MINISTRY OF HEALTH OF REPUBLIC OF BELARUS
EDUCATIONAL ESTABLISHMENT
«VITEBSK STATE MEDICAL UNIVERSITY »

BIOORGANIC CHEMISTRY

GUIDES FOR THE CONTROL-TESTS AND EXAM

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**For the 1-st year students
of the Overseas Students Training Faculty
in specialty «General Medicine»**

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This issue contains questions for the control-tests and materials for examination. The issue was wrote according to the typical educational program for the students of higher medical educational establishments.

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Утверждено и рекомендовано к изданию Центральным учебно-методическим Советом непрерывного медицинского и фармацевтического образования Витебского государственного медицинского университета 16 марта 2016 г., протокол № 3.

CONTENTS

Introduction

The purpose of teaching of bioorganic chemistry.

Bioorganic chemistry is the sphere of science studying structure and mechanisms of functioning of biologically active molecules on the base of theoretical organic chemistry. The discipline is related to pharmacology, physiology and other medical and biologic disciplines.

The principal purpose of discipline studying is the formation of systematized knowledge about the relationship between structures and chemical properties of biologically important organic compounds as bases for understanding the essence of metabolism and its regulation at molecular level.

Goals of bioorganic chemistry.

The principal goals of bioorganic chemistry teaching at medical universities are the formation of modern ideas about the following:

- structures of natural biologically significant compounds;
- major factors influencing thermodynamic stability of organic molecules;
- mechanisms and features of poly- and heterofunctional organic compounds chemical transformations in vitro as bases for the following understanding processes of enzyme catalysis in vivo;
- principles of biological macromolecules synthesis and self-organizing in vitro and in vivo.

After finishing the course of bioorganic chemistry a student must possess the knowledge of:

- a place of bioorganic chemistry in the system of natural sciences as a branch of chemical sciences studying organic compounds that participate in processes of ability to live;
- a role of bioorganic chemistry in professional training of a doctor and specificity of bioorganic approach to studying processes of ability to live;
- modern physical and chemical methods of investigation of organic compounds structure and their properties;
- modern structural theory, types of chemical bonds, the relationship between the nature of substances, their structure, their reactivity and their biological importance;
- principles of symmetry, chirality and stereoisomerism of natural heterofunctional organic compounds;
- major factors influencing thermodynamic and conformational stability of organic molecules, principles of self-organizing of bioorganic macromolecules and their functioning;

- the newest chemical discoveries and prospects of their use in professional work.

A student must be able to use:

- the basic fundamental laws of chemistry necessary for an explanation of processes proceeding in alive organisms;
- rules of the international chemical (IUPAC) nomenclature;
- the electronic effects of substituents leading formation of the reaction centers in a molecule and typical reactivity on the main functional groups and the possible mechanisms of transformations of organic compounds in vitro and in vivo;
- the general chemical laws that is the base of processes proceeding in an organism;
- chemical properties and biological importance of the main families of organic compounds participating in processes of ability to live.

A student must gain the following skills:

- carrying out of qualitative tests for determination of the main functional groups, unsatiration, the asid-base and reducing properties of organic compounds;
- usage of reference-book of physical and chemical sizes and tabulated data;
- carrying out of the elementary chemical experiments with following analysis and registration of results in the form of a report;
- prevention of accidents in chemical laboratory.

CONTROL-TEST № 1.

«Theoretic bases of main organic compounds families structure and reactivity»

Theoretical part.

Question ***№ 1:***

Define in the following compounds - nicotinamide (3-pyridine-caboxamide); noradrenaline (2-amino-1-(3,4-dihydroxyphenyl) ethanol); benzocain (4-aminoethyl benzoate); acetylsalicylic acid (2-acetyloxybenzoic acid); adrenaline(2-methylamino-1-(3,4-dihydroxyphenyl)ethanol); serine (2-amino-3-hydroxypropanoic acid); alanine (2-aminopropanoic acid); tyrosine (2-amino-3-(4-hydroxyphenyl)-propanoic acid):

1. a) The hybridization type of carbon atoms and heteroatoms (pyridine and pyrrole type).

   b) The type of conjugation and show the electronic structure of the conjugated systems. Designate electron's movement with curved arrows.

2. a) The sign (negative or positive) of inductive and resonance effects of functional groups and heteroatoms. Show these effects with arrows. Indicate electrono-donating (ED) or electrono-accepting (EA) effect of functional groups.

Question ***№ 2:***

Write the Newman projection formulas of all staggered and eclipsed conformations and indicate the most stable for the following compounds: 2-aminobutanoic acid (along C_2-C_3 bond); 2-amino-3-hydroxypropanoic acid (along C_2-C_3 bond).

Draw the standard Fischer projection formulas of stereoisomers that correspond to the following compounds. Indicate diastereoisomers and enantiomers: 2-amino-3-hydroxybutanoic acid; 2-amino-3-methylpentanoic acid; 2,3-dihydroxybutanedioic acid; 2,3,4-trihydroxybutanal.

Write two chair conformations for cis-1,4-dimethylcyclohexane; trans-cyclohexanediol-1,3. Show the most stable conformation.

Question ***№ 3:***

Reactivity of saturated hydrocarbons. Free–radical substitution reactions as homolytical reactions with participation of C–H bonds at a sp^3 hybridized carbon atom. The mechanism of free-radicals substitution reactions on the example of the halogenation of alkanes.

Electrophilic addition reactions to alkenes as heterolycal reactions with participation of π–bond between two sp^2 hybrid carbon atoms. The mechanism of the hydration reaction. The acidic catalysis. The effect of static and kinetic factors on the regioselectivity of addition reactions. Markovnikov's rule. The features of electrophilic addition to the conjugated systems: hydration of α, β – unsaturated carboxylic acids.

Electrophilic aromatic substitution reactions as heterolytical reactions with participation of the π–electron cloud of an aromatic system. The mechanism of the reaction. The role of catalysts in the electrophile formation. Effect of substituents in an aromatic ring on its reactivity in electrophilic (aromatic) substitution. Orienting effect of substituents.

Reaction centers of alcohols, phenols, thiols and amines. Acidity or basicity: Bronsted-Lowry and Lewis theories. Nucleophilic substitution reactions at sp^3–hybrid carbon atom. S_{N1} and the S_{N2} – mechanisms. Stereochemistry of nucleophilic substitution reactions. Nucleophilic substitution of the hydroxyl group in alcohols. The role of acid catalysis. The alkylation reactions of alcohols, thiols, amines. Elimination reactions (dehydration) of alcohols. The biologically important dehydration reactions of alcohols. Nucleophilic properties of alcohols. Oxidation reactions of alcohols, phenols, thiols.

Reaction centers of aldehydes and ketones. Nucleophilic addition reactions. The mechanism of nucleophilic addition reaction. The reactions of carbonyl compounds with water, alcohols, amines. Formation of cyclic hemiacetals. The aldol addition reactions. Reversibility of nucleophilic addition reactions. Oxidation and reduction reactions of carbonyl compounds.

Reaction centers of carboxylic acids. Acidic properties of mono- and dibasic, saturated, unsaturated and aromatic carboxylic acids. Nucleophilic substitution reactions at the sp^2–hybrid carbon atom of carboxylic acids and their derivatives. The acylation reactions such as formation of carboxylic acid anhydrides, haloanhydrides, esters, amides. Hydrolysis reaction of derivatives of carboxylic acids. The acylating reagents: carboxylic acid anhydride, acid chlorides, carboxylic acids, esters, thioesters.

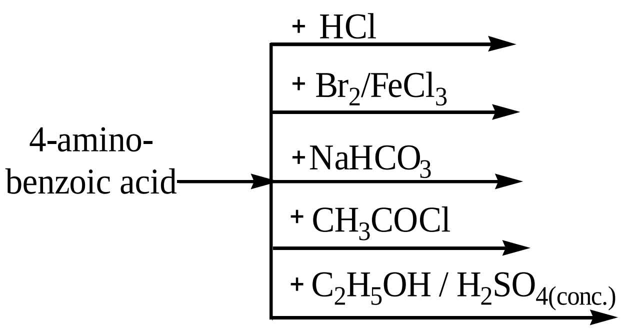
Classification of poly- and heterofunctional compounds. Polyalcohols, dihydric phenols, dicarboxylic acids, amino alcohols, amino phenols, hydroxy-acids, oxo-acids (aldehyde and keto acids). Examples. Acid-base properties. Typical reactivity of poly- and heterofunctional compounds. Specific features of chemical behaviour of poly- and heterofunctional compounds: the features of acid and base properties manifestation, cyclization and chelates formation and the features conditioned by interference of functional groups in dependence of their arrangement. Intramolecular cyclization (γ- and δ-hydroxyaldehydes, γ- and δ-hydroxy- and aminoacids, dicarboxylic acids with 4 or 5 carbon atoms) intermolecular cyclization (α- hydroxy- and aminoacids). Cyclic hemiacetals, cyclic anhydrides, lactides, diketopiperasines, lactones, lactames. Decarboxylation reactions. The elimination reactions of β-hydroxy- and β-amino acids. Tautomerization: keto–enol tautomerization and lactam–lactim tautomerization.

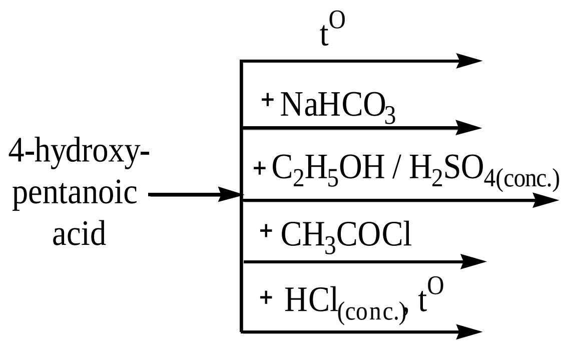
Question *№ 4:*

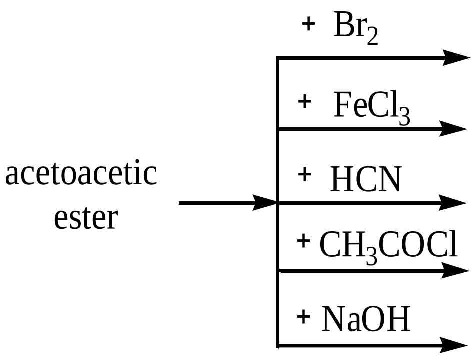
Compare reactivity of several compounds in characteristic reactions (S_E aromatic, S_N at sp^3 carbon atom, S_N at sp^2 carbon atom, A_N, E); write the schemes and outline the mechanisms for the most reactive compounds.

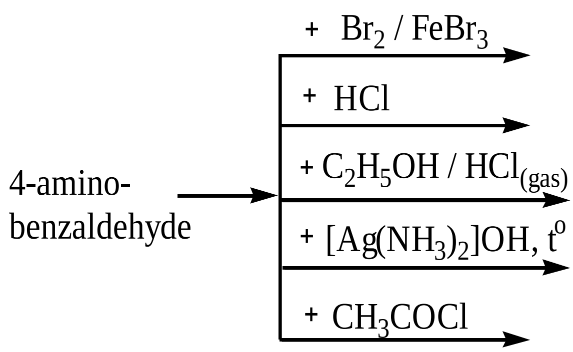
Question *№ 5:*

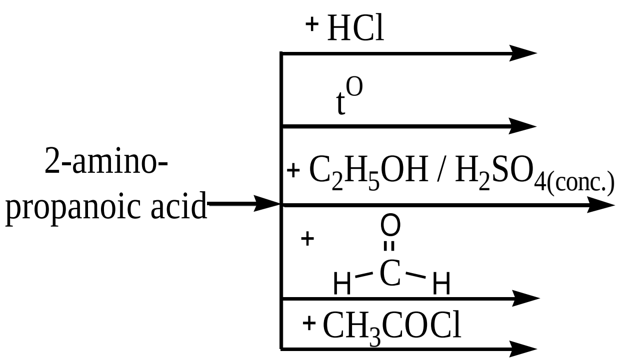
Write the schemes of reactions, represent and name reaction centers, taking part in each reaction, indicate the mechanism of the following reactions:

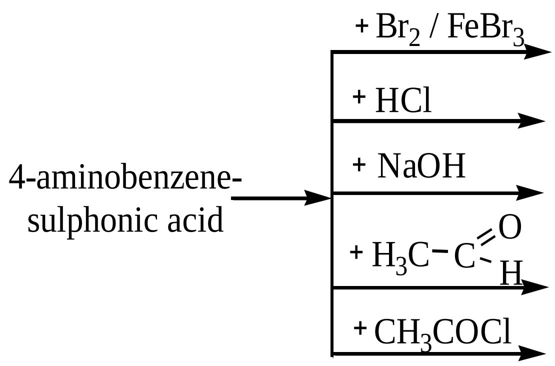


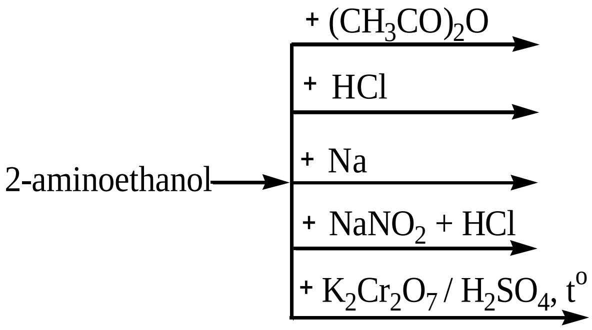


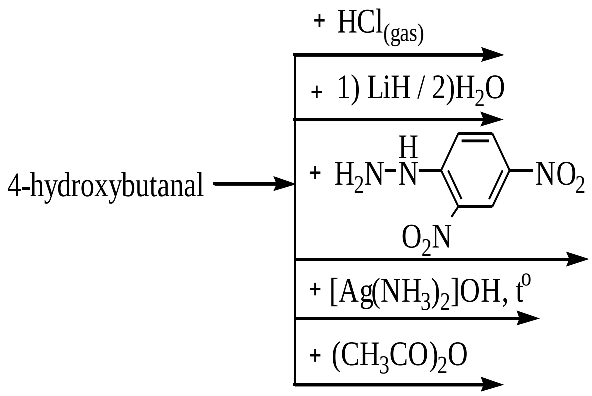


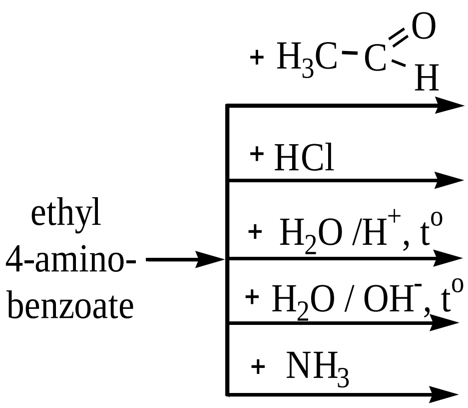


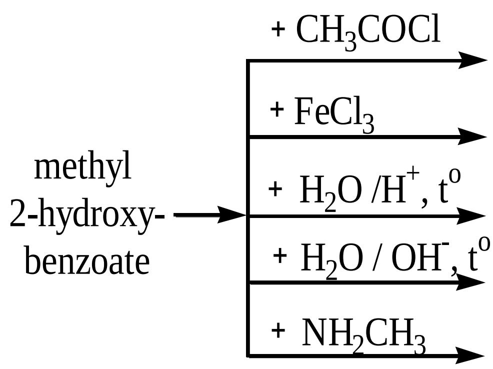


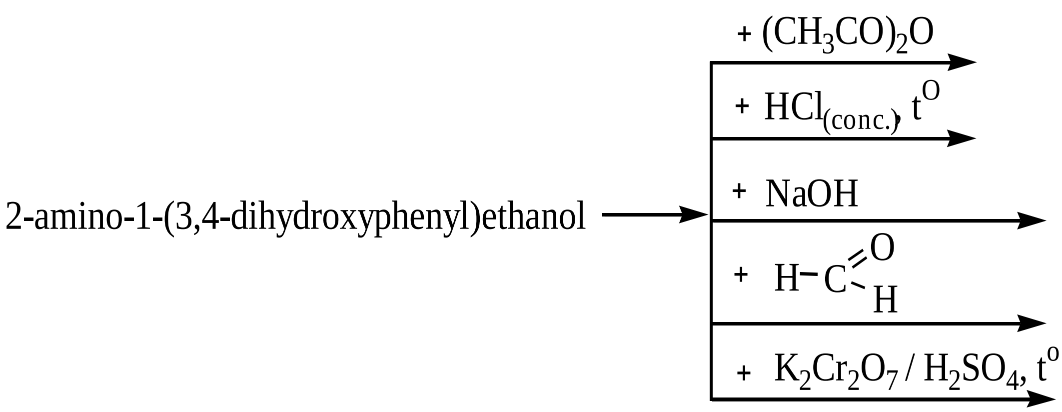


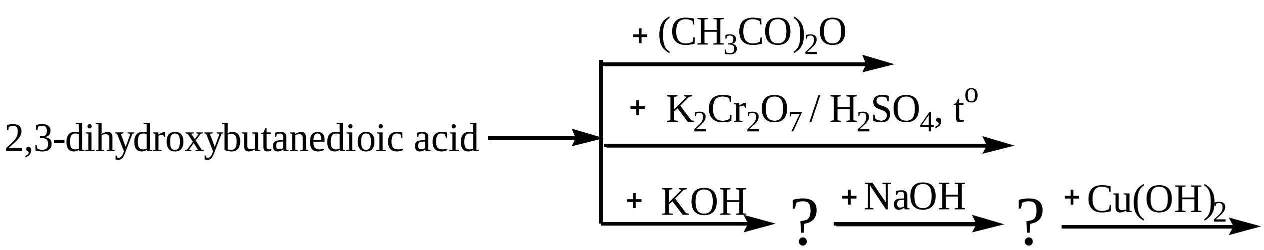

2-aminoethanol
+ (CH3CO)2O
+ HCl
+ Na
+ NaNO2 + HCl
+ K2Cr2O7 / H2SO4, to


4-hydroxybutanal
+ HCl(gas)
+ 1) LiH / 2)H2O
+ H2N-N(H)- (2,4-dinitrophenyl) NO2 O2N
+ [Ag(NH3)2]OH, to
+ (CH3CO)2O


ethyl
4-amino-
benzoate
+ H3C-C(=O)H
+ HCl
+ H2O /H+, to
+ H2O / OH-, to
+ NH3

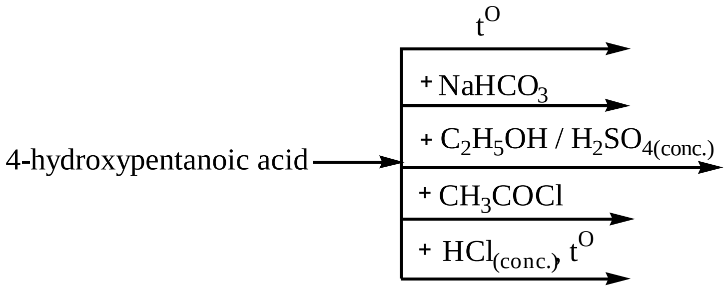

methyl
2-hydroxy-
benzoate
+ CH3COCl
+ FeCl3
+ H2O /H+, to
+ H2O / OH-, to
+ NH2CH3


2-amino-1-(3,4-dihydroxyphenyl)ethanol
+ (CH3CO)2O
+ HCl(conc.) tO
+ NaOH
+ H-C(=O)H
+ K2Cr2O7 / H2SO4, to


2,3-dihydroxybutanedioic acid
+ (CH3CO)2O
+ K2Cr2O7 / H2SO4, to
+ KOH
?
+ NaOH
?
+ Cu(OH)2

An example of the variant:
TEST №1

1. Define the sign (negative or positive) of inductive and resonance (mesomeric) effects of functional groups and heteroatoms in the structure of benzocain (ethyl 4–aminobenzoate). Show these effects with arrows. Indicate electrono-donating (ED) or electrono-accepting (EA) effects of functional groups.
2. Draw the standard Fischer projection formulas of stereoisomers that correspond to the structure of 2,3,4-trihydroxybutanal. Indicate diastereoisomers and enantiomers.
3. Carboxylic acids: acidic properties of mono- and dicarboxylic, saturated, unsaturated and aromatic carboxylic acids.
4. Show the reaction centers of butanamine-1, butanethiol-1 and butanol-1. Write the scheme and outline mechanism of the S_N reaction with HCl for the most active compound.
5. Write the schemes of reactions, represent and name reaction centers, taking part in each reaction, indicate the mechanism of the following reactions:

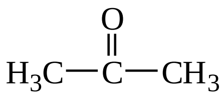
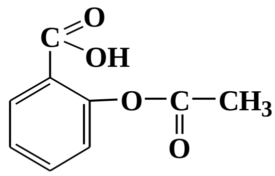
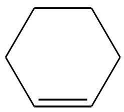
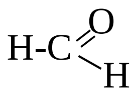
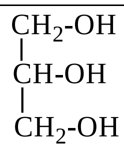
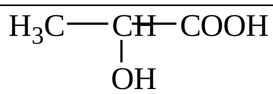
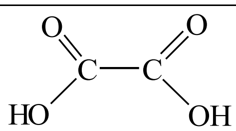
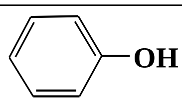
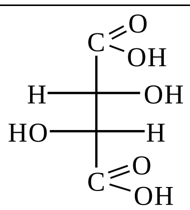


PRACTICAL SKILLS.
Qualitative functional analysis of organic compounds.

THE STUDENT EDUCATIONAL-INVESTIGATIVE WORK №1

The student educational-investigative work is experimental investigation of the given organic compound to choose from two proposed compounds on base qualitative tests for discovery of functional groups and specific qualitative reactions for certain compounds. The student must know the structural formulas, aggregative state, colour and solubility in the water of the compounds proposed for qualitative functional analysis. For theoretical explanation and experimental carrying out of the practical skills task the student must know the schemes of qualitative reactions for discovery of functional groups in the structure of proposed compounds and specific qualitative reactions for certain compounds.

LIST OF COMPOUNDS
FOR QUALITATIVE FUNCTIONAL ANALYSIS
(student educational-investigative work №1)

The name	The structural formula	Aggregative state, colour	Solubility in the water
1	2	3	4
Acetone		colorless liquid, specific smell	partially water soluble
Acetylsalicylic acid		solid, white powder	water insoluble
Cyclohexene		colorless liquid, specific smell	water insoluble
Ethanol	$CH_3—CH_2—OH$	liquid, specific smell	water soluble
Formaldehyde		irritative colorless liquid	water soluble
Glycerol		viscous colorless liquid	water soluble slowly
Lactic acid		yellow-brown liquid, cold smell	water soluble
Oxalic acid		solid, white powder	water soluble
Phenol		colorless, solid	water insoluble
(+)-tartaric acid		solid, white powder	water soluble

AN EXAMPLE OF THE PRACTICAL SKILLS VARIANT PAPER:

TEST№ 1
“Theoretical bases of the main organic compound families structure and reactivity”

PRACTICAL SKILLS.
Qualitative functional analysis of organic compounds.
Student educational-investigative work №1

Define, which of the following compounds is present in task № 30:
lactic acid or acetone.

REQUIREMENTS FOR WRITING ANSWER

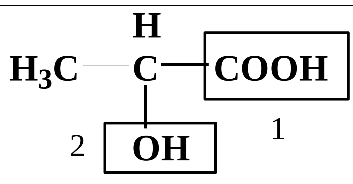
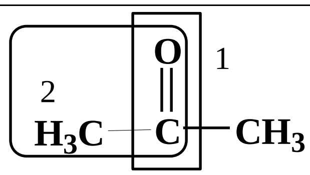
1) To write the structural formulas of the investigated organic compounds, to classify them according to the functional groups and principles of classification as bioorganic compounds.
2) To write the schemes of qualitative reactions for discovery of functional groups in investigated compounds and to show the specific reactions for some groups of compounds, to indicate its conditions and results.
3) To make the qualitative tests according to the sequence of operations, to check the practical results.
4) To analyse and to explain the experiment results, to write the final conclusion as answer of experimental task.

SPECIFIC EXAMPLE OF PRACTICAL TASK SOLUTION.

THE TASK: Define, which of the following compounds is present in task №30: ***lactic acid or acetone***.

I. To write:

1. The structural formulas of the investigated organic compounds and their classification according to the families of functional groups and principles of classification as bioorganic compounds.

 ***lactic acid***	 ***Acetone***

1. A carboxyl group, a carboxilic acid, 2. A hydroxyl group, a secondary alcohol. 1,2. An α-hydroxyacid.	1. A carbonyl group, a ketone, 2. An α-methylketone.

2. Proposed physical properties: aggregative state (solid or liquid), colour, smell, solubility in the water.

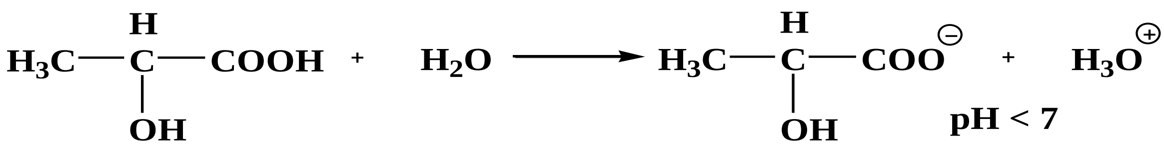
Lactic acid - colourless liquid, cold smell, water soluble.

Acetone - colourless liquid, specific smell, water soluble.

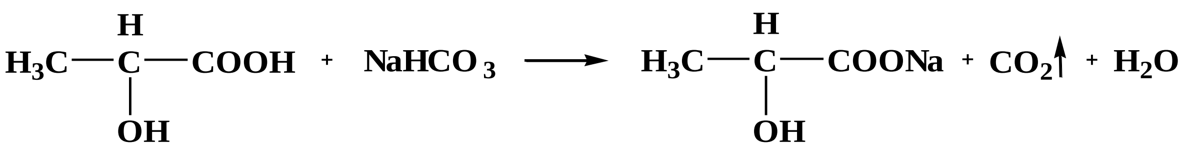
3. The schemes of the qualitative reactions for discovery of functional groups in investigated compounds and the specific reactions for some groups of compounds, their results.

Lactic acid

- The qualitative tests for discovery of carboxyl group in the structure of lactic acid as water soluble carboxylic acid.

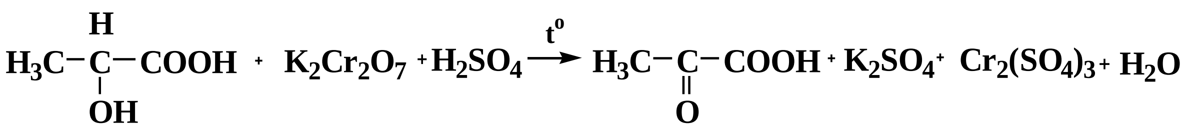


The practical result: indicator paper becomes red.



The practical result: bubbles of gas.

- The qualitative test for discovery of secondary alcohol hydroxyl group in the structure of lactic acid.



The practical result: orange solution of $K_2Cr_2O_7$ becomes blue-green solution of $Cr_2(SO_4)_3$.

- The specific qualitative test for discovery of lactic acid as α-hydroxycarboxylic acid.

$$CH_3\text{-}\underset{OH}{CH}\text{-}C\overset{O}{\underset{OH}{\lessgtr}} \xrightarrow{t^o\ (H_2SO_4(concd))} H\text{-}C\overset{O}{\underset{OH}{\lessgtr}} + CH_3\text{-}C\overset{O}{\underset{H}{\lessgtr}}$$

lactic acid → methanoic acid + ethanal

$$H\text{-}C\overset{O}{\underset{OH}{\lessgtr}} \xrightarrow{t^o} CO + H_2O$$

methanoic acid

The practical result: the blue flame.

$$I_2 + 2NaOI \longrightarrow NaI + NaOI + H_2O$$

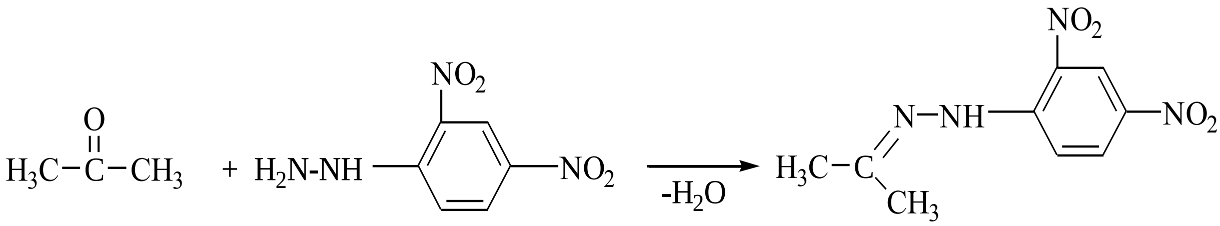
$$CH_3\text{-}C\overset{O}{\underset{H}{\lessgtr}} + 3NaOI \xrightarrow[-3NaOH]{} I_3C\text{-}C\overset{O}{\underset{H}{\lessgtr}} + NaOH \longrightarrow CHI_3\downarrow + H\text{-}C\overset{O}{\underset{O^-Na^+}{\lessgtr}}$$

ethanal; iodoform

The practical result: white-yellow precipitate in the test-tube №2.

Acetone.

- The qualitative test for discovery of carbonyl group in the structure of acetone.



2,4-dinitrophenylhydrazine; acetone 2,4-dinitrophenylhydrazone

The practical result: yellow precipitate.

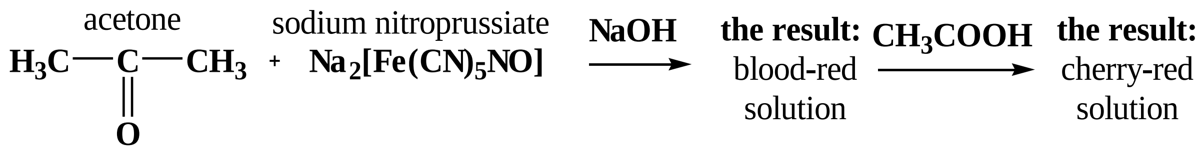
- The qualitative test for discovery of α-methylketo group in the structure of acetone as α-methylketone (iodoform test).

$$I_2 + 2NaOH \longrightarrow NaI + NaOI + H_2O$$

$$CH_3\text{-}\underset{\|}{\underset{O}{C}}\text{-}CH_3 + 3NaOI \xrightarrow[-3NaOH]{} CH_3\text{-}\underset{\|}{\underset{O}{C}}\text{-}CI_3 + NaOH \longrightarrow CH_3\text{-}C\overset{O}{\underset{O^-Na^+}{\lessgtr}} + CHI_3\downarrow$$

The practical result: white-yellow precipitate.

- The specific qualitative test for discovery of acetone with sodium nitroprussiate.



II. To write in a separate paper:
The plan of investigation:

Investigated compounds / Reagents, conditions	***Lactic acid***	***Acetone.***
1) H_2O, indicator paper, pH<7	+	-
2) $NaHCO_3$	+	-
3) $K_2Cr_2O_7/H_2SO_4(2n)/t^o$	+	-
4) a) H_2SO_4(conc.)/t^o b) I_2/NaOH	+	+
5) 2,4-Dinitrophenylhydrazine	-	+
6) I_2/NaOH (immediately)	-	+
7) a) $Na_2[Fe(CN)_5NO]$/NaOH b) CH_3COOH	-	+

III. To make the qualitative tests experimentally according to sequence of operations.

IV. To write the report about the experiment and conclusions according to results about discovering functional groups and families, the final conclusion about the discovering compound.

1) Task № 30 contains a colourless liquid water soluble compound with cold smell.
2) The water solution of investigated compound №30 is a weak acid (pH<7) because an indicator paper becomes red. It means task №30 contains a carboxyl group of a water soluble carboxylic acid.
3) Addition of the $NaHCO_3$ saturated solution to the water solution of investigated compound №30 gives bubbles of gas. It means task №30 contains a carboxyl group of a carboxylic acid.
4) Heating of investigated compound №30 with the water solution of $K_2Cr_2O_7$ and diluted H_2SO_4 leads to change of colour from orange to blue-green. It means task №30 contains a hydroxyl group of a primary or a secondary alcohol.

5) Heating of investigated compound №30 with concentrated H_2SO_4 gives the blue flame. Heating of the investigated compound №30 with concentrated H_2SO_4 and the following iodoform test of the gaseous product leads to form the white-yellow precipitate in test-tube №2. This gaseous product contains a α-methylcarbonyl group of a α-methylcarbonyl compound resulted decomposition of a α-hydroxyacid. That's why the gaseous product is identical with acetaldehyde. It means task №30 is identical with lactic acid.
6) Addition of 2,4-Dinitrophenylhydrazine to investigated compound №30 doesn't give the yellow precipitate. It means task №30 doesn't contain a carbonyl group of an aldehyde or a ketone.
7) Addition of investigated compound №30 to I_2/NaOH doesn't give the white-yellow precipitate immediately. It means task №30 doesn't contain a α-methylketo group of a α-methylketone.
8) Addition of investigated compound №30 to the mixture of the sodium nitroprussiate and the NaOH solutions doesn't give blood-red colour. It means task №30 doesn't contain acetone.

Final conclusion: the compound of task №30 is identical with lactic acid.

CONTROL-TEST № 2.

«Biopolimers and their structural units»

Theoretical part.

Question *№ 1.* Program questions of the following topics:

Monosaccharides. Classification of monosaccharides. Stereoisomerism. D- and L-families. The structures of the most important pentoses and hexoses. Amino sugars and their properties. Open-chain structures and cyclic forms. Furanoses and pyranoses; α- and β-anomers. Fischer projection formulas and Haworth formulas. A cyclo-oxo tautomerization. Mutarotation. The conformations of pyranose forms of monosaccharides. Chemical properties of monosaccharides. Nucleophilic substitution at an anomeric atom in cyclic forms of monosaccharides. O- and N-glycosides. Hydrolysis of glycosides. Phosphates of monosaccharides. Oxidation of monosaccharides. Reducing properties of aldoses. Aldonic, aldaric, uronic acids. Reduction of monosaccharides to alditols. Epimerization reaction of monosaccharides, the reversible transformation of aldoses to ketoses.

Oligosaccharides and polysaccharides. Classification of polysaccharides. Oligosaccharides. The disaccharides: maltose, cellobiose, lactose, sucrose. The conformational structure. The cyclo-oxo tautomerization. The reducing properties. Hydrolysis. Polysaccharides. Homo- and heteropolysaccharides. Homopolysaccharides: starch (amylose, amylopectine), glycogen, dextran, cellulose. Primary structure, hydrolysis. Notion about secondary structure (amylose, cellulose). Pectins. Heteropolysaccharides: hyaluronic acid, chondroitin sulfates. Primary structure.

Natural amino acids. Amino acids that can be obtained from proteins. Classification of naturally occurring amino acids taking into account different signs: acid and base properties, chemical nature of a side chain and its substituents. Structure, nomenclature. Stereoisomerism. Acid and base properties, dipolar ions. Essential amino acids. The formation of α-amino acids: hydrolysis of proteins, synthesis from α-halo acids. Reducing amination reactions and transamination reactions. Chemical properties of α-amino acids as heterofunctional compounds. Formation of intracomplex salts. Esterification, acylation, alkylation, deamination reactions, formation of imines. Biologically important reactions of α-amino acids.

Peptides and proteins. Electronic and steric structure of a peptide bond. Hydrolysis of polypeptides. The establishment of primary structure of polypeptides. The strategy of peptide synthesis. Secondary, tertiary (domains) and quaternary structures.

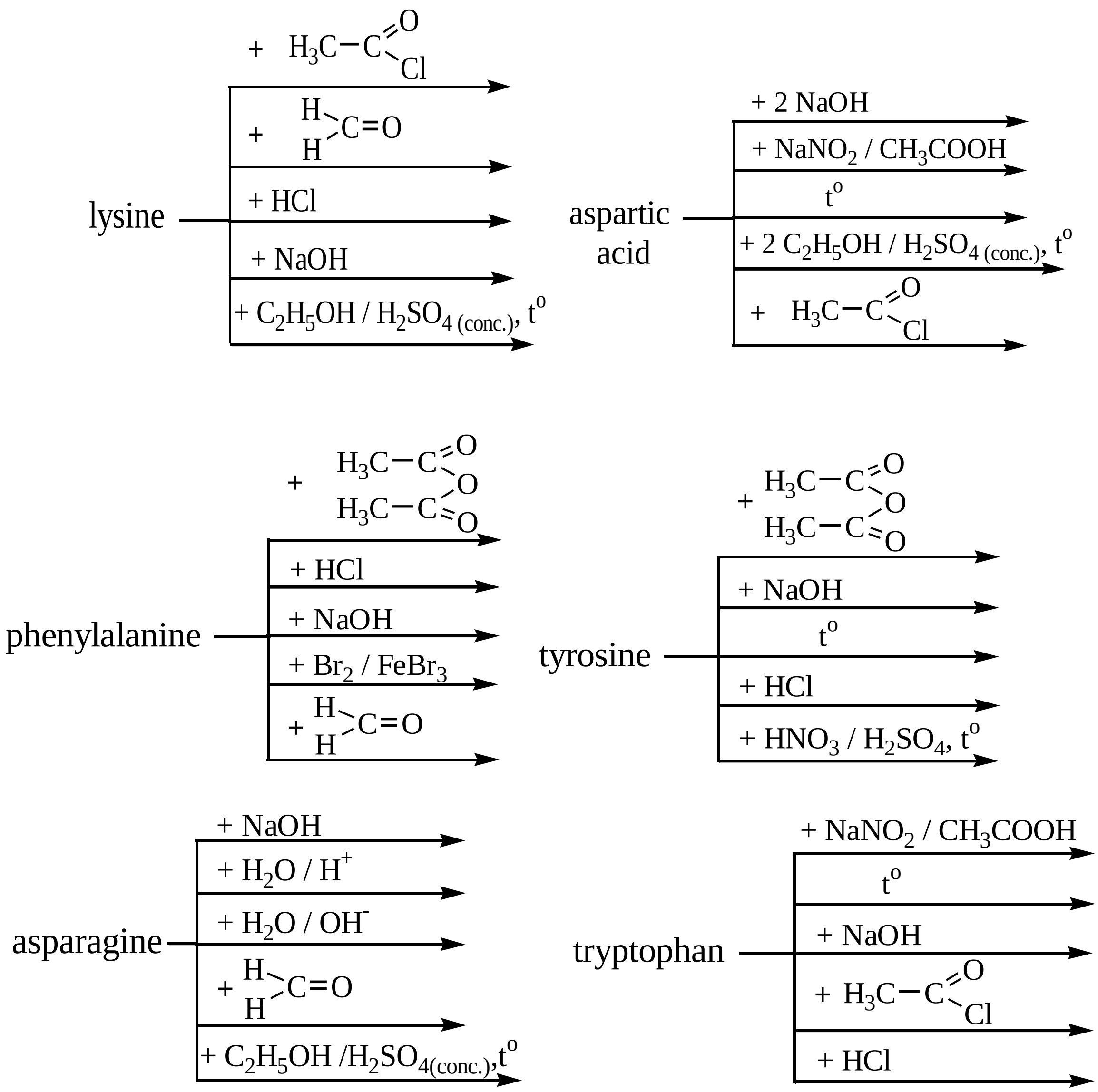
Nucleosides. Nucleotides. Nucleic acids. Nucleic (heterocyclic) base that can be obtained from nucleic acids. A lactim–lactam tautomerization. Deamination reactions. Structure of nucleosides and mononucleotides that can be obtained from nucleic acids. Nomenclature. Hydrolysis. Primary structure of nucleic acids. Ribonucleic and deoxyribonucleic acids. The nucleotides found in RNA, the nucleotides found in DNA. Hydrolysis of nucleic acids. Secondary structure of DNA. The role of hydrogen bonds in formation of the DNA secondary structure. Complementarity of heterocyclic bases. The hydrogen bonds in the complementary pairs of heterocyclic bases. Nucleoside mono- and polyphosphates. AMP, ADP, ATP. The role of ATP as the accumulator and the carrier of free energy in cell. Coenzymes. Structures of NAD^+ and its phosphate ($NADPh^+$). NAD^+-NADH system; hydride transfer as one of the stages of the biological oxidation–reduction reactions with participation of this system.

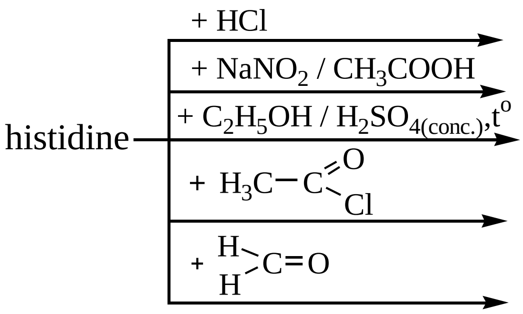
Question *№ 2.* Write the formulas of:

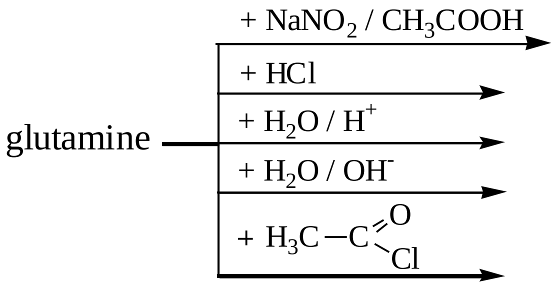
- Oxo- and cyclic forms of biologically important monosaccharides;

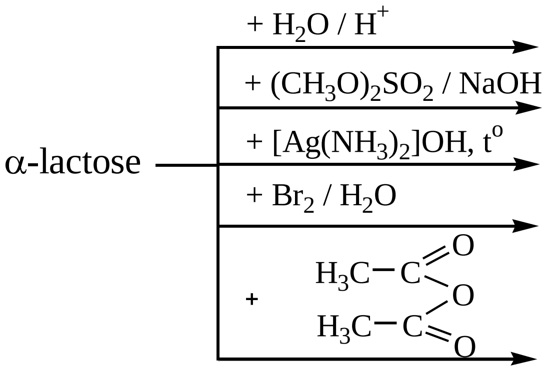
- Disaccharides;
- Ionic forms of natural α-amino acids at given pH;
- Dipeptides;
- Nucleosides, nucleotides and dinucleotides.

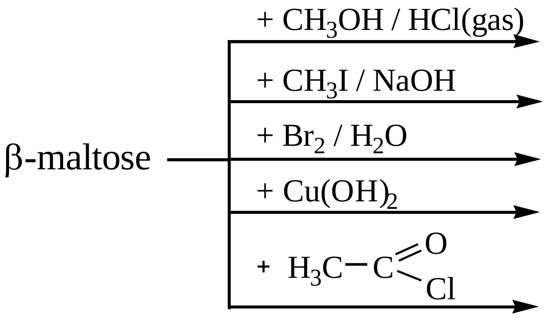
Question *№ 3.* Write the schemes of reactions, represent and name reaction centers, taking part in each reaction, indicate the mechanisms of the following reactions:

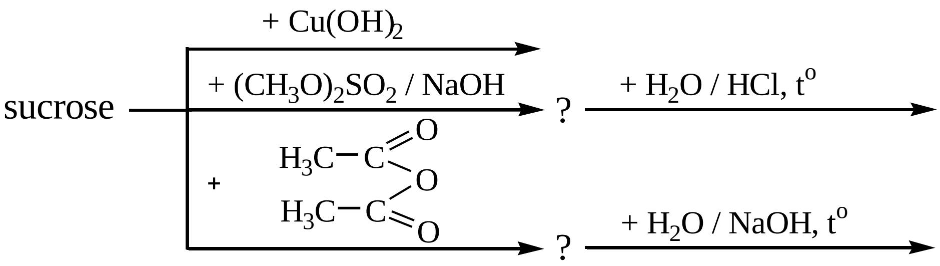


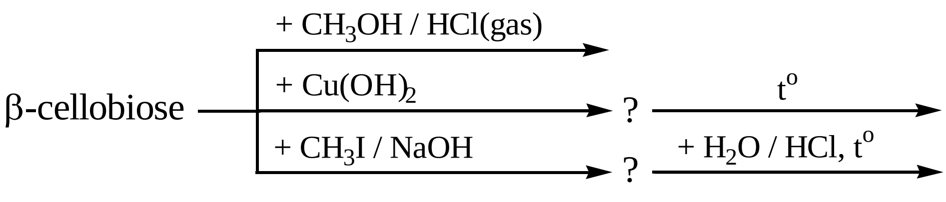

histidine
+ HCl
+ NaNO2 / CH3COOH
+ C2H5OH / H2SO4(conc.),to
+ H3C–C(=O)Cl
+ H2C=O

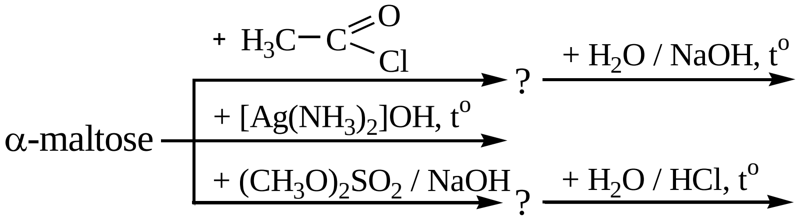

glutamine
+ NaNO2 / CH3COOH
+ HCl
+ H2O / H+
+ H2O / OH-
+ H3C–C(=O)Cl

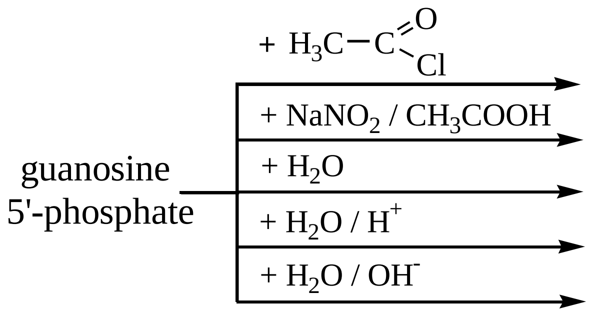

α-lactose
+ H2O / H+
+ (CH3O)2SO2 / NaOH
+ [Ag(NH3)2]OH, to
+ Br2 / H2O
+ (CH3CO)2O

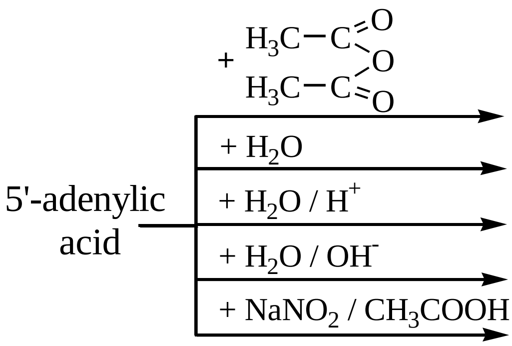

β-maltose
+ CH3OH / HCl(gas)
+ CH3I / NaOH
+ Br2 / H2O
+ Cu(OH)2
+ H3C–C(=O)Cl

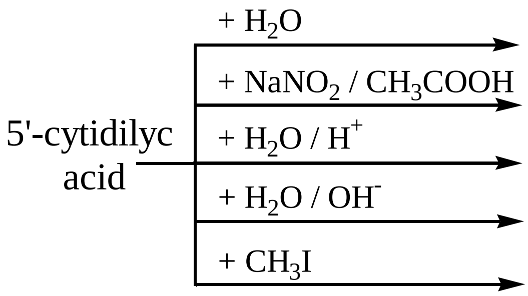

sucrose
+ Cu(OH)2
+ (CH3O)2SO2 / NaOH
?
+ H2O / HCl, to
+ (CH3CO)2O
?
+ H2O / NaOH, to


β-cellobiose
+ CH3OH / HCl(gas)
+ Cu(OH)2
?
to
+ CH3I / NaOH
?
+ H2O / HCl, to


α-maltose
+ H3C–C(=O)Cl
?
+ H2O / NaOH, to
+ [Ag(NH3)2]OH, to
+ (CH3O)2SO2 / NaOH
?
+ H2O / HCl, to







pK_a values for the 20 common amino acids

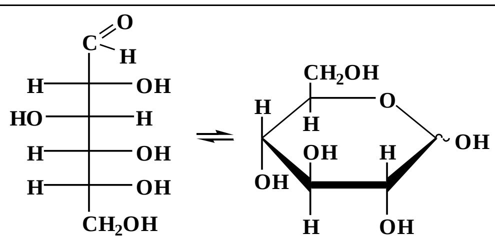
α-Amino Acid	$p(K_a)_1$ (α-COOH Group)	$p(K_a)_2$ (α-NH_3^+ Croup)	pK_{aR} (Side Chain Group)	pI
Alanine	2.3	9.9	-	6.0
Arginine	1.8	9.0	12.5	10.8
Asparagine	2.1	8.8	-	5.4
Aspartic acid	2.0	9.9	3.9	3.0
Cysteine	1.9	10.8	8.3	5.0
Glutamic acid	2.1	9.5	4.1	3.2
Glutamine	2.2	9.1	-	5.7
Glycine	2.3	9.8	-	6.0
Histidine	1.8	9.3	6.0	7.6
Isoleucine	2.3	9.8	-	6.1
Leucine	2.3	9.7	-	6.0
Lysine	2.2	9.2	10.8	9.8

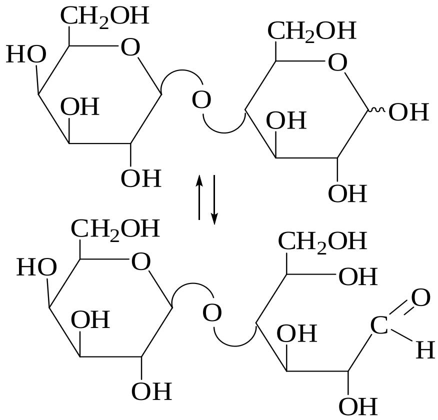
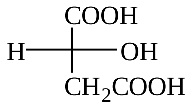
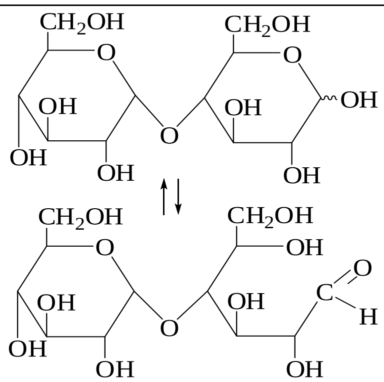
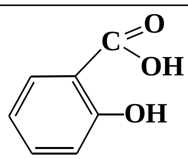
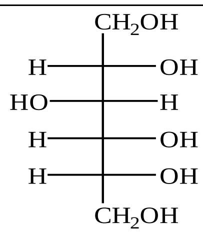
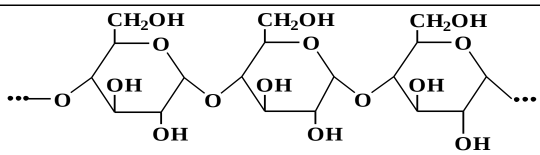
Methionine	2.1	9.3	-	5.8
Phenylalanine	2.2	9.2	-	5.5
Proline	3.0	10.6	-	6.3
Serine	2.2	9.2	-	5.7
Threonine	2.1	9.1	-	5.6
Tryptophan	2.4	9.4	-	5.9
Tyrosine	2.2	9.1	10.1	5.7
Valine	2.3	9.7	-	6.0

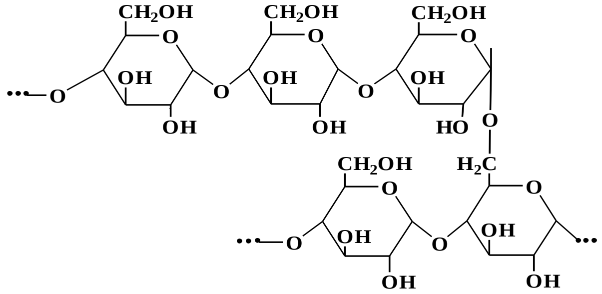
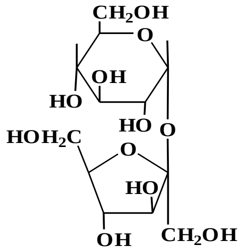
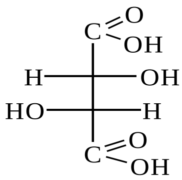
PRACTICAL SKILLS:
THE STUDENT EDUCATIONAL-INVESTIGATIVE WORK №2

The student educational-investigative work is experimental investigation of the given bio-organic compound to choose from two proposed compounds on base qualitative tests for discovery of functional groups and specific qualitative reactions for certain compounds. The student must know the structural formulas, tautumerism, aggregative state, colour and solubility in the water of the compounds proposed for qualitative functional analysis. For theoretical explanation and experimental carrying out of the practical skills task the student must know the schemes of qualitative reactions for discovery of functional groups in the structure of proposed compounds and specific qualitative reactions for certain compounds.

LIST OF COMPOUNDS
FOR QUALITATIVE FUNCTIONAL ANALYSIS

The name	The structural formula	Aggregative state, colour	The solubility in the water
1	2	3	4
D-(+)-glucose		solid, white powder	water soluble
Glycine	$H_2N\text{-}CH_2\text{-}C(=O)OH$	solid, white powder	water soluble

Lactose		solid, white powder	water soluble
(+)-Malic acid		solid, white powder	water soluble
Maltose		solid, white powder	water soluble
Salicylic acid		solid, white powder	partially water soluble
D-sorbitol		solid, white powder	water soluble
Starch	 Amylose	solid, white powder	insoluble in cold water, in heating with water forms gel

	 amylopectine		
Sucrose		solid, white powder	water soluble
(+)-tartaric acid		solid, white powder	water soluble

AN EXAMPLE OF THE PRACTICAL SKILLS VARIANT PAPER:

PRACTICAL SKILLS.
Qualitative functional analysis of organic compounds.
Student educational-investigative work №2.

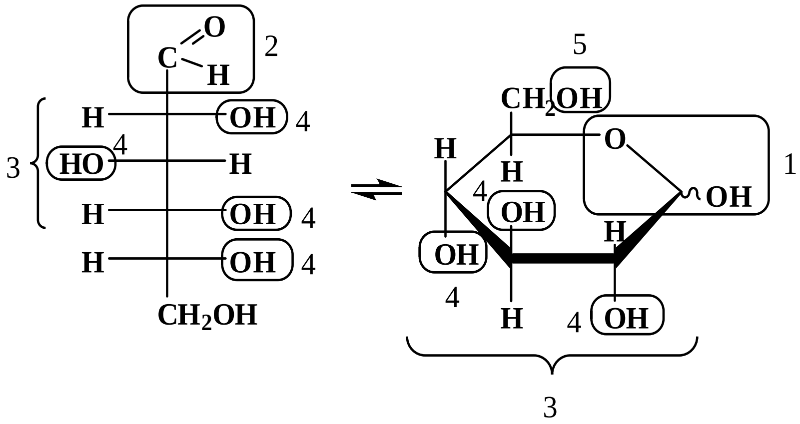
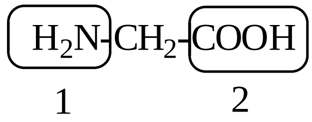
Define, which of the following compounds is present in task № 55:
D-(+)-glucose or glycine.

REQUIREMENTS FOR WRITING ANSWER AND SPECIFIC EXAMPLE OF PRACTICAL TASK SOLUTION.

I. To write in the exercise book:

1) The structural formulas of investigated organic and bioorganic compounds and their classification according to the families of functional groups and principles of classification as bioorganic compounds. In the water solution D-(+)-glucose exist as the mixture of five tautomeric forms: the open-chain structure and four cyclic forms. Everyone provides one of qualita-

tive tests. It is necessary to write equilibrium between the open-chain structure and at least one of cyclic forms of D-(+)-glucose

 **D-(+)-glucose:** *I. Classification according to the functional groups:* 1. A hemiacetal; 2. A carbonyl group, an aldehyde; 3,4,5. Hydroxyl groups: 3. A polyhydric vicinal alcohol; 4. A secondary alcohol; 5. A primary alcohol. *II. Classification as bioorganic compound:* 1. A monosaccharide; 2. An aldohexose.	 **Glycine:** *I. Classification according to the functional groups:* 1. An amino group, a primary aliphatic amine. 2. A carboxyl group, carboxylic acid. II. *Classification as bioorganic compound:* A neutral α-amino acid.

2) Proposed physical properties: aggregative state (solid or liquid), colour, smell, solubility in the water.

D-(+)-glucose – solid, white powder, water soluble.

Glycine - solid, white powder, water soluble.

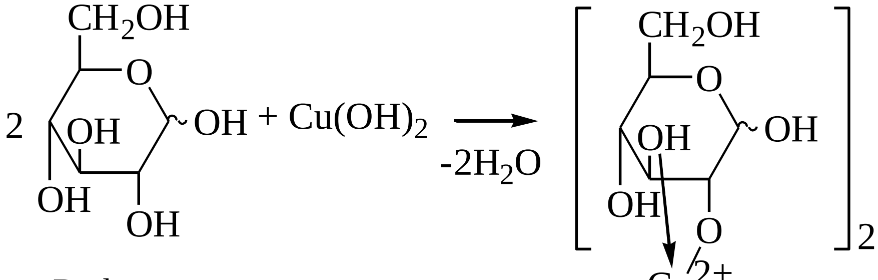
3) The schemes of qualitative reactions for discovery of functional groups in the investigated compounds and specific reactions for some groups of compounds, practical results.

D-(+)-glucose

- The qualitative test for discovery of polyhydric vicinal alcohol in the structure of D-(+)-glucose as a monosaccharide.

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

light-blue precipitate



D-glucose

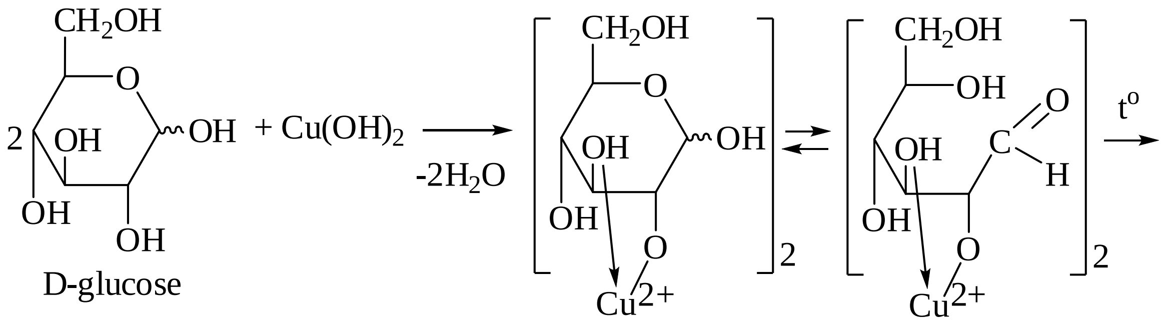
The practical result: the dark-blue solution.

- Qualitative tests for proof of an aldehyde functional group presence in the structure of D-(+)-glucose as an aldose.

a) The copper mirror reaction with $Cu(OH)_2$:

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

light-blue precipitate



$$\longrightarrow Cu_2O\downarrow + 2H_2O + \text{D-glucose oxidation products}$$

cuprous oxide

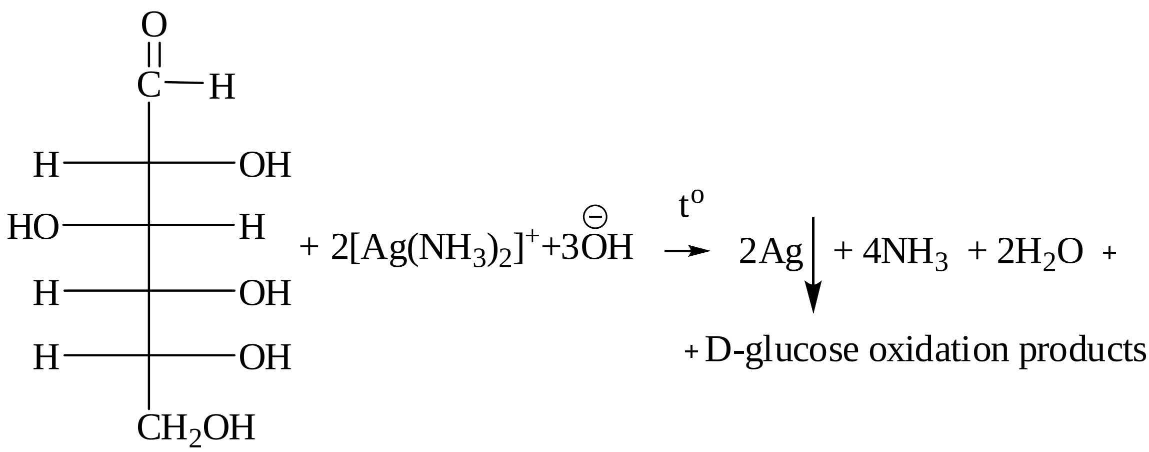
The final practical result: brick-red precipitate of cuprous oxide.

b) The silver mirror reaction with Tollen's reagent.

$$AgNO_3 + NaOH \longrightarrow Ag_2O\downarrow + NaNO_3 + H_2O$$

$$Ag_2O + NH_4OH \longrightarrow [Ag(NH_3)_2]OH$$

Tollen's reagent



Practical result: silver coating on walls inside of a test tube (silver mirror).

Glycine.

- The qualitative test for proof that glycine is a neutral α-amino acid contained the same number of a carboxyl and a primary amino groups simultaneously on base the neutral pH value of its water solution.

$$H_2N\text{-}CH_2\text{-}COOH \underset{}{\overset{H_2O}{\rightleftharpoons}} H_3\overset{\oplus}{N}\text{-}CH_2\text{-}CO\overset{\ominus}{O} \qquad pH{\sim}7$$

The practical result: the indicator methyl red becomes orange.

- The qualitative test to discover an amino group in the structure of glycine as a primary amine.

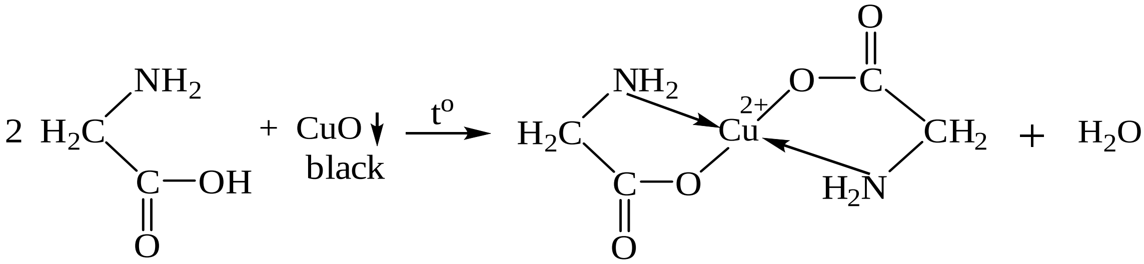
$$NaNO_2 + CH_3COOH \rightarrow HNO_2 + CH_3COONa$$

$$H_2N\text{-}CH_2\text{-}COOH + HNO_2 \longrightarrow HO\text{-}CH_2\text{-}COOH + N_2\uparrow + H_2O$$

The practical result: bubbles of gas.

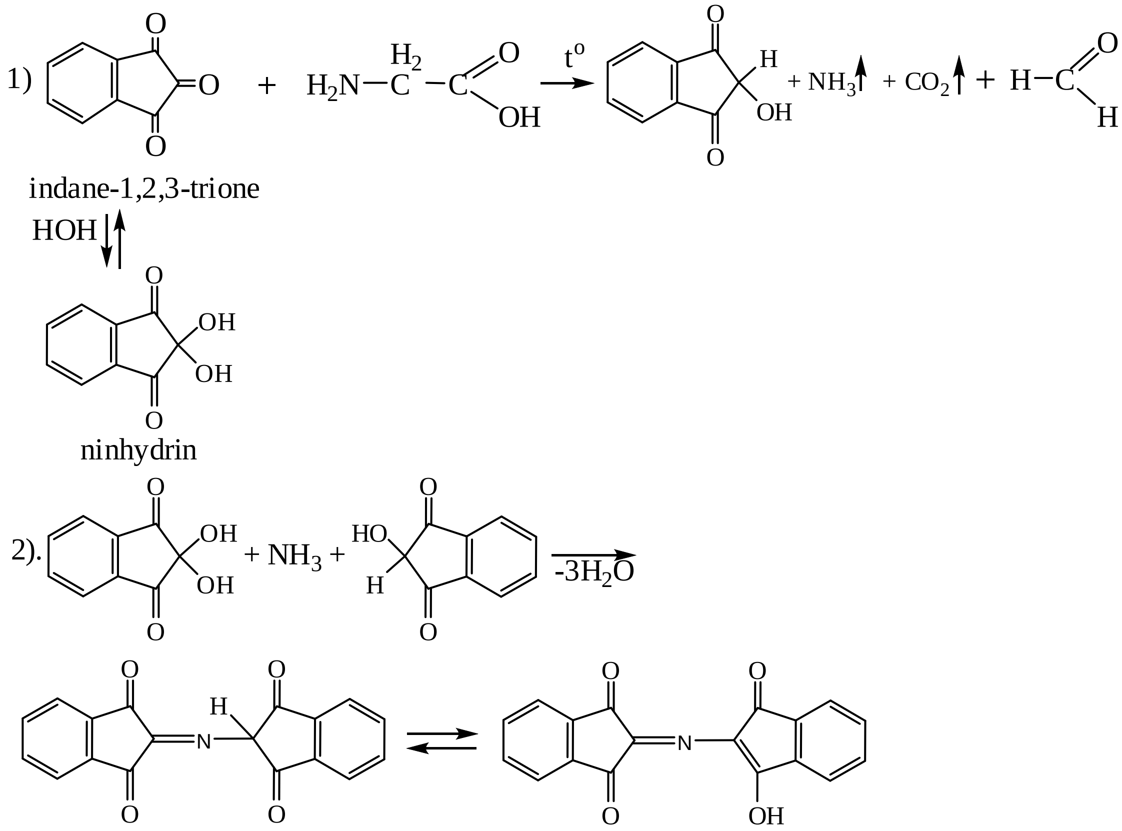
- Specific qualitative tests to discover of glycine as a α-amino acid.

1) Formation of copper and α-amino acid (α-hydroxy acid) complex compound.



The practical result: dark-blue copper salt glycine solution.

2) The reaction with ninhydrin.



The practical result: blue-violet colour.

II. To write on a separate paper:

The possible plan of investigation:

investigated compounds / Reagents, conditions.	***D-(+)-glucose***	***Glycine.***
1. H_2O, methyl red.	+	+
2. $Cu(OH)_2$ ($CuSO_4$, NaOH).	+	+
3. $Cu(OH)_2$ ($CuSO_4$, NaOH) / t^0.	+	-
4. $NaNO_2$, CH_3COOH(conc.).	-	+
5. CuO / t^0.	-	+
6. Ninhydrin / t^0.	-	+

III. To do the qualitative tests experimentally according to sequence of operations.

IV. To write the report about the experiment and conclusions according to results about discovering functional groups and families, the final conclusion about the discovering compound.

1. Task №55 contains solid white powder.
2. It is water soluble compound.
3. Addition of the indicator methyl red to the water solution of investigated compound №55 gives orange solution; so it is neutral. It means task №55 contains the same number of carboxyl and amino groups simultaneously in the structure of α-amino acid. The neutral water solution can mean also that task №55 doesn't have any carboxyl or amino group.
4. Mixing of the water solution $CuSO_4$ and excess of the water solution of NaOH makes light-blue precipitate of the fresh prepared reagent $Cu(OH)_2$. Following addition of the investigated compound water solution to the $Cu(OH)_2$ precipitate gives the dark – blue solution. It means task №55 contains vicinal hydroxyl or (and) amino groups. So task №55 can be vicinal polyhydric alcohol or α-amino acid.
5. Following heating of the investigated compound №55 copper complex (the dark-blue solution) received in point 3 leads to form the brick-red precipitate. It means task №55 contains a carbonyl group of an aldehyde.
6. Presence of an aldehyde and a polyhydric vicinal alcohol group in investigated compound №55 simultaneously proves that task №55 is identical with a monosaccharide family.
7. Addition of the $NaNO_2$ solution and concentrated acetic acid doesn't give bubbles of nitrogen gas. It means task №55 doesn't have a primary amine.
8. Heating of the investigated compound №55 water solution with CuO (copper oxide) doesn't give the stable dark-blue solution. It means task №55 is not α-amino acid.
9. Heating of the investigated compound №55 water solution with ninhydrin solution doesn't give the blue violet colour. It means task №55 is not an α-amino acid.

Final conclusion: the compound of task №55 is identical with D-(+)-glucose.

EXAMINATION ON PRACTICAL SKILLS.

LIST OF PRACTICAL SKILLS
in bioorganic chemistry for specialty "general medicine".

1. To write the structural formulas according to systematic names and to give the names according to structural formulas of the biologically important organic compounds.

2. To determine the presence of reaction centers (acidic, basic, electrophilic, and nucleophilic) in the structure of biologically important molecules; qualitative estimation of reactivity and possible mechanisms of organic compound reactions.

3. To analyze the potential energy of conformations of biologically important compounds. To determine the presence of chiral centers in molecular structure; to represent them by Fisher's projections and to designate them by the system of D, L – stereochemical nomenclature.

4. To carry out qualitative reactions to determine main functional groups, unsaturation and reducing properties of organic compounds.

Students take final examination on practical skills in bioorganic chemistry at the end of semester during laboratory class according to the calendar-thematic plan and time-table of the laboratory classes in bioorganic chemistry.

An examination practical skills paper contain**s:**

I-st question about classification of giving bioorganic compound structural formula according to the functional groups families and main reactivity on base reaction centers of this families.

II-nd question about experimental investigation of organic or bioorganic compound.

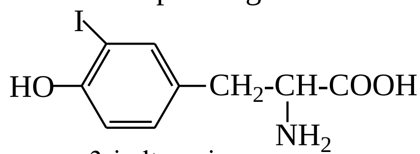
An example of the final examination practical skills variant paper.

PRACTICAL SKILLS
EXAMINATION PAPER № 1

EXAMINATION: the course project

EDUCATIONAL DISCIPLINE: bioorganic chemistry

1. Classify the following compound according to the functional groups. Find, represent and name reaction centres of the corresponding families of organic compounds.

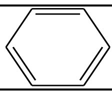
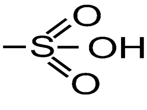
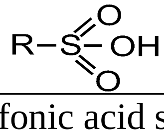
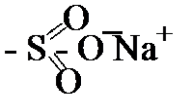
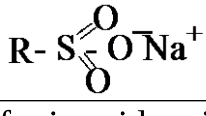
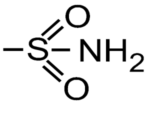
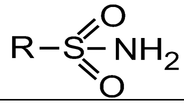


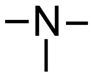
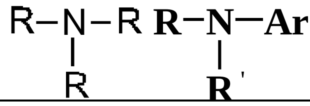
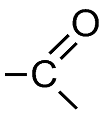
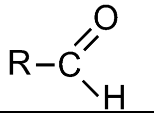
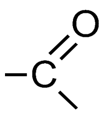
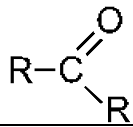
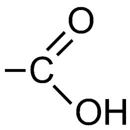
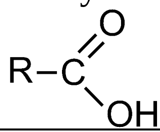
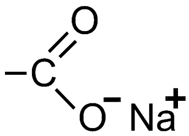
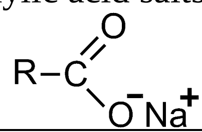
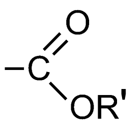
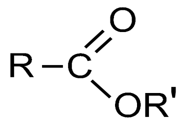
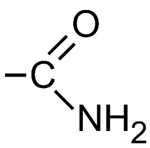
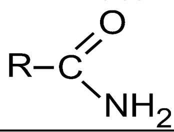
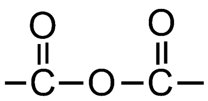
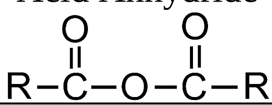
3-iodtyrosine

2. Define, which of the following compounds is present in the task № 33
phenol or (+)-Malic acid.

I. CLASSIFICATION OF BIOLOGICALLY IMPORTANT ORGANIC COMPOUNDS ACCORDING TO THE FAMILIES OF FUNCTIONAL GROUPS.

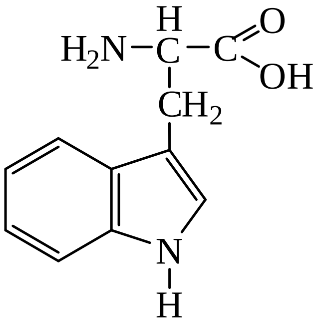
The first of practical skills is skill of classification of given biologically important organic compound according to the families of functional groups, naming of this functional groups, representation and naming of the reaction centres of this functional groups. Student must know the structure, the name of functional groups and the name of functional groups families.

№	Functional group*	Name of functional group	Family name General formula
1.	2.	3.	4.
1.	$>C=C<$	The carbon-carbon double bond	Alkenes
2.	$–C≡C–$	The carbon-carbon triple bond	Alkynes
3.		Aromatic ring	Arenes
4.	–F, –Cl, –Br, –I (Hal)	Fluoro; chloro; bromo; iodo groups)	Haloalkanes **R–X, X=F,Br,I.**
5.	–OH	The hydroxyl group: - alcohol - phenol	**Alcohols R–OH,** **Phenols Ar–OH,**
6.	–OR	An alkoxy group	Ethers **R–O–R, R'–O– R**
7.	–SH	Thiol group	Thiols **R–SH**
8.	–SR	Sulfide group	Sulfides **R–S–R**
9.	–S–S–		Disulfides R–S–S–R
10.		The sulfonic acid group	Sulfonic acids 
11.			Sulfonic acid salts 
12.			Sulfonic acid amides 

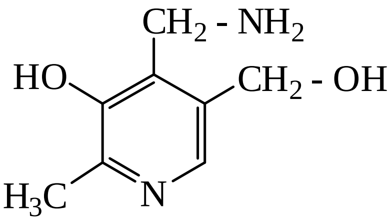
1	2	3	4
13.	$-NH_2$	The amino group	1^0(primary) amines $R-NH_2$; $Ar-NH_2$
14.	–NH–		2^0 (secondary) amines R–NH–R; R-NH-Ar
15.			3^0(tertiary) amines 
16.	–C≡N		Nitriles **R–C≡N**
17.		The carbonyl group	Aldehydes 
18.			Ketones 
19.		The carboxyl group	Carboxyl Acids 
20.		The carboxylate anion	Carboxylic acid salts 
21.		The ester group	Esters 
22.		Amide group	Amides 
23.		Anhydride group	Acid Anhydride 

* A bond line indicates that the functional group is bonded to the carbon of any alkyl or aryl group.

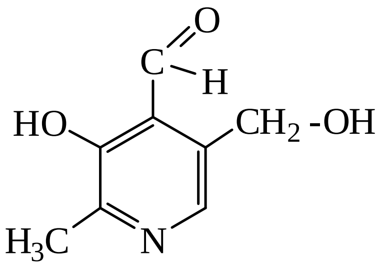
THE LIST OF COMPOUNDS FOR CLASSIFICATION ACCORDING TO FUNCTIONAL GROUPS.



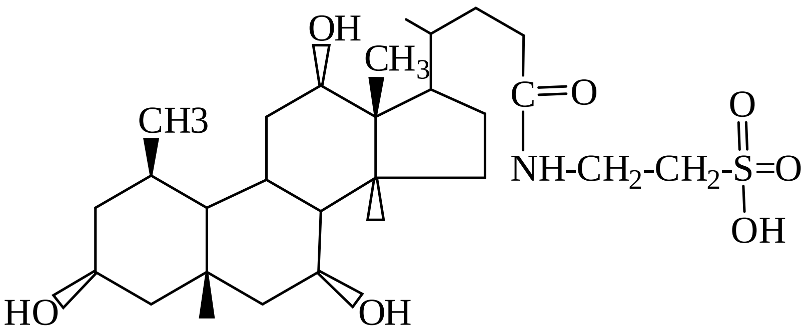
Serotonin



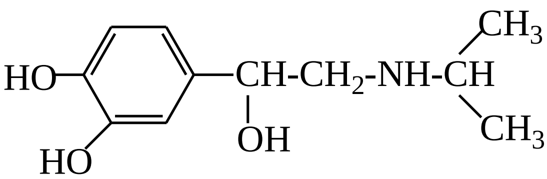
Pyridoxamine



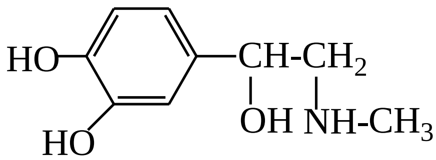
Pyridoxal



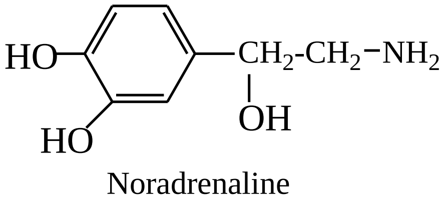
Taurocholic acid



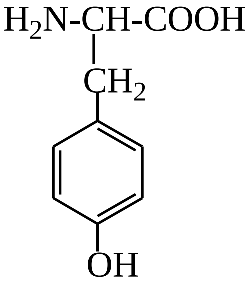
Isoprenaline

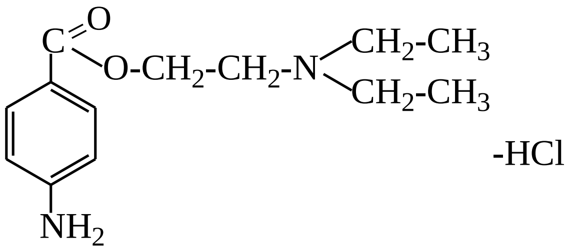


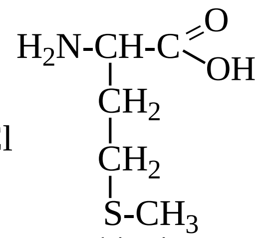
Adrenaline (epinephrine)

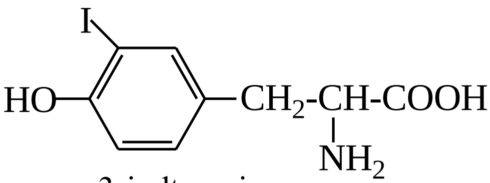


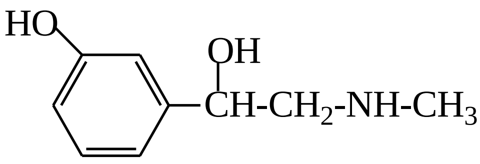
Noradrenaline
(norepinephrine)

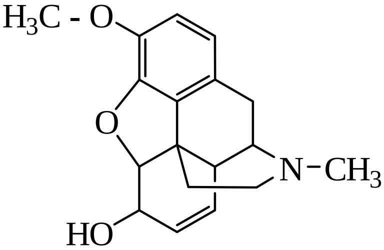

Tyrosine

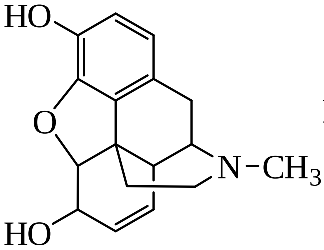

Procaine hydrochloride

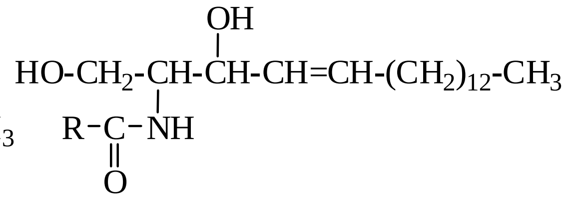

Methionine

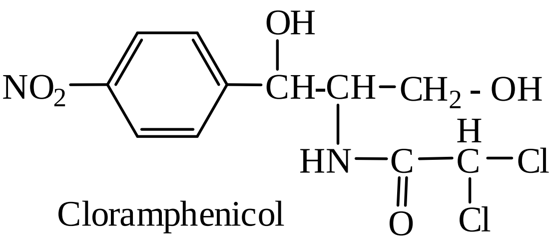

3-iodtyrosine

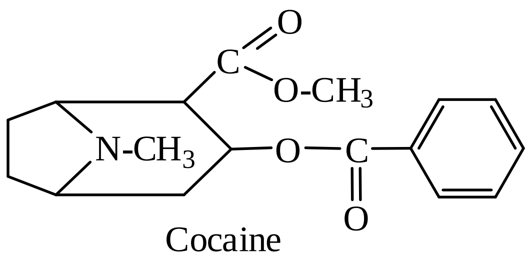

Phenylephrine

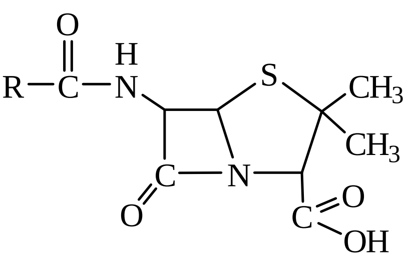

Codeine

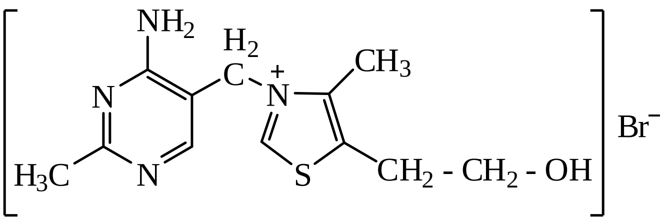

Morphine

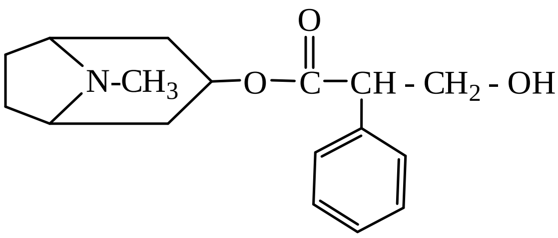

Ceramide


Cloramphenicol

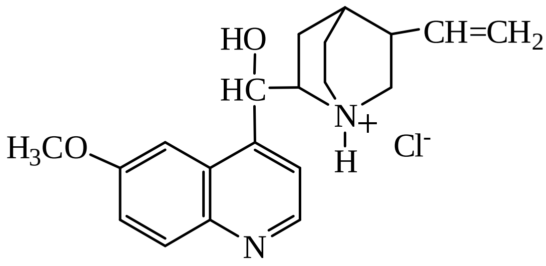

Cocaine


Penicillin

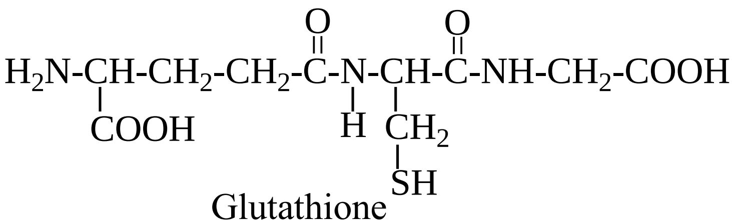

Thiamine



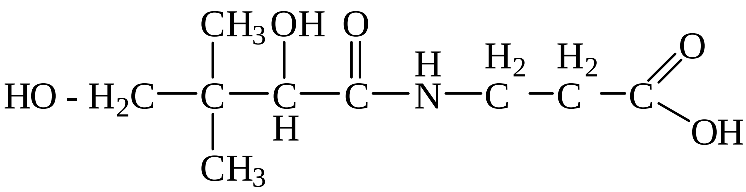
Atropine



Quinine hydrochloride



Glutathione



Pantothenic acid

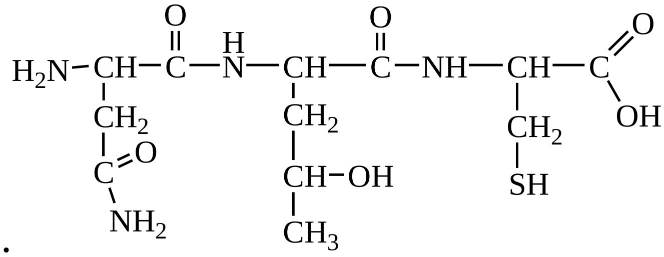
REQUIREMENTS FOR WRITING ANSWER:

1. To indicate the functional groups in the structure of organic compounds.
2. To name the families of organic compounds according to the functional groups.
3. To represent and to name the reaction centres of the corresponding families of organic compounds.

SAMPLE PROBLEM №1.

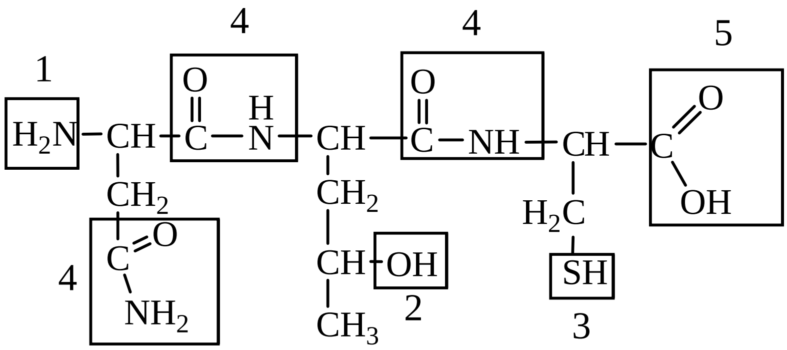
Classify the following compound according to the functional groups.

Example 1



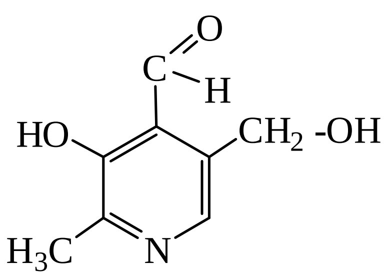
Tripeptide Asn-Thr-Cys

Solution:



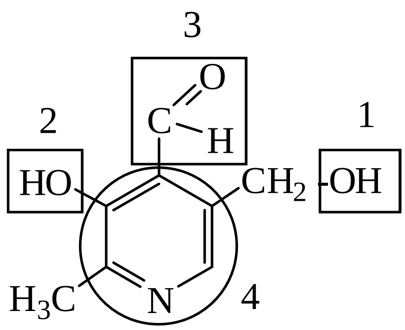
1. An amino group, a primary amine.
2. A hydroxyl group, a secondary alcohol.
3. A thiol group, a thiol.
4. An amide group, an amide.
5. A carboxyl group, a carboxylic acid.

Example 2



Pyridoxal

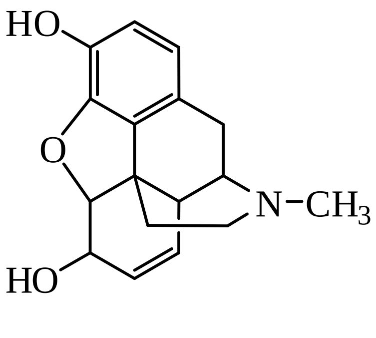
Solution:



Pyridoxal

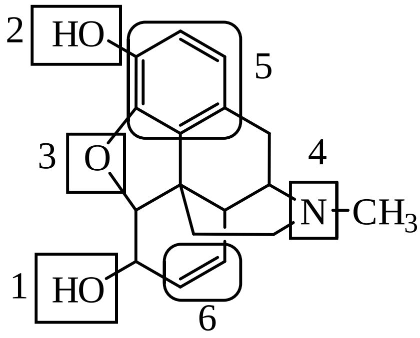
1. A hydroxyl group, a primary alcohol.
2. A hydroxyl group, a phenol.
3. A carbonyl group, an aldehyde.
4. An aromatic heterocycle.

Example 3



Morphine

Solution:



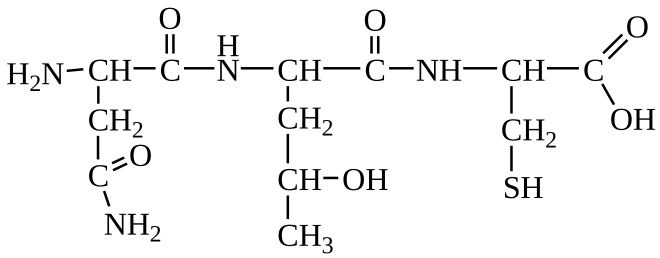
Morphine

1. A hydroxyl group, a secondary alcohol.
2. A hydroxyl group, a phenol.
3. An alkoxy group, an ether.
4. An amino group, a tertiary amine.
5. Aromatic ring, an arene.
6. A double bond, an alkene.

SAMPLE PROBLEM №2.

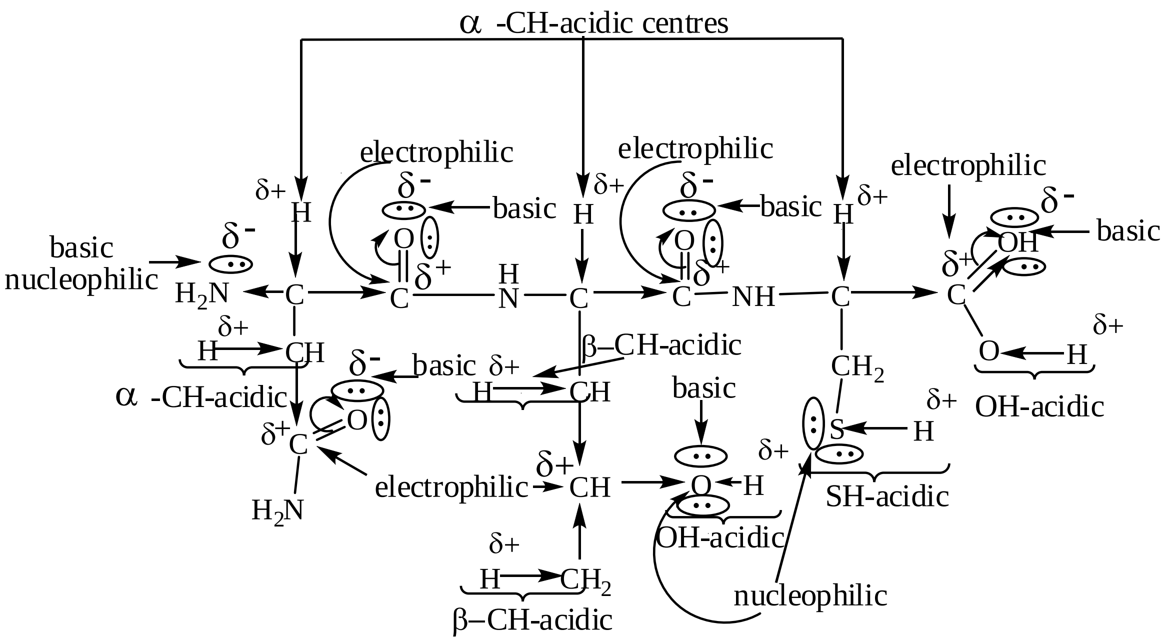
Find, represent and name reaction centres of the coresponding families of organic compounds.

Example 1.

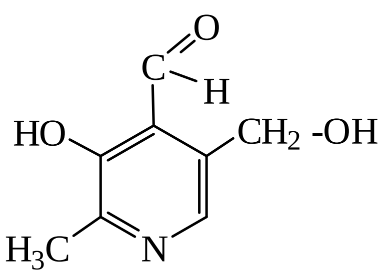


Tripeptide Asn-Thr-Cys

Solution:

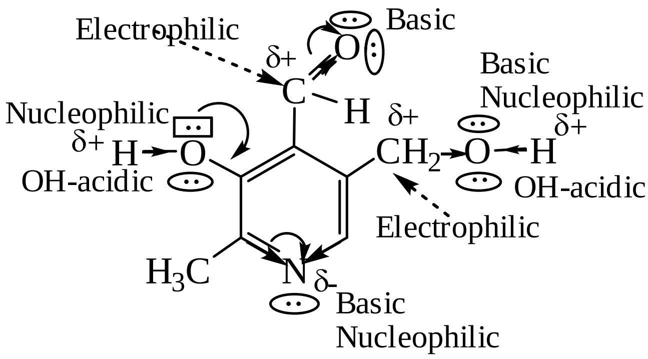


Example 2



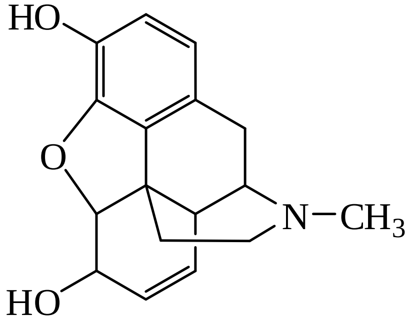
Pyridoxal

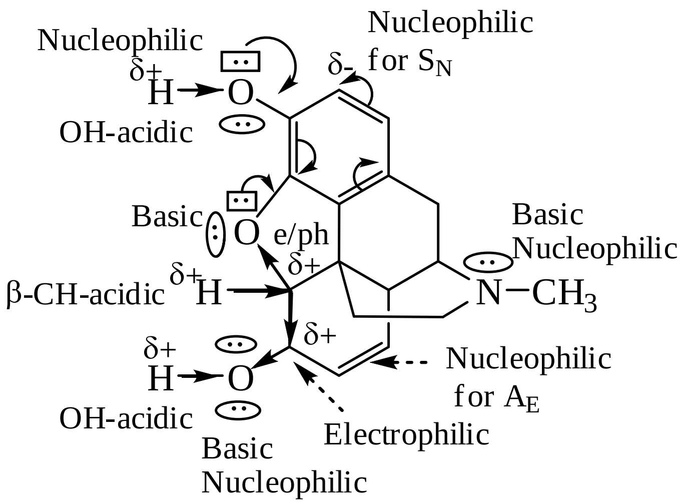
Solution:



Pyridoxal

Example 3 ***Solution:***





Morphine Morphine

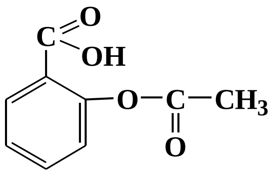
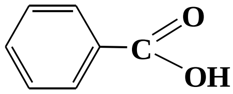
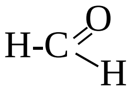
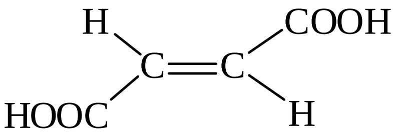
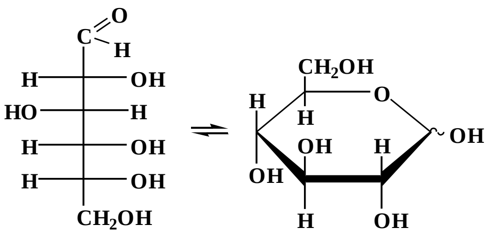
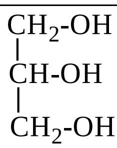
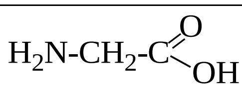
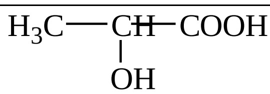
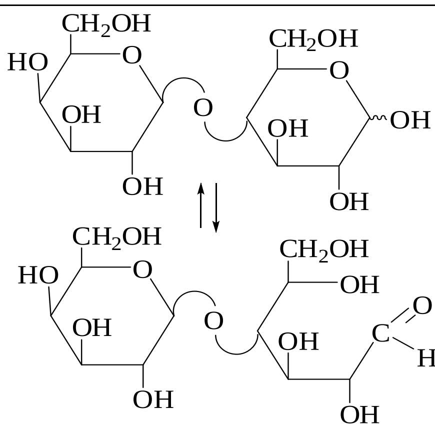
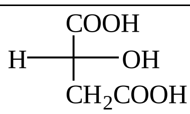
II. QUALITATIVE FUNCTIONAL ANALYSIS OF ORGANIC COMPOUNDS.

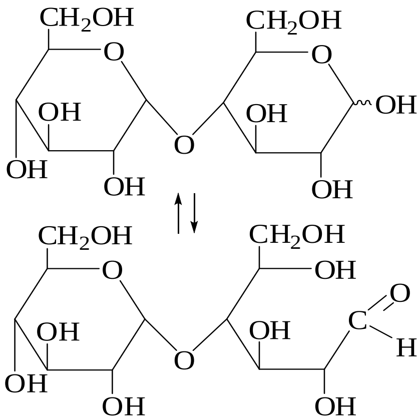
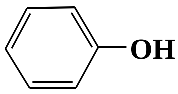
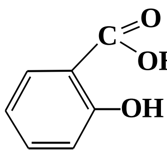
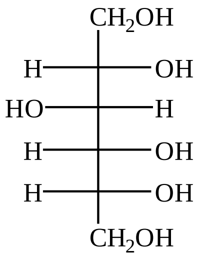
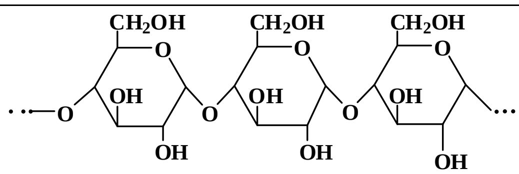
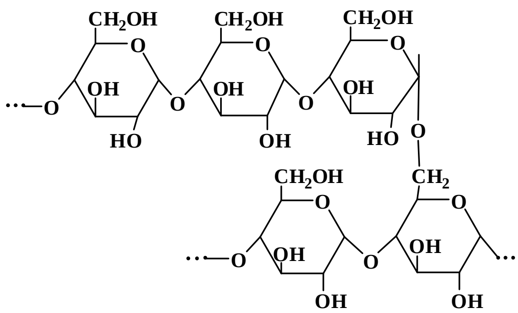
the student educational-investigative work

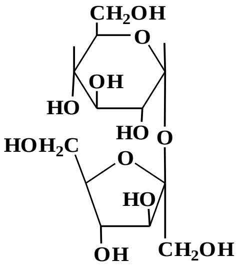
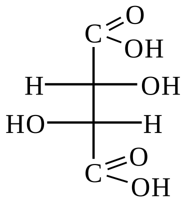
The student educational-investigative work is experimental investigation of the given organic or bio-organic compound to choose from two proposed compounds on base qualitative tests for discovery of functional groups and specific qualitative reactions for certain compounds. The student must know the structural formulas, tautomerism, aggregative state, colour and solubility in the water of the compounds proposed for qualitative functional analysis. For theoretical explanation and experimental carrying out of the practical skills task the student must know the schemes of qualitative reactions for discovery of functional groups in the structure of proposed compounds and specific qualitative reactions for certain compounds.

LIST OF COMPOUNDS
FOR QUALITATIVE FUNCTIONAL ANALYSIS
(student educational-investigative work)

Name	Structural formula	Aggregative state, colour	The solubility in the water
1	2	3	4
Acetone	$H_3C-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$	colorless liquid, specific smell	partially water soluble

Acetylsalicylic acid		solid, white powder	water insoluble
Benzoic acid		solid, white powder,	water insoluble
Formaldehyde		irritative colorless liquid	water soluble
Fumaric acid		solid, white powder	partially water soluble
D-(+)-glucose		solid, white powder	water soluble
Glycerol		viscous colorless liquid	water soluble slowly
Glycine		solid, white powder	water soluble
Lactic acid		yellow-brown liquid, cold smell	water soluble
Lactose		solid, white powder	water soluble
(+)-Malic acid		solid, white powder	water soluble

Maltose		solid, white powder	water soluble
Phenol		colorless, solid	water insoluble
Salicylic acid		solid, white powder	partially water soluble
D-sorbitol		solid, white powder	water soluble
Starch	 Amylose  amylopectine	solid, white powder	insoluble in cold water, in heating with water forms gel

Sucrose		solid, white powder	water soluble
(+)-tartaric acid		solid, white powder	water soluble

THE REQUIREMENTS FOR WRITING ANSWER

5) To write the structural formulas of the investigated organic compounds, to classify them according to the functional groups and principles of classification as bioorganic compounds.
6) To write the schemes of qualitative reactions for discovery of functional groups in the investigated compounds and to show the specific reactions for some groups of compounds, to indicate its conditions and results.
7) To do the qualitative tests according to the sequence of operation, to check the practical results.
8) To analyse and to explain the experiment results, to write the final conclusion as answer of experimental task.

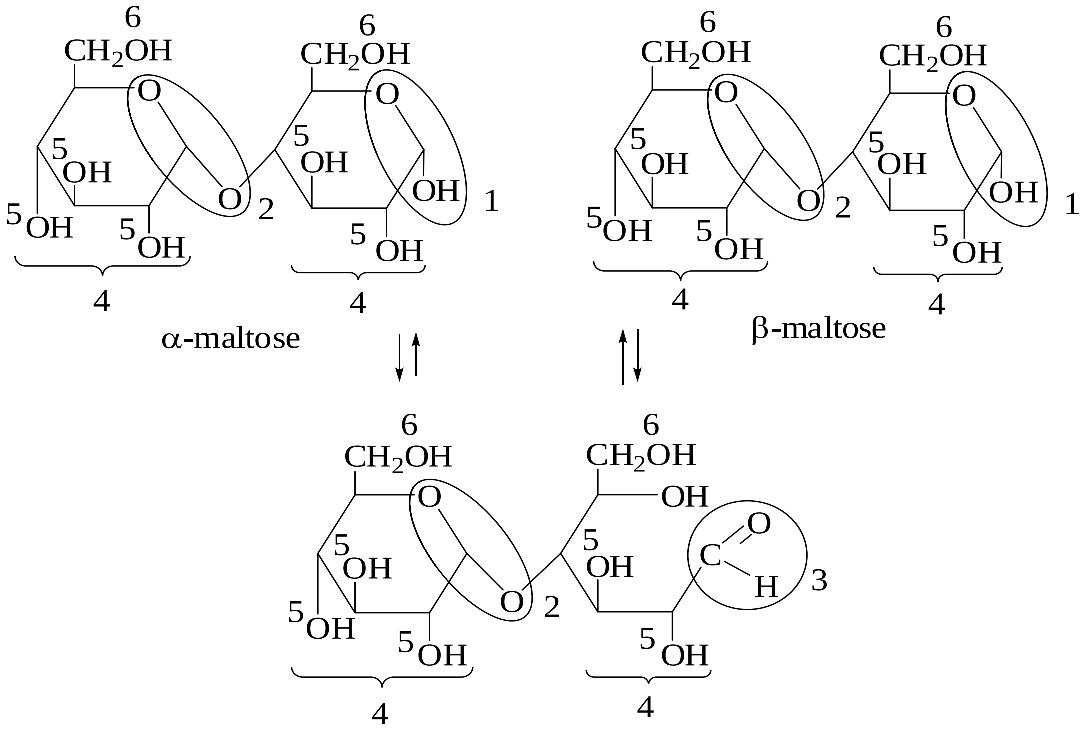
SPECIFIC EXAMPLE OF PRACTICAL TASK SOLUTION.

THE TASK: Define, which of the following compounds is present in task №70: ***maltose or sucrose***.

I. To write in the exercise book:

4) The structural formulas of the investigated organic and bioorganic compounds and their classification according to the families of functional groups and principles of classification as bioorganic compounds. In the water solution maltose exists as mixture of primarily three tautomeric forms: the open-chain structure and two cyclic forms. Everyone provides one of qualitative test. It is necessary to write equilibrium between the open-chain structure and at least one of cyclic forms of maltose.

Maltose:



I. Classification according to the functional groups:

1. A hemiacetal;
2. An acetal, a glycoside;
3. A carbonyl group, an aldehyde;

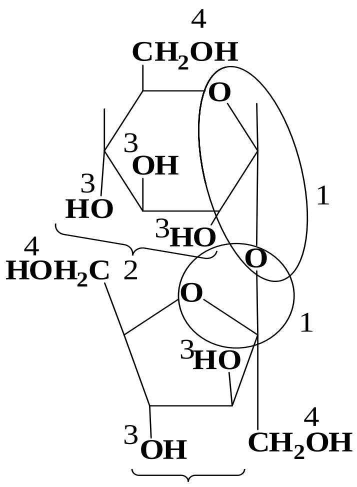
4,5,6. Hydroxyl groups:

4. A polyhydric vicinal alcohol;
5. A secondary alcohol;
6. A primary alcohol.

II. Classification as bioorganic compound:

6. A reducing disaccharide.

Sucrose:



I. Classification according to the functional groups:

1. An acetal, a glycoside;

2,3,4. Hydroxyl groups:

2. A polyhydric vicinal alcohol;
3. A secondary alcohol;
4. A primary alcohol.

II. Classification as bioorganic compound:

5. A nonreducing disaccharide.

5) Proposed physical properties: aggregative state (solid or liquid), colour, smell, solubility in the water.

Maltose – solid, white powder, water soluble.

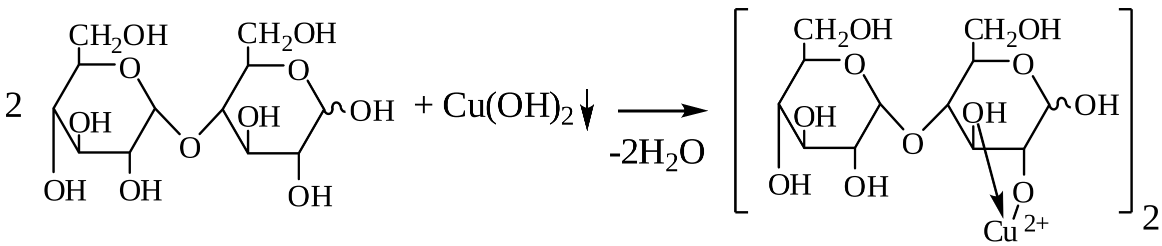
Sucrose - solid, white powder, water soluble.

6) The schemes of qualitative reactions for discovery of functional groups in investigated compounds and the specific reactions for some groups of compounds, its practical results.

Maltose

- The qualitative test for discovery of a polyhydric vicinal alcohol in the structure of maltose as an oligosaccharide (disaccharide).

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

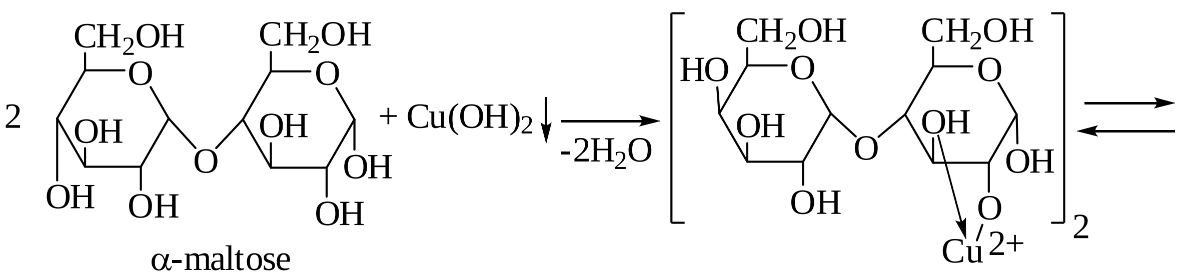


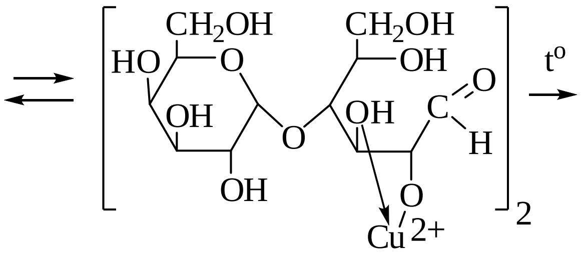
The practical result: the dark-blue solution.

- The qualitative tests for proof of an aldehyde functional group presence existed in equilibrium with hemiacetal group in the structure of maltose as a reducing disaccharide.

a) The copper mirror reaction with $Cu(OH)_2$:

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





$\xrightarrow{t^o}$ $Cu_2O\downarrow + 2H_2O$ + maltose oxidation products

cuprous oxide

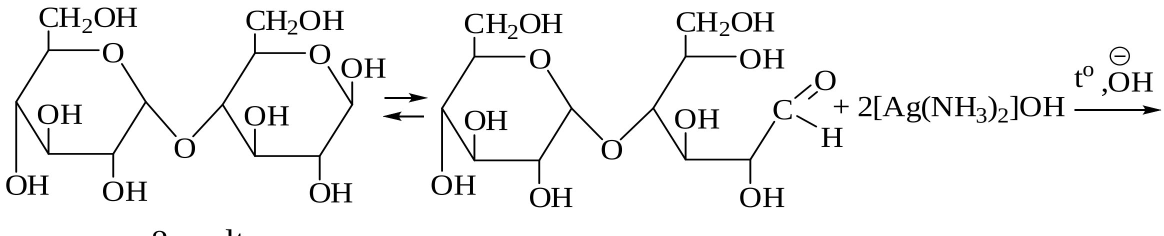
The final practical result: brick-red precipitate of cuprous oxide.

b) The silver mirror reaction with Tollen's reagent.

$$AgNO_3 + NaOH \longrightarrow Ag_2O\downarrow + NaNO_3 + H_2O$$

$$Ag_2O + NH_4OH \longrightarrow [Ag(NH_3)_2]OH$$

Tollen's reagent



β-maltose

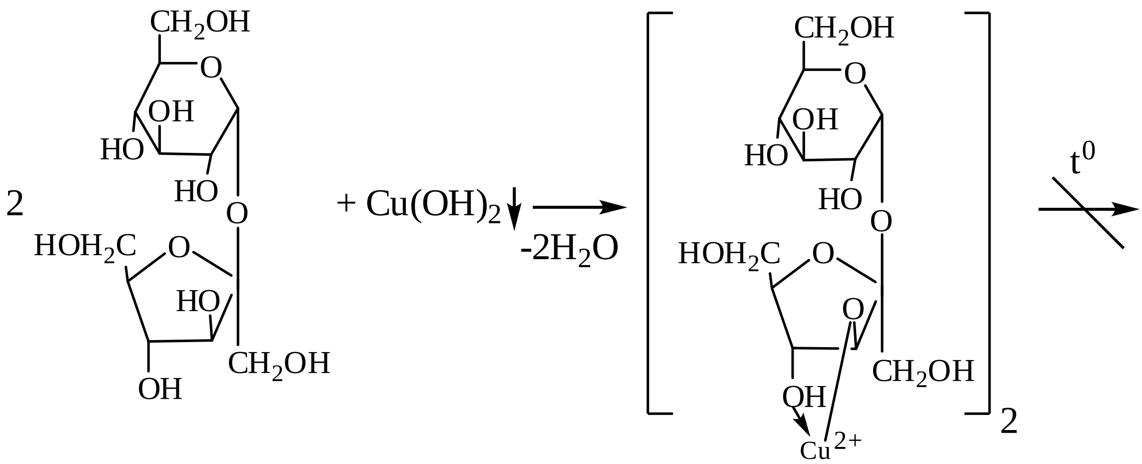
$$\longrightarrow 2Ag\downarrow + 4NH_3 + 2H_2O + \text{maltose oxidation products}$$

The practical result: silver coating on walls inside of test tube (silver mirror).

Sucrose

- The qualitative test for discovery of a polyhydric vicinal alcohol in the structure of sucrose as a oligosaccharide (disaccharide).

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



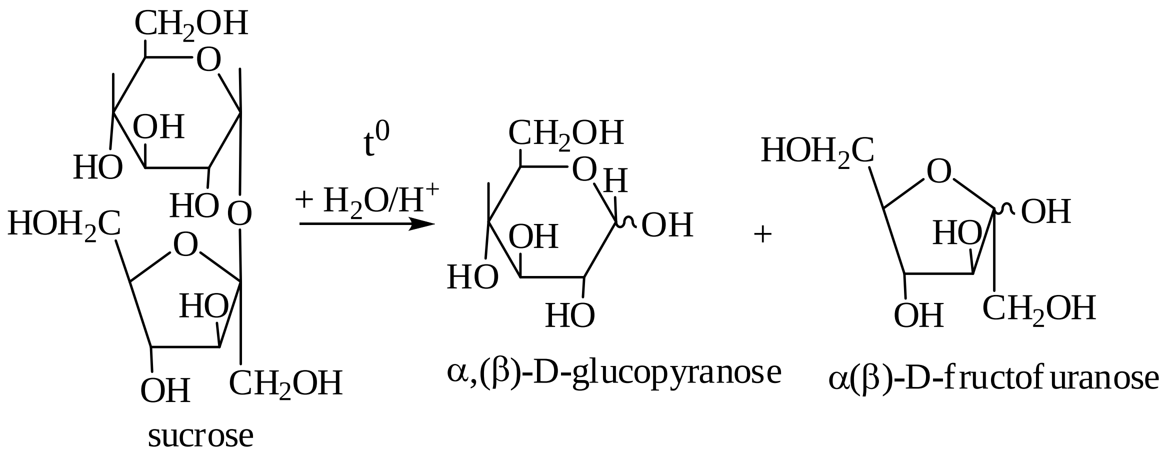
The practical result: the dark-blue solution that is not changed in heating.

Sucrose as a nonreducing disaccharide unlike maltose gives negatively the reactions with $Cu(OH)_2$ and Tollen's reagent in heating.

It is necessary to do acid hydrolysis of sucrose with following qualitative analysis of formed monosaccarides to prove that it is an oligosaccharide, but not only a vicinal polyhydric alcohol.

- The qualitative test for proof that sucrose is an oligosaccharide contained fructose.

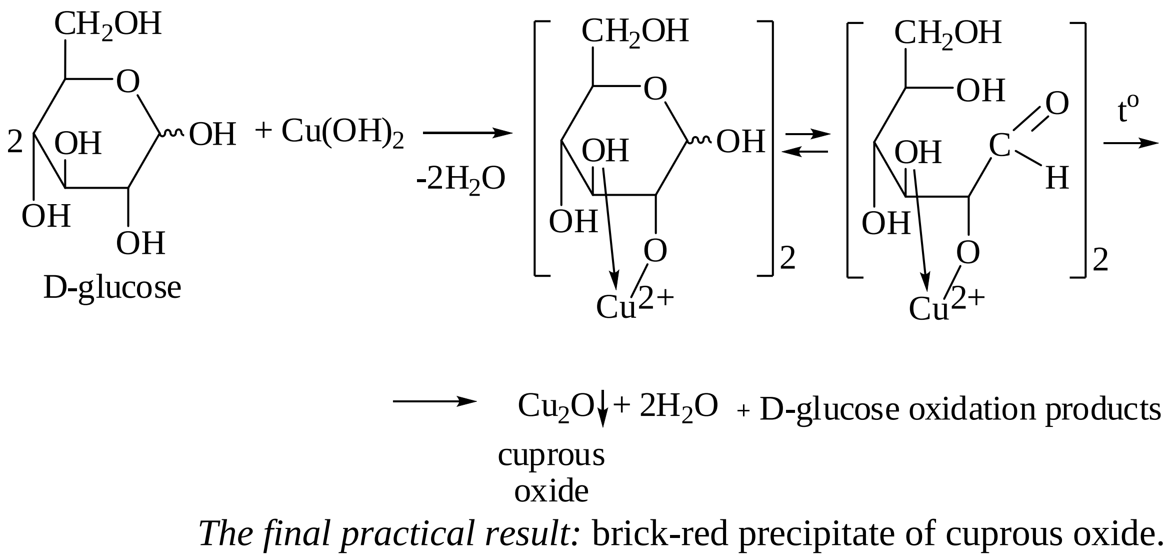
1) Sucrose hydrolysis:



2) Proof the monosaccharide formation with example of D-glucose:

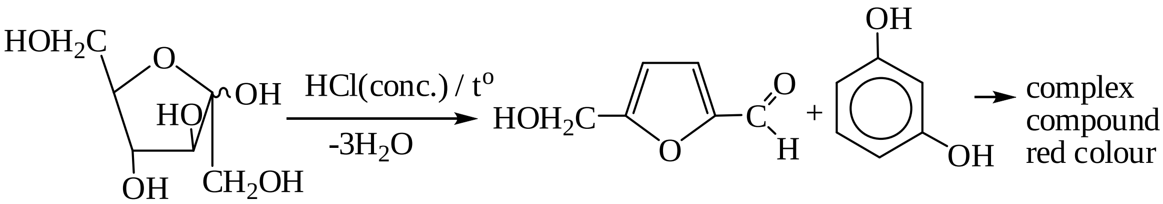
$$CuSO_4 + 2NaOH \longrightarrow Cu(OH)_2\downarrow + Na_2SO_4$$

light-blue precipitate



The final practical result: brick-red precipitate of cuprous oxide.

3) Proof fructose formation.



The practical result: red colour.

III. To write on a separate paper:

The possible plan of investigation:

Investigated compounds / Reagents, conditions.	***Maltose***	***Sucrose.***
1. $Cu(OH)_2$ ($CuSO_4$, NaOH).	+	+
2. $Cu(OH)_2$ ($CuSO_4$, NaOH) / t^0.	+	-
3. H_2O, HCl / t^0.	+	-
3.1. $Cu(OH)_2$ ($CuSO_4$, NaOH).	+	+
3.2. $Cu(OH)_2$ ($CuSO_4$, NaOH) / t^0.	+	+
3.3. HCl(conc.), resorcinol / t^0.	-	+

III. To do the qualitative tests experimentally according to sequence of operation.

IV. To write the report about the experiment and conclusions according to results about discovering functional groups and families, final conclusion about discovering compound.

1. Task №70 contains solid white powder; it is water soluble compound.
2. Mixing of 0.2 $CuSO_4$ water solution and excess of 2n NaOH water solution makes light-blue precipitate of the fresh prepared reagent $Cu(OH)_2$. Following addition of the investigated compound №70 water solution to the $Cu(OH)_2$ precipitate gives the dark – blue solution. It means task №70 contains vicinal hydroxyl groups of a vicinal polyhydric alcohol.
3. Following heating of the investigated compound №70 copper complex (the dark-blue solution) received in the point 3 doesn't give the brick-red precipitate. It means task №70 doesn't contain a carbonyl group of an aldehyde in equilibrium with a hemiacetal group. That's why compound №70 is not a reducing disaccharide.

It is necessary to do acid hydrolysis of investigated compound №70 with following qualitative analysis of formed monosaccarides to prove that it is an oligosaccharide, but not only a vicinal polyhydric alcohol.

4. Heating of the investigated compound №70 water solution with 2n HCl doesn't give any practical result.

4.1. Mixing of 0.2n $CuSO_4$ water solution and excess of 2n NaOH water solution makes the light-blue precipitate of the fresh prepared reagent $Cu(OH)_2$. Following addition of the part of the hydrolysis product (neutralized by 2n NaOH water solution) to the $Cu(OH)_2$ precipitate gives the dark-blue solution. It means the product of hydrolysis contains vicinal hydroxyl groups of a vicinal polyhydric alcohol.

4.2. Following heating of product of hydrolysis copper complex gives the brick-red precipitate. It means product of acid hydrolysis of investigated compound №70 contains an aldehyde group of an aldehyde.

Presence of an aldehyde and a polyhydric vicinal alcohol group in the investigated compound №70 acid hydrolysis product simultaneously proves that it is identical with a monosaccharide family. Because started investigated compound №70 doesn't have an aldehyde functional group, we can conclude that task №70 contains the nonreducing oligosaccharide.

4.3. Heating of the investigated compound №70 hydrolysis product with concentrated HCl (hydrochloric acid) and resorcinol gives the red solution. It means the investigated compound №70 hydrolysis product contains fructose. That's why investigated compound №70 is identical with sucrose.

Final conclusion: the compound of task №70 is identical with sucrose.

QUESTIONS FOR THEORETICAL EXAM

1. Theoretical base of the structure and reactivity of organic compounds.

1.1 Introduction. Classification and nomenclature of organic compounds.

1. Classification of organic compounds according to the structure of carbon skeleton and according to the functional groups.

2. Principal rules of IUPAC nomenclature of organic compounds; substitutive and radicofunctional nomenclature.

1.2 Chemical bond and mutual influence of atoms in organic compounds.

3. Electronic structure of carbon atom and heteroatoms (N, O). Hybridization.

4. Chemical bonding in organic compounds. Main characteristics of the σ- and π-bonds in organic compounds. Hydrogen bonds.

5. Conjugation (π, π- and p, π-conjugation). Conjugated systems with an open chain: 1, 3 – diens, polyenes, allylic radical).

6. Conjugated systems with a closed chain. Aromaticity: criterions (conditions) of aromaticity, Huckel′s rule of aromaticity. Aromaticity of benzenoid (benzene, naphthalene, phenanthrene), nonbenzenoid compounds. Conjugation (delocalization) energy. Thermodynamic stability of biologically important molecules with opened and closed conjugated systems.

7. Mutual influence of atoms in organic compounds: inductive effect and mesomeric effect. Electron–withdrawing and electron–releasing substituents. Electron density delocalization in the molecule. Reaction centres.

1.3 Stereochemistry of organic compounds. Configuration and conformation of organic compounds.

8. Configuration and conformation of organic compounds. The relationship between steric structure of organic compounds and the hybridization type of a carbon atom: sp^3, sp^2, sp – hybridization. Molecular models (ball-and-stick models, space-filling models); three-dimensional (stereo-chemical) formulas. Newman and Fischer projection formulas.

9. Chirality. Chiral molecules. The chiral carbon atom. A stereocenter. Enantiomerism. Optical activity. Relative configuration. The D-, L-system of a stereochemical designation. Glyceraldehyde as a configurational standard. Absolute configuration of stereoisomers. Notion of the R-, S –system of a stereochemical designation.

10. Stereoisomerism of molecules with one stereocenter. Stereoisomerism of molecules with more than one stereocenter: enantiomers and diastere-

omers. Meso compounds. Racemate, racemic mixtures. Notion of methods of racemic mixtures separation. π-Diastereomers.

11. Conformations of open chain compounds. Newman projection formulas. Torsional and Van Der Waals strains in the molecules. Energy characteristics of alkanes` conformations.

12. The primary formation of five- and six-membered cycles. Stability of conformations. Axial and equatorial bonds. 1,3-diaxial interaction. Conformational inversion of cyclohexane.

1.4 Reactivity of hydrocarbons.

13. Chemical reaction as a process. Terms: reactants (a substrate, a reagent), products (the product of interest, the by- product), a reaction center, an activation energy, the rate of the reaction, the mechanism of the reaction. Classification of organic reactions according to the result (substitution, addition, elimination reactions; rearrangements; oxidation-reduction reactions) and mechanisms such as radical reactions, ionic reactions (electrophilic, nucleophilic).

14. Types of reagents: radical, nucleophilic, electrophilic, acidic, basic. Types of bond cleavage in organic compounds and forming species: free radicals as the result of homolysis, carbocations and carbonions as the result of heterolysis). Electronic and steric structures of these intermediates. Factors of their relative stability.

15. Reactivity of saturated hydrocarbons. Free–radical substitution reactions as homolytical reactions with participation of C–H bonds at a sp^3 hybridized carbon atom. The mechanism of free – radicals substitution reactions on the example of the halogenation of alkanes. Free-radical substitution reactions as regioselective reactions. Ways of free radicals formation. Notion of chain processes. The role of free radical oxidation reactions in biological processes. Active forms of oxygen, peroxides.

16. Electrophilic addition reactions to alkenes as heterolycal reactions with participation of π–bond between two sp^2 hybrid carbon atoms. The mechanism of the hydration reaction. The acidic catalysis. The effect of static and kinetic factors on regioselectivity of addition reactions. Markovnikov's rule.

17. Electrophilic addition to conjugated systems: hydration of α, β – unsaturated carboxylic acids. Qualitative reactions for the unsaturated hydrocarbons (for the double bond).

18. Electrophilic aromatic substitution reactions as heterolytical reactions with participation of the π–electron cloud of an aromatic system. The mechanism of the reaction. The role of catalysts in the electrophile formation.

19. Electrophilic aromatic substitution reactions. Effect of substituents in an aromatic ring on its reactivity in electrophilic (aromatic) substitution. Orienting effect of substituents. Halogenation and alkylation reactions in vivo.

1.5 Reactivity of alcohols, phenols, thiols and amines. Acid-base properties of organic compounds.

20. Reaction centers of alcohols, phenols, thiols and amines. Acidity or basicity: Bronsted-Lowry and Lewis theories. Qualitative and quantitative characteristics of acidic and basic properties of organic compounds.

21. The acidic and basic properties: the chemical nature of the atom in acidic and basic centers, electronic effects of substituents, solvatation effect. Toxicity of strong acids and bases. Amphoterism. The hydrogen bond as specific manifestation of acid and basic properties.

22. Nucleophilic substitution reactions at sp^3–hybrid carbon atom. S_{N1} and the S_{N2} – mechanisms. Stereochemistry of nucleophilic substitution reactions.

23. Nucleophilic substitution of the hydroxyl group in alcohols. The role of acid catalysis.

24. The alkylation reactions of alcohols, thiols, amines. The alkylation in vivo.

25. Elimination reactions (dehydration) of alcohols. The biologically important dehydration reactions of alcohols.

26. Oxidation reactions of alcohols, phenols, thiols. Reduction reactions of disulfides. NAD^+-NADH system; hydride transfer as one of the stages of the biological oxidation–reduction reactions with participation of this system. Phenols and thiols as antioxidants.

1.6 Reactivity of aldehydes and ketones.

27. Reaction centers of aldehydes and ketones. Nucleophilic addition reactions. The mechanism of nucleophilic addition reaction. Reactions of carbonyl compounds with water, alcohols, amines. Formation of cyclic hemiacetals. The biological role of acetalization reactions

28. Nucleophilic addition reactions. The aldol addition reactions. Reversibility of nucleophilic addition reactions. The biological role of aldol addition reactions.

29. Nucleophilic addition-elimination reactions of aldehydes and ketones with amines. Toxicity of aldehydes. Aldehydes as disinfectants and sterilizing agents.

30. Oxidation and reduction reactions of carbonyl compounds in vitro and in vivo. Qualitative reactions for aldehyde group and for acetone.

1.7 Reactivity of carboxylic acids and their derivatives.

31. Reaction centers of carboxylic acids. Acidic properties of mono- and dibasic, saturated, unsaturated and aromatic carboxylic acids.

32. Nucleophilic substitution reactions at the sp^2–hybrid carbon atom of carboxylic acids and their derivatives. The acylation reactions such as formation of carboxylic acid anhydrides, haloanhydrides, esters, amides. Hydrolysis reactions of derivatives of carboxylic acids.

33. The acylating by carboxylic acid anhydrides, acid chlorides, carboxylic acids, esters, thioesters. The acylation ability of carboxylic acids derivatives. Relative reactivity of esters and thioesters. Biological importance of esters and thioesters. Acylcoenzyme A. Acylphosphates. Biologically important acylation reactions that proceed with participating of acylphosphates. Notion about phosphorilation reactions.

34. Amides of carboxylic acids. The structure of amide-group. Acid-base properties of amides. Hydrolysis of amides. Amide of benzoic acid.

35. Derivatives of carbonic acid: the urea (carbamide) as the complete amide of the carbonic acid, carbamic acid. Acid-base properties and biological importance of carbamic acid and carbamide. Biuret. Urethanes, ureides, ureidoacids in the medicine. Biological importance of creatine and phosphocreatine.

2. Biologically important heterofunctional compounds.

2.1 Poly- and heterofunctional compounds: participating in biological processes and using in medicine (compounds, which are origin of the most important medicament groups).

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

37. Specific features of chemical behaviour of poly- and heterofunctional compounds: features of acid and base properties, cyclization and chelates formation. Chelate complex formation as the qualitative test for a diol fragment.

38. Intramolecular cyclization (γ- and δ-hydroxyaldehydes, γ- and δ-hydroxy- and aminoacids, dicarboxylic acids with 4 or 5 carbon atoms) intermolecular cyclization (α- hydroxy- and aminoacids). Cyclic hemiacetals, cyclic anhydrides, lactides, diketopiperasines, lactones, lactames.

39. Decarboxylation reactions. The elimination reactions of β-hydroxy- and β-amino acids. Tautomerization: keto–enol tautomerization and lactam–lactim tautomerization.

40. Polyalcohols. Their examples: ethylene glycol, glycerol, inositol, xylitol, sorbitol. Esters of polyhydric alcohols with inorganic acids (nitroglycerol, glycerol and inositol phosphates) and with fatty acids.

41. Dihydric phenols. Their examples: hydroquinone, resorcinol, catechol. Oxidation of dihydric phenols. Hydroquinone-quinone system. Phenols as antioxidants. Tocopherols.

42. Dicarboxylic acids. Their examples: oxalic acid, malonic acid, succinic acid, glutaric acid, fumaric acid. The transformation of succinic acid to fumaric acid as an example of a biologically important dehydrogenation reaction.

43. Amino alcohols. Their examples: 2-aminoethanol, choline, acetylcholine. Forming of choline from L-serine. Amino phenols. Their examples: dopamine, noradrenaline (norepinephrine), adrenaline (epinephrine).

44. Hydroxy-acids. Lactic acid, malic acid, tartaric acid, citric acid. Oxidation reactions of lactic acid and malic acid with participating of NAD^+. Citric acid. Citrates: preservation of donor blood. Dehydration of citric acid in vivo.

45. Oxo-acids (aldehyde and keto acids). Their examples: pyruvic acid, acetoacetic acid, oxaloacetic acid, α-ketoglutaric acid. Acid properties and reactivity. The decarboxylation reaction of β-ketobutyric acid and the oxidizing decarboxylation reactions of pyruvic acid. Keto–enol tautomerization. β-hydroxybutyric acid, β-ketobutyric acid, acetone as representatives of “ketone bodies”, their biological and diagnostic importance.

46. The heterofunctional benzene derivatives as medicaments. Salicylic acid and its derivatives (acetylsalicylic acid, methyl-salicylate, phenyl-salicylate).

47. p-Aminobenzoic acid and its derivatives (benzocain, novocaine). Biological role of p-aminobenzoic acid (folic acid as the growth factor). Modern anesthetics.

48. Sulfanilic acid and its amide. Sulfanamides. Notion of antimetabolites.

2.2 Biologically important heterocyclic compounds. Alkaloids.

49. Heterocycles with one heteroatome. Pyrrole, indole, pyridine, quinoline. Heterocycles with several heteroatoms. Pyrazole, imidazole, pyrimidine, purine. Electronic and spacial structure of pyrrolic and pyridinic heteroatoms. Aromaticity of heterocycles. Influens of heteroatoms on reactivity of pyrrole and pyridine in S_E reactions.

50. Heterocycles with several heteroatoms. Acid-base properties of heterocyclic compounds. The tautomerisation on the example of imidazole. Biologically important pyridine derivatives: nicotinic amide, pyridoxal, isonicotinic acid and its derivatives.

51. Barbituric acid and its derivatives (phenobarbital). The hydroxypurines: hypoxanthine, xanthine, uric acid. Notion about alkaloids.

3. Biopolymers and their structural units. Low-molecular bioregulators.
3.1 Carbohydrates.

52. Monosaccharides. Classification of monosaccharides. Aldoses, ketoses; trioses, tetroses, pentoses, hexoses. Stereoisomerism of monosaccharides. D- and L-families. Biological importance of monosaccharides and their derivatives.

53. Structures of the most important pentoses (D-ribose, D-xylose, 2-deoxy-D-ribose) and hexoses (D-glucose, D-mannose, D-galactose, D-

fructose). Amino sugars (D-glucosamine, D-mannosamine, D-galactosamine) and their properties. Neuraminic acid, sialic acids.

54. Open-chain structures and cyclic forms. Furanoses and pyranoses; α- and β-anomers. Fischer projection formulas and Haworth formulas. A cyclo-oxo tautomerization. Mutarotation. Conformations of pyranose forms of monosaccharides. Physical properties of monosaccharides.

55. Chemical properties of monosaccharides. Nucleophilic substitution at an anomeric atom in cyclic forms of monosaccharides. O- and N-glycosides. Hydrolysis of glycosides. Biologically important phosphorylation reactions of monosaccharides. Phosphates of monosaccharides.

56. Oxidation of monosaccharides. Reducing properties of aldoses. Aldonic, aldaric, uronic acids. Reduction of monosaccharides to alditols (xylitol, glucitol (sorbitol), mannitol); application of alditols in medicine. Epimerization reaction of monosaccharides, the reversible transformation of aldoses to ketoses.

57. Nucleophilic addition reaction with participation of oxo-group of open-chain form of glucose (glycylation reactions of peptides). Ascorbic acid. Its structure, properties, and biological importance.

58. Oligo- and polysaccharides. Common characteristic and classification of polysaccharides. Oligosaccharides. Disaccharides: maltose, cellobiose, lactose, sucrose. Structures, the cyclo-oxo tautomerization. Reducing properties. Hydrolysis.

59. Maltose, cellobiose, lactose. The conformational structure. The role of lactose oligosaccharides in formation of not pathogenic microflora in the intestines, which is necessary for normal digestion.

60. Polysaccharides. Homo- and heteropolysaccharides. Homopolysaccharides: starch (amylose, amylopectine), glycogen, dextran, cellulose. Primary structure, hydrolysis. Notion about secondary structure (amylose, cellulose). Pectins (polygalacturonic acid). Plasma replacing solutions on the basis of dextran and starch.

61. Heteropolysaccharides: hyaluronic acid, chondroitin sulfates.
Primary structure. Notion of mixed biopolymers: proteoglycans, glycoproteins, glycolipids.

3.2 Amino acids. Peptides and proteins.

62. Amino acids that can be obtained from proteins. Classification of naturally occurring amino acids taking into account different signs: acid and base properties, chemical nature of a side chain and its substituents. Structure, nomenclature. Stereoisomerism.

63. Acid and base properties, dipolar ions. Essential amino acids.

64. The formation of α-amino acids: hydrolysis of proteins, synthesis from α-halo acids. Reducing amination reactions and transamination reactions. Pyridoxal catalysis.

65. Chemical properties of α-amino acids as heterofunctional compounds. Formation of intracomplex salts. Esterification, acylation, alkylation, deamination reactions, formation of amines. Qualitative tests for α-amino acids.

66. Biologically important reactions of α-amino acids. Decarboxylation of α-amino acids - the way of formation of biogenic amines and biological regulators (2-aminoethanol, histamine, tryptamine, serotonin, dopamine, γ-amino butyric acid), their biological importance. Notion about neuromediators.

67. Oxidative and not oxidizing deamination reactions. Hydroxylation reactions: phenylalanine → tyrosine, tyrosine → 3, 4-dihydroxyphenylalanine, tryptophan → 5-hydroxytryptophan, proline → 4-hydroxyproline. Cysteine oxidation. Disulfide bond.

68. Peptides. Electronic and steric structure of a peptide bond. Hydrolysis of polypeptides. Individual representatives of polypeptides: aspartame, glutathione, neuropeptides, insulin.

69. Establishment of primary structure of polypeptides. Notion about the strategy of peptide synthesis.

70. Primary structure of proteins. Notion of secondary, tertiary (domains) and quaternary structures. Hemoglobin, heme group structure. Notion of complex proteins: glycoproteins, phosphoproteins, metalloproteins, hemoproteins, nucleoproteins.

3.3 Nucleic acids.

71. Nucleic (heterocyclic) base that can be obtained from nucleic acids. Pyrimidines (uracil, thymine, cytosine) and purines (adenine, guanine). Aromatic properties. A lactim–lactam tautomerization. Deamination reactions.

72. Nucleosides. Nucleotides. Structure of mononucleotides that can be obtained from nucleic acids. Nomenclature. Nucleotides hydrolysis.

73. Primary structure of nucleic acids. The phosphate diester linkage. Ribonucleic and deoxyribonucleic acids. Nucleotides found in RNA, nucleotides found in DNA. Hydrolysis of nucleic acids. Structure and properties of m-RNA, t-RNA, r-RNA.

74. Notion of the secondary structure of DNA. The role of hydrogen bonds in formation of the DNA secondary structure. Complementarity of heterocyclic bases. Hydrogen bonds in complementary pairs of heterocyclic bases.

75. Medicaments on base of the modified heterocyclic bases. Change of heterocyclic base structures caused with chemical mutagens, UV irradiation and radiation.

76. Nucleoside mono- and polyphosphates. AMP, ADP, ATP. The role of ATP as the accumulator and carrier of free energy in cell. Nucleoside cy-

clophosphates (cyclic AMP, cyclic GMP) as secondary mediators in the regulation of cell metabolism.

77. Notion of coenzymes. Structures of NAD^+ and its phosphate ($NADPh^+$). NAD^+-NADH system; hydride transfer as one of the stages of the biological oxidation–reduction reactions with participation of this system.

3.4 Lipids.

78. Classification. Biological importance. Neutral fats. Notion of the structure of waxes.

79. Common natural fatty acids that can be obtained from lipids: palmitic, stearic, oleic, linoleic, linilenic, arachidonic acids. Features of unsaturated fatty acids, ω-nomenclature. The role of free fatty acids in the energy reservation and thermoregulation

80. Phospholipids. Phosphatidic acids. Phosphatidylethanolamines (cephalins), phosphatidylserines, phosphatidylcholines (lecithines), phosphatidylinositols as structural components of cellular membranes. Notion about composition and the role of surfactant.

81. Sphingolipids and glycolipids, the role in myelinization of nerve fibers.

82. Rancidness of fats that is free radical chain process as the model of the peroxidation of polyunsaturated fatty acids in the cell membranes, its mechanism and its biological role. The role of the peroxide lipid oxidation in realization of damage by environment factors. Notion about antioxidant protection systems.

3.5 Low-molecular bioregulators.

83. Steroids. Notion about their biological role. Gonan (steran, perhydrocyclopentanophenanthrene), stereochemical structure of 5α, 5β series of steroids. Physical properties of steroids. Hydrocarbons that are parent structures of steroid groups: estrane, androstane, pregnane, cholane, cholestane.

84. Steroid hormones. Sex hormones: estrogens, androgens; progestins; adrenocortical hormones. Structure, biological role.

85. Bile acids: cholic acid, conjugated bile acids (glycocholic, taurocholic acids), their structure, their biological role.

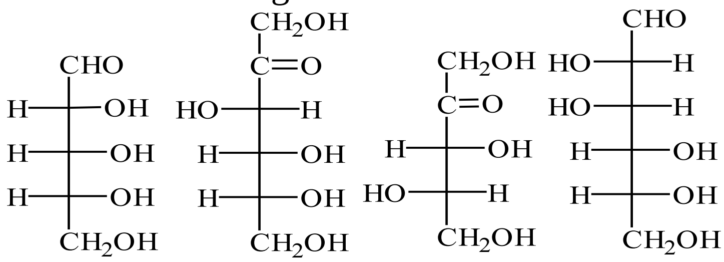
86. Cholesterol as one of sterols, its conformational structure. Its properties, its role in metabolism and structure of cell membranes, in development of cardiac pathology. 7-Dehydrocholesterol, its transformation to vitamin D_3 (cholecalciferol). Ergosterol, its transformation to vitamin D_2 (ergocalciferol). The role of vitamin D in regulation of calcium-phosphorus metabolism.

APPROXIMATE LIST OF EXAMINATING PROBLEMS

Carbohydrates.

1. Direct oxidation of an aldose affects the aldehyde group first, converting in to a carboxylic acid, and most oxidazing agents that will attack 2^o alcohol groups. Cleary, then, a laboratory synthesis of a uronic acid from an aldose requires profecting these groups from oxidation. Keeping this in mind, suggest a method for carrying out a specific oxidation that would convert D-galactose to D-galacturonic acid.

2. Write the structure of the aldonic acids and aldaric acids obtained by oxidation of each of the following monosaccharides.



3. Write the structure of the products, if any, of the reaction of α-D-galactopyranose with each of the following reagents.

(a) CH_3OH/HCl;

(b) $(CH_3CO)_2O$ / CH_3COONa;

(c) $Cu(OH)_2$ / t^0;

(d) Br_2/H_2O.

4. Write the structure of the products, if any, of the reaction of □-D-mannopyranose with each of the following reagents.

(a) CH_3OH/HCl;

(b) $(CH_3O)_2SO_2/NaOH$;

(c) Br_2/H_2O;

(d) HNO_3.

5. Write the reaction of the acid-catalyzed hydrolysis of methyl α-D-glucopyranoside and its pentamethyl derivative.

6. Write the reaction of the acid-catalyzed and base-catalyzed hydrolysis of esters of β-D-mannopyranose (resulted from reaction with acetic anhydride).

7. Write the structure of the product of the reactions of β-lactose and β-cellobiose with each of the following reagent**s:**

a) HOH/H^+

b) Br_2/HOH

c) $CH_3COCl/CH_3COO^-Na^+$

d) $(CH_3O)_2SO_2/NaOH$

8. Write the structure of the product of the reaction of α-maltose with each of the following reagents:

a) HOH/H^+

b) Br_2/H_2O

c) $(CH_3CO)_2O/CH_3COO^-Na^+$

d) Tollen's reagent/t^0

Amino acids. Peptides and proteins.

9. Write the structure of the predominant form of each of the following amino acids at the pH of blood-7,4.

a) Valine; b) Glutamic acid; c) Lysine; d) Glycine.

10. Write the structure of the predominant form of each of the following aminoacids at the pH of blood 7,4.

a) Lys, b) Gly, c) Met, d) Asp.

11. Write the structure of the predominant form of each of following amino acids at the pH of blood 7,4.

a) Ser; b) Glu; c) His; d) Gly

12. Write the structure of the product of each of the following reactions:

(a) Histidine $\xrightarrow{\text{decarboxylase}}$

(b) Write the scheme of the deamination reaction of Glu.

13. Write the structure of the predominant form of each of the following aminoacids at the pH of blood 7,4.

a) Arg, b) Val, c) Glu, d) Ser.

14. Write the structure of the predominant form of lysine in each solution of the following pH:

a) pH=0,2; b) pH=5; c) pH=9,8; d) pH=13

15. Write the structure of the predominant form of threonine in each solution of the following pH:

a) pH=0,2; b) pH=5; c) pH=11.

16. Write the structure of the predominant form of aspartic acid in each solution of the following pH:

a) pH=0.2; b) pH=3; c) pH=7.4; d) pH=13

17. Write the structure of the predominant form of tyrosine in each solution of the following pH:

a) pH=0,2; b) pH=5; c) pH=9,5; d) pH=13

18. Write the structure of the product of each of the following transamination reactions:

a) 2-oxopropanoic acid + Glutamic acid $\xrightarrow{\text{transaminase}}$

b) 2-oxobutandioic acid + alanine $\longrightarrow$

19. Write the structure of the product of each of the following reactions:

(a). 2-oxopropanoic acid + Glutamic acid $\xrightarrow{\text{aminotransferase}}$

(b). 2-oxobutandioic acid + methionine $\xrightarrow{\text{aminotransferase}}$

20. Write the structure of tripeptide Ala-Met-Glu and write its structure of the predominant form in each solution of the following pH.

a) pH=3 b) pH=8 c) pH=11

21. Write the sructure of tripeptide Leu-Asn-Glu in solution at:

(a) pH= 1; (b) pH=3; (c) pH=11

22. Write the sructure of tripeptidel Phe-Val-Lys in solution at:

(a) pH= 1; (b) pH=7.4; (c) pH=13.

23. Show all steps in the synthesis of Gly-Met-Ser using the benzyloxycarbonyl group as a protecting group.

24. Aspartame a widely used nonnutritive sweetener, is the methyl ester of the dipeptide Asp-Phe. Draw the full structure of aspartame. The isoelectric point of aspartame is 5,9. Draw the structure present in aqueous solution at this pH.

25. Write the reactions showing how 2,4-dinitrofluorobenzene could be used to identify the N-terminal amino acid of Val-Ala-Gly.

26. What products would you expect (after hydrolysis) when Val-Lys-Gly is treated with 2,4-dinitrofluorobenzene?

Nucleic acids.

27. The most stable tautomeric form of guanine is the lactam form. This is the form normally present in DNA and it pairs specifically with cytosine. If guanine tautomerazes to the abnormal lactim form, it pairs with thymine. Write structural formulas showing the hydrogen bonds in these base pairs.

28. Uridine and 2-deoxyguanosine are stable in dilute base/ In dilute acid, however, they undergo rapid hydrolysis yielding a sugar and heterocyclic base. Write the reaction of nucleosides hydrolysis.

29. Write the structure of mRNA portion with following nucleotides sequences:

a) 5'-end U-A-C 3'-end;

b) 5'-end G-U-A 3'-end.

30. Write the structure of the nucleoside formed by combining each of the following pairs of heterocyclic bases and pentoses.

a) Guanine and ribose; c) Cytosine and ribose;

b) Thymine and 2-deoxyribose; d) Adenine and 2-deoxyribose.

31. Write the structures of 5'-guanilic acid, 5'-uridilic acid. Write the hydrolysis reaction of nucleotides UMP and GMP in dilute acid and dilute base.

32. Write the structures of 5'-guanilic acid, 5'-cytidilic acid. Write the hydrolysis reaction of nucleotides CMP and GMP in dilute acid and dilute base.

33. Write the structures of 2'-deoxyguanosine–5'-monophosphate, 5'-cytidylic acid. Write the reaction of acid and base-catalyzed hydrolylis of nucleotides d-GMP, CMP.

34. Write the structures of 5'-adenylic acid; 2'-deoxythymidine-5'-monophosphate. Write the reaction of acid and base-catalyzed hydrolylis of nucleotides d-TMP, AMP

35. Write the structures of 2'-deoxyguanosine–5'-monophosphate, 5'-adenylic acid; 2'-deoxythymidine-5'-monophosphate; 5'-cytidylic acid. Write the reaction of acid and base-catalyzed hydrolylis of nucleotides d-TMP, AMP.

36. Write the structure of mRNA portion with following nucleotides sequence: 5'-end U–A–C 3'-end.

37. Write the structure of mRNA portion with following nucleotides sequences: 5'-end G–U–A 3'-end.

38. Write the structures of 2’-deoxyadenosine-5’-phosphate, 5’-cytidilic acid. Write the hydrolysis reaction of nucleotides in dilute acid and dilute base.

39. A portion of one chain of a DNA molecule has the following nucleotides sequence 5’-end A-G-A-C-T-A-T-G-C-A-T 3’-end. Write the sequence of nucleotides with letters in the complementary chain of this portion of the DNA molecule. Draw the structure of the portion of one chain of DNA molecule with following nucleotides sequence: 5’-end A-C-T 3’-end.

40. A portion of one chain of a DNA molecule has the following nucleotides sequence 5’-end A-G-G-C-T-A-T-T-C-G-T 3’-end. Write the sequence of nucleotides with letters in the complementary chain of this portion of the DNA molecule. Draw the structure of the portion of one chain of DNA molecule with following nucleotides sequence: 5’-end G-C-T 3’-end.

Lipids. Steroids.

42. Write the scheme of acid-catalyzed and base-catalyzed hydrolysis of:

a) 1-O-stearoyl-2-O-linoleoyl-3-O-palmitoylglycerol;
b) 1-O-myristoyl-2-O-oleyl-3-O-linolenoylglycerol.

Name the products of this reactions.

43. Write the scheme of acid-catalyzed and base-catalyzed hydrolysis of:

a) 1-O-stearoyl-2-O-linoleoyl-3-O-palmitoylglycerol;
b) 1-O-myristoyl-2-O-linolenoy-3-O-oleoylglycerol.

Name the products of these reactions.

44. Write the structure of triacylglycerol formed by combining of the following fatty acids with glycerol: palmitic acid, oleic acid, stearic acid. Write the acid-catalyzed hydrolysis for this triacylglycerol.

45. Write the structure of triacylglycerol formed by combining of the following fatty acids with glycerol: linolenic acid, palmitic acid, stearic acid. Write the base-catalyzed hydrolysis for this triacylglycerol.

46. Write the structure of triacylglycerol formed by combining of the following fatty acids with glycerol: linoleic acid, palmitic acid, linolenic acid. Write the acid-catalyzed hydrolysis for this triacylglycerol.

47. Write the structure of triacylglycerol formed by combining of the following fatty acids with glycerol: linoleic acid, stearic acid, linolenic acid. Write the base-catalyzed hydrolysis for this triacylglycerol.

48. Write the structure and name triacylglycerol formed by combining of oleic acid, linoleic acid, stearic acid with glycerol. Write the reaction of acid-catalyzed hydrolylis for this triacylglycerol.

49. Write the structure of phosphatidyl serine contained stearic acid and linolenic acid and show it's the hydrophilic and hydrophobic portions.

50. Write the structure of lecithin (phosphatidyl choline) contained palmitic acid and linoleic acid and show it's the hydrophilic and hydrophobic portions.

51. Write the structure of cephalin (phosphatidyl colamine(2-aminoethanol)) contained stearic acid and oleic acid and show it's the hydrophilic and hydrophobic portions.

52. Norethynodrel, a synthetic steroid that has been widely used in oral contraceptives, has the systematic name 17 α-ethynyl-17β-hydroxy-5(10)-estren-3-one. Give a three-dimensional formula for norethynodrel. (Ethynyl radical is -C≡CH).

53. The adrenocortical steroids are apparently involved in the regulation of a large number of biological activities including carbohydrate, protein, and lipid metabolism, water and electrolyte balance, and reactions to allergic and infammatory phenomena. Write the structures of adrenocortical hormones:

a) Cortisone 17α, 21-dihydroxy-4-pregnene-3,11,20-trione.

b) Cortisone 11β, 17α, 21-trihydroxy-4-pregnene-3,20 dione.

54. Androsterone, a secondary male sex hormone, has the systematic name 3α-hydroxy-5α-androstan-17-one. Give a three-dimensional formula for androsterone.

APPENDIX
QUALITATIVE REACTIONS

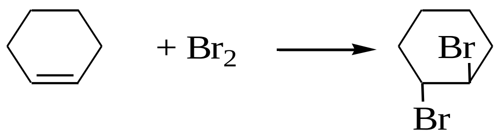
<u>Schemes of qualitative reactions to discover functional groups in the structure of examined compounds.</u>

Qualitative tests to discover multiple bonds (double and triple bonds).

Fumaric acid and cyclohexene contain double bond among proposed compounds.

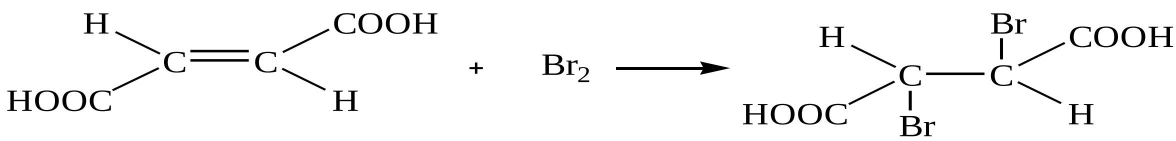
1. Reaction with bromine water.

Cyclohexene:



The practical result: yellow-brown solution of Br_2 becomes colorless solution.

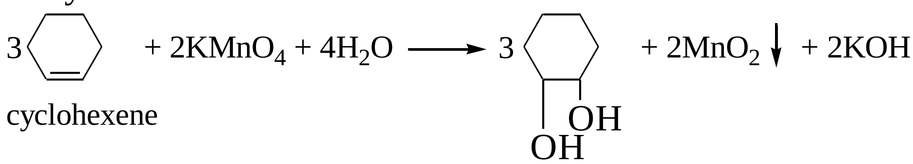
Fumaric acid:



The practical result: yellow-brown solution of Br_2 becomes colorless solution.

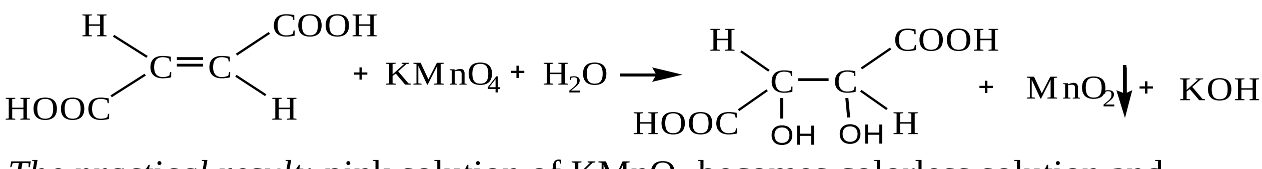
2. **Oxidation by $KMnO_4$.**

Cyclohexane:



The practical result: pink solution of $KMnO_4$ becomes colorless solution and brown precipitate of MnO_2.

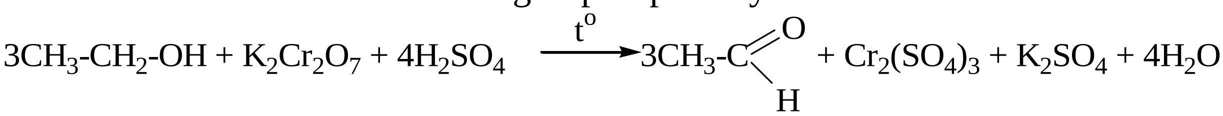
Fumaric acid:



The practical result: pink solution of $KMnO_4$ becomes colorless solution and brown precipitate of MnO_2.

Qualitative tests to discover primary and secondary alcohols.

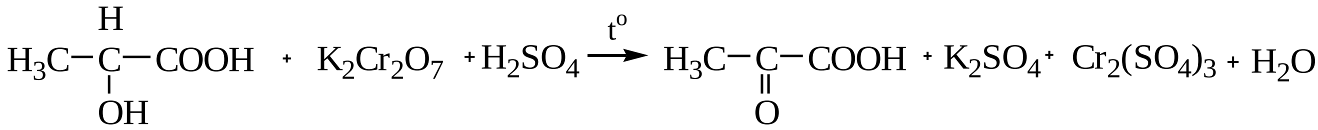
Ethanol contains functional group of primary alcohol:



The practical result: orange solution of $K_2Cr_2O_7$ becomes blue-green solution of $Cr_2(SO_4)_3$.

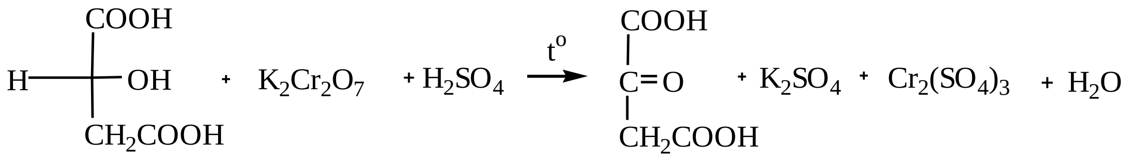
The functional group of the secondary alcohol is presented in the structures of lactic acid and malic acid.

Lactic acid:



The practical result: orange solution of $K_2Cr_2O_7$ becomes blue-green solution of $Cr_2(SO_4)_3$.

Malic acid:



The practical result: the orange solution of $K_2Cr_2O_7$ becomes the blue-green solution of $Cr_2(SO_4)_3$.

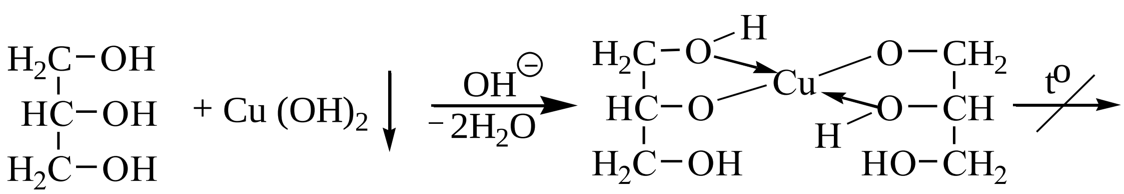
Qualitative tests for discovery of polyhydric vicinal alcohols.

The several compounds have vicinal diol or polyol fragments. There are glycerol, D-sorbitol, (+)-tartaric acid, D-glucose, maltose, lactose and sucrose among the proposed compounds.

Glycerol:

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

light-blue precipitate

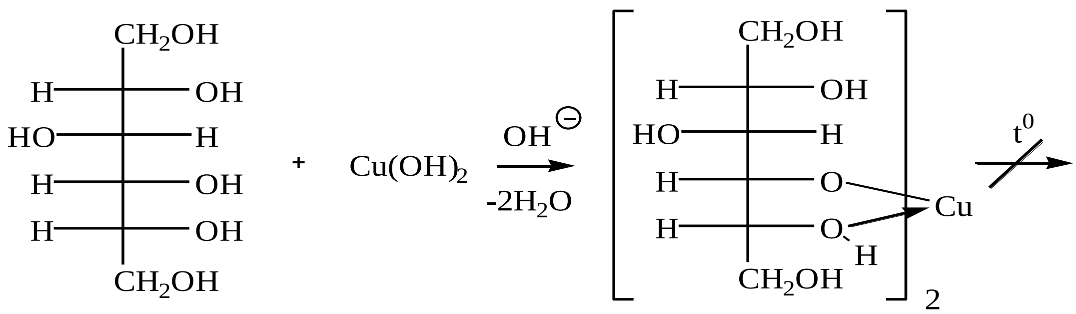


The practical result: the dark-blue solution of copper glycerate, which is not changed in heating

D-Sorbitol:

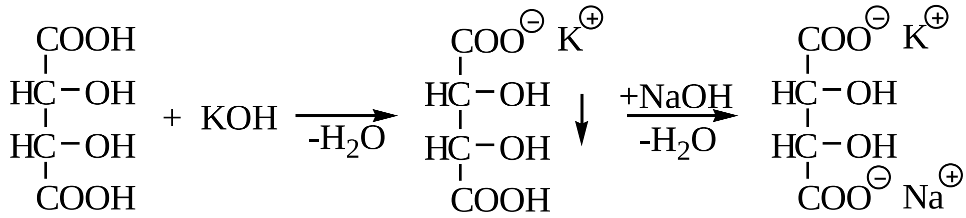
$$CuSO_4 + 2NaOH \longrightarrow Cu(OH)_2\downarrow + Na_2SO_4$$

light-blue precipitate



The practical result: the dark-blue solution, which is not changed in heating.

(+)-Tartaric acid:

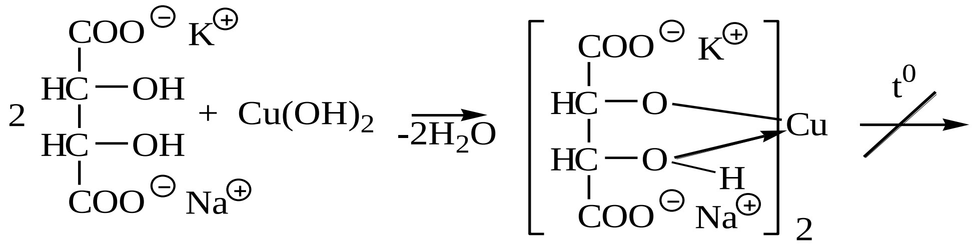


tartaric acid   potassium hydrotartrate   potassium sodium tartrate

The practical result: 1. The white precipitate. 2. The clear solution.

$$CuSO_4 + 2NaOH \longrightarrow Cu(OH)_2\downarrow + H_2O$$

light-blue precipitate



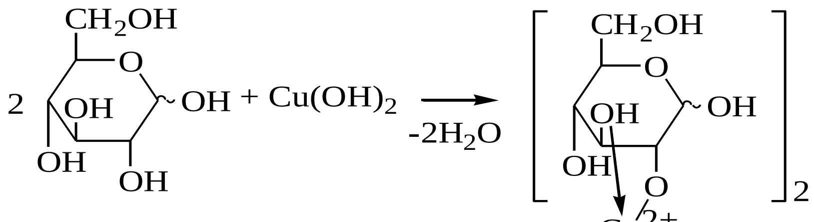
potassium sodium tartrate

The final practical result: the dark-blue solution, which is not changed in heating.

D-Glucose:

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

light-blue precipitate

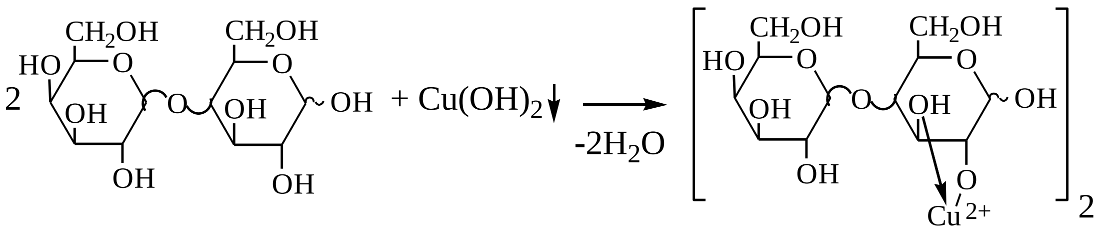


D-glucose

The practical result: the dark-blue solution.

Lactose:

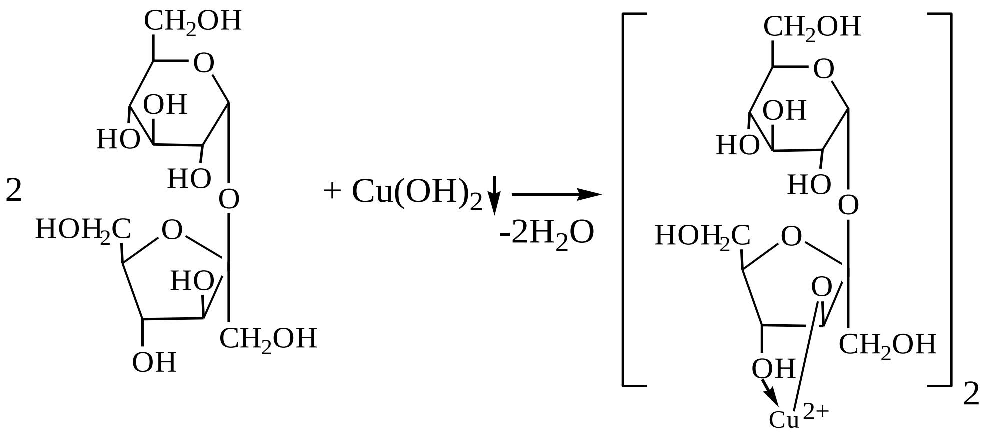
$$CuSO_4 + 2NaOH \longrightarrow Cu(OH)_2\downarrow + Na_2SO_4$$



The practical result: the dark-blue solution.

Sucrose:

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



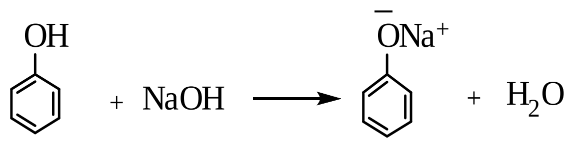
The practical result: the dark-blue solution.

Qualitative tests to discover phenol.

There are phenol and salicylic acid containing phenol group among the proposed compounds.

1. The reaction with NaOH (sodium hydroxide).

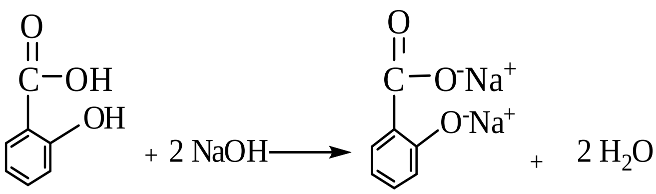
Phenol:



phenol

The practical result: the emulsion of phenol in the water becomes clear solution of sodium phenoxide.

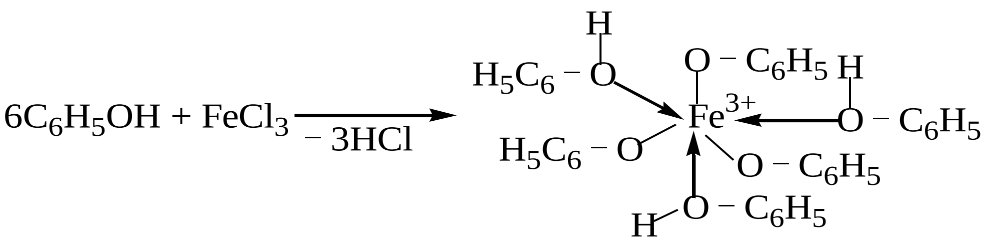
Salicylic acid



The practical result: the precipitate of salicylic acid becomes clear solution.

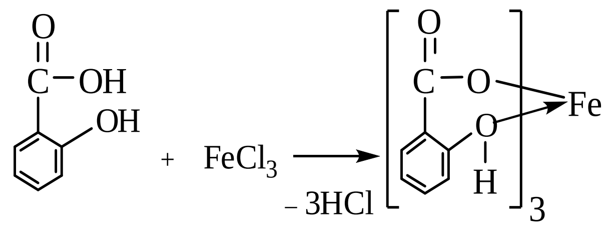
2. The reaction with $FeCL_3$ (ferric chloride).

Phenol:



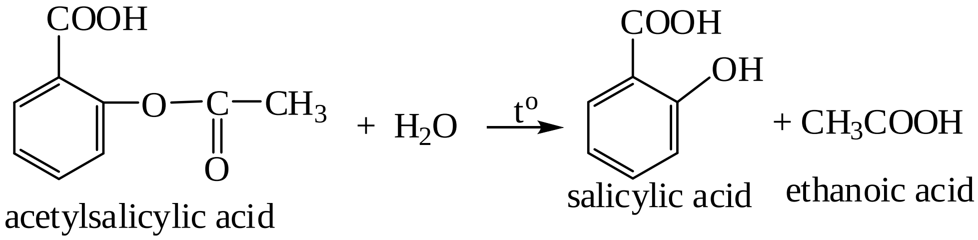
The practical result: the blue-violet colour.

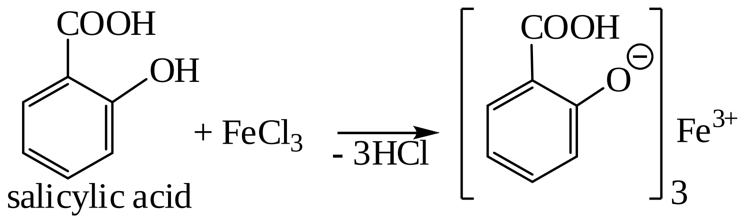
Salicylic acid:



The practical result: the blue-violet colour.

Hydrolysis of acetylsalicylic acid in heating lead to formation of salicylic acid. Salicylic acid is discovered by the reaction with ferric chloride.



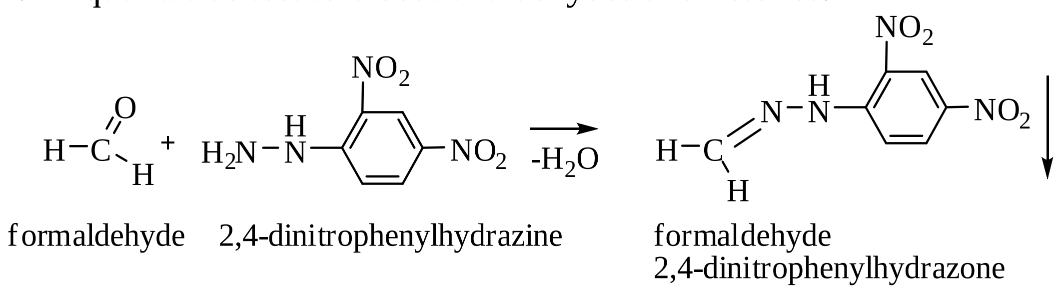


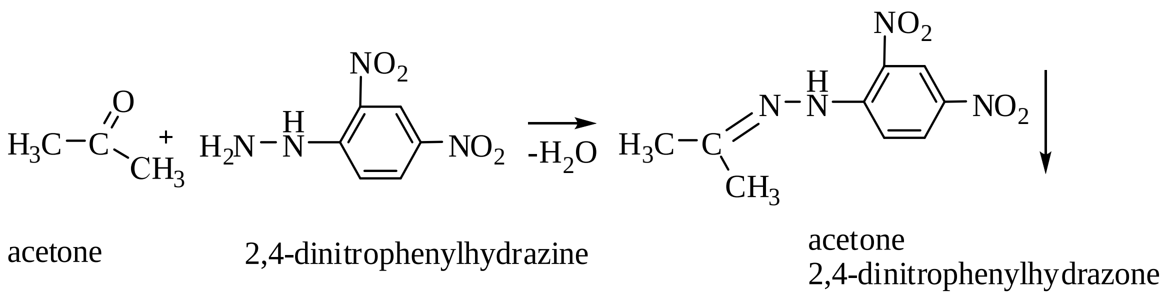
The final practical result: the blue-violet colour.

Qualitative tests to discover aldehydes and ketons.

Several compounds have aldehyde fragment. There are formaldehyde, D-glucose, maltose and lactose among the proposed compounds. Ketone is acetone.

1. A qualitative test to discover aldehydes and ketones.





The practical result: yellow precipitate.

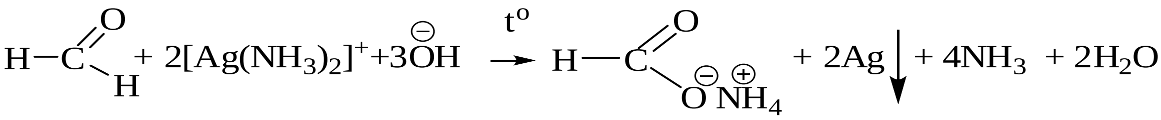
2. Qualitative tests to differ aldehydes from ketones.
   2.1. Silver mirror reaction with Tollen's reagent.

Tollen's reagent preparation:

$$AgNO_3 + NaOH \longrightarrow Ag_2O\downarrow + NaNO_3 + H_2O$$

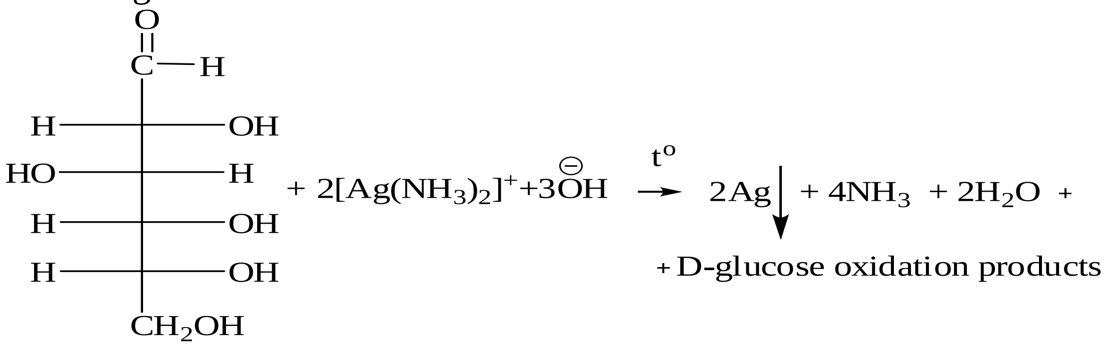
$$Ag_2O + NH_4OH \longrightarrow [Ag(NH_3)_2]OH$$

Formaldehyde:



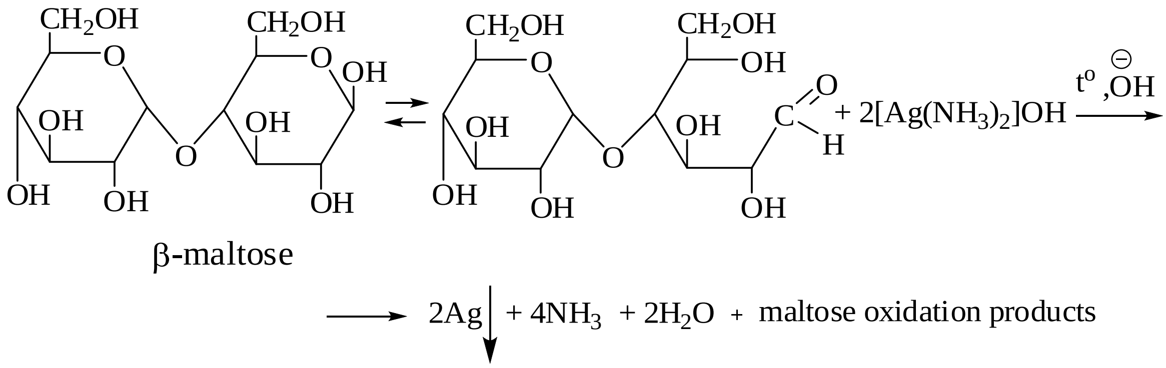
The practical result: the silver coating on the walls inside of test tube (silver mirror).

D-glucose:



The practical result: the silver coating on the walls inside of test tube (silver mirror).

Maltose:



β-maltose

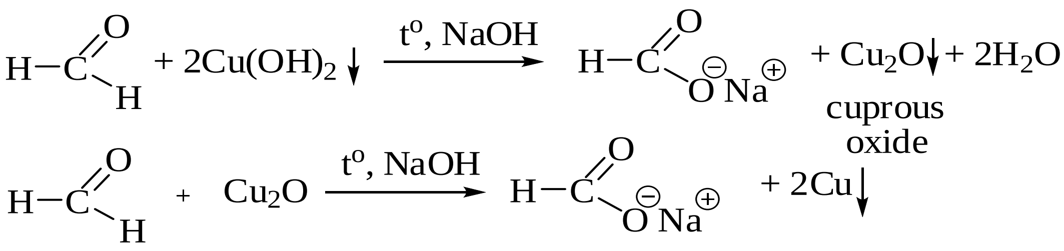
The practical result: the silver coating on the walls inside of test tube (silver mirror).

2.2. Copper mirror reaction.

Formaldehyde:

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

light blue precipitate

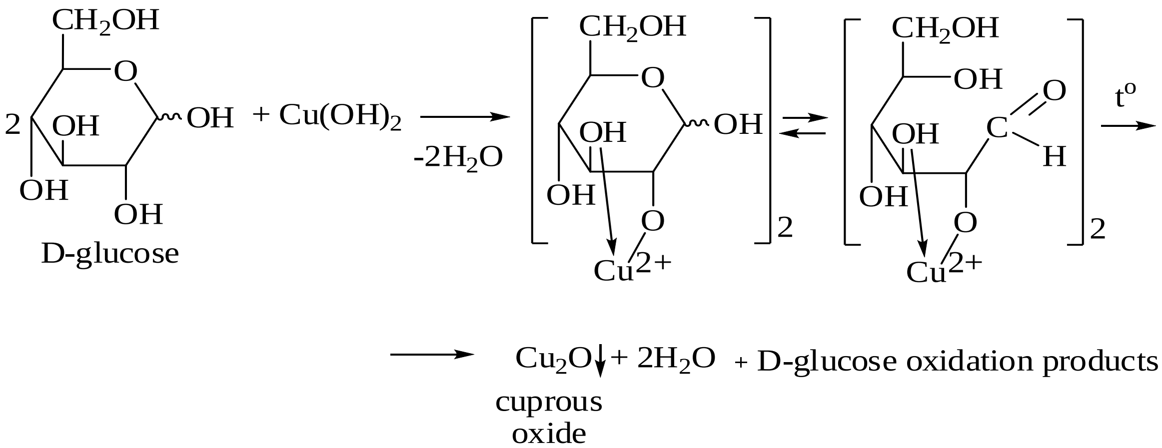


The final practical result: brick-red precipitate of cuprous oxide or (and) copper coating on the walls inside of the test tube (copper mirror).

D-glucose:

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

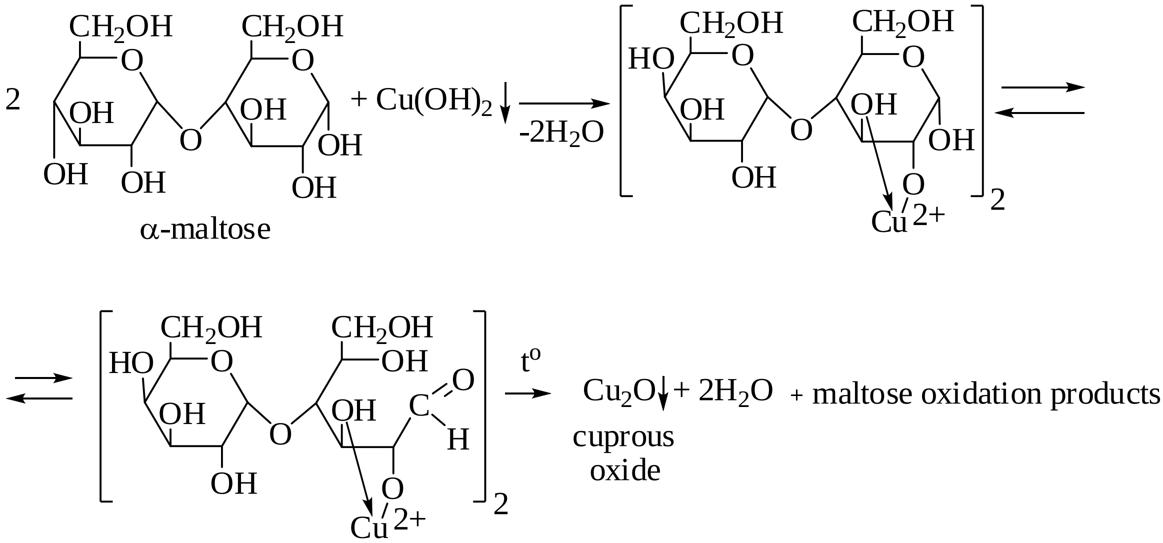
light-blue precipitate



The final practical result: brick-red precipitate of cuprous oxide.

Maltose:

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



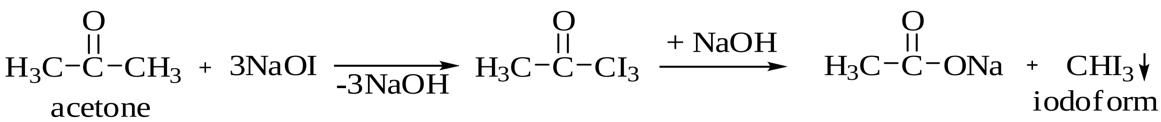
The final practical result: brick-red precipitate of cuprous oxide.

The positive practical results of reactions with Tollen's and Benedict's (or $Cu(OH)_2$) reagents prove that maltose end lactose reduce sugars. Sucrose is nonreducing sugar; it gives negative result of tests with Tollen's and Benedict's (or $Cu(OH)_2$) reagents.

3. The qualitative test for discovery of α-methylketo group in the structure of α -methylketone – iodoform test.

Acetone is α -methylketone:

$$I_2 + 2NaOH \longrightarrow NaI + NaOI + H_2O$$



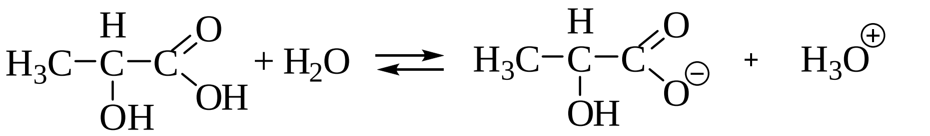
The practical result: white-yellow precipitate of iodoform.

Qualitative tests to discover carboxylic acids.

Solubility in the water is important for qualitative analysis of carboxylic acids. Water soluble compounds containing carboxylic groups are lactic acid, malic acid, oxalic acid and tartaric acid. Water insoluble compounds with carboxylic groups are acetylsalicylic acid, benzoic acid, fumaric acid and salicylic acid.

1. The qualitative tests for discovery of water soluble carboxylic acids.
   1.1. Carboxylic acids dissociation reaction.

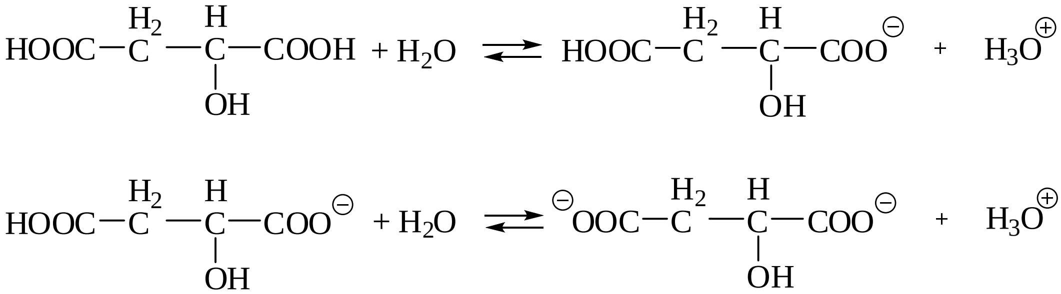
Lactic acid:



pH<7

The practical result: universal indicator paper becomes red.

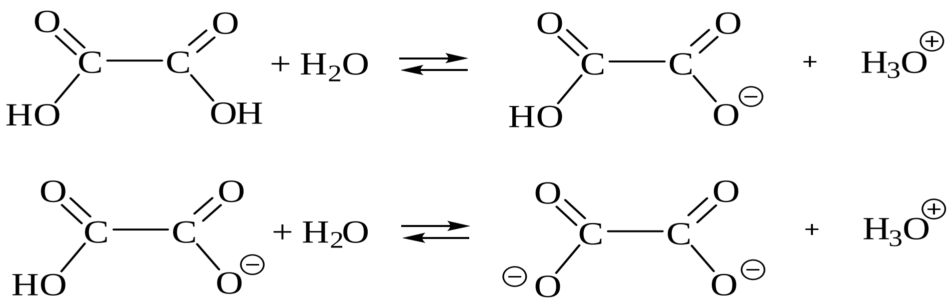
Malic acid:



pH<7

The practical result: universal indicator paper becomes red.

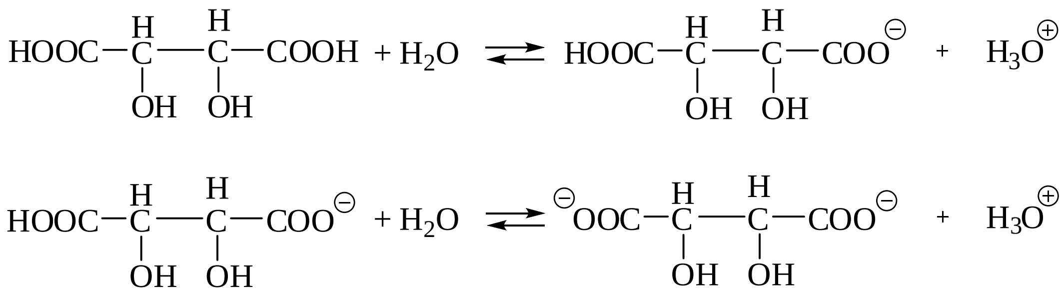
Oxalic acid:



pH<7

The practical result: universal indicator paper becomes red.

Tartaric acid:



pH<7

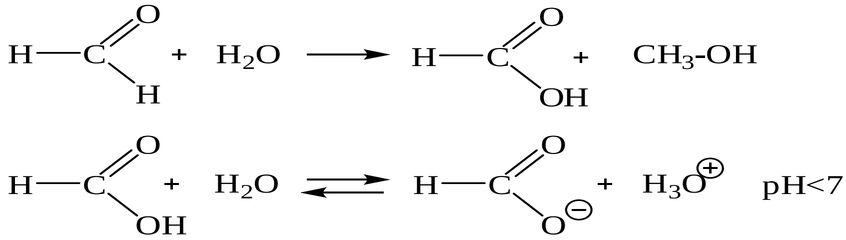
The practical result: universal indicator paper becomes red.

Glycine contains simultaneously carboxylic group with acid properties and amino group with base properties. That's why the water solution of glycine is neutral.

$$H_2N\text{-}CH_2\text{-}COOH \xrightleftharpoons{H_2O} \overset{\oplus}{H_3N}\text{-}CH_2\text{-}\overset{\ominus}{COO} \qquad pH \sim 7$$

The practical result: the indicator methyl red becomes orange.

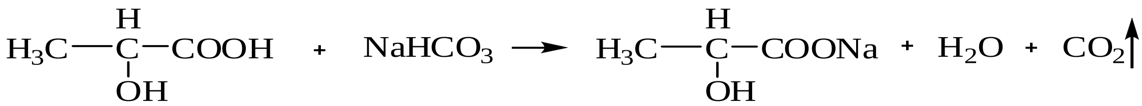
Formaldehyde undergoes disproportion reaction in the water solution to give formic acid and methanol. Formic acid dissociates in the water solution. That’s why water solution of formaldehyde (formol) is weak acidic.



The practical result: methyl red becomes red, universal indicator paper is not change.

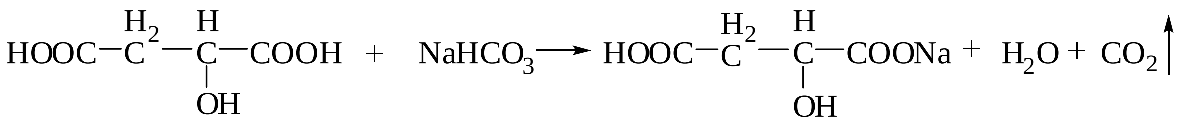
1.2. The reaction with $NaHCO_3$ (sodium hydrocarbonate).

Lactic acid:



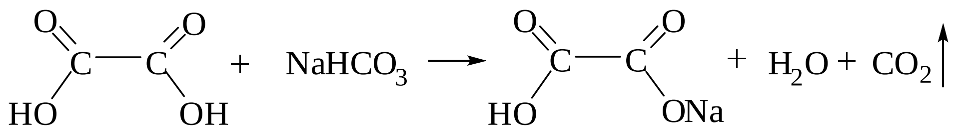
The practical result: Bubbles of gas.

Malic acid:



The practical result: Bubbles of gas.

Oxalic acid:

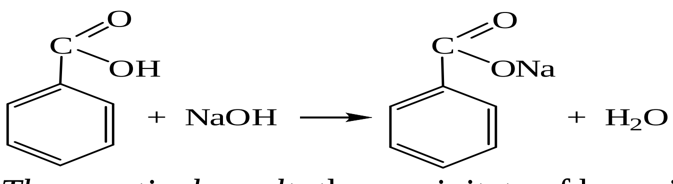


The practical result: Bubbles of gas.

2. Qualitative tests to discovery water insoluble carboxylic acids.

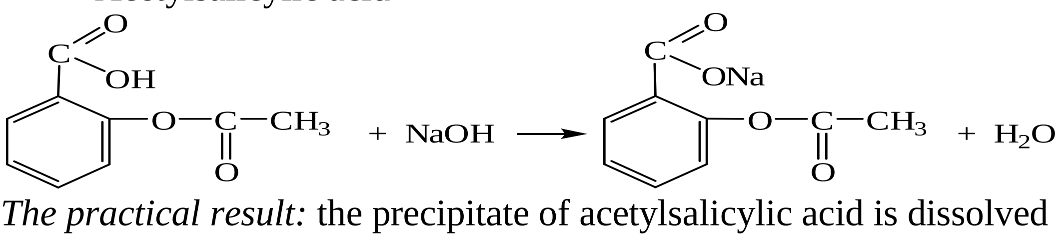
2.1. The reaction with NaOH (sodium hydroxide).

Benzoic acid



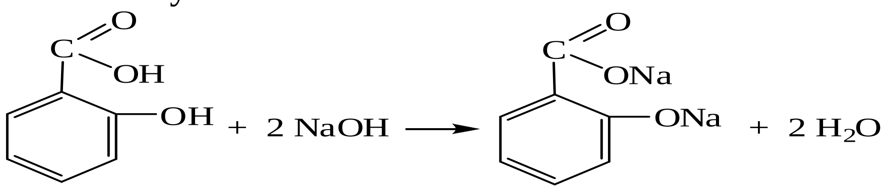
The practical result: the precipitate of benzoic acid is dissolved to make clear solution of sodium benzoate.

Acetylsalicylic acid



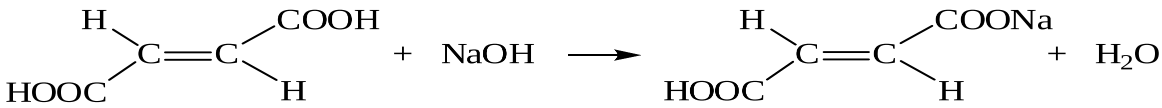
The practical result: the precipitate of acetylsalicylic acid is dissolved to make clear solution of sodium acetylsalicylate.

Salicylic acid



The practical result: the precipitate of salisylic acid is dissolved to make clear solution of disodium salicylate.

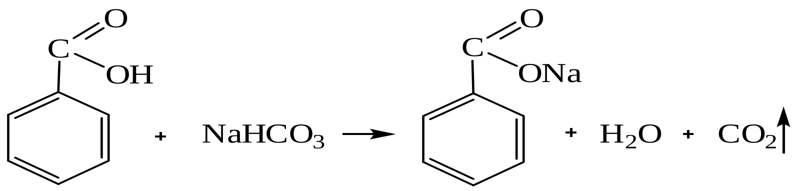
Fumaric acid



The practical result: the precipitate of fumaric acid is dissolved to make clear solution.

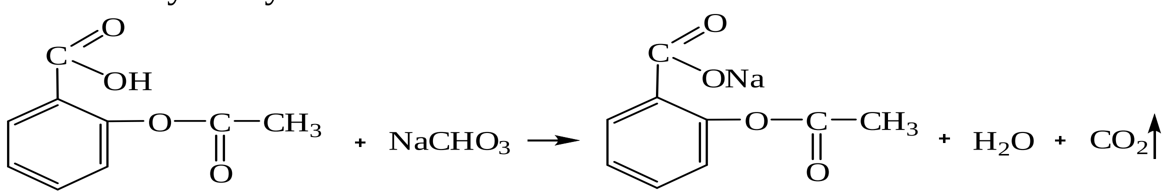
2.2. The reaction with $NaHCO_3$ (sodium hydrocarbonate).

Benzoic acid



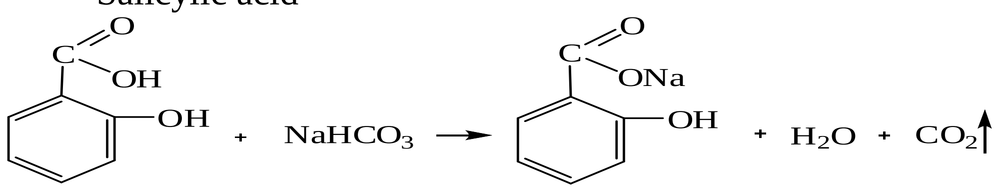
The practical result: the precipitate of benzoic acid is dissolved to make clear solution of sodium benzoate and releases bubbles of gas.

Acetylsalicylic acid



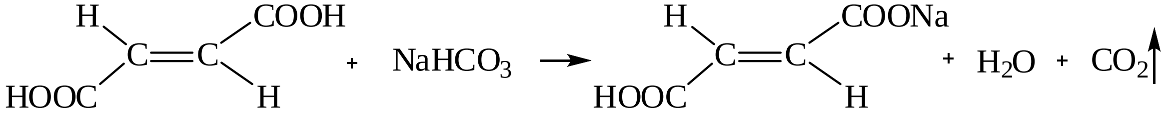
The practical result: the precipitate of acetylsalicylic acid is dissolved to make clear solution of sodium acetylsalicylate and releases bubbles of gas.

Salicylic acid



The practical result: the precipitate of salicylic acid is dissolved to make clear solution of sodium salicylate and releases bubbles of gas.

Fumaric acid



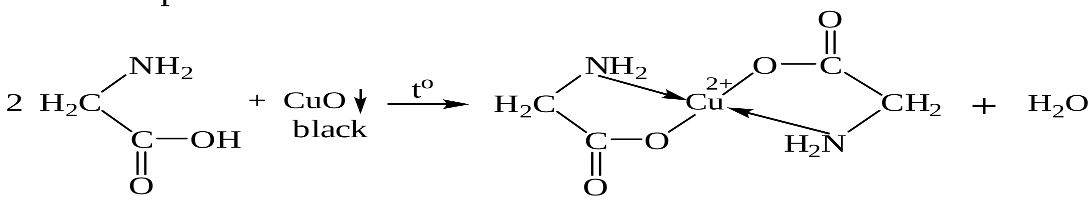
The practical result: the precipitate of fumaric acid is dissolved to make clear solution and releases bubbles of gas.

Schemes of specific qualitative reactions to discover some bioorganic compounds.

Qualitative tests to discover α-amino acids.

Glycine is α-amino acid among the examined compounds.

1. Formation of copper and α-amino acid (α-hydroxy acid) complex compound.



The practical result: dark-blue copper salt glycine solution.

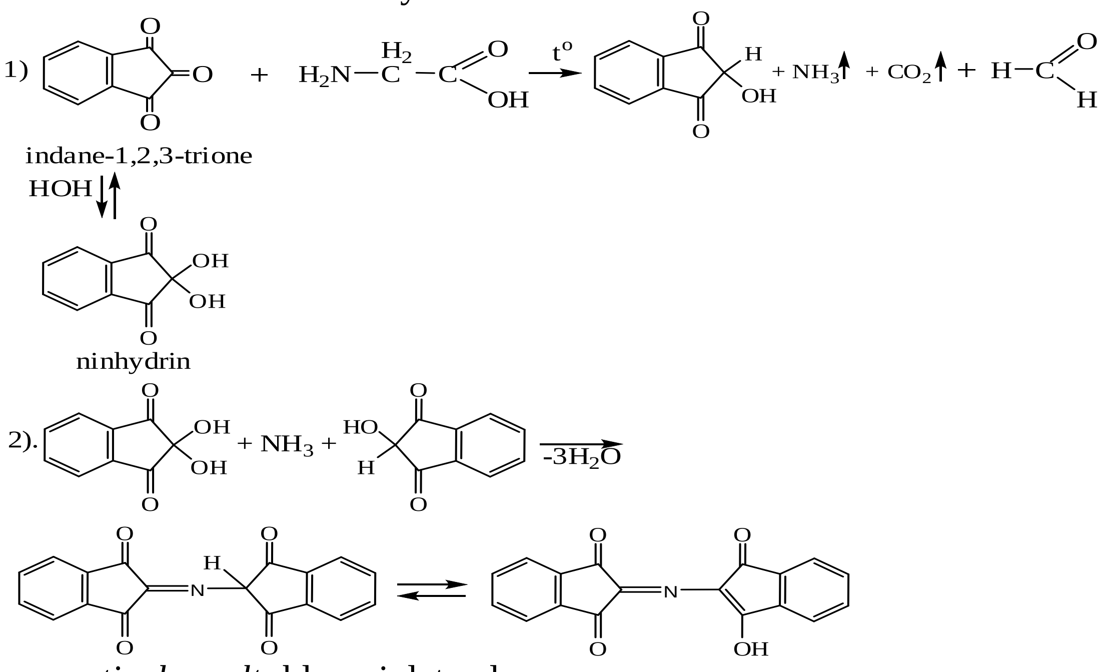
2. Discovery of amino group in the structure of α-amino acid. The reaction with nitrous acid.

$$NaNO_2 + CH_3COOH \rightarrow HNO_2 + CH_3COONa$$

$$H_2N\text{-}CH_2\text{-}COOH + HNO_2 \longrightarrow HO\text{-}CH_2\text{-}COOH + N_2\uparrow + H_2O$$

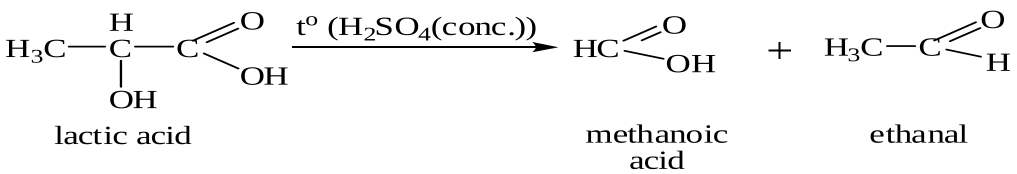
The practical result: bubbles of gas.

3. The reaction with ninhydrin.

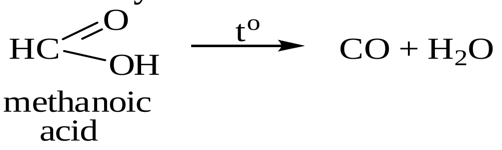


The practical result: blue-violet colour.

Qualitative test to discover lactic acid.



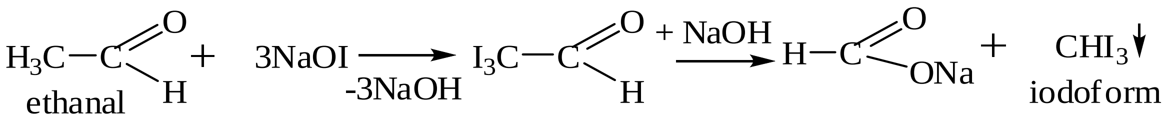
1) Discovery of metanoic acid



The practical result: the blue flame.

2) Discovery of ethanal:

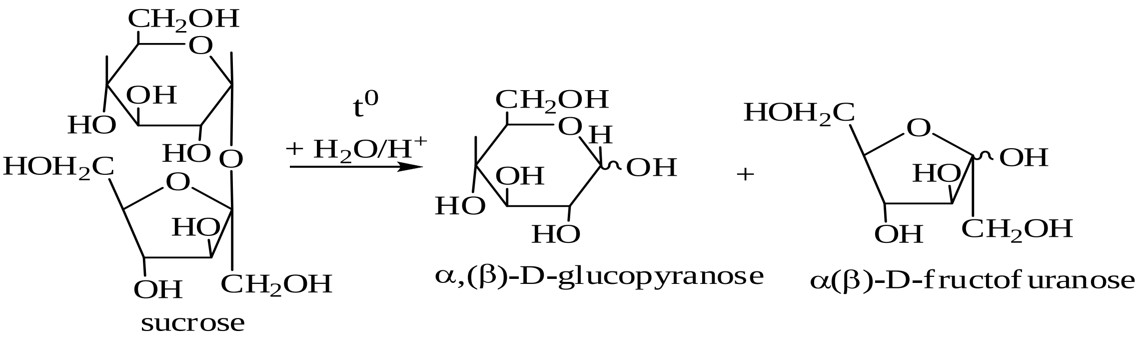
$$I_2 + 2NaOH \rightarrow NaI + NaOI + H_2O$$



The practical result: light yellow precipitate of iodoform.

Proof that sucrose is oligosaccharide contained fructose.

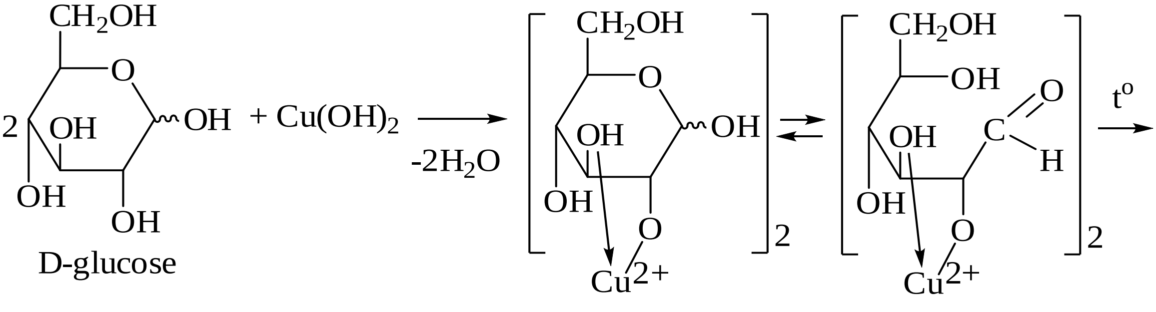
Sucrose hydrolysis:



Proof the monosaccharide formation with example of D-glucose:

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

light-blue precipitate

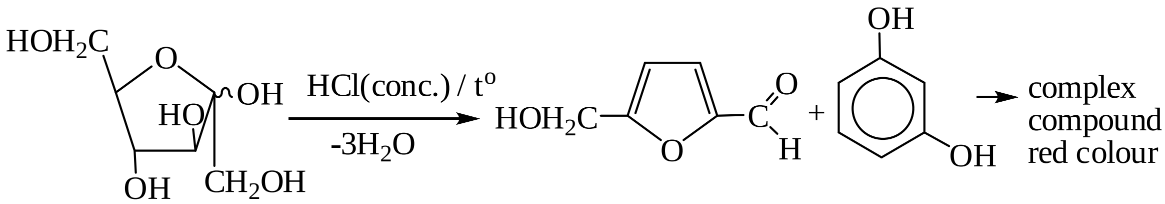


$$\rightarrow Cu_2O\downarrow + 2H_2O + \text{D-glucose oxidation products}$$

cuprous oxide

The final practical result: brick-red precipitate of cuprous oxide.

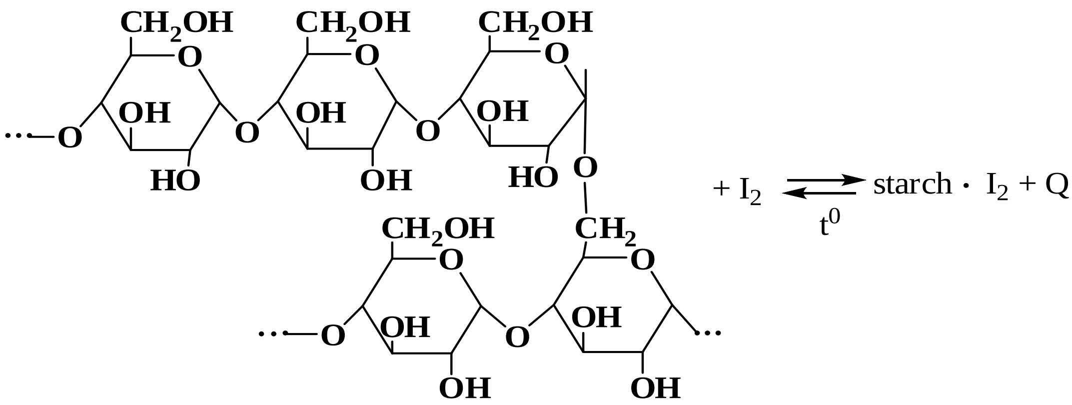
Proof fructose formation.



The practical result: red colour.

Qualitative tests to discover starch.

1. The reaction of complex formation with iodine solution.

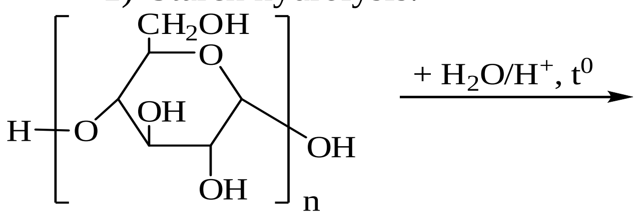


starch: amylopectin

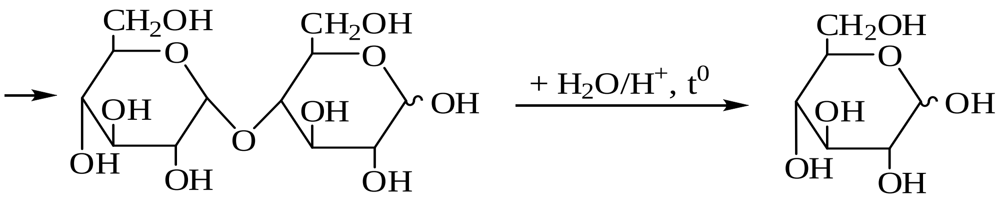
The practical result: dark-blue solution; it becomes coluorless solution after heating, but dark-blue colour is returned back in cold state.

Prove that starch is polysaccharide.

1) Starch hydrolysis.



starch: amylose

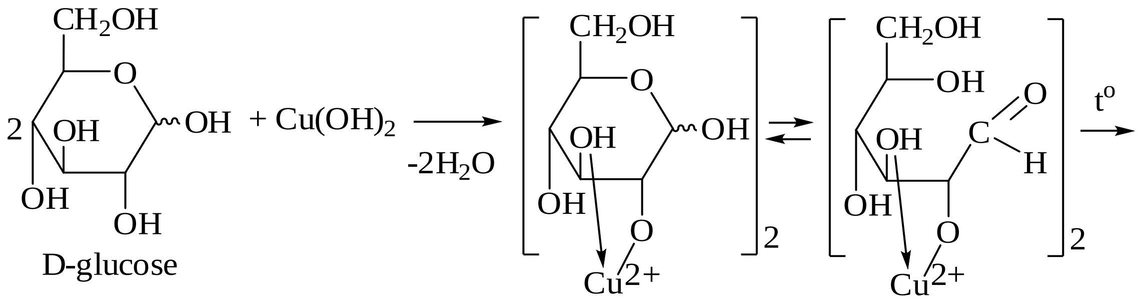


maltose D-glucose

2) Prove the final monosaccharide formation:

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

light-blue precipitate



$$\longrightarrow Cu_2O\downarrow + 2H_2O + \text{D-glucose oxidation products}$$

cuprous oxide

The final practical result: brick-red precipitate of cuprous oxide.

SEQUENCE OF OPERATIONS TO CARRY OUT QUALITATIVE TESTS.

Many of qualitative reactions are carried out in the water solution. That's why previously it is necessary to make the water solution (or the mixture with the water) of the investigated compound.

Qualitative tests to discover multiple bonds (double and triple bonds).

1. Reaction with bromine water.

Place 3 drops of bromine water in the test-tube. Add one by one several drops of investigated compound solution in the test-tube. Shake up the test-tube.

The practical result: yellow-brown solution of bromine water becomes colorless solution.

2. Oxidation by $KMnO_4$ in neutral solution.

Place 2 drops of 0.1n $KMnO_4$ solution in the test-tube. Add one by one several drops of investigated compound soluton in the test-tube. Shake up the test-tube.

The practical result: pink solution of $KMnO_4$ becomes colorless solution and brown precipitate of MnO_2.

Qualitative tests to discover primary and secondary alcohols by oxidation reaction with $K_2Cr_2O_7$ in acid solution.

Place 2 drops of investigated compound solution in the first test-tube. Add 2 drops of 2n H_2SO_4 solution and 2 drops of 0.5n $K_2Cr_2O_7$ solution. Warm the mixture.

The practical result: orange solution of $K_2Cr_2O_7$ becomes blue-green solution of $Cr_2(SO_4)_3$.

Qualitative tests to discover polyhydric vicinal alcohols.

Place 3 drops of 0.2n $CuSO_4$ solution and 3 drops of 2n NaOH solution in the test-tube. The blue precipitate is the result. Add 2 drops of investigated compound solution in the test-tube. Shake up the test-tube.

The practical result: the dark-blue solution.

Qualitative tests to discover phenol.

1.The reaction with NaOH (sodium hydroxide).

Place 3-5 drops of water and some of investigated compound in the test-tube. Add several drops of NaOH solution.

The practical result: clear solution.

2. The reaction with $FeCl_3$ (ferric chloride).

Place 1 drop of $FeCl_3$ in the test-tube. Add some of investigated compound in the test-tube.

The practical result: the blue-violet colour.

Qualitative tests to discover aldehydes and ketons.

1. ***Qualitative test to discover aldehydes and ketones: formation of 2,4-dinitrophenylhydrazones.***

Place 1 drop of investigated compound in the test-tube. Add 2 drops of 2,4-dinitrophenylhydrazine in the same test-tube.

The practical result: yellow precipitate.

2. ***Qualitative tests to differ aldehydes from ketones.***

2.1. Silver mirror reaction.

Place 1 drop of 0.2n $AgNO_3$ solution and 2 drops of 2n NaOH solution in the test-tube. The result is dark-brown precipitate. Add 4 drops of 2n NH_4OH in this test-tube while clear solution becomes. This solution is named Tollen’s reagent. Add 2 drops of investigated compound in the test-tube. Warm the test-tubes.

The practical result: the silver coating on the walls inside of test tube (silver mirror).

2.2. Copper mirror reaction.

Place 6 drops of 2n NaOH and 1 drop of 0.2n $CuSO_4$ solutions in the test-tube. The result is blue precipitate. Add 2 drops of investigated compound in the test-tube. Warm test-tube.

The practical result: brick-red precipitate of cuprous oxide or (and) copper coating on the walls inside of the test tube (copper mirror).

3. Qualitative test to discover α-methylketo group in the structure of α -methylketone – iodoform test.

Place 1 drop of I_2 (in KI solution) in the test-tube. Add 3 drops of NaOH solution and 1 drop of investigated compound.

The practical result: white-yellow precipitate.

Specific reaction to discover acetone with sodium nitroprussiate.

Place 1 drop of sodium nitroprussiate solution ($Na_2[Fe(CN)_5NO]$, 5 drops of water and 1 drop of investigated compound in the test-tube. Add 1 drop of NaOH solution.

The practical result: the blood-red colour.

Pour the part of the mixture in the other test-tube. Add 1 drop of CH_3COOH in one of the test-tubes.

The practical result: the cherry-red colour.

Qualitative tests to discover carboxylic acids.

1. Qualitative tests to discover water soluble carboxylic acids.

1.1. Carboxylic acids dissociation reaction.

Place a small drop of investigated compound solutions on the indicator paper.

The practical result: universal indicator paper becomes red.

1.2. The reaction with $NaHCO_3$ (sodium hydrocarbonate).

Place several drops of investigated compound solution in the test-tube. Add 2-3 drops of $NaHCO_3$ saturated solution.

The practical result: bubbles of gas.

2. Qualitative tests to discover water insoluble carboxylic acids.

2.1. The reaction with NaOH (sodium hydroxide).

Place several crystals of investigated compound and 2 drops of water in the test-tube. Add 3 drops of NaOH. Shake up the test-tube.

The practical result: the precipitate is dissolved to make clear solutione.

1.2. The reaction with $NaHCO_3$ (sodium hydrocarbonate).

Place several crystals of investigated compound and 2 drops of water in the test-tube. Add 2-3 drops of $NaHCO_3$ saturated solution. Don't shake the test-tube.

The practical result: the precipitate is slowly dissolved to make clear solution and releases bubbles of gas.

Specific qualitative reactions to discover some bioorganic compounds.

Formaldehyde disproportionation in water solutions.

Place 3 drops of the investigated compound solution in the test-tube. Add 1 drop of 0.2% methyl orange (indicator) solution.

The practical result: the solution becomes red.

Qualitative tests to discover alpha-amino acids.

1. The neutral alpha-amino acid solution has neutral pH value.

Place 3 drops of the investigated compound solution in the test-tube. Add 1 drop of 0,2% methyl red (indicator) solution.

The practical result: the indicator methyl red becomes orange.

2. Formation of copper and □-amino acid (□-hydroxy acid) complex compound.

Place CuO on tip spade in the test-tube. Add 3 drops of the investigated compound solution and warm the test-tube.

The practical result: dark-blue solution.

3. Discovery of amino group in the structure of □-amino acid. Reaction with nitrous acid.

Place 5 drops of the investigated compound solution in the test-tube. Add 5 drops of 5% sodium nitrite ($NaNO_2$) solution and 2 drops of concentrated acetic acid. Shake up mixture carefully.

The practical result: bubbles of gas.

4. Reaction with ninhydrin.

Place 4 drops of the investigated compound solution in the test-tube. Add 2 drops of 0.2% ningidrin solution. Warm the test-tube carefully.

The practical result: blue-violet colour.

Qualitative test to discover lactic acid.

1. Discovery of metanoic acid

Place 1 drop of investigated compound and 1 drop of concentrated H_2SO_4 (Take care!) Warm the mixture.The result is black foam.

To convince that CO is forming, set it on fire near the aperture of the test-tube.

The practical result: the blue flame.

2. Discovery of ethanal:

Place 2 drops of H_2O, 1 drop of concentrated H_2SO_4 and 1 drop of the investigated compound in the test-tube № 1.

Close it with the cork with the glass pipe. Lower the end of the glass pipe in the test-tube № 2 with 1 drop of I_2 (in KI solution) and 2 drops of NaOH in it. Warm the test-tube №1.

The practical result: white-yellow precipitate in the test-tube №2.

Proof that sucrose is oligosaccharide contained fructose.

1. Sucrose hydrolysis:

Take 2 test-tubes. Place 1 drop of the investigated compound solution in the test-tube № 1. Add 1 drop of 2n HCl and 6 drops of H_2O. Warm the test-tube № 1 during 0,5-1 minute. 2.

2. Proof the monosaccharide formation with example of D-glucose:

Pour half of the solution, received in the test-tube № 1 in the test-tube № 2. Add 6 drops of 2n NaOH, 4 drops of H_2O and 1 drop of 0.2n $CuSO_4$ in the test-tube № 2. Warm the test-tube №2.

The final practical result: brick-red precipitate of cuprous oxide.

3. Proof fructose formation.

Add 1 crystal (or 2 drops of resorcinol solution) and 2 drops of concentrated HCl (Take care!) in the test-tube № 1.

The practical result: red colour.

Qualitative tests to discover starch.

1. The reaction of complex formation with iodine solution.

Place 5 drops of the investigated compound solution in the test-tube. Add 1 drop of very diluted iodine solution.

The practical result: blue solution.

Warm the test-tube.

The practical result: colourless solution.

In getting cold the solution becomes blue again.

2. Proof that starch is polysaccharide.

2.1. Starch hydrolysis.

Place 1 drop of the investigated compound solution in the test-tube. Add 2 drops of 2n H_2SO_4. Warm the test-tube on the water bath during 20 minutes. Place 1 drop of this solution on the glass. Add 1 drop of very diluted I_2 (with KI) solution.

The practical result: solution has no blue colour.

2.2. Proof the final monosaccharide formation:

Add 8 drops of 2n NaOH and 1 drop of 0.2n $CuSO_4$ solutions in the test-tube. Warm the test-tube.

The final practical result: brick-red precipitate of cuprous oxide.

Literature:

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