 1-2 drops of water to the test tube. Explain the appearance of crimson color.

Reaction scheme:





Observation:

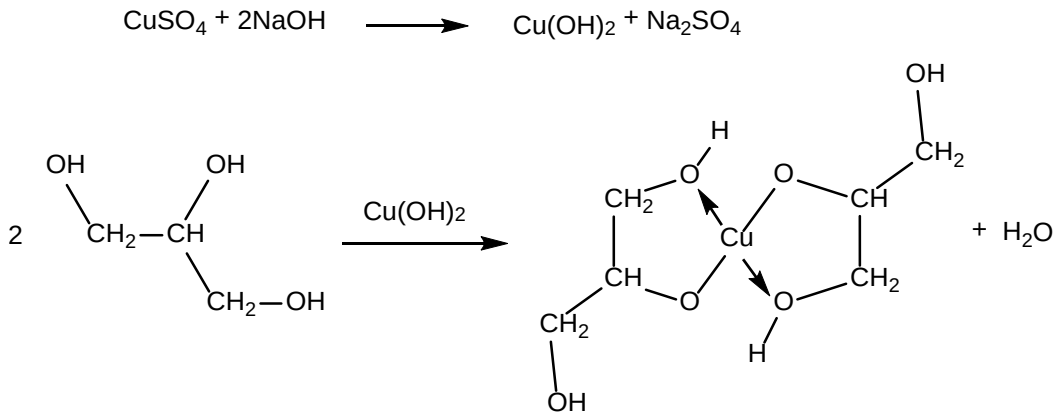
Conclusions:

Experiment № 2

Obtaining of copper(II) glycerate.

Place 2 drops of 2% copper(II) sulphate solution and 2 drops of 10% sodium hydroxide solution in a test tube. A blue precipitate of copper(II) hydroxide is formed. Add 1-2 drops of glycerin solution to it and shake the test tube. When copper(II) hydroxide interacts with glycerin, copper glycerate is formed, the solution of which has a blue color. This reaction is used to detect organic compounds containing a vicinal diol moiety (two hydroxyl groups at adjacent carbon atoms).

Reaction scheme:



Observation:

Conclusions:

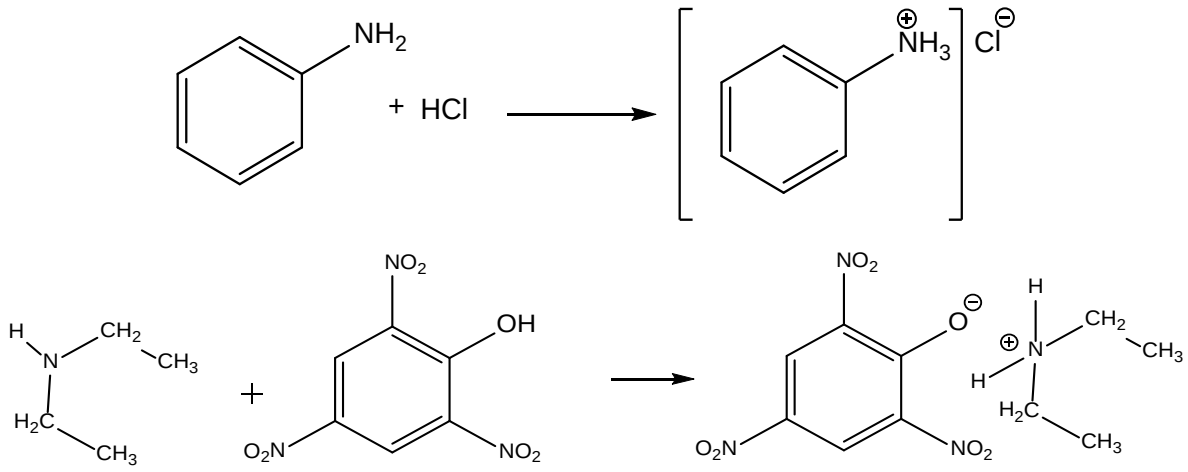
Experiment № 3

The basic properties of aliphatic and aromatic amines.

1. Place 2 drops of water in two test tubes. Then add 1 drop of aniline to the first test tube and 1 drop of diethylamine to the second and shake. Compare the solubility of these amines in water. Apply 1 drop of the contents of each test tube to a strip of universal indicator paper. Determine the pH of aniline and diethylamine solutions.

2. Add 1 drop of 10% hydrochloric acid solution to the aniline emulsion in water. A clear solution is formed. Add 3 drops of saturated aqueous picric acid solution to the diethylamine solution and mix. Place the test tube in a glass of cold water. After some time, a precipitate of diethylamine picrate is formed.

Reaction scheme:



Observation:

Conclusions:

CHALLENGE QUESTIONS

1. Compare the electron density distribution in the molecule of hepta-2,4-dienoic acid and buta-1,3-diene.

2. Describe the mutual influence of the aldehyde group and the benzene moiety in the benzaldehyde molecule.

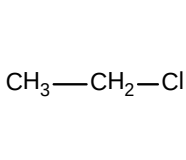
3. Specify the type and sign of the electronic effects of substituents in the following molecules: toluene, phenol, benzenesulfonic acid.

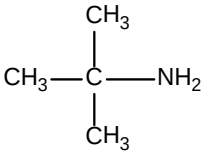
4. Compare the acidity of ethanol and 2,2,2-tribromoethane (narcolan).

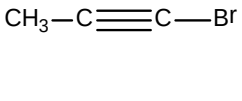
5. Compare the basicity of the following compounds: ethanol and diethyl ether.

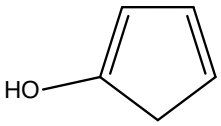
6. Compare the acidic properties: ethane, ethylene, acetylene.

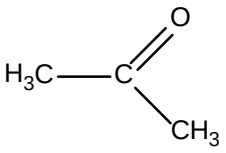
7. Graphically indicate the electronic effects of substituents (inductive ±I and mesomeric ±M) in the following formulas:

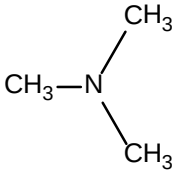


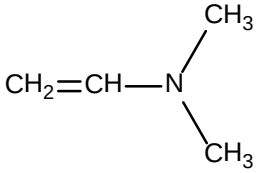


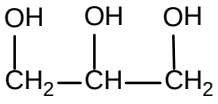


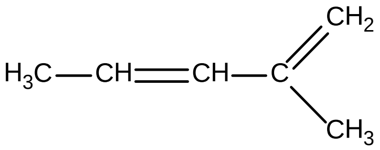
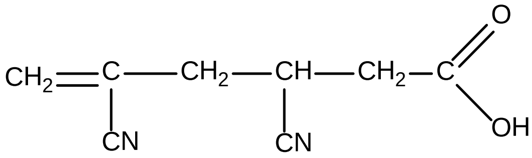
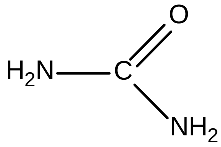
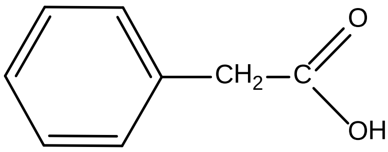
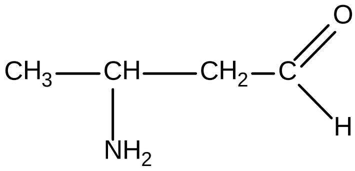
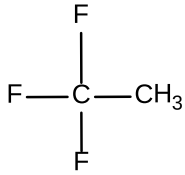
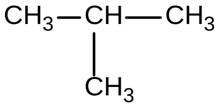
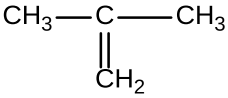
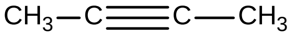
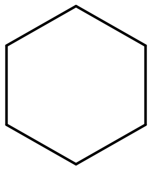
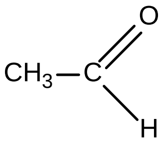
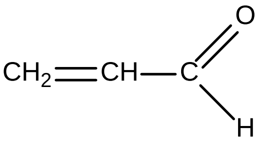
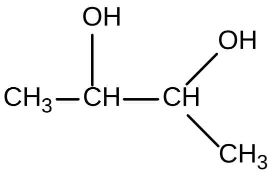
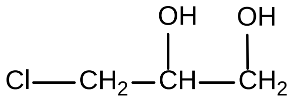
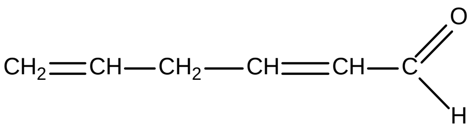
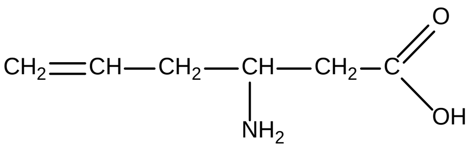
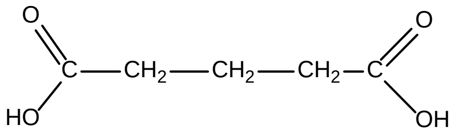
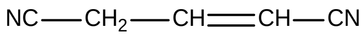
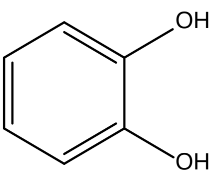
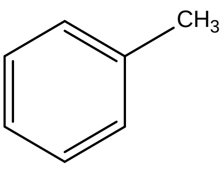
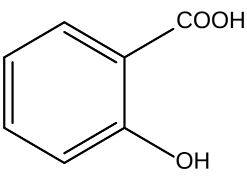
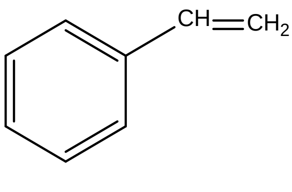










LESSON 3

TOPIC: BASICS OF ORGANIC SYNTHESIS. ISOLATION AND PURIFICATION OF ORGANIC COMPOUNDS. EVALUATION OF STRUCTURE BY METHODS OF ELEMENTAL ANALYSIS, IR, UV, NMR, MASS SPECTROMETRY.

Subject motivation: Organic synthesis is one of the most important and interesting sections of organic chemistry as a science, which is devoted to the development of methods for obtaining of previously unknown substances. Thus, without the “art” of organic synthesis, most of the known drugs would be inaccessible to mankind. Specialists in the field of organic synthesis must have both deep theoretical knowledge and refined skills for isolation and purification of reaction products. An understanding of the basic methods of isolation and purification of organic matter is also necessary for any student studying a course in organic chemistry. IR, UV, NMR spectroscopy and mass spectrometry are currently the main methods for establishing the structure of organic compounds and studying it’s features. Also, these methods can be used for qualitative and quantitative analysis of organic compounds, including drugs. Knowledge of the spectral characteristics of a class of substances contributes to a deeper understanding of structural organic chemistry.

Objective: To consider the main methods of isolation and purification of organic substances. To generalize theoretical ideas about the methods of IR, UV, NMR spectroscopy and mass spectrometry. To consolidate and creatively develop the ability to implement techniques for the synthesis, isolation, purification and identification of organic compounds.

THEORETICAL QUESTIONS FOR ISELF-TRAINING TO THE CLASSES

1. Organic synthesis as a section of organic chemistry.
2. Planning of synthetic works. Retrosynthetic analysis.

3. The main methods of organic substances separation from the reaction mixture.

4. Basic methods of purification of organic compounds (distillation, recrystallization, chromatography).

5. Physicochemical methods of organic compounds study and their classification.

6. IR-spectroscopy and its application. Stretching and bending vibrations.

7. NMR-spectroscopy and its application. Chemical shift and spin-spin interaction.

8. UV-spectroscopy and its application.

9. Mass-spectroscopy and its application.

10. Spectra interpretation.

11. Application of physicochemical research methods in pharmaceutical analysis.

12. Qualitative reactions of a functional groups.

Topics of abstracts for the lesson:

1. IR-spectroscopy as a tool for establishing the organic compounds structure.

2. Scheme of an infrared spectrometer.

3. Proton-magnetic resonance spectroscopy.

4. Mass spectrometry as a tool for the chemical structure studying.

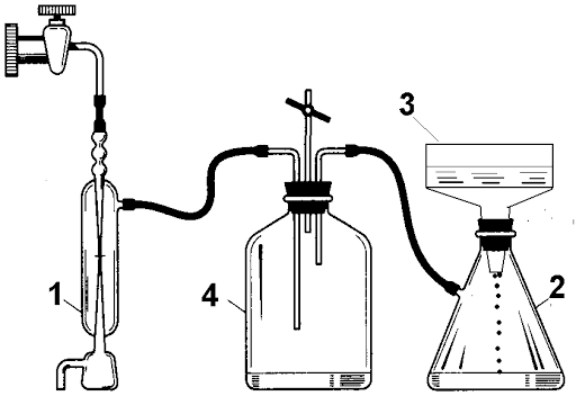
PRACTICAL WORKS PERFORMED IN THE CLASS.

Protocol № 3

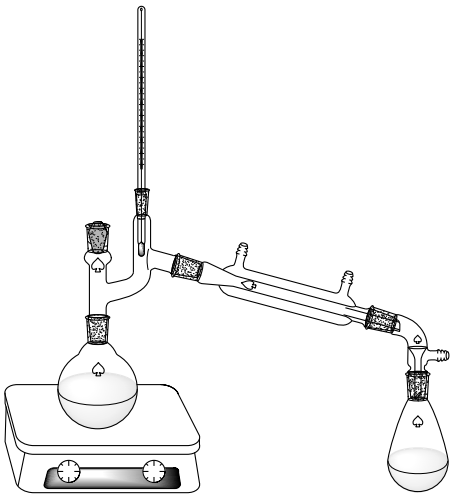
Date_____

Experiment 1. Examine the devices shown in the figure and get acquainted with the technique:

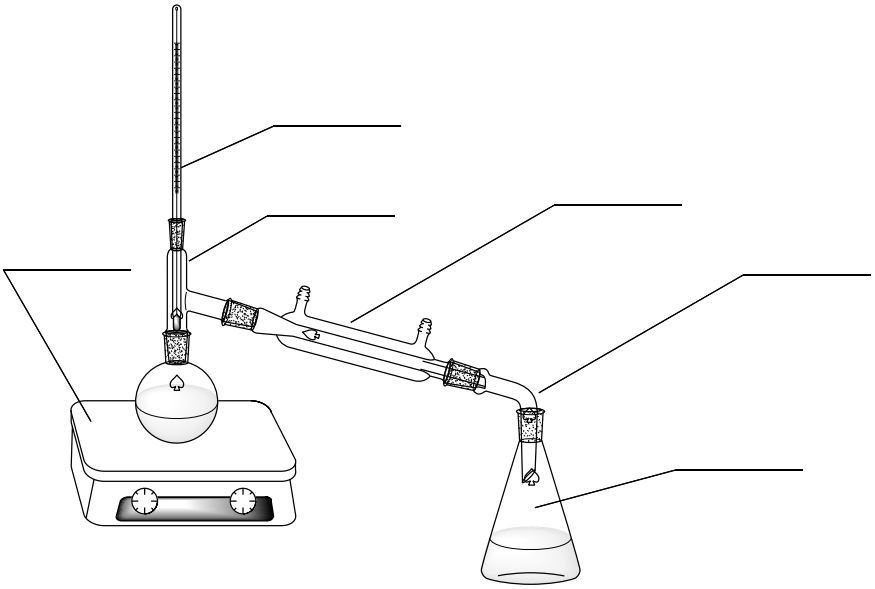
Filtration at the atmospheric pressure and under vacuum.



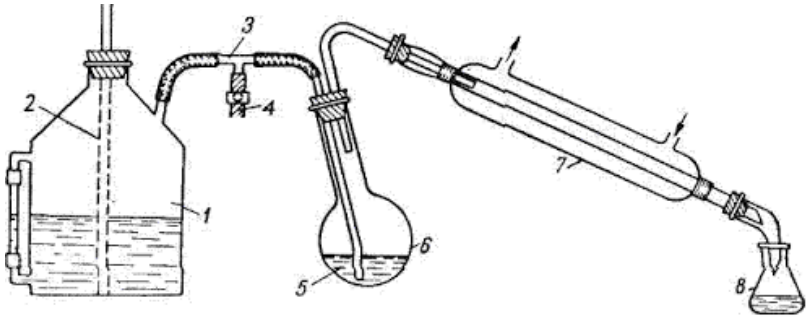
Simple distillation at the atmospheric pressure



Distillation under vacuum

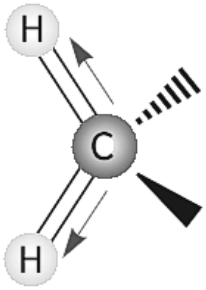


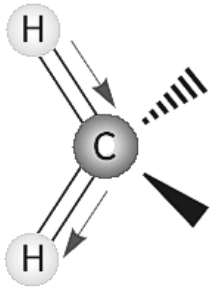
Distillation with water vapor



Experiment 2. **Interpretation of IR spectra.**

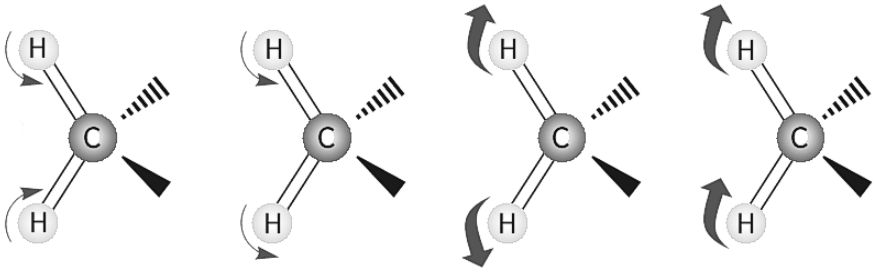
1. Write the type of stretching vibration (ν):





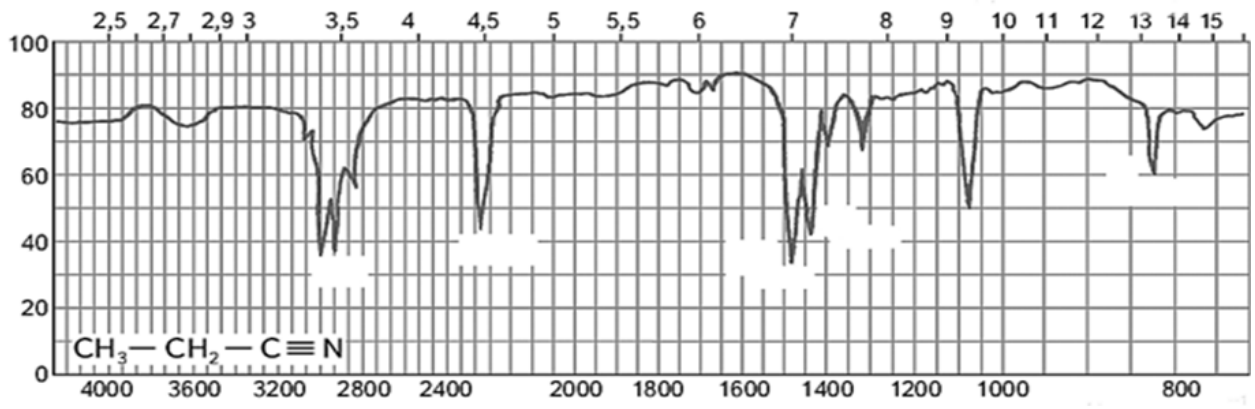
_____ _____

2. Write the type of bending vibrations (δ):



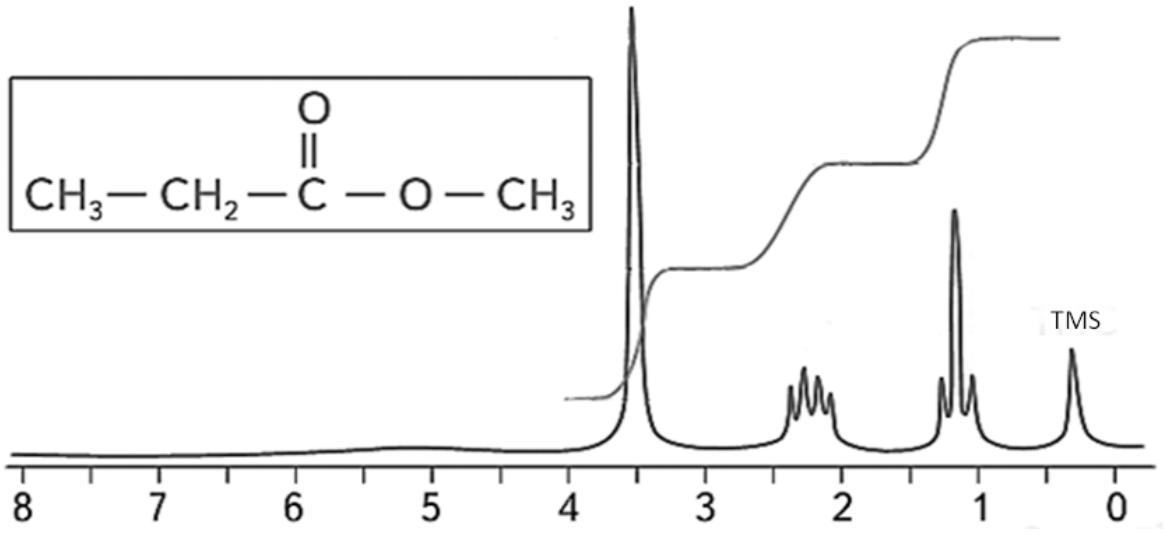
3. Using the tables of absorption bands, denote the groups of atoms and the types of vibrations in the IR spectrum of propionitrile.

wavenumber, μm



frequency, cm^{-1}

Experiment 3. Using chemical shift tables and spin-spin interaction constants, interpret the ^{1}H NMR spectrum of methylpropionate.



δ (ppm)

LESSON 4

TOPIC: HYDROCARBONS AS A CLASS OF ORGANIC COMPOUNDS. STRUCTURE AND PROPERTIES OF ALKANES AND CYCLOALKANES. RADICAL SUBSTITUTION REACTIONS.

Subject motivation: Acyclic and cyclic saturated hydrocarbons are widespread in nature: they are a part of natural gas, oil and solid combustible minerals. They underlie all classes of biologically active substances, are widely used in organic synthesis and medicine.

Objective: To form the ability to predict the reactivity of alkanes and cycloalkanes in relation to their structure.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

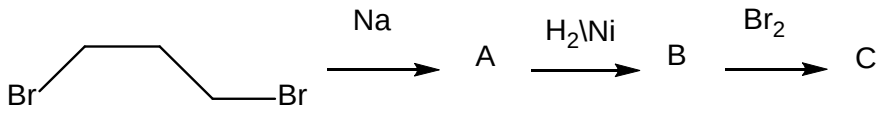
1. Methods of alkanes and cycloalkanes synthesis.
2. Chemical properties of alkanes.
3. The mechanism of radical substitution of alkanes and cycloalkanes.
4. Chemical properties of cycloalkanes. Bayer's strain theory.
5. Conformations of cycloalkanes.

CHALLENGE QUESTIONS

1. Write the reactions of cyclobutane with chlorine, hydrogen, hydrogen chloride. How the typical for alkenes reaction, namely the tendency of cyclobutane to the addition reaction can be explained?

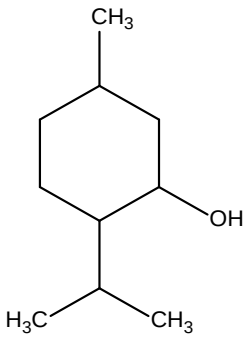
2. Write the structural formulas of *cis*- and *trans*- isomers of 1-methyl-2-ethyl-cyclopropane. Will this compound have optical activity?

3. Fill in the scheme of the following transformations. Name the products and explain the reaction mechanism:

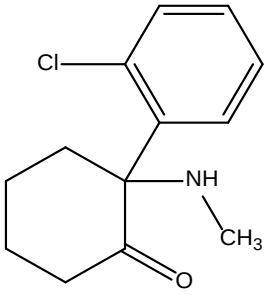


4. Describe the possible confirmations of *cis*- and *trans*- isomers of 1,2-dimethyl-cyclohexane and compare their relative stability.

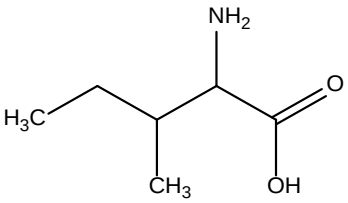
5. Carry out a structural analysis of the following compounds:



menthol



ketamine



isoleucine

LESSON 5
TOPIC: UNSATURATED HYDROCARBONS (ALKENES, ALKADIENES, ALKYNES). ELECTROPHILIC ADDITION REACTIONS.

Subject motivation: Unsaturated acyclic hydrocarbons are characterized by high reactivity and are often used as a starting material for the synthesis of substances used in engineering, medicine, pharmacy. Alkenes and alkadienes are monomers that occupy a prominent place in the chemistry of macromolecular compounds and are widely used as a basis for various dosage forms, packaging material, sanitation and hygiene items, surgical material, etc.

Objective: To form knowledge about the chemical behavior of unsaturated aliphatic hydrocarbons based on the nature of the carbon atom and its chemical bonds.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

1. Nomenclature of unsaturated acyclic hydrocarbons.
2. Methods of the unsaturated hydrocarbons synthesis.
3. Chemical properties of alkenes:

a. electrophilic addition reaction;

b. hydrogenation reaction;

c. oxidation reaction;

d. polymerization reaction.

4. Chemical properties of alkynes.

CHALLENGE QUESTIONS

1. The hydration of ethylene, obtained by oil cracking, is the economical way to synthesize ethyl alcohol in industry. The reaction proceeds in the presence of sulfuric or phosphoric acids. Write the interaction of ethylene with water, describe the mechanism, explain the role of the acid catalyst.

2. Carry out the hydration reaction of acetylene (Kucherov reaction). What product is formed as a result of the reaction? What is the uniqueness of this reaction?

3. Ethylene oxide (oxirane) is used to sterilize medical instruments made of polymeric materials, that lose their properties after heat treatment. Write the equation of the reaction of epoxidation of ethylene: a) by peracetic acid: b) by oxygen in the presence of silver. Which product is obtained by hydrolysis of the resulting epoxide?

LESSON 6

TOPIC: AROMATICITY AS A COMPLEX OF SPECIFIC PROPERTIES OF ORGANIC COMPOUNDS. AROMATIC CARBOHYDRATES OF BENZENOID AND NON-BENZENOID TYPE. PROPERTIES OF AROMATIC HYDROCARBONS. ELECTROPHILIC SUBSTITUTION REACTIONS.

Subject motivation: Arenes and their functional substitutes are widely used in industrial organic synthesis (production of dyes, polymeric materials, explosives, etc.). Based on them, the production of a range of important pharmaceuticals has been developed. Knowledge of the electronic structure of benzene is necessary for a deep and successful study of the relevant sections of pharmaceutical chemistry, pharmacology and the acquisition of professional skills.

Objective: To form knowledge of the peculiarities of the structure of aromatic compounds, the ability to predict the chemical behavior of arenes in accordance with the structure of the molecule and the electronic effects of substituents.

THEORETICAL QUESTIONS FOR SELF-TRAINIG TO THE CLASSES

1. Nomenclature of arenes.
2. Methods of arenes synthesis.
3. The concept of aromaticity.
4. The mechanism of the electrophilic substitution reaction (S_E).
5. The influence of functional groups in substitution electrophilic reactions (S_E).
6. Oxidation reactions of arenes.
7. Reduction reactions of arenes.

PRACTICAL WORKS PERFORMED IN THE CLASS.

Protocol № 6

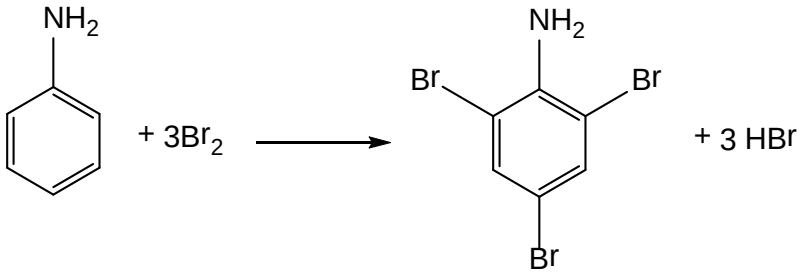
Date_____

Experiment № 1

Formation of tribromoaniline.

Place one drop of aniline and 5-6 drops of water in a test tube, shake well and add a few drops of bromine water to the emulsion until a white precipitate of 2,4,6-tribromoaniline appears. The bromination reaction of aniline proceeds quantitatively and is used in pharmaceutical analysis to discover aniline and a number of its derivatives.

Reaction scheme:



Observation:

Conclusions:

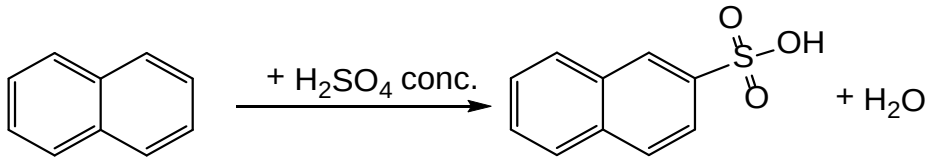
Experiment № 2

Naphthalene sulfonation.

Place few crystals of naphthalene in a dry test tube. Heat the tube until the naphthalene melts. Then let it cool and add 10 drops of concentrated sulfuric acid (add in the fume hood!). Carefully heat the tube over the burner flame, shaking constantly until the mixture is completely homogeneous. Then allow the mixture to

cool, add 10 drops of water and heat again slightly. After cooling, crystals of naphthalene-2-sulfonic acid (*β*-sulfonaphthalic acid) are observed.

Reaction scheme:



Observation:

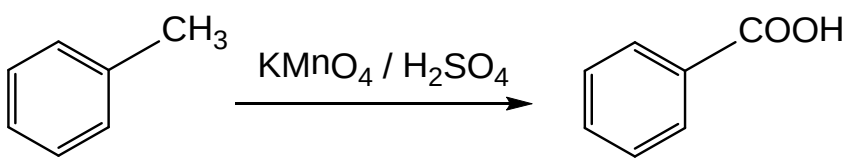
Conclusions:

Experiment № 3

Oxidation of 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 a test tube. Add 1-2 drops of toluene and shaking vigorously heat the tube over the flame of the burner. Note which changes have occurred with the original color of the solution.

Reaction scheme:



Observation:

Conclusions:

CHALLENGE QUESTIONS

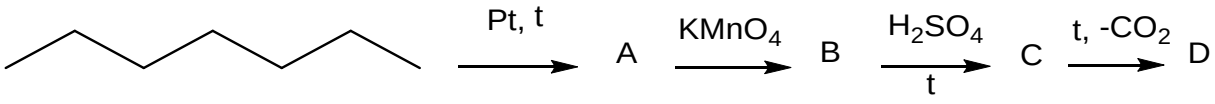
1. Give the mechanism of the bromination reaction of toluene and name the obtained products:

a) in the presence of $FeBr_3$:

b) under the influence of UV light and temperature.

2. The identification of salicylamide (antirheumatic agent) is determined by the reaction with bromine water. The formation of a white flaky precipitate of dibromo derivative is observed. Indicate the most probable positions in the salicylamide molecule for attack by electrophilic reagent.

3. Write the indicated scheme:



LESSON 7
TOPIC: FINAL LESSON ON THE TOPIC «THEORETICAL BASICS OF THE STRUCTURE OF ORGANIC COMPOUNDS. STRUCTURE AND PROPERTIES OF HYDROCARBONS».

Objective: To consolidate and creatively develop knowledge and skills related to the structure of organic compounds. To study the ways of organic molecules representation, classification by carbon chain structure, by the nature of

the functional group and nomenclature systems: trivial, rational and international (IUPAC). Consider the main types of chemical bonds in organic compounds: ionic, covalent, coordination, semipolar, hydrogen. Electronic structure.

Double and triple bond, inductive and mesomeric effects. Carry out classification of organic reactions and reagents. The concept of organic acids and bases. Consolidate and creatively develop knowledge and understanding of the principles of predicting the reactivity of the main hydrocarbons groups, and their ability to undergo homolytic and heterolytic reactions.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

1. Explain the statements of the A. Butlerov theory of the organic compounds.

2. Define the term “hybridization of atomic orbitals”. Describe the electronic structure and spatial structure of the carbon atom in the sp^3, sp^2, sp-hybridization states. Define the σ- and π-bonds. Give the scheme of σ-bonds in ethane and propane, the scheme of σ- and π-bonds in ethyne, propyne. Specify the length and binding energy of C-C, C=C, C≡C bonds.

3. Define the following concepts: conjugation, conjugation (resonance) energy of an electronegative atom. Describe the phenomenon of conjugation on the example of 1,3-butadiene. Determine the type of conjugation in the molecule of hexatriene-1,3,5, *N*,*N*-dimethylvinylamine and naphthylamine. Compare the thermodynamic stability of the compounds in each pair: pentadiene-1,3 and pentadiene-1,4; aniline and benzylamine. Compare the polarity of the CH bond in ethane, ethene and ethyne.

4. Define the concepts: inductive effect, mesomeric effect. Speak about positive and negative mesomeric effects, electron donor and electron acceptor substituents. Determine the type and sign of electronic effects of substituents in the following compounds: toluene, ethylamine, benzonitrile, propenoic acid, phenol,

propanol-1, methanoic acid, propanal, propenal, ethyl chloride, vinyl chloride, *p*-hydroxybenzoic acid, *p*-aminobenzenesulfonic acid, ethanesulfonic acid, benzenesulfonic acid, 1-nitropropane, nitrobenzene, benzyl chloride.

5. Define the concepts: chirality, enantiomers, diastereomers. Formulate the rules for converting Fisher's projection formulas. Write the projection formulas of stereoisomers of the following compounds: 3-bromo-2-hydroxybutanedioic acid, 2-hydroxybutanoic acid, 2-bromo-3-chlorobutane, 4-amino-3-mercaptobutanal, 3-amino-2-mercapto-3-methylbutanoic acid, 2-hydroxypropanoic acid, 2,3-dihydroxypentanedioic acid, 2-amino-3-mercaptopropanoic acid, glyceric aldehyde, 2-amino-4-methylthiobutanoic acid, 2-mercaptopropanoic acid, pentanol-2, 2-bromo-3-chlorobutane, 2-butanamine, 2-bromobutanol-1.

6. Name the enantiomers by the nomenclature, write the diastereomers of butene-2, butenedioic acid.

7. Define the concepts: conformation, configuration. Draw in the form of Newman projections ethanol, 2-bromoethanol-1, ethane, 1-chloropropane, 1,2-dichloroethane, 2-aminoethanol-1, ethyl mercaptan, butane, pentane, 2-mercaptoethanol-1. Name the conformations, give their energy curve and show the stereochemical formulas of dichloromethane, chloroform.

8. Define the concepts: Brønsted-Lowry acid and base. Give the classification of acids and bases depending on the nature of the center of acidity and basicity. Compare the acidity of the following acids in aqueous solution according to the Brønsted-Lowry: ethyl mercaptan and 2-methyl-propanethiol-1; ethanol and 2-methylpropanol-1; phenol and *p*-nitrophenol, *p*-methylphenol; propanol-1 and propanthiol-1; methanethiol and 3-methyl-butanthiol-1; methanol and 2,2-dimethylpropanol-1; phenol, *p*-chlorophenol and *p*-methoxyphenol; ethanol and ethylamine.

9. Compare the basicity in an aqueous solution of the following bases according to the Brønsted-Lowry: dimethylamine and trimethylamine; ethanol and diethyl ester; aniline and diphenylamine; diethyl ester and diethyl sulfide; *p*-

nitroaniline and aniline, *p*-methoxyaniline; ethanol and ethylamine; propanol-1 and propanethiol-1, aniline and ammonia.

11. Carry out the classification of organic reactions in the direction (addition, substitution, elimination).

12. Identify the types of reagents (nucleophilic, electrophilic, radical).

13. Give methods for alkanes and cycloalkanes synthesis.

14. Justify the ability of alkanes to substitution radical reactions (S_R). Define the concept of «chain process». Indicate the significance of the works of M.M. Semenov, devoted to radical reactions. Describe the mechanism of reactions:

- bromination of propane;
- chlorination of 2-methylpropane;
- nitration (Konovalov reaction) of propane, 2-methylpropane.

15. Describe the reactivity of alicycles (addition, substitution) depending on the cycle size. The Baeyer's strain theory.

16. Give the electronic structure of cyclopropane and indicate the peculiarity of its chemical behavior.

17. Methods of alkenes synthesis. Write the equations of the corresponding reactions.

18. Justify the reactivity of alkenes to undergo electrophilic addition (A_E) reactions. Describe the mechanisms of reactions:

- bromination of ethene, cyclopentene;
- hydrobromination (hydrochlorination) of propene, butene-1;
- hydration of butene-1.

Formulate the Markovnikov's rule and explain it from the standpoint of a modern electronic representations (static and dynamic factors). Compare the reactivity of propene and ethene in the addition reactions.

19. Carry out qualitative reactions to prove the presence of a double bond.

20. Classify dienes with cumulative, conjugated and isolated double bonds.

21. Write: the reaction to obtain butadiene-1,3 by the Lebedev method; the scheme of its polymerization; the reaction with bromine. By what mechanism does

the last reaction proceed? Specify the features of its course (1,2- and 1,4-types of addition).

22. Give a fragment of the structural formula of isoprene, chloroprene rubber and explain the stereoregularity of their structure.

23. List the methods to synthesize alkynes. Write the equations of the reactions.

24. Explain the appearance of the CH-acid center in alkynes. Write a reaction scheme that proves the CH-acidity of ethyne.

25. Write for ethyne schemes of general qualitative reactions to multiple bonds and specific qualitative reaction to prove multiple bond.

26. Explain the electronic structure of benzene (conjugated molecular ring system, energy stabilization, aromatic conditions, Hückel's rule). Compare aromatics in a series: benzene, naphthalene, anthracene.

27. List the methods of arenes synthesis.

28. Justify the ability of arenes to electrophilic substitution reaction (S_E). Describe the mechanisms of reactions:

- Friedel-Crafts alkylation of benzene, toluene, naphthalene;
- Friedel-Crafts acylation of benzene, azulene;
- bromination of benzoic acid, 2-methylnaphthalene;
- chlorination of chlorobenzene;
- sulfonation of aniline;
- nitration of benzaldehyde, phenol, naphthalene, naphthol-1.

29. Classify substituents according to their electronic effects (ortho-, meta-, para- orientation). Explain the influence of substituents, namely hydroxyl group, carbonyl group, chlorine, on the direction and rate of S_E-reaction in the benzene ring (static and dynamic factors, activating and deactivating substituents with matching and non-matching orientation).

30. Compare the reactivity in the S_E reaction of benzoic acid, nitrobenzene, toluene and ethylbenzene, ethyl phenyl ketone and benzene.

31. Give the reactions of halogenation (bromination, chlorination) of toluene: a) in the side chain; b) in the benzene ring. Specify the conditions and mechanism of the reactions.

32List reagents which allow to distinguish the following compounds:

- butane, 1-butene, 1-butyne;
- propane, propyne;
- 1-butyne, 2-butene.

33. Describe the tendency to oxidation reactions of:

- alkanes, alkenes, alkynes, arenes;
- benzene, naphthalene, anthracene;
- benzene and alkylbenzenes.

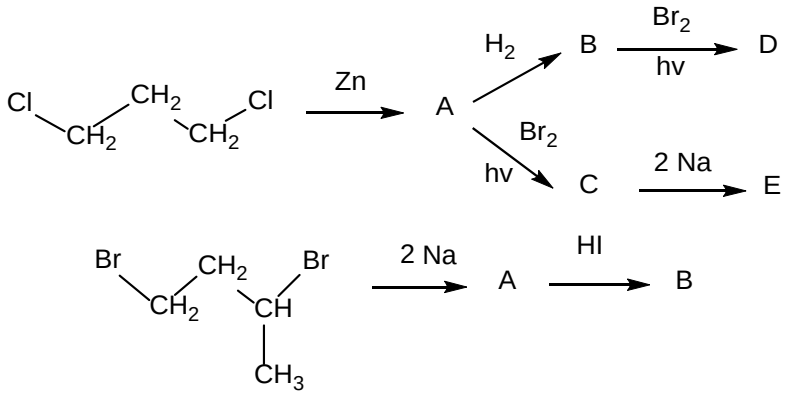
33. Write the formulas of biphenyl, diphenylmethane, triphenylmethane. Write the cation, anion and radical of triphenylmethane. Identify the factors that affect the stabilization of organic ions and radicals.

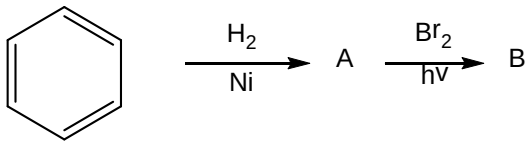
34. Describe the role of free radicals in the metabolism of living organisms and organic synthesis.

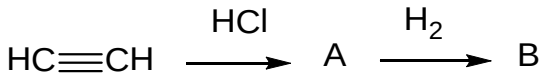
35. Give the structural formulas of cyclopentadienyl anion, ferrocene, cycloheptatrienyl cation (tropylium ion), azulene and explain their aromaticity.

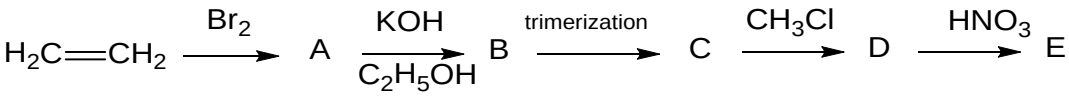
36. Indicate the importance of hydrocarbons as starting materials in the synthesis of drugs.

37. Using knowledge of the reactivity of hydrocarbons, perform the following transformations according to the following schemes:









LESSON 8

TOPIC: HALOGEN-CONTAINING DERIVATIVES OF HYDROCARBONS. NUCLEOPHILIC SUBSTITUTION REACTIONS.

Subject motivation: Halogenated hydrocarbons are widely used as starting compounds in organic synthesis and, in particular, in the manufacture of drugs. The physiological action of alkyl halides is based on their ability to dissolve in fats. This aspect leads to physical and colloidal changes in the lipoids of nervous tissue, and thus, the manifestation of the anesthetic effect (chloroform, ethyl chloride, fluoroethane). Knowledge of the electronic structure and mechanisms of chemical processes allows to determine the optimal conditions of the synthesis, to predict the stereochemical direction of the reaction in the case of optically active substrates, to estimate the possibility of metabolism of halogen-containing drugs in living organisms.

Objective: To form knowledge and skills to predict the reactivity of halogen-containing derivatives of hydrocarbons in competitive reactions of nucleophilic substitution and elimination.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

1. Methods of halogen-derived alkanes, alkenes and arenes synthesis.

2. Comparison of the reactivity of halogen in alkyl-, alkenyl- and arylhalides.

3. Nucleophilic substitution reactions (S_N). Hydrolysis, alcoholysis, ammonolysis. The nitriles, nitro derivatives of hydrocarbons and Grignard reagents synthesis.

The reaction mechanism of biomolecular nucleophilic substitution (S_{N2}).

The reaction mechanism of monomolecular nucleophilic substitution (S_{N1}).

4. Stabilization of carbocation.

5. Elimination reactions (E) (dehydrohalogenation, dehalogenation).

6. Zaitsev's Rule.

8. The value of halogenated hydrocarbons for pharmacy.

PRACTICAL WORKS PERFORMED IN THE CLASS.

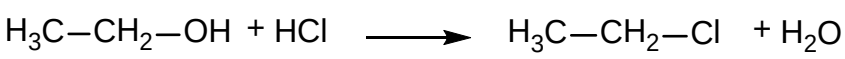
Protocol № 8

Date_____

Experiment № 1

The synthesis of ethyl chloride from ethanol:

Put crystals of sodium chloride in a test tube, add 5-6 drops of ethanol, then add 3-4 drops of sulfuric acid. When heated on a low flame burner, chloroethane is formed. If to put the open end of the test tube close to the flame of the burner, the formed chloroethane burns with the green fire border.



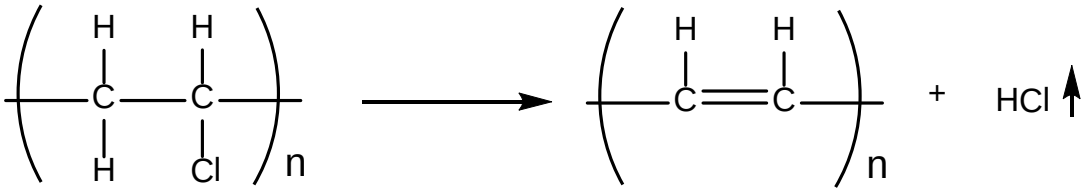
Observation:

Conclusions:

Experiment № 2

Decomposition of polyvinyl chloride (PVC):

Place a small piece (pea-sized) of PVC in a dry test tube and gently heat in a gas burner flame until decomposition. Wet universal indicator paper raised to a test tube turns red (acid reaction). Elimination of hydrogen chloride occurs.



Observation:

Conclusions:

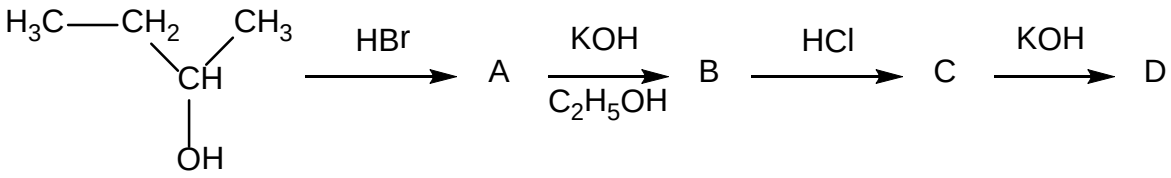
CHALLENGE QUESTIONS

1. Which of the following halogenated hydrocarbons easily undergo the S_N-reaction: 2-bromopropane, 2-bromobutene-1, benzyl chloride, toluene chloride?

2. Determine the reaction mechanism (S_{N1} or S_{N2}) of 2-bromobutane and allyl bromide with nucleophiles.

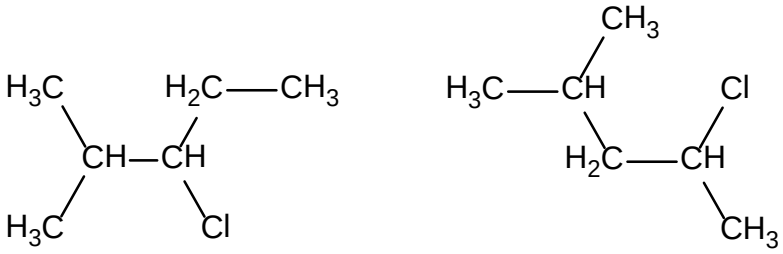
3. Write the product of the elimination reaction (E) for the secondary pentyl bromide.

4. Fill the scheme:



Determine the mechanism by which reactions occur at each stage of these transformations. Name the initial, intermediate and final compounds.

5. Give the structural formula of the alkene, which is preferably formed during the interaction of an alcoholic solution of potassium hydroxide with the following alkyl halides:



Name the given haloalkanes and their corresponding alkenes according to the IUPAC system.

LESSON № 9

TOPIC: STRUCTURE AND CHEMICAL PROPERTIES OF NITRO DERIVATIVES, NITROSO DERIVATIVES, AMINES, DIAZO AND AZO COMPOUNDS.

Subject motivation: Organic compounds contain nitrogen, which are involved in the formation of biopolymers, proteins and nucleic acids, without which the existence of living matter is impossible. Most drugs contain ionic groups, thus the main drugs are in an ionized state or capable of ionization at physiological pH values. Based on aliphatic and aromatic amines a number of valuable drugs of hypotensive, diuretic, neuroleptic, analgesic and other types of activity are obtained. The emergence of large class of the organic chemistry of

diazo compounds and the chemistry of azo dyes is associated with the discovery of the diazotization reaction. Diazo compounds are used as products in the synthesis of dyes, drugs, as well as for the identification of phenols and amines in pharmaceutical analysis. Nitro compounds are the starting point for the synthesis of amines, in addition, the nitro group is a structural fragment of many drugs, mainly antimicrobial (chloramphenicol, nitrofural, etc.). Nitroso compounds are not used in medical practice due to their toxicity, but they are intermediates in the synthesis of a number of practically significant organic substances.

Objective: to obtain the knowledge of the basic and nucleophilic properties of amines based on their structure. To apply knowledge of the structure and chemical activity of diazo compounds, conditions of diazotization reaction in pharmaceutical analysis. To form knowledge about the peculiarities of the structure and reactivity of nitro- and nitroso derivatives.

THEORETICAL QUESTIONS SELF-TRAINING TO THE CLASSES

1. Structure, classification, synthesis methods and chemical properties of nitro- and nitroso derivatives of hydrocarbons.
2. Nomenclature, classification of aliphatic and aromatic amines.
3. Methods of aliphatic and aromatic amines synthesis. Zinin reaction.
4. The basic properties of amines.
5. Amines as nucleophilic reagents.
6. Qualitative reactions of amines.
7. Electrophilic substitution reactions of aromatic amines.
8. The structure of diazonium salts.
9. Theory of chromaticity.

PRACTICAL WORKS PERFORMED IN THE CLASS.

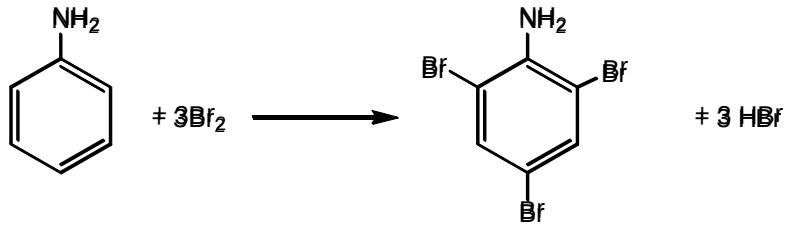
Protocol № 9

Date_____

The formation of tribromoaniline.

Place one drop of aniline and 5-6 drops of water in a test tube, shake well and add a few drops of bromine water until a white precipitate of 2,4,6-tribromoaniline appears. The bromination reaction of aniline proceeds quantitatively and is used in pharmaceutical analysis to discover aniline and several its derivatives.

Reaction scheme:

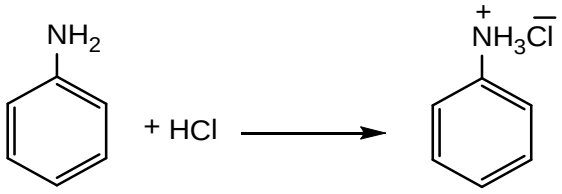


Conclusions:

Experiment № 2

The basic properties of aromatic and aliphatic amines.

1. Place 2 drops of water in two test tubes. Then place 1 drop of aniline in the first test tube and 1 drop of diethanolamine (colamine) in the second and shake. Compare the solubility of these amines in water. Apply 1 drop of the contents of each tube to a strip of universal indicator paper. Determine the pH of aniline and colamine solutions. Add 5 drops of HCl solution to the aniline emulsion, describe the observation.



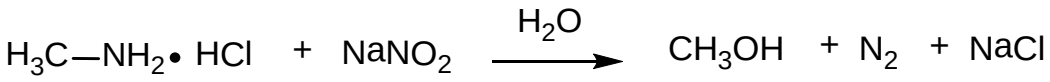
Observation:

Conclusions:

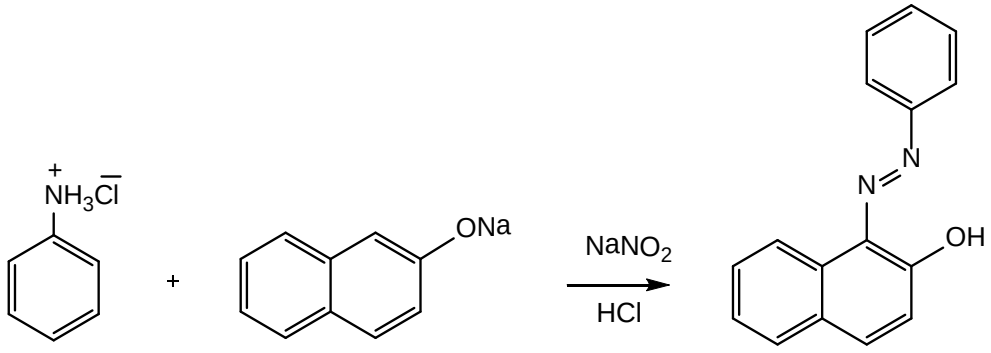
Experiment № 3

Interaction of amines with nitric acid.

1. Place 5 drops of 5% methylamine hydrochloride solution in a test tube. Carefully add 3-5 drops of 5% sodium nitrite solution. Formation of gaseous nitrogen is observed.



2. In another test tube put 10 drops of aniline hydrochloride solution (obtained in experiment 1). Add to the solution 3-5 drops of 5% sodium nitrite solution, and then 2-3 drops of alkaline solution of 2-naphthol. Pay attention to the changes that occur during the formation of the dye.



Observation:

Conclusions:

CHALLENGE QUESTIONS

1. Arrange the following pairs of compounds in descending order of basicity in aqueous solution: dimethylamine and aniline, diethylamine and diisopropylamine.

2. Write a scheme of interaction between ethylamine and aniline with:

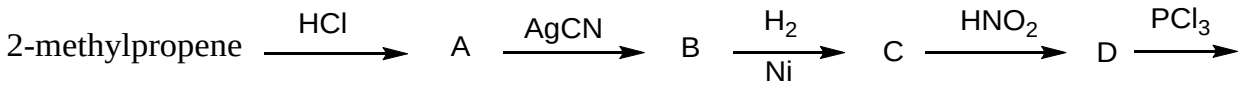
a) ethyl iodide;

b) acetic anhydride;

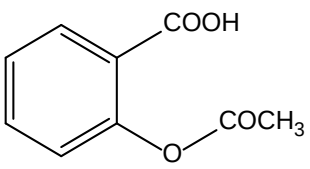
c) acetone;

d) chloroform in an alkaline medium.

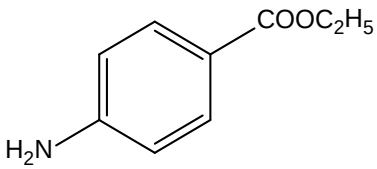
3. Fill in the scheme, name the intermediate and final products.



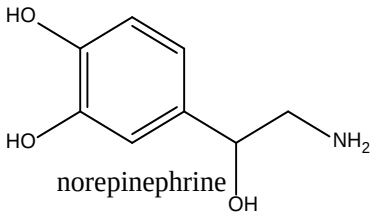
4. Perform a functional analysis of the following drugs:



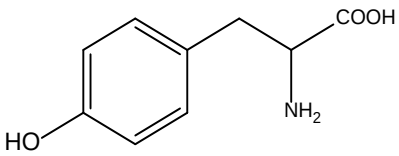
aspirin



anesthesin



norepinephrine



tyrosine

LESSON №10

TOPIC: ALCOHOLS, PHENOLS AND ETHERS: STRUCTURE AND CHEMICAL PROPERTIES.

Subject motivation: Representatives of the classes of alcohols, phenols and ethers are important natural and synthetic drugs of narcotic (lower alcohols), antiseptic (thymol, corvalol, resorcinol), antihistamine (diphenhydramine) activity. Functional groups of these classes of compounds are contained in vitamins, alkaloids, hormones, essential amino acids, cardiac glycosides and other biologically important compounds. Alcohols, phenols and ethers are widely used in organic synthesis. Knowledge of the relationship between the chemical structure and properties of the considered classes of compounds makes it possible to address the issue of identification and compatibility of drugs, to predict the conditions of their synthesis, analysis and storage.

Objective: To form knowledge of the reactivity of alcohols, phenols and ethers, which determine the course of many chemical reactions in living organisms. To develop the skills to predict the chemical behavior of organic compounds according to their chemical structure.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

1. Electronic structure of the hydroxyl group.

2. Alcohols: structure features, classification and physicochemical properties. Influence of intermolecular hydrogen bond on physical properties.

3. Reactivity of alcohols: nucleophilic substitution reactions, oxidation, elimination, acidic properties.

4. Features of the structure and reactivity of polyhydric alcohols. Participation of polyhydric alcohols in complexation reactions.

5. Features of the structure of phenols. The nature of the influence of the aromatic moiety on the acidic properties of phenols.

6. Electrophilic substitution reactions (S_E) in phenols.

7. Ethers. Features of structure, nomenclature and physicochemical properties. Methods of ethers synthesis.

PRACTICAL WORKS PERFORMED IN THE CLASS.

Protocol № 10

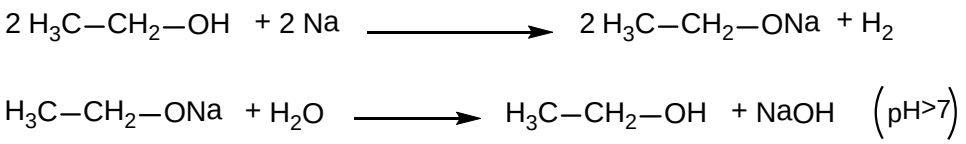
Date_____

Experiment № 1

Sodium ethylate synthesis and its hydrolysis.

Place 3 drops of absolute ethanol in a dry test tube and add a piece of sodium metal (the size of a match head), pre-squeezed from kerosene on a filter paper. Collect the hydrogen released by covering the tube with a stopper. Then remove the stopper and lift the tube through the hole to the burner flame. The mixture of hydrogen and air burns with a characteristic "barking" sound. Dissolve the white precipitate of sodium ethylate in 2-4 drops of ethanol and add 1 drop of 1% alcohol solution of phenolphthalein. Then add 1-2 drops of water to the test tube. Explain the appearance of crimson color.

Reaction scheme:



Observation:

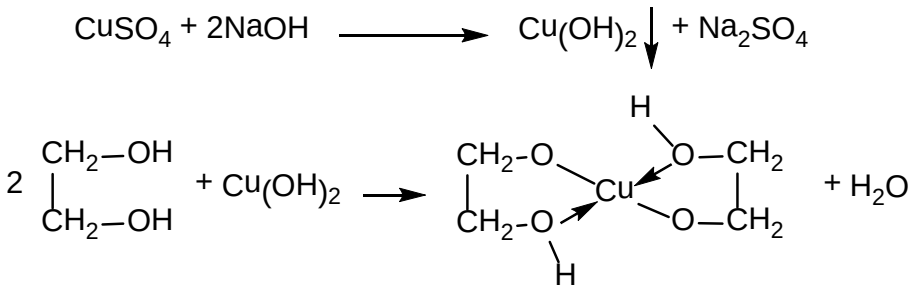
Conclusions:

Experiment № 2

Preparation of the copper(II)-ethylene glycol complex..

Add 2 drops of 2% copper(II) sulfate solution and 2 drops of 10% sodium hydroxide solution to the test tube. A blue precipitate of copper(II) hydroxide is formed. Add 1 drop of ethylene glycol and shake the tube. The interaction of copper(II) hydroxide with ethylene glycol produces copper glycolate, the solution of which has a blue color. This reaction is used to detect organic compounds containing a diol moiety (two hydroxyl groups at adjacent carbon atoms).

Reaction scheme:



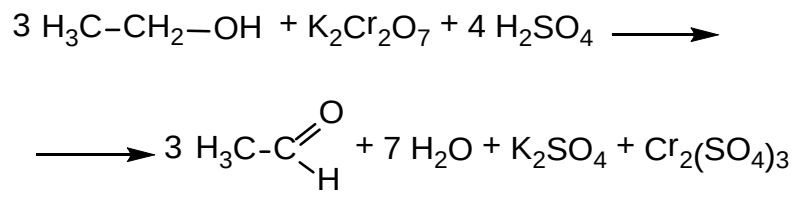
Observation:

Conclusions:

Experiment № 3

Place 2 drops of ethyl alcohol in a test tube, add 1 drop of 10% sulfuric acid solution and 2 drops of 10% potassium dichromate solution. Heat the resulting orange solution over a burner flame until it changes color. After a few seconds, the solution becomes bluish-green (chromium(III) sulfate is formed). At the same time there is a characteristic smell of acetaldehyde (smell of rotten apples).

Reaction scheme:



Observation:

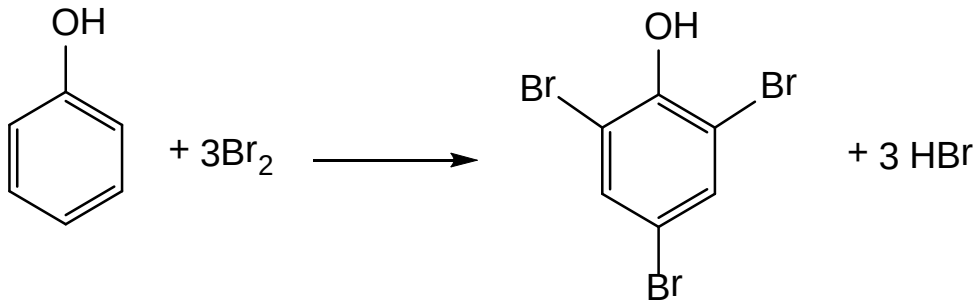
Conclusions:

Experiment № 4

The formation of tribromophenol:

Place five drops of 0,5% aqueous phenol solution in a test tube and add a few drops of bromine water until decolorization. A white precipitate of 2,4,6-tribromophenol appears. The phenol bromination reaction proceeds quantitatively and is used in the assay to detect phenol and some of its derivatives.

Reaction scheme:



Observation:

Conclusions:

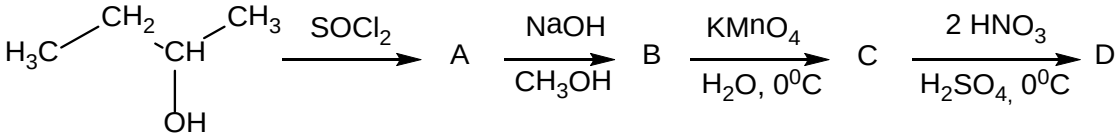
CHALLENGE QUESTIONS

1. Explain the mechanism by which dehydration of propanol-2 occurs when heated with a small amount of concentrated sulfuric acid.

2. Write schemes for the oxidation reactions of *iso*-butyl and *sec*-butyl alcohols, ethylene glycol, phenol. Name the reaction products.

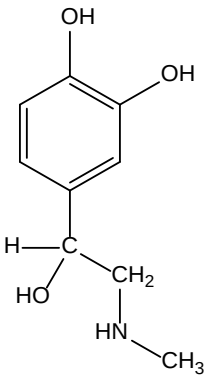
3. Give qualitative reactions to monohydric and polyhydric alcohols.

4. Fill in the diagram of the following transformations and name the products:

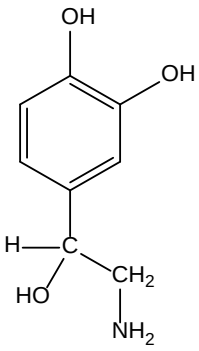


5. Write a qualitative reaction of diphenhydramine with concentrated sulfuric acid. Explain the sence of this reaction.

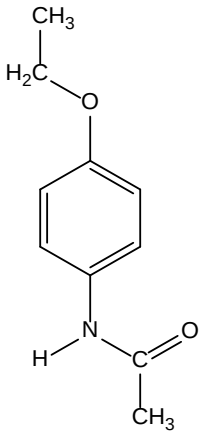
6. Conduct a structural and functional analysis of the following drugs:



Adrenaline



Norepinephrine



Phenacetin

LESSON №11

TOPIC: THIOLS, THIOETHERS, SULFOXIDES, SULFONES, SULFONIC ACIDS AND THEIR DERIVATIVES.

Subject motivation: Organic compounds containing a sulfur atom are quite common in nature and are also often used as drugs. Thus, sulfur-containing functional groups are present in the molecules of proteinogenic amino acids cysteine and methionine, a known antidote - unithiol, solvent and drug dimethyl sulfoxide, antibacterial drugs - sulfonamides. Knowledge of the structure and reactivity of sulfur-containing functional groups is a necessary condition for studying the chemistry of sulfur-containing heterocyclic compounds.

Objective: To form knowledge of the reactivity of thiols, sulfides (thioethers), sulfones, sulfoxides, sulfonic acids and their derivatives.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

1. Mercaptans: structure features, synthesis methods, reactivity.

2. Acidic properties of thiols and their more pronounced acidity compared to alcohols.

3. Oxidation of thiols.

4. Sulfides (thioethers): structure, methods of synthesis and reactivity.

5. Sulfoxides: structure, methods of synthesis and reactivity.

6. Dimethyl sulfoxide and its practical significance.

7. Sulfones: structure, methods of synthesis and their reactivity.

8. Sulfonic acids: structure, methods of synthesis and their reactivity.

9. Sulfanilic acid amides as drugs.

CHALLENGE QUESTIONS

1. Compare the acidic properties of ethyl mercaptan, ethanol, phenol and thiophenol. Explain the factors that affect the acidity of these compounds.

2. Write a scheme for the oxidation of ethyl mercaptan to diethyldisulfide and ethanesulfonic acid. Justify the choice of oxidant in each case.

3. Write the known methods of mustard gas synthesis.

4. Compare the acidic properties of thiophenol and benzenesulfonic acid.

5. Write a multi-stage scheme for the synthesis of sulfanilamide (streptocide) from aniline. Indicate the mechanism by which each reaction takes place.

6. Write the reaction of diethyl sulfide with ethyl iodide.

LESSON №12

TOPIC: FINAL LESSON ON THE TOPIC «HALOGEN-CONTAINING AND NITROGEN-CONTAINING DERIVATIVES OF HYDROCARBONS. ALCOHOLS, PHENOLS, ETHERS AND THEIR THIOANALOGUES. SULFOXIDES, SULFONES, SULFONIC ACIDS AND THEIR DERIVATIVES».

Subject motivation: Halogen-, hydroxy- and thio- derivatives of hydrocarbons have various effects on the regulatory processes of living organisms, which has an impact on all levels of metabolism. In addition, they are

intermediates for the synthesis of various biologically active substances and drugs. A significant number of compounds that are the derivatives of the mentioned classes are used in various sectors of the economy (production of plastics, agrochemicals, herbicides, etc.).

Objective: To consolidate and generalize knowledge about the structure and chemical behavior of halogen-, hydroxy-, nitrogen- and thio- containing hydrocarbons, as well as products of their modification, which play an important role in the metabolism of biological systems.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

1. List the methods of alkyl-, alkenyl-, arylhalides synthesis. Write reaction schemes.

2. Describe the mechanism of nucleophilic substitution and elimination reactions.

3. Write schemes for the synthesis of vinyl chloride and allyl chloride. Explain the reasons for their different reactivity in nucleophilic substitution reactions. Describe the mechanism of hydrolysis of allyl chloride.

4. Explain why haloalkanes easily react with nucleophilic substitution, and alcohols only in the presence of an acid catalyst. Explain the catalytic role of acid?

5. Write schemes for the synthesis of chlorobenzene, benzyl chloride and compare the mobility of halogen in the aromatic nucleus and in the side chain. Explain the nucleophilic substitution of halogen in the nucleus (addition-cleavage reactions).

6. Explain the practical significance of halogen derivatives.

7. List the synthesis methods of: alcohols, phenols and their thioanalogues.

8. Write a scheme for the synthesis of pentanol-2 from 1-bromopentane. Obtain from the corresponding haloalkane propanol-1, carry out its methylation and describe the mechanism of this reaction.

9. Give the scheme of the synthesis of ethylene glycol from ethanol. How can the reaction product be distinguished from the starting material?

10. Write a scheme for the synthesis of 2-methylpentanol-2 from the corresponding unsaturated hydrocarbon and write interaction of 2-methylpentanol-2 with following reagents:

a) with thionyl chloride;

b) with acetic acid;

c) with H_2SO_4 when heated.

11. Write a scheme for the synthesis of ethanol by reduction of the corresponding aldehyde. Carry out its intramolecular dehydration and describe its mechanism.

12. Give schemes for conversion of toluene to benzyl alcohol. Carry out the reaction of benzyl alcohol with HBr and describe its mechanism.

13. Write a scheme for the synthesis of 4-nitro-1,2-dimethoxybenzene from the corresponding quinone.

14. Using benzene as a starting compound, write schemes for the synthesis of p-nitrophenol, 2-nitro-1,4-dimethoxybenzene, 4-nitroresorcinol, phloroglucinol.

15. Using naphthalene as a starting compound write schemes for the synthesis of 1-nitro-2-methoxynaphthalene, 1-nitro-naphthalen-2-ol, 2-naphthyl acetate.

16. Write schemes for oxidation of propanthiol and diethyl sulfide in the mild and hard conditions.

17. Write the reaction of dimethyl sulfide with ethyl iodide.

18. Explain with specific examples what is the hydrogen bond and how it affects the physical properties of alcohols and ethers.

19. Compare the basic and nucleophilic properties of phenol and ethanol, give examples of reactions that can confirm their difference; compare the acidic properties of phenol, p-nitrophenol and ethanol; give reactions that confirm their different acidic properties.

20. Compare the activity of methanol, propanol-2 and 2-methylpropanol-2 in reactions with metallic sodium. Explain the result.

21. Compare the acid-base properties of alcohols and thiols. Write the appropriate reactions.

22. Formulate Zaitsev's rule and explain the reason for the instability of vinyl alcohol.

22. Give qualitative reactions for the detection of phenols. Write reactions that would differentiate the ethyl mercaptan and dimethyl sulfide.

23. What reactions can be used to distinguish ethanol and glycerin?

24. Draw the structural formula of the substance of the empirical formula $C_4H_{10}O$. It is known that it reacts with metallic sodium with the evaluation of hydrogen, the subsequent dehydration forms butene-1, and its oxidation in mild conditions yielded aldehyde of empirical formula C_4H_8O. Write reaction schemes.

25. Explain how the hydroxy group in phenol affects the reactivity of the benzene moiety, give examples of reactions.

26. Explain the fundamental differences in the oxidation of thiols and alcohols. Write the oxidation reactions.

27. Give examples of alcohols, phenols and their thioanalogues that are important for medicine.

28. Give the known methods of the ether’s synthesis, indicate the mechanism of reactions.

29. Describe the chemical properties of ethers.

30. Compare the basicity of diethyl ether, anisole, diphenyl ether, diethyl sulfide. Evaluate their ability to the cleavage reaction under action of

hydriodic acid.

31. Explain why the ether bond is broken down by strong acids but is resistant to alkalis. Write the cleavage reaction of diethyl ether under the influence of hydriodic acid.

32. The cleavage of methyl *tert*-butyl ether by the hydriodic acid produces methyl alcohol and *tert*-butyl iodide. Explain the result of the reaction in terms of its mechanism.

33. The cleavage of methylpropyl ether by hydroiodic acid produces methyl iodide and propanol-1. Explain the result of the reaction in terms of its mechanism.

34. Mercaptans: structural features, methods of synthesis, reactivity.

35. Describe acidic properties of thiols in comparison to acidic properties of alcohols.

36. Oxidation of thiols.

37. Sulfides (thioethers): structure, methods of synthesis and reactivity.

38. Sulfoxides: structure, methods of synthesis and reactivity.

39. Dimethyl sulfoxide and its practical usage.

40. Sulfones: structure, methods of synthesis and reactivity.

41. Sulfonic acids: structure, methods of synthesis and reactivity.

42. Amides of sulphanilic acid as drugs.

LESSON №13

TOPIC: STRUCTURE AND CHEMICAL PROPERTIES OF ALDEHYDES AND KETONES. NUCLEOPHILIC ADDITION REACTIONS.

Subject motivation: The high reactivity of carbonyl-containing compounds (aldehydes and ketones) has led to their versatile usage in organic synthesis, namely in the production of effective drugs. Numerous biologically active compounds of plant and animal origin (vitamins, hormones, corticosteroids, cardiac glycosides, saponins, etc.). contain aldehyde or ketone. Knowledge of the chemical structure and properties of aldehydes and ketones is essential for understanding of their identification and chemical modification possibilities.

Objective: To form knowledge of chemical reactions of oxo compounds that are important in biological systems and are widely used in the synthesis and

analysis of drugs. To develop the skills to conduct identification and quantification reactions with aldehydes and ketones.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

1. Aliphatic and aromatic aldehydes and ketones, methods of their synthesis.
2. Structure and chemical properties of oxo groups in aldehydes and ketones.
3. The mechanism of nucleophilic addition reaction (A_N).
4. Oxidation reactions.
5. Reactions of nucleophilic addition (A_N) to the oxo group.
6. Reduction of oxo group.
7. Aldol addition reaction (aldol condensation).
8. Disproportionation reaction (Cannizzaro-Tishchenko reaction).
9. Reactions with amino components as identification reactions on the carbonyl group.
10. Haloform - reaction.
11. Quinones.
12. Structure and chemical properties of acetals and hemiacetals.

PRACTICAL WORKS PERFORMED IN THE CLASS.

Protocol № 13

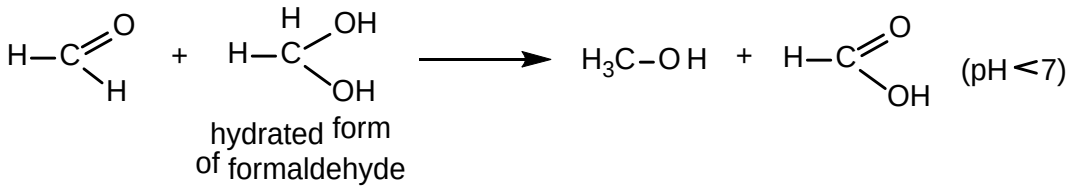
Date_____

Experiment 1

Disproportionation of formaldehyde in aqueous solutions.

Place 2-3 drops of 40% formaldehyde solution in a test tube. Add 1 drop of 0.2% methyl red indicator solution. Solution becomes red, that indicates an acidic reaction of the medium.

Reaction scheme:



Observation:

Conclusions:

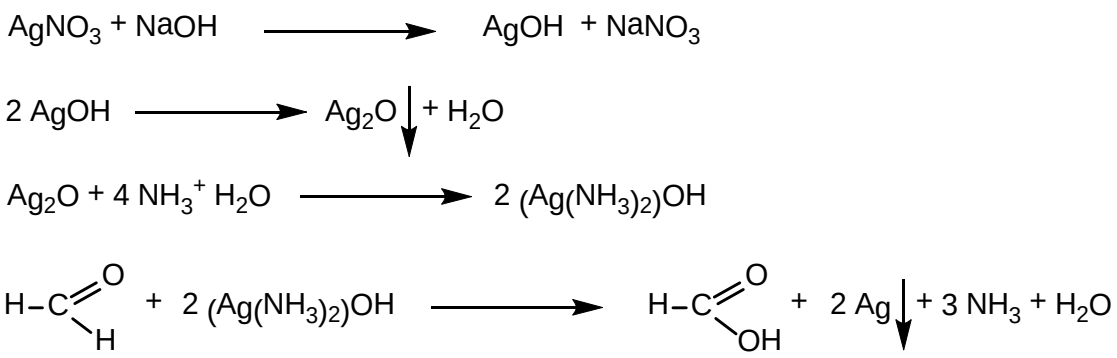
Experiment № 2

The oxidation of formaldehyde and acetone by alkaline solutions of heavy metal oxides.

1. *Oxidation by silver hydroxide.*

Take two test tubes and place 1 drop of 5% silver nitrate solution and 10% sodium hydroxide solution in each. To the resulting brown precipitate add dropwise 10% aqueous ammonia solution until complete dissolution of the precipitate. Then add 2 drops of 40% formaldehyde solution to the first test tube and 2 drops of acetone to the second. In the first test tube, a black precipitate is formed, which when gently heated can form on the walls of the test tube a shiny mirror coating. In the second test tube, the formation of precipitate is not observed.

Reaction scheme:



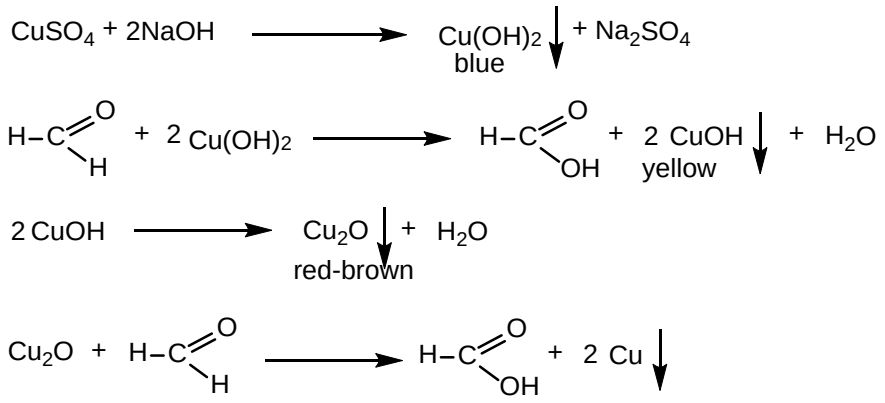
Observation:

Conclusions:

2 Oxidation by copper(II) hydroxide.

Put in a test tube 5 drops of 10% sodium hydroxide solution and water, add 1 drop of 2% solution of copper(II) sulfate. Add 3 drops of 40% formaldehyde solution to the precipitate of copper(II) hydroxide, that was formed. Carefully heat the tube till the boiling point. In the test tube, the precipitate first turns yellow, then red, and if the test tube is clean, metallic copper ("copper mirror") may be formed on its walls.

Reaction scheme:



Observation:

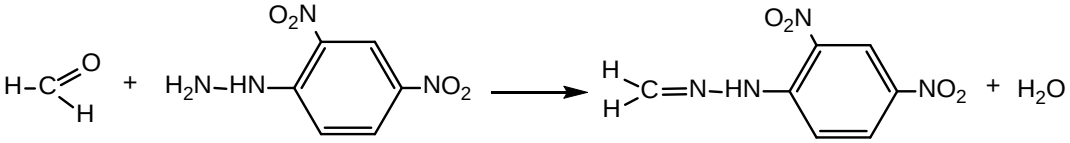
Conclusions:

Experiment № 3

Formation of 2,4-dinitrophenylhydrazone formaldehyde.

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

Reaction scheme:



Observation:

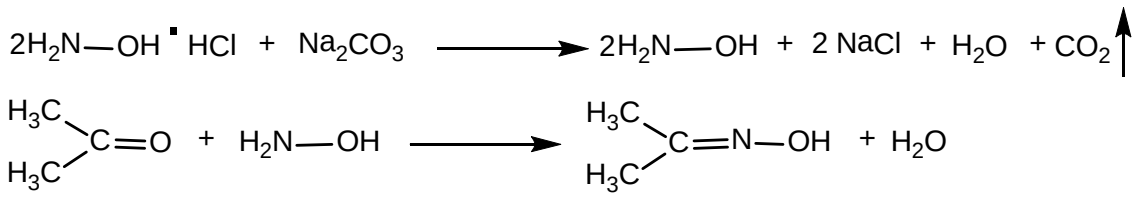
Conclusions:

Experiment № 4

Preparation of acetone oxime.

Place 1 spatula of hydroxylamine hydrochloride, 1 spatula of crystalline sodium carbonate in a test tube and dissolve in 10-25 drops of water. After evaluation of the carbon dioxide, place the tube in cold water and add with thorough mixing 15 drops of acetone. White crystals are formed.

Reaction scheme:



Observation:

Conclusions:

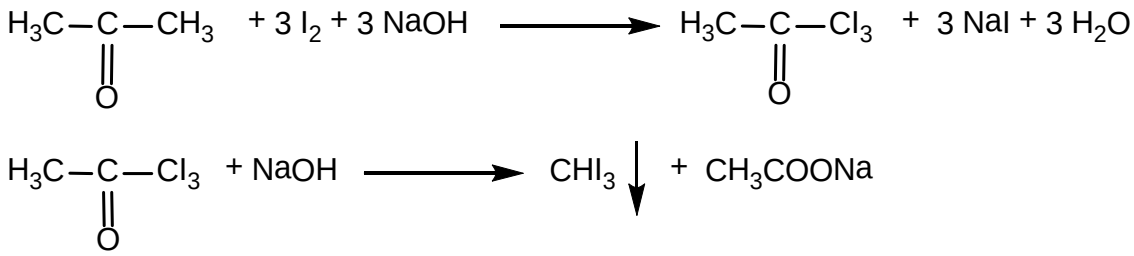
Experiment № 5

Identification of acetone.

Place 1 drop of iodine solution in potassium iodide in a test tube and add 10% sodium hydroxide solution dropwise until the decolorization. Add 1 drop of acetone to the decolorized solution. While weak heating (from heat of hands) the yellowish-white precipitate with a characteristic smell of iodoform forms. This

reaction is used in clinical laboratories and is of practical importance for the diagnosis of diabetes.

Reaction scheme:



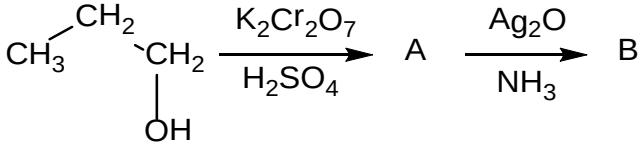
Observation:

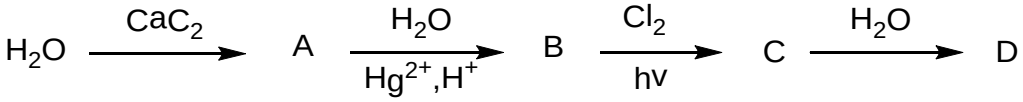
Conclusions:

CHALLENGE QUESTIONS

1. Describe the mechanism of conversion of acetaldehyde to dimethyl acetal. Explain the role of the acid catalyst and ability of dimethylacetal to hydrolysis.

2. Complete the schemes and name all the compounds:





3. Write the formulas of substances and indicate which functional groups are part of them: chloral hydrate, vanillin, acetophenone. Give qualitative reactions to functional groups.

LESSON №14

TOPIC: STRUCTURE AND CHEMICAL PROPERTIES OF CARBOXYLIC ACIDS. NUCLEOPHILIC SUBSTITUTION REACTIONS OF CARBOXYLIC ACIDS.

Subject motivation: The high reactivity of carboxylic acids and their functional derivatives is widely used in organic synthesis. Carboxylic acids play an extremely important role in the metabolic processes of plant and animal organisms. Carboxylic acids are involved in the biosynthesis of amino acids, steroids, alkaloids, saponins, etc as intermediates in the oxidation of carbohydrates, fats and proteins. In addition, carboxylic acids are known as harmless natural preservatives, protective plant substances and components of many essential oils, balms with a complex of valuable biological properties.

Objective: To form knowledge of regularities and features of chemical behavior of carboxylic acids in interrelation with their structure

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

1. Classification of carboxylic acids.

2. Electronic structure of the carboxyl group, acidic properties of carboxylic acids.

3. The influence of substituents on the acidic properties of the carboxyl group.

4. The mechanism of the nucleophilic substitution reaction (S_N).

5. Functional analysis of -COOH group.

6. Decarboxylation reaction.

7. Halogenation reaction of acids.

8. Electrophilic substitution reactions (S_E) in a range of aromatic carboxylic acids.

9. Dicarboxylic acids. Classification, structure, methods of synthesis and chemical properties.

PRACTICAL WORKS PERFORMED IN THE CLASS.

Protocol № 14

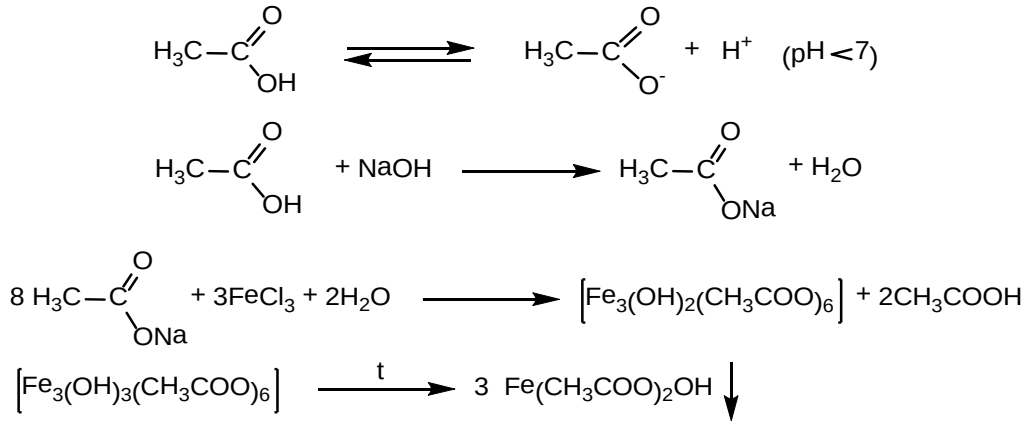
Date_____

Experiment №1

Discovery of acetic acid.

Put 3 drops of acetic acid and water in a test tube. Test the reaction of the solution to litmus. Add 2-3 drops of 10% sodium hydroxide solution to the solution until the acetic acid is completely neutralized. Then add 2-3 drops of 1% solution of iron(III) chloride. A yellow-red color of iron(III) acetate appears. Heat the solution till the boiling point, a red-brown precipitate of water-insoluble iron(III) hydroxide diacetate is observed.

Reaction scheme:



Observation:

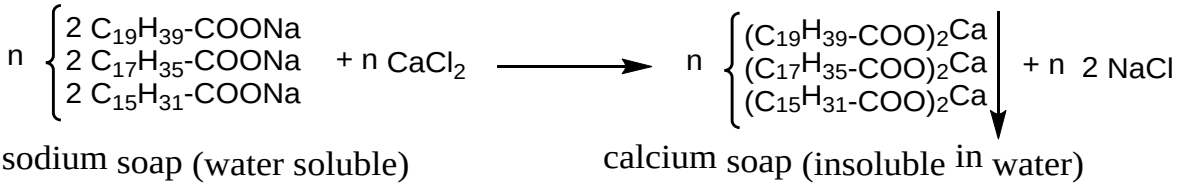
Conclusions:

Experiment № 2

Formation of insoluble calcium salts of fatty acids.

Place 5 drops of soap solution in a test tube and add 1 drop of calcium chloride solution. Shake the contents of the test tube. A white precipitate appears.

Reaction scheme:



sodium soap (water soluble) calcium soap (insoluble in water)

Observation:

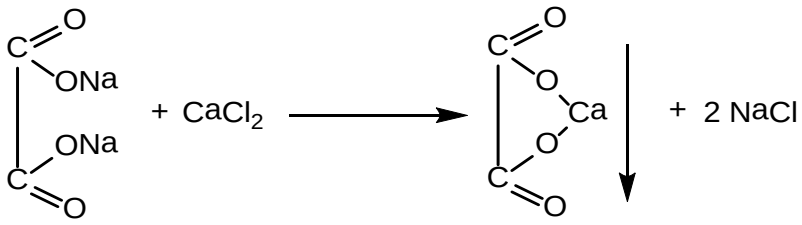
Conclusions:

Experiment № 3

Identification of oxalic acid.

Put a spatula of sodium salt of oxalic acid in a test tube and add 4-5 drops of water until it will be completely dissolved. Add 1 drop of calcium chloride solution. A crystalline precipitate is formed. Calcium oxalate crystals can be found in a clinical examination of urine. They have form of postal envelopes and are clearly visible under a microscope.

Reaction scheme:



Observation:

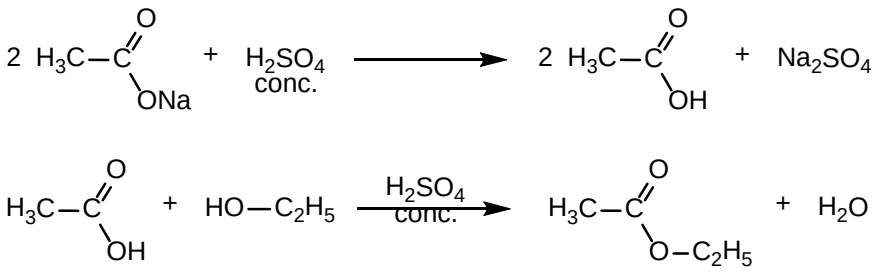
Conclusions:

<u>Experiment № 4</u>

Preparation of ethyl acetate.

Place anhydrous sodium acetate powder (about 2 mm high) and 3 drops of ethyl alcohol in a dry test tube. Add 2 drops of concentrated sulfuric acid (add in the fume hood) and gently heat over the burner flame (Caution! The solution may spill out!). After a few seconds there is a pleasant smell of ethyl acetate. The reaction is used to discover ethyl alcohol.

Reaction scheme:



Observation:

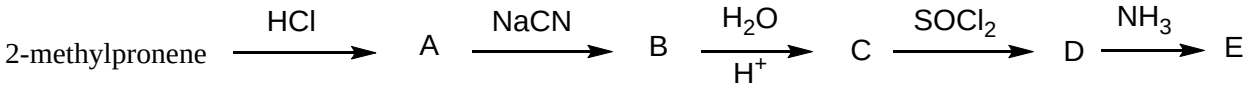
Conclusions:

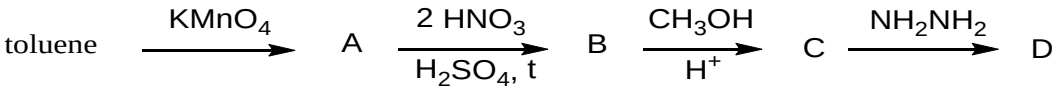
CHALLENGE QUESTIONS

1. Write the alkaline saponification reaction of ethyl propionate. Describe the reaction mechanism.

2. Write a scheme for the hydrolysis of propanamide in an acidic environment. Describe the reaction mechanism.

3. Write the following scheme





LESSON №15

TOPIC: FUNCTIONAL DERIVATIVES OF CARBOXYLIC ACIDS AND HETEROFUNCTIONAL CARBOXYLIC ACIDS (HALOGEN-, HYDROXY-, OXO-). DERIVATIVES OF CARBONIC ACID.

Subject motivation: Functional derivatives of carboxylic acids are extremely interesting objects to study, especially considering their significant practical value. It is known that representatives of this class of compounds show high biological activity. Heterofunctional acids (hydroxy-, oxo-, amino- acids) play an important role in the natural biochemical processes in living organisms, perform energy, structural and plastic functions of the cell. Halogen acids in many cases have an inhibitory effect on cellular enzymes (inhibitors of fatty acid oxidation). Also, halocarboxylic acids are the most important class of reagents that are widely used for the synthesis of hydroxy- and amino- acids. One of the most important classes of bioorganic compounds are aminocarboxylic acids, which are monomers of peptides and proteins, precursors of bioregulators and are widely used in drugs synthesis. Many compounds of this class are drugs. Carbonic acid derivatives - esters of carbamic acid, urea, guanidine are widely used in the synthesis of various heterocycles and drugs. Knowledge of the ways of chemical transformation of these compounds allows to predict methods of qualitative and quantitative determination of drugs that are derivatives of carboxylic acid.

Objective: To form knowledge about the chemical behavior of esters, amides, anhydrides of carboxylic acids and acylhalides, as well as halogeno-, amino-, hydroxy-, oxo- acids, taking into account the mutual influence of functional groups. Ability to carry out mutual transformations of the studied classes as the basis of their metabolic transformations and drugs synthesis. To form knowledge of the most important chemical properties and general synthesis methods of a range of carboxylic acid derivatives, which are drugs or starting materials for their synthesis.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

1. The concept of functional derivatives of carboxylic acids.

2. Structure, synthesis methods and chemical properties of esters.

3. Acidic and alkaline hydrolysis of esters. Fundamental differences of these processes.

4. Features of structure and chemical properties of diethylmalonate. The value of diethylmalonate as a reagent in organic chemistry.

5. Structure, synthesis methods and chemical properties of amides.

6. Structure, synthesis methods and chemical properties of carboxylic acid halides (acyl halides).

7. Structure, synthesis methods and chemical properties of carboxylic acid anhydrides.

8. The concept of acylation reactions and acylating agents.

9. Structure, synthesis methods and chemical properties of halogenated, hydroxy-, oxo- and amino- acids.

10. Features of the nomenclature of halogenated, hydroxy-, oxo- and amino-acids.

11. Structure, synthesis methods and chemical properties of halocarboxylic acids.

12. Structure, synthesis methods and chemical properties of hydroxy acids.

13. Structure, synthesis methods and chemical properties of oxoacids.

14. The phenomenon of keto-enol tautomerism in a range of β-oxoacids. CH-acid properties of ketocarboxylic acids.

15. The value of acetoacetic ester as a reagent in organic chemistry.

16. Structure, synthesis methods and chemical properties of amino acids.

17. Conversion of α-, β-, λ- hydroxy- and amino acids during their heating.

18. Practical importance of heterofunctional carboxylic acids.

19. Phosgene: structure, synthesis methods, practical importance in organic synthesis.

20. Diethyl carbonate: structure, synthesis methods, practical importance in organic synthesis.

21. Carbamic acid derivatives, synthesis methods, practical importance in organic synthesis.

22. Urea: structure, synthesis methods, practical importance in organic synthesis.

23. Guanidine: structure, synthesis methods, practical importance in organic synthesis.

PRACTICAL WORKS PERFORMED IN THE CLASS.

Protocol № 15

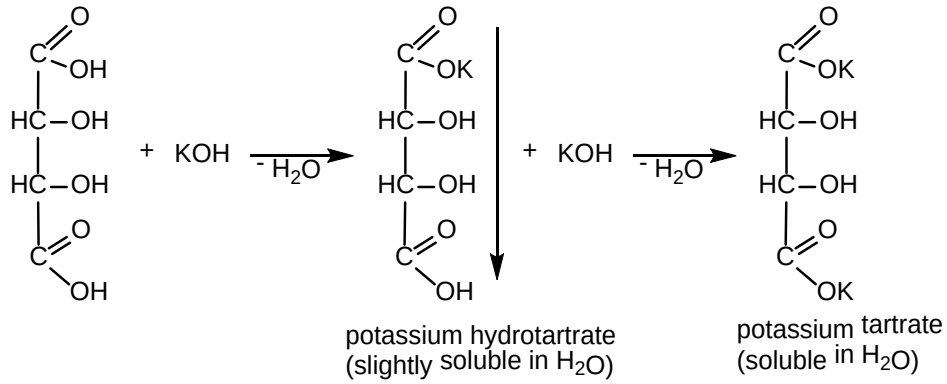
Date_____

Experiment №1

The evidence of the two carboxyl groups in tartaric acid.

Place 1 drop of 15% tartaric acid solution, 2 drops of 5% potassium hydroxide solution in a test tube and shake. White crystalline precipitate insoluble in water gradually begins to form, that is acidic potassium salt of tartaric acid (potassium hydrotartrate). When the precipitate does not fall out, cool the tube under running water and rub the inner wall of the tube with a glass rod. Add another 4-5 drops of potassium hydroxide solution to the test tube. The crystalline precipitate gradually dissolves, due to the formation of as a well-soluble in water medium potassium salt of tartaric acid (potassium tartrate). Save the potassium tartrate solution for the next experiment.

Reaction scheme:



Observation:

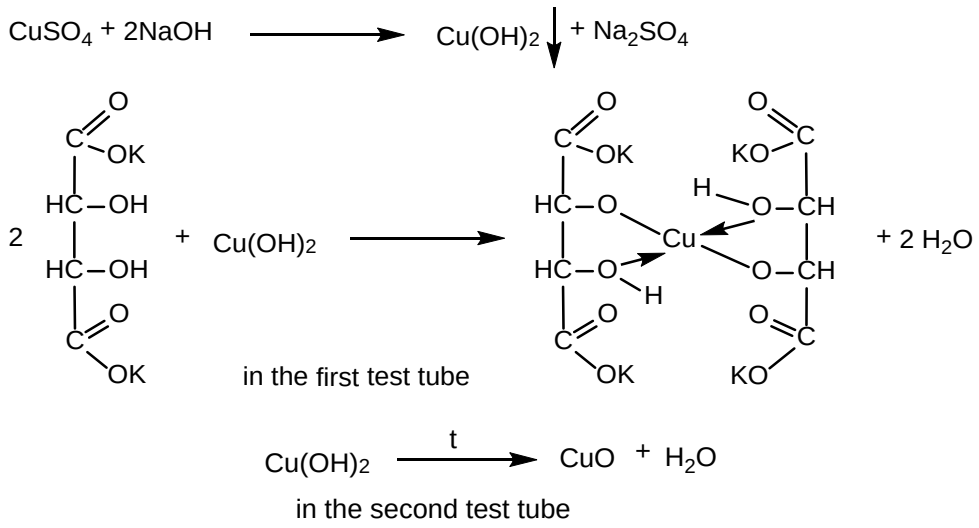
Conclusions:

Experiment № 2

The evidence of the hydroxyl groups in tartaric acid.

Place 2 drops of 2% copper(II) sulphate solution and 10% sodium hydroxide solution in two test tubes. A blue precipitate of copper(II) hydroxide forms. In the first tube, add the potassium tartrate solution obtained in the previous experiment. The precipitate of copper(II) hydroxide dissolves with formation of a blue solution. Heat the liquids in both tubes until the boiling point. In the first test tube, the color of the liquid does not change, in the second - a blue precipitate of copper(II) hydroxide is converted into copper(II) oxide, that has a black color. The blue solution, that was formed in the first test tube is called Fehling's reagent and is used to detect glucose in the urine.

Reaction scheme:



Observation:

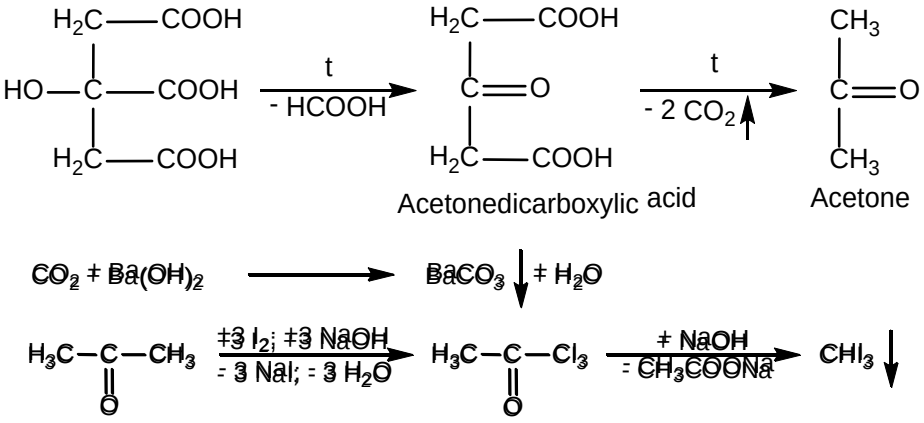
Conclusions:

Experiment № 3

Decomposition of citric acid.

In a dry test tube, with a gas delivery tube, place a spatula of citric acid and 10 drops of concentrated sulfuric acid, then heat the test tube. Dip the end of a gas delivery tube into the first tube with 5 drops of barium hydroxide solution in it, after the solution becomes cloudy, transfer a gas delivery tube to a second tube containing 2 drops of iodine solution in potassium iodide, previously decolorized by adding a few drops of 10% sodium hydroxide solution. In the second test tube a pale yellow precipitate of iodoform is formed.

Reaction scheme:



Observation:

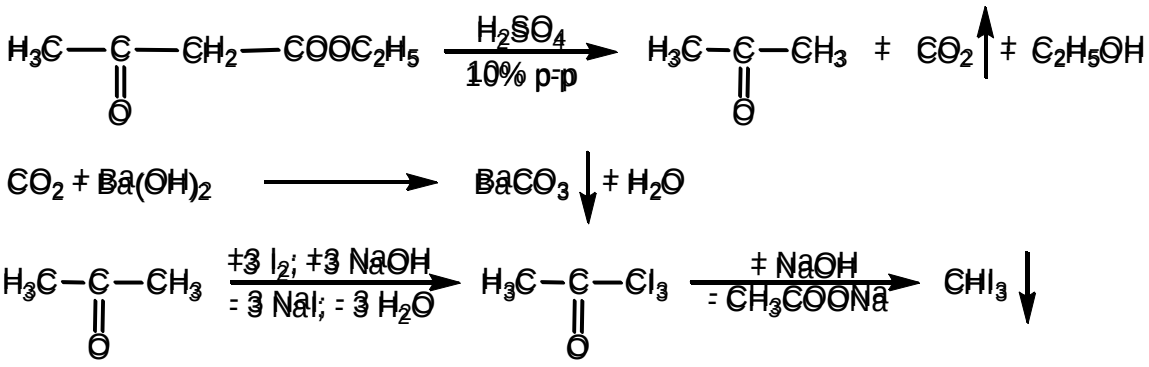
Conclusions:

Experiment № 4

Ketone cleavage of acetoacetic ester.

Place 5 drops of acetoacetic ester and 5 drops of 10% sulfuric acid solution in a test tube with a gas delivery tube, heat. Dip the end of the gas delivery tube into the first tube with 5 drops of barium hydroxide solution in it, after the solution becomes cloudy, transfer the gas delivery tube to the second tube containing 2 drops of iodine solution in potassium iodide, previously decolorized by adding a few drops of 10% sodium hydroxide solution. In the second test tube a pale yellow precipitate of iodoform is formed.

Reaction scheme:



Observation:

Conclusions:

CHALLENGE QUESTIONS

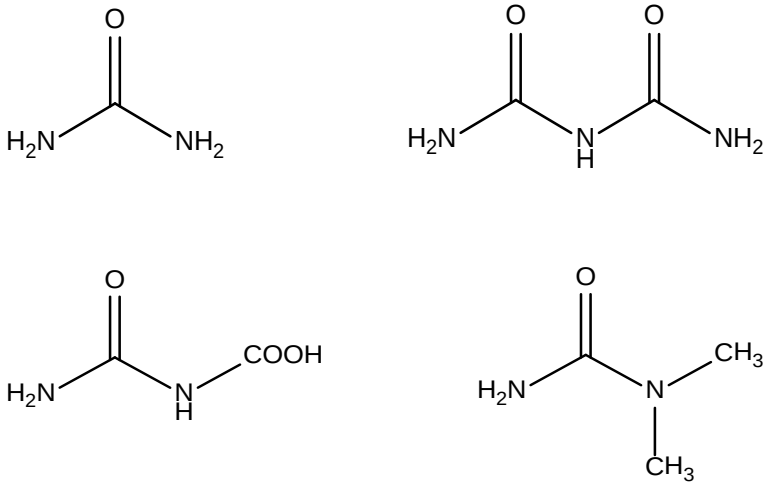
1. Lactic acid, used in medicine, is produced by industry in the form of 4% aqueous solution. Why is it impractical to further thicken the solution by evaporation when heated?

2. Write the formulas of all possible products formed by heating a mixture of α-aminopropionic and α-aminoacetic acids.

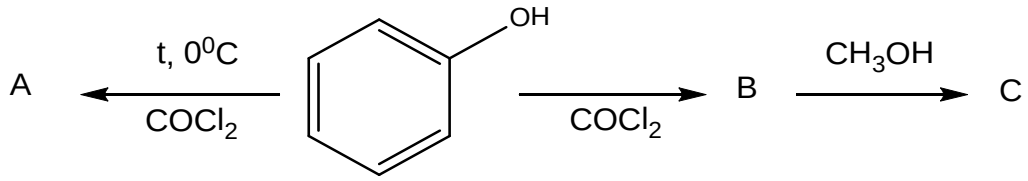
3. One of the stereoisomers of 2-amino-3-thiopropanoic acid is a part of proteins. Write the formulas of all possible stereoisomers of this acid and name them.

4. Why some derivatives of carbonic acid are not known in its pure form: carbonic acid monochloride and monoamide (carbamic acid)? Explain the answer.

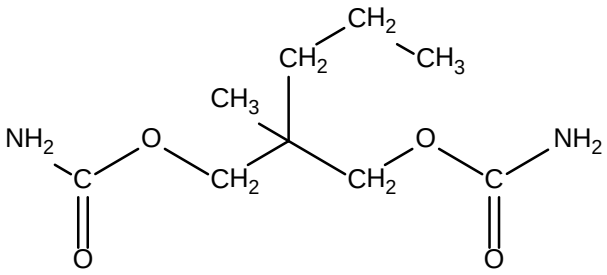
5. Arrange the following compounds in a row of their basicity reducing:



6. When phosgene interacts with alcohols, depending on the conditions, mono- and disubstituted products can be obtained. Write reaction schemes and name the final products:



7. The drug meprobamate (tranquilizer) is chemically related to carbamic acid esters - urethanes:



Suggest a way to synthesis it. Name the starting products of drug synthesis.

LESSON 16

TOPIC: FINAL LESSON ON THE TOPIC «ALDEHYDES, KETONES, CARBOXYLIC ACIDS AND THEIR DERIVATIVES».

Subject motivation: Carbonyl-containing compounds, carboxylic acids and carboxylic acid derivatives are involved in various tissue, cytosolic and genetic processes, showing a expressed effect on important functions of organisms. Many compounds of this class are strong bioregulators of physiological processes. A significant number of representatives of this class of compounds are drugs, as well as intermediates in the synthesis of drugs.

Objective: to generalize knowledge about the structure, methods of synthesis, chemical properties and practical significance of carbonyl-containing compounds, carboxylic acids and their derivatives, carbonic acid derivatives.

THEORETICAL QUESTIONS FOR SELF-TRAINING TO THE CLASSES

1. Methods of synthesis of aliphatic and aromatic aldehydes and ketones.
2. Structure and chemical properties of oxo group in aldehydes and ketones.
3. The mechanism of nucleophilic addition (A_N).
4. Oxidation reactions.
5. Reactions of nucleophilic addition (A_N) to the oxo group.
6. Reduction reaction of oxo group.
7. Aldol addition reaction (aldol condensation).
8. Disproportionation reaction (Cannizzaro-Tishchenko reaction).
9. Reactions with amino components as qualitative reactions to reveal the carbonyl group.
10. Haloform reaction.
11. Quinones.
12. Structure and chemical properties of acetals and hemiacetals.
13. Classification of carboxylic acids.

14. Electronic structure of the carboxyl group, acidic properties of carboxylic acids.

15. The influence of the chemical environment on the acidic properties of the carboxyl group.

16. The mechanism of the nucleophilic substitution reaction (S_N).

17. Functional analysis of -COOH group.

18. Decarboxylation reaction.

19. Halogenation reaction of acids.

20. Electrophilic substitution reactions (S_E) in a range of aromatic carboxylic acids.

21. Dicarboxylic acids. Classification, structure, methods of synthesis and chemical properties.

22. The concept of functional derivatives of carboxylic acids.

23. Structure, methods of synthesis and chemical properties of esters.

24. Acid and alkaline hydrolysis of esters. Fundamental differences of these processes.

25. Features of structure and chemical properties of diethylmalonate. The value of diethylmalonate as a reagent in organic chemistry.

26. Structure, methods of synthesis and chemical properties of amides.

27. Structure, methods of synthesis and chemical properties of carboxylic acid halides (acyl halides).

28. Structure, methods of synthesis and chemical properties of carboxylic acid anhydrides.

29. The concept of acylation reactions and acylating agents.

30. Structure, methods of synthesis and chemical properties of halogen-, hydroxy-, oxo- and amino acids.

31. Features of the nomenclature of halogenated, hydroxy-, oxo- and amino acids.

32. Structure, methods of synthesis and chemical properties of halocarboxylic acids.

33. Structure, methods of synthesis and chemical properties of hydroxy acids.

34. Structure, methods of synthesis and chemical properties of oxoacids.

35. Keto-enol tautomerism of *β*-oxoacids derivatives. CH-acid properties of ketocarboxylic acids.

36. The value of acetoacetic ester as a reagent in organic chemistry.

37. Structure, methods of synthesis and chemical properties of amino acids.

38. Conversion of *α*-, *β*-, *λ*-hydroxy- and amino acids when heated.

39. Applied value of heterofunctional carboxylic acids.

40. Phosgene: structure, methods of synthesis, importance in organic synthesis.

41. Diethyl carbonate: structure, methods of synthesis, importance in organic synthesis.

42. Carbamic acid derivatives, methods of synthesis, importance in organic synthesis.

43. Urea: structure, methods of synthesis, value in organic synthesis

44. Guanidine: structure, methods of synthesis, value in organic synthesis.

45. Write the specific reactions that occur when *α*-, *β*-, *γ*-hydroxy- and *α*-, β-, *γ*-aminopentanoic acids are heated.

46. Write the hydrolysis reaction in the acidic environment of the lactone of *γ*-hydroxybutanoic acid (γ-hydroxybutyric acid).

47. Using Fisher's projection formulas, write *L*-malic and *D*-aminobutyric acid.

48. Write the structural formulas of the following acids:

a. 3-bromo-3-methylpropanoic acid;

b. 2,3-dibromosuccinic acid;

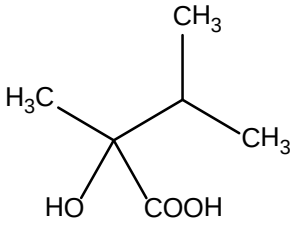
c. 2,5-diaminoheptanoic acid;

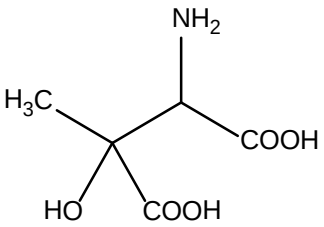
d. 4-hydroxybuten-2-oic acid;

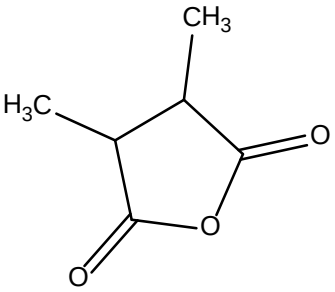
e. *o*-aminobenzoic acid;

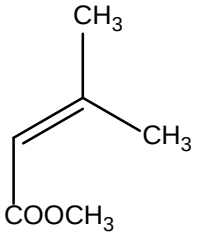
f. *p*-acetaminobenzoic acid;

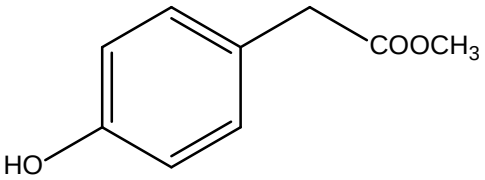
49. Name the following compounds:

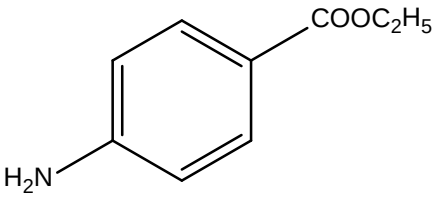


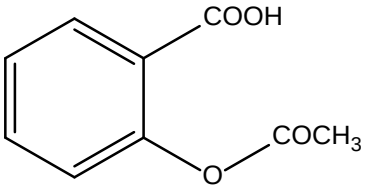


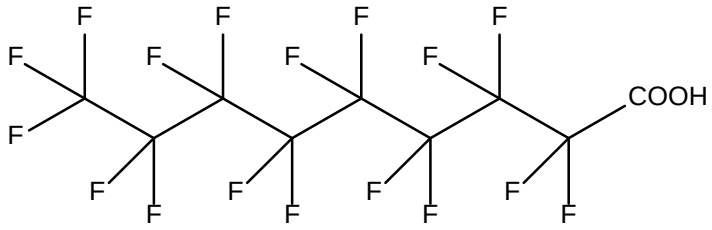












50. Write the reactions of salicylic acid with the following reagents: $NaHCO_3 + H_2O$; $NaOH + H_2O$; $(CH_3CO)_2O$; CH_3CH_2OH (H^+); $PC1_5$, C_6H_5ONa; $HNO_3 + H_2SO_4$; Name the reaction products.

LESSON № 17
FINAL CONTROL.
LIST OF KNOWLEDGE AND PRACTICAL SKILLS REQUIRED BY A STUDENT OF THE 2ND COURSE OF THE PHARMACEUTICAL FACULTY FOR SUCCESSFUL PASSING OF THE SEMESTR

STUDENT MUST KNOW:

1. definition of organic chemistry as a science. Know the objects and subjects studied by organic chemistry;

2. the meaning of the terms "organic compound" and "organogenic chemical element";

3. basic organogenic elements;

4. the main stages of development of organic chemistry as a science;

5. basics of structural theory (the theory of A.M. Butlerov) in organic chemistry;

6. definition of isomerism, the main types of isomerism of organic compounds;

7. basic principles of the nomenclature of organic compounds;

8. definition of the "electronegativity", "inductive effect" and "mesomeric effect";

9. the concept of "hybridization of electronic orbitals" and have an idea of the principles of conjugate systems formation;

10. definition of the "acid" and "base" in the framework of the theories of Brønsted–Lowry acid–base theory and Lewis theory;

11. the main principles of the theory of hard and soft acids and bases according to Lewis theory;

12. the nature of the influence of structural fragments on the acid-base properties of compounds;

13. definition of the term "hydrocarbons";

14. classification of hydrocarbons;

15. basic information about the molecular structure, methods of synthesis and chemical properties of alkanes and cycloalkanes;

16. basic information about the mechanism of the radical substitution reaction;

17. reactions of alkanes with halogens, chlorine and Sulfur(IV) oxide, diluted nitric acid;

18. features of the structure and reactivity of cycloalkanes with a small cycle (cyclopropane and cyclobutane);

19. reactions of cyclopropane and cyclobutane with halogens, hydrogen halides and hydrogen;

20. basic information about the molecular structure, production methods and chemical properties of alkenes, alkynes, alkadienes;

21. basic information about the reaction mechanism of electrophilic addition;

22. Markovnikov`s rule and exclusion from the Markovnikov`s rule;

23. reaction of alkenes and alkynes with hydrogen, halogens, hydrogen halides, water, Wagner reaction;

24. basic information about CH-acidity of terminal alkynes;

25. classification of alkadienes, features of a structure of conjugated alkadienes;

26. reaction of 1,3-butadiene with bromine and acrylonitrile (Diels-Alder reaction);

27. basic information about the molecular structure, production methods and chemical properties of arenes;

28. meaning of the term "aromaticity", to have an idea of the criteria of aromaticity;

29. basic information about the mechanism of electrophilic substitution reaction;

30. halogenation, alkylation, acylation, nitration and sulfonation of arenes (for example, benzene, toluene or nitrobenzene);

31. features of oxidation of alkylbenzenes (for example, toluene);

32. halogenation reactions of toluene in the presence of Lewis acids and when irradiated with light;

33. basic information about the molecular structure, production methods and chemical properties of halogenated hydrocarbons;

34. basic information about the mechanism of monomolecular and bimolecular nucleophilic substitution reactions;

35. dehydrohalogenation reactions of aliphatic halogen derivatives, Zaitsev's rule;

36. reactions of halogen derivatives with amines, salts of carboxylic acids, sodium alcoholates;

37. basic information about the molecular structure, methods of synthesis and chemical properties of organometallic compounds (for example, organomagnesium compounds);

38. basic information about the molecular structure, methods of synthesis and chemical properties of alcohols and phenols;

39. the nature of the electron density distribution in the hydroxyl group of alcohols, phenols and ethers;

40. basic information about the acidity of alcohols and phenols;

41. reactions of alcohols with alkali metals, intramolecular and intermolecular dehydration of alcohols, alcohols with concentrated hydrobromic acid;

42. basic information about the molecular structure, production methods and chemical properties of aldehydes and ketones;

43. the nature of the electron density distribution in the carbonyl group of aldehydes and ketones;

44. basic information about the mechanism of nucleophilic addition reactions and nucleophilic addition followed by the cleavage;

45. reactions of aldehydes and ketones with alcohols, cyanide acid, primary amines, oxidation and reduction of aldehydes and ketones, aldol condensation, disproportionation;

46. basic information about the molecular structure, production methods and chemical properties of carboxylic acids and their functional derivatives;

47. the nature of the electron density distribution in the carboxyl group of carboxylic acids;

48. basic information on the mechanism of nucleophilic substitution reactions for carboxylic acids, esters, acyl halides and amides;

49. reactions of carboxylic acids with hydroxides and carbonates of alkali metals, alcohols, halogenating agents (thionyl chloride, phosphorus

chloride), decarboxylation of carboxylic acids;

50. reactions of carboxylic acid anhydrides and halides with alcohols and amines (primary and secondary);

51. features of acidic and alkaline hydrolysis of carboxylic acid esters;

52. basic information about the molecular structure, production methods and chemical properties of heterofunctional carboxylic acids;

53. basic information about the conversion of hydroxy- and aminocarboxylic acids under high temperature;

54. basic information about the molecular structure, production methods and chemical properties of amines;

55. alkylation and acylation reaction of amines;

56. features of the interaction of amines with nitrous acid;

57. reactions of ethylamine, diethylamine, aniline, *N*-methylaniline and *N*,*N*-dimethylaniline with nitrous acid;

58. basic information about the molecular structure, methods of synthesis and chemical properties of diazo compounds;

59. diazotization reactions (on the example of aniline) and azo coupling (on the example of phenyldiazonium chloride and *β*-naphthol)

The student must be able to:

1. name the compounds using IUPAC rules;

2. determine the electronic influence of substituents (inductive and mesomeric effects) and to predict the influence of substituents on the distribution of electron density in the molecule;

3. compare the acidic-basic properties of compounds;

4. predict the direction of the reaction using the theory of hard and soft acids and bases according to Lewis;

5. determine the main reaction centers in the molecule;

6. compare the reactivity of compounds;

7. know the structural formulas of the following compounds: ***methane,***

ethane, propane, butane, pentane, cyclopropane, cyclobutane, cyclopentane, cyclohexane, ethene (ethylene), propene, butene-1, butene-2, pentene-1, pentene-2, ethyne (acetylene), propyne, butyne-1, butyne-2, pentyne-1, pentyne-2, butadiene-1,3, benzene, toluene, methanol, ethanol, propanol-1, propanol-2, butanol-1, butanol-2, 2-methylpropanol-1, 2-methylpropanol-2, ethanediol-1,2, glycerin, phenol, picric acid, chloromethane, chloroethane, dichloromethane, chloroform, carbon tetrachloride, chloroethane, bromoethane, iodethane, vinyl chloride, allyl chloride, methyl iodide, formaldehyde, ethanal (acetaldehyde), propanone-2 (acetone), pentanone-3, benzaldehyde, salicylic aldehyde, acetophenone, formic acid, acetic acid, propionic acid, butanoic acid (butyric acid), succinic acid, glutaric acid, benzoic acid, stearic acid, palmitic acid, oleic acid, linoleic acid, linolenic acid, salicylic acid, ethyl acetate, acetamide, acetyl chloride, acetoacetic ester, acetic anhydride, phthalic acid, phthalic anhydride, acrylic acid, acrylonitrile, chloroacetic acid, glycolic acid, glycine, glyoxalic acid, pyruvic acid, 2-chlorobutanoic acid, 2-hydroxybutanoic acid, 2-aminobutanoic acid, 3-chlorobutanoic acid, 3-hydroxybutanoic acid, 3-aminobutanoic acid, 4-chlorobutanoic acid, 4-hydroxbutanoic acid, 4-aminobutanoic acid, methylamine, ethylamine, propylamine, diethylamine, triethylamine, aniline, N-methylaniline, N,N-dimethylaniline, o-toluidine, m-toluidine, p-toluidine, o-anisidine, m-anisidine, p-anisidine, phenyldiazonium chloride, carboxylic acid, phosgene, diethyl carbonate, chlorocarbonic acid ethyl ester, ethyl ester of carbamic acid, urea, guanidine.

RECOMMENDED LITERATURE

Basic

1. Chernykh, V. P. Organic Chemistry. Basic lecture course : the study quide for students of higher schools / V. P. Chernykh, L. A. Shemchuk ; ed. by V. P. Chernykh ; NUPh. - 5th ed., rev. - Kharkiv : NUph : Golden Pages, 2019. - 440 p.

Additional

1. Bruice P. Y. Organic Chemistry : Hardcover / P. Y. Bruice, 6th ed. Prentice Hall, 2010. - 1440 p.
2. Clayden J. Organic Chemistry : Paperback / J. Clayden, N. Geeves, S. Warren. – 2nd ed. – Oxford University Press, 2012. – 1234 p.
3. Smith M. B. March's Advanced Organic Chemistry. Reactions, Mechanisms, and Structure Hardcover / M. B. Smith, J. March. – 6th ed. – Wiley, 2007. – 2384 p.

Information resources

1. A Publication of Reliable Methods for the Preparation of Organic Compounds // Organic Syntheses. URL : http://www.orgsyn.org
2. Chemical Synthesis Database. URL : http:/www.chemsynthesis.com
3. SynArchive : A total synthesis database // SynArchive. URL : http://synarchive.com
4. Organic chemistry Portal. URL : http://www.organic-chemistry.org
5. Antypenko Oleksii. Playlists. URL : https://www.youtube.com/c/OleksiiAntypenko/playlists
6. Educational E-library // Department of Organic and Bioorganic Chemistry. URL : https://zsmu.sharepoint.com/sites/orgchem/SitePages/NMZ.aspx