LECTURE COMPLEX

Discipline: "Chemistry"

Discipline code: Him 1202

EP: 6B10115 - "Medicine"

Total study hours/credits: 120 hrs / 4 cr

Year: 1

Semester: I

Lecture hours: 8 hours

Shymkent, 2025

The lecture complex was developed in accordance with the EP 6B10115 - "Medicine" and discussed at the department meeting

Head of the Department _____ Daurenbekov K.N.

Protocol: no. 11.1 from "26" 06. 2025

Lecture № 1

1. **Topic: Introduction. Thermodynamics of biological processes. Basic concepts and laws.**
2. **Objective**: Chemistry is one of the main disciplines in the field of medical education, playing a significant role in the training of highly qualified medical specialists. This subject develops chemical thinking, determines the patterns of physicochemical processes and the conditions for achieving chemical equilibrium, teaches how to analyze and draw conclusions about the influence of external factors and the nature of substances on the course of chemical reaction.

3. Lecture abstract:

Thermodynamics studies:

1) the conversion of various forms of energy into one another, including the conversion of chemical energy into other forms of energy, i.e., chemical thermodynamics;
2) the energy effects of various physicochemical processes and their relationship with external factors;
3) the direction, possibility, and limits of spontaneous processes.

The objective of chemical thermodynamics is to apply the fundamental laws of thermodynamics and thermodynamic research methods to the study of chemical physicochemical phenomena.

A system is any selected set of substances separated from the external environment by a defined interface. If a system is completely unable to exchange matter or energy with the external environment, it is called *isolated*.

If a system can only exchange energy with the environment, it is called *closed*. It should be emphasized that real systems can only approximate these concepts but never fully coincide with them.

A phase is defined as the totality of all parts of a system that are homogeneous in composition and physical and chemical properties, separated by a clear and defined interface, i.e., it is possible to isolate a given phase from the rest of the system.

State functions

The **internal energy of a system U,** refers to its total energy, determined by all types of motion and interactions of its constituent molecules, atoms, ions, and elementary particles. This energy includes the energy of the translational, vibrational, and rotational motions of molecules, atoms, ions, electrons, protons, neutrons, etc.;

The sum of the internal energy of a system and the product of volume and pressure in thermodynamics is called *enthalpy H:*

$$H=U+pV$$

Enthalpy is a thermodynamic function that, like temperature, pressure, volume, and internal energy, characterizes one of the properties of a system. The absolute value of enthalpy for a given system cannot be determined, and thermodynamic calculations only consider the enthalpy change ΔH that occurs when the system transitions from one state to another.

1st Law of Thermodynamics:

Based on the law of conservation of energy:

1. If one form of energy disappears in a process, another form of energy appears in its place in a strictly equivalent amount.
2. Different forms of energy are converted into each other in strictly equivalent amounts.
3. In an isolated system, the energy content of the system is constant**.**

In mathematical form, the first law of thermodynamics is written as follows:

$Q = \Delta U + A$

Thermochemistry is one of the main branches of thermodynamics. It studies the thermal effects of chemical reactions, the heat capacities of systems, and quantities associated with them.

Thermochemical equations are equations for chemical reactions that specify their thermal effects, for example:

A+B = C+D + 20kDj

The thermal effect of a chemical reaction is the amount of heat released or absorbed during a reaction. In thermodynamics, this quantity is defined as the change in the enthalpy of the system (ΔH, kJ/mol).

The second law of thermodynamics states that every spontaneous process in an isolated system proceeds with an increase in entropy. Thus, if the process results in $\Delta S>0$, the process is thermodynamically possible; if $\Delta S<0$, then its spontaneous occurrence is excluded.

It was advisable to introduce a state function that takes into account the combined influence of both factors. Such a function is the difference

$\Delta G=\Delta H-T\Delta S$

This state function is called the **Gibbs** free energy and is a measure of the system's stability at constant pressure.

4. Illustrative material:

Presented as a multimedia presentation.

5. Literature:

In Kazakh:

Main:

1. Қ. Н. Дауренбеков, Қ. М. Серимбетова, А. Ш. Өмірқұлов Химия : оқу құралы /. - Шымкент : Әлем баспаханасы, 2019. - 272 бет.
2. Химия : оқу құралы / Қ. Н. Дәуренбеков, Қ. М. Серимбетова, А. Ш. Өмірқұлов . - Алматы : ЭСПИ, 2023. - 304 бет.

Additional:

1.Попков, В. А. Жалпы химия [Мәтін] : оқулық / В. А. Попков, С. А. Пузаков ; Қазақ тіліне ауд. С. Н. Ділмағамбетов; Жауапты ред. Ж. Ж. Ғұмарова. - ; Ресей мед. және фарм. жоғарғы білім оқу-әдіст. бірлестігі ұсынған. - М. : ГЭОТАР - Медиа, 2014. - 992 бет. эл. опт. диск (CD-ROM).

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1 . Веренцова Л.Г., Нечепуренко Е.В. Неорганическая, физическая и коллоидная химия. – Алматы: издательство «Эверо», 2014.

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7. Zan Legal Information System - https://zan.kz/ru
8. Medline Ultimate EBSCO
9. eBook Medical Collection EBSCO
10. Scopus - https://www.scopus.com/

6. Quiz (feedback):

1. Subject and objectives of physicocolloid chemistry.
2. Chemical thermodynamics - the theoretical basis for the study of metabolism and energy.
3. The concept of enthalpy.
4. Hess's law.
5. Changes in enthalpy during various chemical and physicochemical processes.
6. The second law of thermodynamics. Entropy. Gibbs free energy.

Lecture № 2

1. Topic: Chemical Kinetics and Enzyme Catalysis

2. Objective: When solving specific problems, students should be able to predict the laws of chemical kinetics, the direction of reactions, and calculate equilibrium concentrations using the law of mass action.

3. Lecture Summary:

The rate of chemical reactions is measured by the change in the concentration of one of the reactants per unit time, i.e., $\upsilon = \pm C/t$, where the "+" sign indicates a change in the concentration of the reaction product (C>0), and the "-" sign indicates a change in the concentration of the reactant

(C<0). The reaction rate depends on the nature of the reactants, their concentration, temperature, and the catalyst.

The dependence of reaction rate on concentration is determined by the law of mass action: *at a constant temperature, the rate of a chemical reaction directly depends on the product of the concentrations of the reactants.*

For example, the law of mass action for the reaction A + 2B → AB can be written as follows:

$$\upsilon = \mathbf{k}[\mathbf{A}][\mathrm{B}]^{\mathbf{2}}$$

Where k is the reaction rate constant, the magnitude of which depends on the nature of the reactants and the temperature.

The concentrations of substances in the solid state in a heterogeneous reaction usually do not change during the reaction, i.e., they are not taken into account in the kinetic equation according to the law of mass action.

The dependence of the reaction rate (or rate constant) on temperature is determined by the **Van't Hoff law**.

For every 100°C increase in temperature, the reaction rate increases by 2-4 times. The mathematical expression for this law is:

$$\frac{\upsilon_{\mathbf{1}}}{\upsilon_{\mathbf{2}}} = \boldsymbol{\gamma}^{\frac{\mathbf{\Delta t}}{\mathbf{10}}}$$

Where υ_1- t^0C is the velocity value at temperature υ_2 – t^0+10^0C is the velocity value at temperature t0+100C, γ is the temperature coefficient of the reaction rate, the value of which is in the range of 2-4, and Δt is the change in temperature.

Every chemical reaction is characterized by a known energy barrier. To overcome this barrier, that is, for molecular collisions to be effective or for a new substance to form, an excess amount of energy (compared to the average molecular energy at a given temperature) is required. This excess energy is called the **activation energy**.

As temperature increases, the number of active molecules increases, and the reaction rate also increases.

Arrhenius proposed an equation relating the rate constant of a chemical reaction to temperature:

$$\mathbf{k} = \mathbf{A} \cdot \mathbf{e}^{\frac{\mathbf{-Ea}}{\mathbf{RT}}}$$

Where k-rate constant, A-constant representing the total number of molecular collisions, E-activation energy, R-gas constant, T-absolute temperature, and E-base of the natural logarithm.

The reaction rate is accelerated in the presence of a catalyst, as an unstable intermediate is formed, and its decomposition yields the reaction product. At this point, the reaction activity decreases, and molecules that would otherwise be considered low-energy without a catalyst become active. As a result, the number of active molecules increases, and the reaction rate accelerates.

A catalyst *is a substance that instantly changes the rate of a reaction without undergoing chemical change.* Almost all biochemical reactions are catalytic. Enzymes, produced by the body's cells, act as catalysts for biochemical reactions in living organisms.

Enzymes are specialized proteins found in all living organisms. They accelerate chemical reactions. ***Enzymology, or fermentology****, is the branch of science that studies enzymes*. Enzymes are protein biocatalysts synthesized in cells and involved in biochemical reactions.

From a chemical kinetics perspective, all chemical reactions can be divided into two groups:

1) Irreversible chemical reactions
2) Reversible chemical reactions

For irreversible chemical reactions, the rate of the forward reaction is greater than the rate of the reverse reaction.

Conditions for a process's irreversibility include the formation of a precipitate, the release of a gas that does not participate in the process, or the formation of a poorly dissociating reaction product. Examples of irreversible reactions:

$$KOH+HCI \rightarrow KCI+H_2O$$

$$NaHCO_3 + HCI \rightarrow NaCI+CO_2\uparrow + H_2O$$

$$BaCI_2 + Na_2SO_4 \rightarrow BaSO_4\uparrow+2NaCI$$

Reversible reactions are characterized by the condition of chemical equilibrium, in which the rates of the forward and reverse reactions are equal, and the concentrations of the substances participating in the reaction do not change:

For example: for the reaction **aA + bB → cC + dD**

$$\upsilon_{\text{тура}} = \mathbf{K_1}[\mathbf{A}]^{\mathbf{a}}[\mathbf{B}]^{\mathbf{b}}$$

$$\upsilon_{\text{кері}} = \mathbf{K_1}[\text{C}]^{\text{c}}[\text{Д}]^{\text{д}}$$

In a state of chemical equilibrium $=\upsilon_{\text{тура}} = \upsilon_{\text{кері}}$ т.е $\mathbf{k_1[A]^a[B]^b = k_к[C]^c[D]^d}$

From here: $$\mathbf{K} = \frac{[\mathbf{C}]^{\mathbf{c}}[\mathbf{D}]^{\mathbf{d}}}{[\mathbf{A}]^{\mathbf{a}}[\mathbf{B}]^{\mathbf{b}}}$$

Where K is the equilibrium constant.

The concentrations included in the expression for the equilibrium constant are called equilibrium concentrations.

The higher the equilibrium constant K, the more profound the reaction, i.e., the higher the yield of reaction products. A catalyst does not affect the value of the equilibrium constant, since it equally reduces the activation reactions of the forward and reverse reactions and, therefore, changes the rates of the forward and reverse reactions equally.

A catalyst only accelerates the achievement of equilibrium but does not affect the quantitative yield of reaction products.

When reaction conditions (temperature, pressure, concentration of any substance involved in the reaction) change, the rates of the forward and reverse reactions change differently, disrupting chemical equilibrium. The direction of the equilibrium shift is explained by Le Chatelier's law.

For example, an increase in temperature leads to a shift in the equilibrium in the direction of the reaction that absorbs heat, i.e., the system cools. An increase in pressure allows the equilibrium to shift the molar numbers of substances in the gaseous state downward, i.e., toward decreasing pressure. Removing one of the reaction products shifts the equilibrium directly toward the reaction. A decrease in one of the concentrations of the starting material shifts the equilibrium toward the reverse reaction.

4. Illustrative material:

Presented as a multimedia presentation.

5. Literature:

In Kazakh:

Main:

1. Қ. Н. Дауренбеков, Қ. М. Серимбетова, А. Ш. Өміркұлов Химия : оқу құралы /. - Шымкент : Әлем баспаханасы, 2019. - 272 бет.
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7. Zan Legal Information System - https://zan.kz/ru
8. Medline Ultimate EBSCO
9. eBook Medical Collection EBSCO
10. Scopus - https://www.scopus.com/

6. Quiz (feedback):

1. The rate of a chemical reaction and its dependence on various factors.
2. The law of mass action for homogeneous and heterogeneous systems.
3. Activation energy. The Arrhenius equation. Van't Hoff's rule.
4. Enzyme catalysis and its importance in the functioning of the body.
5. Reversible-irreversible reactions. The chemical equilibrium constant and its dependence on various factors.

Lecture № 3

1. Topic: Buffer Systems. The Importance of Buffer Systems in the Human Body.

2. Objective: The student should be familiar with the fundamental principles of electrolytic dissociation theory. It is also important to understand the importance of buffer solutions in living organisms.

3. Lecture Summary

Buffer systems *are systems in which the pH does not change when a small amount of a strong acid or alkali is added, or when diluted.*

Buffer systems play an important role in maintaining the acid-base balance in the body. The acid-base balance of the body is the stability of the internal environment, resulting from the combined action of the buffer and other physiological systems, i.e., the constancy of the hydrogen ion index (pH). This is one of the most important properties of the body.

The main properties of buffer solutions include their buffer capacity and pH stability. The constancy of pH can be explained by the buffering action of the body's buffer systems.

Buffer solutions are considered mixtures of buffer systems. *Solutions with a buffering effect are called* ***buffer solutions.***

A buffer system is a conjugate weak base (e.g. acetate buffer CH3COOH and CH3COONa) that is in equilibrium with an excess acid, or a conjugate weak base that is in equilibrium with an excess acid (e.g. ammonia buffer NH4OH and NH4Cl).

Such mixtures maintain their pH value when a small amount of a strong acid or base is added and diluted. This ability of buffer systems is called **buffering action**. Let's consider the mechanism of buffering action using the example of an acetate buffer, CH3COOH, and CH3COONa-acetate buffer.

$$CH_3COOH \leftrightarrow CH_3COO^- + H^+$$

$$CH_3COONa \leftrightarrow CH_3COO^- + Na^+$$

When a small amount of hydrochloric acid is added to an acetate buffer solution, hydrogen ions bind with CH3COO- anions (the conjugate base), forming an acid molecule. As a result, the pH of the solution does not change.

$$\mathbf{CH_3COONa + HCl \rightarrow CH_3COOH + NaCl}$$

$$\mathbf{CH_3COO^- + Na^+ + Cl^- + H^+ \rightarrow CH_3COOH + Na^+ + Cl^-}$$

When a small amount of alkali (NaOH) is added to an acetate buffer solution, OH− ions bind to H+, and the acid dissociation equilibrium shifts toward the formation of the conjugate base. As a result, the pH of the solution remains unchanged. The pH of a buffer solution consisting of an acid and its salt is calculated using the following equation.

$$\mathbf{pH = -lgK_Д - lg_{(c_{қыш}/C_{тұз})}} = \text{рК}_{\text{қыш}} - \mathbf{lg_{(c_{қыш}/C_{тұз})}}$$

where Kd is the acid dissociation constant. According to this equation, the pH value depends on the ratio of the concentrations of Kd and the solution components, and does not depend on dilution (within a certain range). The pH of a buffer solution consisting of a weak base and its salt is calculated using the following equation:

$$\text{pH} = \mathbf{14} - \text{рК} + \mathbf{lg_{(c_{негіз}/C_{тұз})}}$$

The magnitude of the buffering effect is determined by the **buffer capacity.** *Its value is equal to the molar mass of the equivalent of a strong acid or strong base required to change the pH of 1 liter of buffer solution by one unit.*

Buffer capacity depends on the total concentration of the buffer solution components or the ratio of their concentrations and the nature of the components. The higher the concentrations of the buffer solution components, or [acid]/[salt] = 1, the greater the buffer capacity. The equation for calculating buffer capacity (B):

$$\text{B} = \frac{\text{C}_\text{H}}{\Delta\text{pH}}$$

To calculate the buffer capacity of an acid buffer system:

$$\text{B}_1 = \frac{\text{C}_{\text{NaOH}}\text{V}_{\text{NaOH}}1000}{\text{V}_{\text{буф}}\Delta\text{pH}}$$

To calculate the buffer capacity of the main buffer system:

$$\text{B}_1 = \frac{\text{C}_{\text{HCl}}\text{V}_{\text{HCl}}1000}{\text{V}_{\text{буф}}\Delta\text{pH}}$$

where pH is the change in pH upon adding known volumes of acid or base to a given volume of buffer solution (Vb). Buffer solutions can be prepared from a given acid and salt (or base and salt) whose pH lies within a certain range.

$$\text{pH} = \text{рК}_{\text{қыш}} \pm 1 \text{ немесе } \text{pH} = \text{рК}_{\text{тұз}} \pm 1$$

The range of pH values in which the buffering effect is maintained is called the buffering zone, which is calculated by the equation:

$$\text{pH} = \text{рК} \pm \mathbf{1} \text{ мұнда } \text{рК} = \mathbf{-lgK}_{\text{дисс.}}$$

4. Illustrative material: presented in the form of a presentation using multimedia, and tables are also used during the lecture.

5. Literature:

In Kazakh:

Main:
1. Қ. Н. Дауренбеков, Қ. М. Серимбетова, А. Ш. Өміркұлов Химия : оқу құралы /. - Шымкент : Әлем баспаханасы, 2019. - 272 бет.
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6. IPR SMART Electronic Library System https://www.iprbookshop.ru/auth

7. Zan Legal Information System - https://zan.kz/ru
8. Medline Ultimate EBSCO
9. eBook Medical Collection EBSCO
10. Scopus - https://www.scopus.com/

6. Test questions:

1. Acid-base theories according to Arrhenius and Brønsted-Lowry.
2. Dissociation constant and degree. Ostwald's dilution law.
3. Water is a weak electrolyte. The ionic product of water or water constancy. The pH value and its importance in medicine.
4. The buffering zone and its calculation.
5. Determining the pH and buffering capacity of acid-base buffer systems.
6. The importance of buffer systems in living organisms.

Lecture №4

1. Topic: Colloidal-dispersed system. Properties of dispersed systems. Stability and coagulation of colloidal solutions.

2. Objective: To study the basic methods of obtaining and purifying sols, the structure of micelles, electrokinetic phenomena (electrophoresis, electroosmosis, percolation potential, sedimentation potential); the optical properties of sols – the Tyndall effect; molecular kinetic properties of dispersed systems.

3. Lecture abstracts:

Colloidal systems are classified as dispersed systems – systems in which one substance, in the form of particles of varying sizes, is distributed within another. Dispersed systems are extremely diverse; virtually every real system is dispersed. Dispersed systems are classified primarily by the particle size of the dispersed phase (or degree of dispersion); Furthermore, they are divided into groups that differ in the nature and state of aggregation of the dispersed phase and dispersion medium.

If the dispersion medium is a liquid and the dispersed phase is solid particles, the system is called a suspension; if the dispersed phase is liquid droplets, the system is called an emulsion. Emulsions, in turn, are divided into two types: direct, or "oil-in-water" (when the dispersed phase is a non-polar liquid and the dispersion medium is a polar liquid) and inverse, or "water-in-oil" (when a polar liquid is dispersed in a non-polar liquid). Dispersed systems also include foams (a gas dispersed in a liquid) and porous bodies (a solid phase in which a gas or liquid is dispersed). Based on their degree of dispersion, the following classes of dispersed systems are typically distinguished:

Coarsely dispersed systems – systems in which the particle size of the dispersed phase exceeds 10^{-7} M

Colloidal systems are systems in which the particle size of the dispersed phase is $10^{-7} – 10^{-9}$ m.

Colloidal systems are characterized by heterogeneity, i.e., the presence of phase interfaces and a very high specific surface area of the dispersed phase. This determines the significant contribution of the surface phase to the state of the system and leads to the emergence of unique properties in colloidal systems.

Colloidal systems, in turn, are divided into two groups that differ sharply in the nature of the interactions between the particles of the dispersed phase and the dispersion medium: lyophobic colloidal solutions (sols) and solutions of high-molecular compounds (HMCs), previously called lyophilic colloids. Lyophobic colloids are systems in which the particles of the dispersed phase interact weakly with the dispersion medium; these systems can only be obtained with the expenditure of energy and are stable only in the presence of stabilizers. High-molecular-weight solutions (HMW) form spontaneously due to the strong interaction of dispersed phase particles with the dispersion medium and can remain stable without stabilizers. Lyophobic colloids and HMW solutions also differ in the structure of the particles that make up the dispersed phase. For lyophobic colloids, the structural unit is a complex multicomponent aggregate of variable composition—a micelle—while for HMW solutions, it is a macromolecule.

Colloidal systems occupy an intermediate position in terms of dispersion between true solutions (molecular or ion-dispersed systems) and coarsely dispersed systems. Therefore, colloidal solutions can be obtained either by association (condensation) of molecules and ions of true solutions or by further fragmentation of the dispersed phase particles of coarsely dispersed systems.

Methods for producing colloidal solutions can also be divided into two groups: condensation and dispersion methods (peptization forms a separate group, which will be discussed later). Another necessary condition for obtaining sols, in addition to bringing the particle size to colloidal values, is the presence of stabilizers in the system—substances that prevent the spontaneous aggregation of colloidal particles.

Dispersion methods are based on crushing solids into colloidal-sized particles, thereby forming colloidal solutions. The dispersion process is accomplished by various methods: mechanical milling of the substance in colloid mills, electric arc atomization of metals, and crushing the substance using ultrasound.

Condensation Methods

A substance in a molecularly dispersed state can be converted to a colloidal state by replacing one solvent with another, a process known as the solvent exchange method. An example is the production of rosin sol, which is insoluble in water but highly soluble in ethanol. Gradually adding an alcohol solution of rosin to water sharply reduces the solubility of the rosin, resulting

in the formation of a colloidal solution of rosin in water. A sulfur hydrosol can be obtained in a similar manner.

Colloidal solutions can also be obtained by chemical condensation, which involves chemical reactions that produce insoluble or poorly soluble substances. Various types of reactions are used for this purpose, including decomposition, hydrolysis, oxidation-reduction reactions, and so on.

For example, red gold sol is obtained by reducing sodium auric acid with formaldehyde:

$NaAuO_2 + HCOH + Na_2CO_3 \longrightarrow Au + HCOONa + H_2O$

The structure of the micelle of this sol can be represented by the following diagram:

$\{[Au]m \cdot n\ AuO_2^{-} (n\text{-}x)\ Na^+\}x^- \cdot xNa^+$

Lyophobic colloids have very high surface energy and are therefore thermodynamically unstable. This enables the spontaneous process of decreasing the degree of dispersion of the dispersed phase (i.e., the aggregation of particles into larger aggregates)—the coagulation of sols. However, sols

possess the ability to maintain their degree of dispersion—aggregative stability—due to, firstly, the reduction in the system's surface energy due to the presence of an electrical double layer on the surface of the dispersed phase particles and, secondly, the presence of kinetic barriers to coagulation in the form of electrostatic repulsion between dispersed phase particles bearing the same electrical charge.

The structure of the structural unit of lyophobic colloids—***the micelle***—can only be shown schematically, since the micelle has no defined composition. Let us consider the structure of a colloidal micelle using the example of a silver iodide hydrosol, obtained by the interaction of dilute solutions of silver nitrate and potassium iodide:

$AgNO_3 + KI \longrightarrow AgI + KNO_3$

A colloidal micelle of silver iodide sol is formed by a silver iodide microcrystal, which is capable of selectively adsorbing Ag+ cations or iodide ions from the surrounding medium. If the reaction is carried out in an excess of potassium iodide, the crystal will adsorb iodide ions; with an excess of silver nitrate, the microcrystal adsorbs Ag+ ions. As a result, the microcrystal acquires either a negative or a positive charge; the ions imparting this charge to it are called potential-determining ions, and the charged crystal itself is called the micelle core. The charged core attracts ions with the opposite charge—counterions—from the solution; an electrical double layer is formed at the interface. Some of the counterions are adsorbed on the surface of the core, forming the so-called adsorption layer of counterions; the core, together with the counterions adsorbed on it, is called a colloidal particle or granule. The remaining counterions, the number of which is determined based on the rule of electroneutrality of the micelle, make up the diffuse layer of counterions; the counterions of the adsorption and diffusion layers are in a state of dynamic equilibrium of adsorption-desorption.

Schematically, a micelle of silver iodide sol obtained in excess potassium iodide (potential-determining ions are I– anions, counterions are K+ ions) can be depicted as follows:

$\{[AgI]m \cdot nI^- \cdot (n-x)K^+\}x^- \cdot x\ K^+$

When silver iodide sol is prepared in excess of silver nitrate, the colloidal particles will have a positive charge.

$\{[AgI]m \cdot nAg^+ \cdot (n-x)NO_3^-\}x^+ \cdot x\ NO_3^-$

A number of empirical principles have been established for the coagulation of sols by electrolytes

1. For sol coagulation to begin, a certain minimum electrolyte concentration, called the coagulation threshold γ, is required.

2. The coagulating effect is exerted by the electrolyte ion whose charge is opposite to the charge of the colloidal particles, with the coagulating effect of the ion being stronger the greater its charge (the Schulze-Hardy rule, or the significance rule). The coagulation thresholds of divalent ions are approximately an order of magnitude smaller, and those of trivalent ions are two orders of magnitude smaller, than those of singly charged ions. The significance rule is approximate and only applies to inorganic ions; some singly charged organic ions have a stronger coagulating effect than divalent inorganic ions, due to their strong specific adsorption. 3. In the series of inorganic ions with the same charges, the coagulating action increases with decreasing hydratability of the

ions; for example, in the series of singly charged alkali metal cations, the coagulating action increases from lithium to rubidium:

$\gamma (Li+) > \gamma (Na+) > \gamma (K+) > \gamma (Rb+)$

Rows in which ions with the same charge are grouped according to increasing or decreasing coagulating action are called lyotropic series.

4. Precipitates obtained during the coagulation of sols with electrolytes always contain the ions that caused the coagulation.

5. During the coagulation of sols with mixtures of electrolytes, independent (additive) action is relatively rarely observed; usually, a mutual enhancement or weakening of the coagulating action (synergism or antagonism of ions) occurs.

Mutual Coagulation of Sols

Coagulation of a sol can be caused by its interaction with another sol whose particles have the opposite charge. For example, mixing an iron hydroxide sol, whose particles are positively charged, with a negatively charged arsenic sulfide sol leads to their mutual coagulation:

$\{[Fe(OH)_3]m \cdot n\ FeO^+ \cdot (n\text{-}x)Cl^-\}x^+ \cdot xCl^-$ $\{[As_2S_3]m \cdot n\ HS^- \cdot (n\text{-}x)H^+\}x^- \cdot xH^+$

In this case, coagulation occurs because colloidal particles of one type act as very large, multiply charged ions—coagulants for particles of another type. Mutual coagulation of colloidal systems can also occur when sol particles have the same charge; in this case, the loss of stability of one sol is caused by the strong, specific adsorption of the ion—the stabilizer of the system—by the surface of the colloidal particles of the other system.

Purification of Colloidal Systems

Some molecular kinetic properties of colloidal systems are used to purify sols from electrolytes and molecular impurities, which often contaminate the resulting sols. The most common methods for purifying colloidal systems are dialysis, electrodialysis, and ultrafiltration, which rely on the ability of certain materials—so-called semipermeable membranes (collodion, parchment, cellophane, etc.)—to allow small ions and molecules to pass through while retaining colloidal particles. All semipermeable membranes are porous bodies, and their impermeability to colloidal particles is due to the fact that the diffusion coefficient for colloidal particles is significantly (by several orders of magnitude) less than for ions and molecules, which have much smaller mass and dimensions.

A device for purifying sols by dialysis is called a dialyzer. The simplest dialyzer is a vessel with a lower opening covered with a semipermeable membrane. The sol is poured into the vessel, which is then placed in a container of distilled water (usually running water); ions and impurity molecules diffuse through the membrane into the solvent.

Dialysis is a very slow process; electrodialysis is used for faster and more complete purification of sols. The electrodialyzer consists of three parts; the sol is poured into the middle part, separated from the other two by semipermeable membranes, behind which electrodes are placed. When a potential difference is applied to the electrodes, cations of the electrolytes contained in the sol diffuse through the membrane to the cathode, and anions to the anode. The advantage of electrodialysis is the ability to remove even traces of electrolytes (it is important to remember that the degree of purification is limited by the stability of the colloidal particles; removal of stabilizer ions from the sol will lead to coagulation).

Another method for sol purification is ultrafiltration—separating the dispersed phase from the dispersion medium by filtering it under pressure through semipermeable membranes. During ultrafiltration, colloidal particles remain on the filter (membrane).

4. **Illustrative material:** presented in the form of a presentation using multimedia, and tables are also used during the lecture.

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2.Glinka, N. L. General chemistry. Volume 2.: manual for graduate students / N. L. Glinka, S. S. Babkina. - 27th ed. - Almaty : "Evero" , 2017. - 176 p.
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1. SKMA Electronic Library - https://e-lib.skma.edu.kz/genres
2. Republican Interuniversity Electronic Library (RIEL) - http://rmebrk.kz/
3. Aknurpress Digital Library - https://www.aknurpress.kz/
4. Epigraph Electronic Library - http://www.elib.kz/

5. Epigraph - Multimedia Textbook Portal https://mbook.kz/ru/index
6. IPR SMART Electronic Library System https://www.iprbookshop.ru/auth
7. Zan Legal Information System - https://zan.kz/ru
8. Medline Ultimate EBSCO
9. eBook Medical Collection EBSCO
10. Scopus - https://www.scopus.com/

6. Quiz (Feedback):

1. Concepts: dispersed system, dispersed phase, dispersion medium.
2. Classification of dispersed systems.
3. Structure of a micelle and its constituent fragments.
4. Methods for obtaining and purifying colloidal solutions.
5. Optical properties of dispersed systems.
6. The Paneth-Fajans rule.
7. Stability of dispersed systems (concept). Types of stability: kinetic (sedimentation), aggregation, condensation.
8. Coagulation. Factors influencing the coagulation process of colloidal solutions. Coagulation with electrolyte mixtures: additivity, synergism, antagonism. Mutual coagulation.
9. The effect of electrolytes on the coagulation process of colloidal particles. Coagulation threshold. Schulze-Hardy rule.
10. Peptization. Colloidal protection and its importance.

Lecture №5

1. Topic: Biologically Important Heterofunctional Organic Compounds.

2. Objective: To develop knowledge of the structure and properties of the most important and chemical foundations of the structural organization of protein molecules for further study of the biological functions of proteins at the molecular level.

3. Lecture Abstracts

General Characteristics

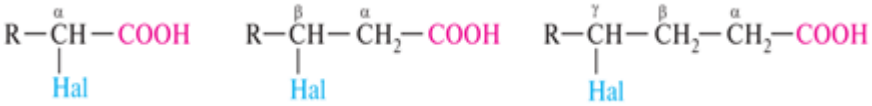
Most substances involved in metabolism are heterofunctional compounds.

Heterofunctional carboxylic acids are derivatives of carboxylic acids in which one or more hydrogen atoms in the hydrocarbon radical are replaced by other atoms or groups of atoms—halogen, hydroxyl, amino, or carbonyl.

The most important heterofunctional carboxylic acids are halogenated carboxylic acids (halogen acids), hydroxycarboxylic acids (oxy acids), oxocarboxylic acids (aldehydes and keto acids), and aminocarboxylic acids (amino acids).

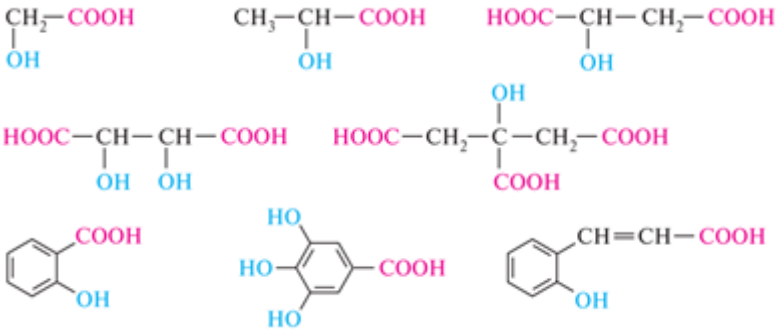
Halocarboxylic acids are derivatives of carboxylic acids in which one or more hydrogen atoms in the hydrocarbon radical are replaced by halogen atoms.

Depending on the nature of the hydrocarbon radical, halocarboxylic acids are classified as aliphatic, alicyclic, and aromatic. Depending on the relative position of the halogen atom and the carboxyl group, aliphatic acids are divided into α-, β-, γ-, and δ-aliphatic:

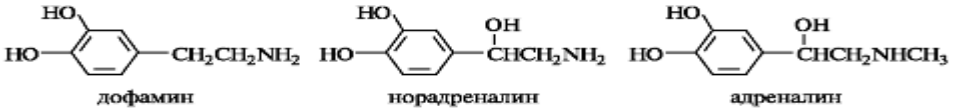


Derivatives of carboxylic acids containing one or more hydroxyl groups in the hydrocarbon radical are called hydroxy acids.

Depending on the nature of the hydrocarbon radicals, they are classified as aliphatic hydroxy acids (alcohol acids) and aromatic hydroxy acids (phenolic acids). Aliphatic hydroxy acids are divided into α-, β-, γ-, and δ-aliphatic hydroxy acids based on the relative positions of the carboxyl and hydroxyl groups.
The carboxyl group in a hydroxy acid molecule determines basicity, while the hydroxyl groups, together with the hydroxyls in the carboxyl group, determine atomicity. Thus, glycolic acid HO-CH2-COOH is a monobasic dihydric acid, while malic acid HOOC-CH(OH)-CH2-COOH is a dibasic trihydric acid.



Amino alcohols are compounds containing both amino and hydroxy groups within a molecule. These two functional groups are loosely held together by a single carbon atom, resulting in the elimination of ammonia or water. The simplest amino alcohol is **2-aminoethanol**, a compound in which both groups are located on adjacent carbon atoms. 2-Aminoethanol (commonly known as **colamine**) is a structural component of complex lipids called phosphatidylethanolamines.
The quaternary ammonium base (2-hydroxyethyl)trimethylammonium hydroxide [HOCH2CH2N+(CH3)3]OH- is of great importance as a vitamin-like substance that regulates fat metabolism. Its cation is called **choline**.
Choline ester derivatives perform various biological functions in the body. Substituted choline phosphates are the structural basis of phospholipids—phosphatidylcholines—the most important building blocks of cell membranes**. Acetylcholine**, an ester of choline and acetic acid, is the most common neurotransmitter in nerve tissue. It is formed in the body by the acetylation of choline by acetyl coenzyme A.
Amino alcohols containing the pyrocatechol residue as a structural fragment play an important role in the body. These are collectively known as *catecholamines*. This group includes representatives of the *biogenic amines* produced in the body. Catecholamines include **dopamine, norepinephrine,** and **adrenaline**, which, like acetylcholine, function as neurotransmitters. Adrenaline is involved in the regulation of cardiac activity, and during physiological stress, it is released into the bloodstream (the "fear hormone").



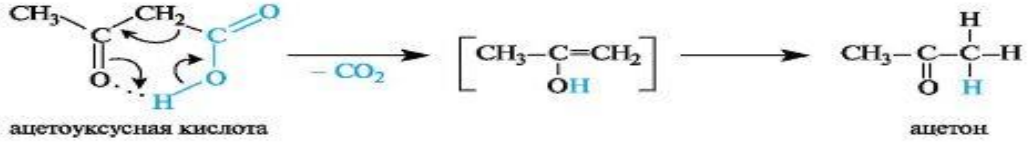
dopamine **norepinephrine** **adrenaline**

Hydroxycarbonyl Compounds

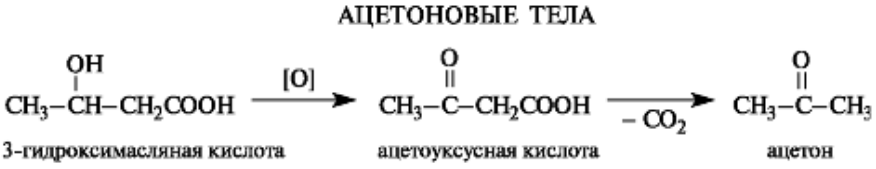
Hydroxycarbonyl compounds are compounds containing both a hydroxyl and an aldehyde (or ketone) group within the molecule. Accordingly, a distinction is made between hydroxyaldehydes and hydroxyketones. The most well-known representatives of these classes of compounds are glyceraldehyde and dihydroxyacetone, which play a significant role in biochemical processes as phosphates.

Polybasic hydroxy acids. Malic, citric, and isocitric acids, as well as oxaloacetic acid and the previously discussed succinic and fumaric acids, discussed in this section, are participants in the *tricarboxylic acid cycle*, also known as the citric acid cycle or the Krebs cycle. This is a universal stage in the oxidative catabolism of carbohydrates and other compounds in the presence of oxygen. The transformations of these acids in the body are essentially oxidation or reduction reactions. For each of these acids, the reactions are catalyzed by specific enzymes using coenzymes.

Acetoacetic acid is a β-oxoacid. In its free state, it is a syrupy liquid that slowly releases carbon dioxide.



As a product of oxidation of 3-hydroxybutyric acid, along with the products of its transformations, it accumulates in the body of patients with diabetes mellitus (the so-called acetone or ketone bodies.



3-hydroxybutyric acid **acetoacetic acid** **acetone**

4. **Illustrative material:** presented in the form of a presentation using multimedia, and tables are also used during the lecture**.**

5. Literature:

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3. Aknurpress Digital Library - https://www.aknurpress.kz/
4. Epigraph Electronic Library - http://www.elib.kz/
5. Epigraph - Multimedia Textbook Portal https://mbook.kz/ru/index
6. IPR SMART Electronic Library System https://www.iprbookshop.ru/auth
7. Zan Legal Information System - https://zan.kz/ru
8. Medline Ultimate EBSCO
9. eBook Medical Collection EBSCO
10. Scopus - https://www.scopus.com/

6. Test questions:

1. Write reaction schemes for the salt formation of leucine, isoleucine, lysine, threonine, valine, and aspartic acid with a dilute sulfuric acid solution and with a dilute alkali solution.
2. Write the decarboxylation and deamination reactions of lysine, tyrosine, tryptophan, histidine, and glutamic acid.
3. Determine the N-terminal amino acid in the peptides Leu-Ala-Phe, Ser-Gly-Tre, and Gly-Ala-Met using the Edman degradation method.

Lecture №6

1. Topic: Amino Acids. Peptides, Proteins.

2. Objective: To develop knowledge of the structure and properties of the most important α-amino acids and the chemical basis for the structural organization of protein molecules for further study of the biological functions of proteins at the molecular level. To study the structure and chemical properties of α-amino acids and peptides.

3. Lecture Abstracts

General Characteristics

Amino acids are carboxylic acids containing an amino group.

Carboxyl groups classify amino acids as aliphatic and aromatic, depending on the nature of the bound hydrocarbon. Aliphatic amines are divided into α-, β-, γ-, and δ-amino acids depending on the location of the amino and carboxyl groups. The most important α-amino acids are those found in proteins.

Amino acids contain 16% nitrogen, which is the primary chemical compound that makes up carbohydrates and fats, which are otherwise considered secondary nutrients. The importance of amino acids in the body is determined by the significant role of proteins in all vital functions. From the largest animal to the smallest microbe, organisms are composed of proteins. In the human body, proteins form muscles, tendons, all organs, hair, and nails; proteins are also the constituents of fluids and bones. Enzymes and hormones, which accelerate and regulate all bodily processes, are also proteins.

Low protein levels in the body lead to water imbalance, which leads to the development of tumors. Each protein in the body is unique and serves a specific purpose. Proteins are not interchangeable. They are synthesized in the body from amino acids, which are formed during the breakdown of proteins in foods. This explains why it is not the proteins themselves, but the amino acids themselves, that are the valuable nutritional element. In addition to the fact that amino acids cause proteins found in the human body and its organs, some act as neurotransmitters. Neurotransmitters, in turn, transmit impulses that direct chemicals to nerve cells. It follows that certain amino acids are essential for the normal functioning of the brain. Amino acids influence how vitamins and minerals function properly.

Proteins are high-molecular-weight natural polymers consisting of α-amino acid residues linked by peptide (amide) bonds.

Proteins are components of the cells and tissues of all living organisms. Protein substances include enzymes, some hormones, and others. Along with nucleic acids, proteins are complex biopolymers created by the forces of nature. The molecular weight of proteins ranges from 5,000 to several million.

*Proteins with low molecular weights are called **peptides**.*

Proteins are high-molecular-weight compounds (polyamides) constructed from α-amino acids. Proteins are a component of the cells and tissues of all living organisms. Enzymes, some hormones, and other chemicals are added to proteins. Along with nucleic acids, proteins are complex biopolymers created by nature. The molecular weight of proteins ranges from 5,000 to several million. Proteins with low molecular weight are called peptides. The monomeric unit of proteins and peptides are α-amino acids.

Proteins often contain approximately 25 different α-amino acids with the general formula RCH(NH2)COOH; each protein molecule contains approximately 20 types.

Trivial names are often used to designate α-amino acids: glycine-Gly, alanine-Ala, valine-Val, etc. There is virtually no systematic naming of natural α-amino acids.
Depending on the number of amino and carboxyl groups in the α-amino acid molecule, they are classified as monoamine monocarbon (glycine, alanine, valine, etc.), monoamine carboxylic (asparagine, glutamic acids and their amides), and diamine monocarbonate (ornithine, lysine, arginine, histidine).
Most α-amino acids are produced in the body (exchangeable amino acids), but some α-amino acids are not synthesized in the human body (non-exchangeable amino acids). Amino acids are typically absorbed by the body through proteins.

4.Illustrative material: presented in the form of a presentation using multimedia, and tables are also used during the lecture.

5. Literature:

In Kazakh:

Main:

1. Қ. Н.Дәуренбеков, Қ. М.Серімбетова, А.Ш. Өміркұлов Химия : оқу құралы/. - Шымкент: Әлем баспаханасы, 2019. - 272 бет.
2. Химия: оқу құралы / Қ. Н. Дәуренбеков, Қ. М. Серімбетова, А. Ш. Өміркұлов . - Алматы: ЭСПИ, 2023. - 304 бет.
3. Органикалық химия. Т. 1: оқу / Қ.Н. Дәуренбеков. - Алматы: жаңа кітап, 2022. - 320 бет. с. (Шифр 547/Д 22-174053)
4. Органикалық химия. Т. 2: оқу / Қ.Н. Дәуренбеков. - Алматы: жаңа кітап, 2022. - 388 бет. с. (Шифр 547/Д 22-897971)

Additional:

1. Тюкавкина Н. А., Бауков Ю. И., Зурабян С. Е., қазақ тіліне аударған ж/е жауапты редакторлары С. Т. Сейтембетов. Биоорганикалық химия: оқу / - М: ГЕОТАР – Медиа, 2014. - 400 б.
2. Патсаев Ә. Қ. Химия пәні бойынша тестілері. 1-бөлім. Бейорганикалық, физколлоидтық химия пәні бойынша тестілері. II-билим. Биоорганикалық химия пән бойынша тестилер: тестилер. - Шымкент: Б. ж., 2010.

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1.Зурабян, С. Э. Органическая химия [Текст] : учеб. для мед.вузов/ С. Э. Зурабян, А. П. Луизин ; под ред. Н. А. Тюкавкиной. - М. : ГЭОТАР - Медиа, 2013. - 384 с. : ил
3. Зурабян С.Э. Органическая химия . Учебник. М: ГЕОТАР-Медиа, 2014

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1. Патсаев, А. К. "Функциональные производные углеводородов" [Текст] : учеб. пособие / А. К. Патсаев ; М-во здравоохранения РК. - Алматы : Эверо, 2014. - 404 с

In English:

1.Azimbayeva, G. T. Organic chemistry : textbook / G. T. Azimbayeva. - Almaty : [s. n.], 2016. - 313 p.
2.Tukibayeva, A. Chemistry of functional derivatives of organic molecules [: study book. - Almaty : "Evero" , 2015. - 180 p

Electronic resources:

1. SKMA Electronic Library - https://e-lib.skma.edu.kz/genres

2. Republican Interuniversity Electronic Library (RIEL) - http://rmebrk.kz/
3. Aknurpress Digital Library - https://www.aknurpress.kz/
4. Epigraph Electronic Library - http://www.elib.kz/
5. Epigraph - Multimedia Textbook Portal https://mbook.kz/ru/index
6. IPR SMART Electronic Library System https://www.iprbookshop.ru/auth
7. Zan Legal Information System - https://zan.kz/ru
8. Medline Ultimate EBSCO
9. eBook Medical Collection EBSCO
10. Scopus - https://www.scopus.com/

6. Test questions:

1. The structure of α-amino acids.
2. Properties of α-amino acids.
3. The balance of protonation and deprotonation.
4. Peptides.
5. The importance of amino acids and proteins in living organisms.

Lecture № 7

1. Topic: Carbohydrates and their biological significance.

2. Objective: To study the structure of carbohydrates, their chemical properties, and significance.

3. Lecture Abstracts

Monosaccharides

Monosaccharides (monosaccharides) are polyhydroxy compounds with aldehyde and ketone groups.

Monosaccharides are very rare in nature, with the exception of glucose and fructose. They are mainly found in oligo- and polysaccharides, glycosides, glycolipids, nucleosides, and other high-molecular compounds.

Monosaccharides are classified according to two criteria: the nature of the oxotope (aldehyde or ketone) and the length of the hydrocarbon chain.

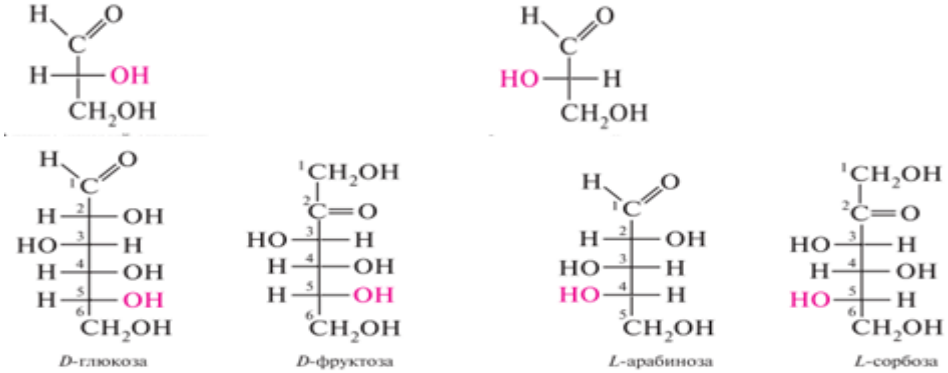
Monosaccharides are classified as aldose or ketose based on the presence of aldehyde or ketone groups in their structure. According to the number of carbon atoms in the molecule, monosaccharides are classified into trioses (C3), tetroses (C4), pentoses (C5), hexoses (C6), and others.

Monosaccharides with more than six carbon atoms are called higher sugars. Most natural monosaccharides are pentoses and hexoses. Classification typically takes into account two classification criteria (aldopentose, aldohexose, ketopentose, ketohexose).

Monosaccharide molecules contain several asymmetric carbon atoms, so they occur as several spatial isomers. Aldopentose has three asymmetric carbon atoms, meaning eight stereoisomers correspond to the same structure (2^3), while aldohexose has four asymmetric carbon atoms, meaning it can exist as 16 stereoisomers (2^4) ($N = 2^n$, where p is the number of asymmetric carbon atoms).

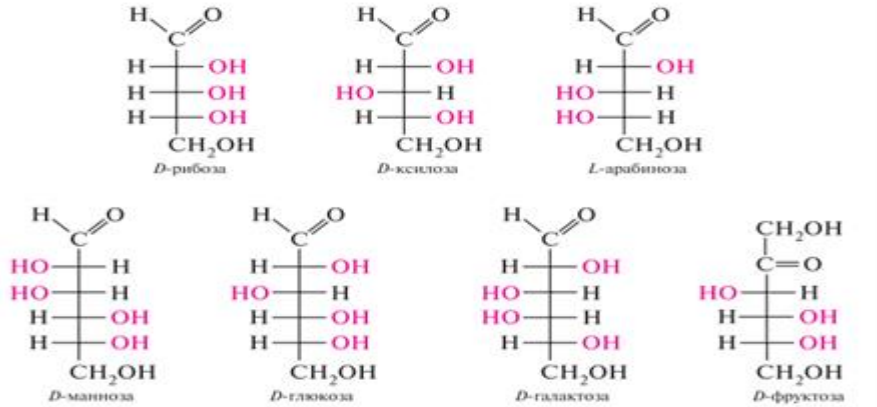
Uses Fischer projection formulas to represent stereoisomers on a plane. Monosaccharide isomers are divided into D- and L-stereochemical series, the class of which is determined by the

configuration of the asymmetric carbon atom furthest from the carbonyl group (C-4 for pentoses, C-5 for hexoses). If the configuration of this chiral center corresponds to that of D-glyceraldehyde, then it belongs to the D-series of monosaccharides, and if it corresponds to the configuration of L-glyceraldehyde, then it belongs to the L-series of monosaccharides.



Thus, eight of the 16 stereoisomers of aldohexose belong to the D-series, the remaining eight belong to the L-series. Representatives of the D-series are optical antipodes of the L-series, i.e., aldohexose is a pair of eight enantiomers. D-glucose and L-glucose are enantiomers.

Most natural monosaccharides belong to the D-series.
Important examples of natural monosaccharides include:

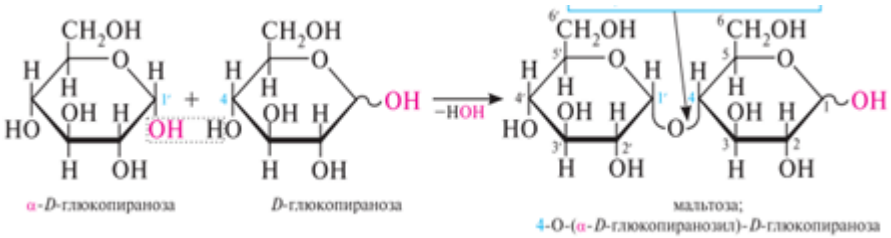


Disaccharides are complex sugars in which each molecule, upon hydrolysis, breaks down into two monosaccharide molecules.
Non-reducing disaccharides include maltose, lactose, and cellobiose. They have reducing properties and exhibit the phenomenon of mutarotation, as oxo-cyclo tautomerism allows for the mutual conversion of the open and cyclic forms of one of the monosaccharides.
Maltose or licorice sugar (-D – glucopyranosyl – 1,4---D – glucopyranose).

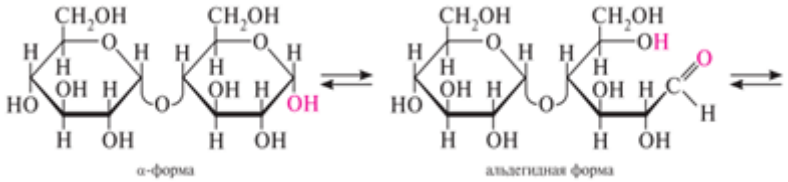
$$C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_6H_{12}O_6$$

maltose glucose

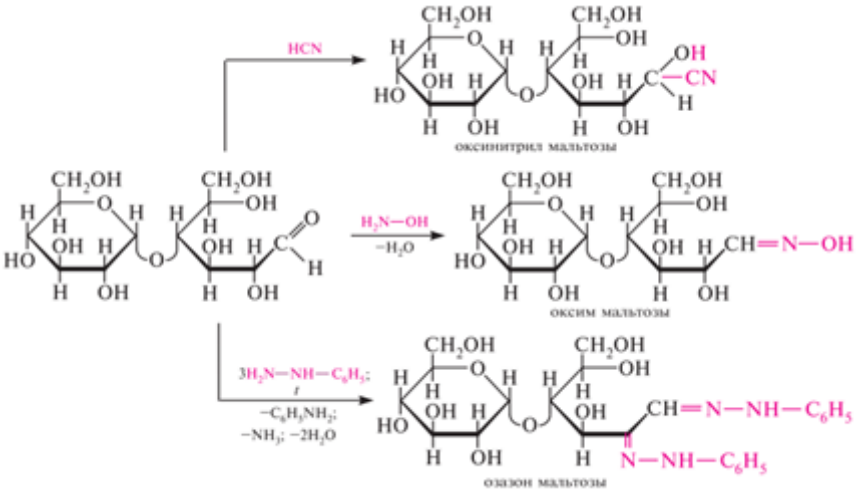
Maltose is the main product of starch breakdown by the enzyme amlase, secreted by the salivary gland. It has a taste three times less sweet than sucrose.
In maltose, the residues of two D-glucopyranose molecules are linked by a (1-4) glycosidic bond.



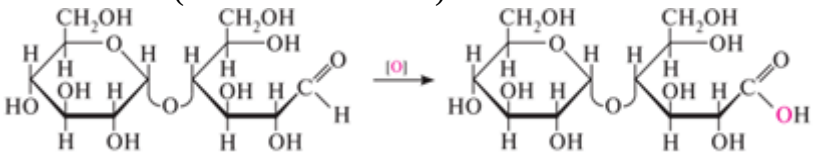
Maltose is present in solution in aldehyde, α- and β-cyclic tautomeric forms.



Maltose contains free hemiacetal hydroxide. Maltose reduces Fehling's reagent, and its solutions undergo mutarotation.
Monosaccharides participate in all reactions. The presence of an aldehyde group in maltose initiates reactions characteristic of monosaccharides.

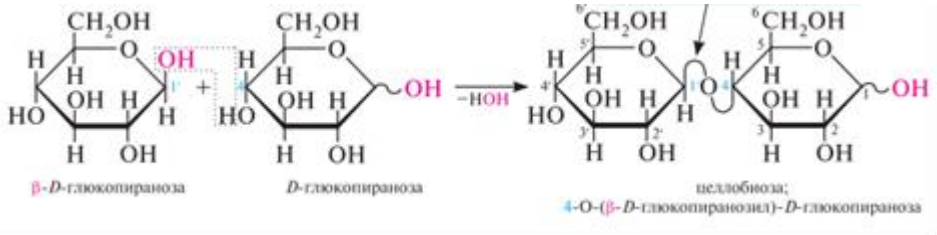


In mild cases (with bromine water) maltose is converted into maltobionic acid:



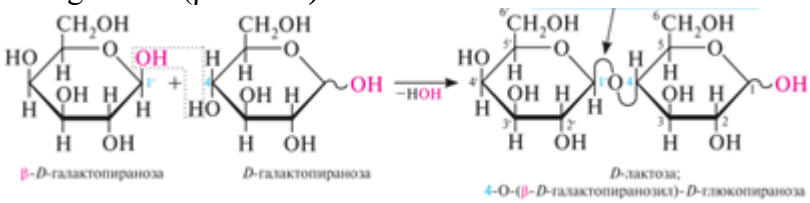
Maltose is found in small amounts in some plants; it is formed during the enzymatic catalysis of starch. In the human body, maltose is broken down into D-glucose in the presence of the enzyme maltase. It is soluble in water, and aqueous solutions have a sweet taste.

Cellobiose. The cellobiose molecule consists of two D-glucopyranose units linked by a 1,4-glycosidic bond, like maltose. In contrast, the anomeric carbon atom in the glucose unit involved in the formation of glycosidic bonds has a β-shape. A glucose unit with a free hemiacetal hydroxyl group, like maltose, can have either an α-configuration (α-cellobiose) or a β-configuration (β-cell).



Depending on the chemical structure, α-cellobiose can be 4-α-(β-D-glucopyranosyl)-α-D-glucopyranose, or β-cellobiose, 4-α-(β-D-glucopyranosyl)-β-D-glucopyranose.

Lactose (milk sugar). The lactose molecule consists of D-galactopyranose and D-glucopyranose residues linked by a 1,4-glycosidic bond. The anomeric carbon atom in the galactose residue, which is involved in the formation of glycosidic bonds, has a β-shape; the glucose residue with a free hemiacetal hydroxyl group can have either the α-configuration (α-lactose) or the β-configuration (β-lactose).



α-Lactose can be called 4-α-(β-D-galactopyranosyl)-α-D-glucopyranose, and β-lactose, 4-O-(β-D-galactopyranosyl)-β-D-glucopyranose.

Lactose is found in milk. It does not undergo alcoholic fermentation and is 4-5 times sweeter than sucrose. D-glucose and D-galactose are formed by acid and enzymatic hydrolysis. Lactose has low hygroscopic properties and is used in pharmaceuticals to prepare powders and tablets.

In non-reduced disaccharides, glycosidic bonds are formed by the hemiacetal hydroxyl groups of two monosaccharides. Such disaccharides do not contain free hemiacetal hydroxyl groups and therefore occur only in cyclic form. Their solutions do not mutate and do not exhibit redox properties. Redox disaccharides do not react with aldehydes and glycoside hydroxyls. Sucrose is a non-reducing disaccharide.

Sucrose (cane or beet sugar). The sucrose molecule consists of D-glucose and D-fructose units linked by a 1,4-glycosidic bond. In addition, sucrose contains the α-D-glucopyranose form of D-glucose and the β-D-fructofuranose form of D-fructose. The glycosidic bond between α-D-glucopyranose and β-D-fructofuranose is provided by the hemiacetal hydroxyl groups of the two molecules. Depending on its chemical structure, sucrose can be called 2-O-(α-D-glucopyranosyl)-β-D-fructofuranoside. Sucrose is a colorless, crystalline substance soluble in water and has a sweet taste. It undergoes acid and enzymatic hydrolysis to form D-glucose and D-fructose.

Sucrose is found in sugarcane (cane) and beets (17-20%); in production, it is obtained from these raw materials. Sucrose is used in pharmacies in the form of powders, fruit juices (syrups), mixtures, and other products. It is also used in food preparation.

Complex carbohydrates, or polysaccharides (polysaccharides), are carbohydrates that can be hydrolyzed to form simple carbohydrates (which cannot be hydrolyzed).

Complex carbohydrates are divided into two subgroups:

1) Sugar-like complex carbohydrates, or oligosaccharides, are similar to simple carbohydrates, readily dissolve in water, and have a sweet taste. Hydrolysis produces several molecules of simple sugar.

2) Non-sugar-like complex carbohydrates, or higher polysaccharides, are unlike simple sugars and do not form true solutions, are either completely insoluble in water (fiber, which forms plant cell walls), or dissolve to form colloidal solutions (starch and glycogen, which are animal

starches). They do not have a sweet taste (tasteless). Hydrolysis produces a large number of monosaccharide molecules.

Polysaccharides include compounds whose molecules consist of more than a dozen monosaccharide bonds linked by O-glycosidic linkages.

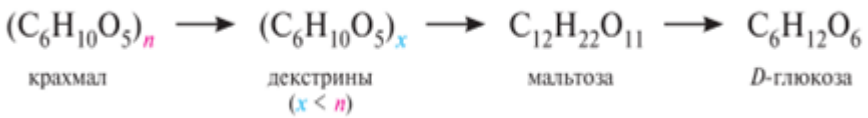
If polysaccharides contain only one monosaccharide residue, they are called **homopolysaccharides**, and if they contain different monosaccharide residues, they are called **heteropolysaccharides**.

Homopolysaccharides formed from pentose residues are called pentosans, and those formed from hexose residues are called hexosans.

The general formula for pentosans is (C5H8O4)n, and the formula for hexosans is (C6H10O5)n. Most natural compounds are hexosans (starch, cellulose, glycogen, dextrans, etc.).

Starch. Starch is the main source of energy in plants. It is found in the seeds, tubers, and roots of plants.

Starch consists of approximately 20% a water-soluble fraction called amylose and approximately 80% a water-insoluble fraction called amylopectin. During acid and enzymatic hydrolysis, amylose and amylopectin are gradually broken down into dextrins (a mixture of low-molecular-weight polysaccharides), further hydrolysis of which leads to the formation of maltose and then D-glucose:

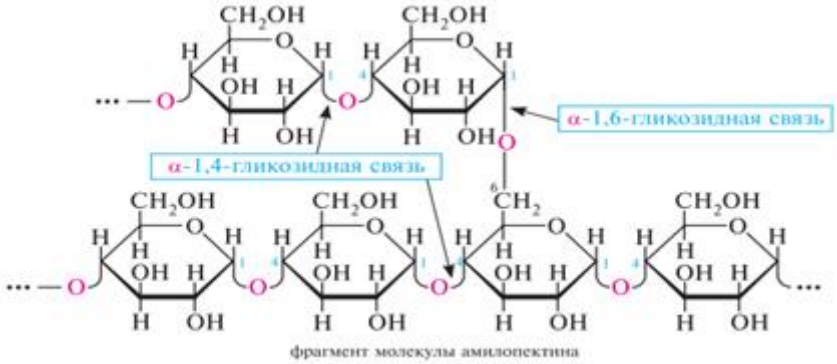


The structural differences between amylose and amylopectin are determined by the nature of the glycosidic bonds.

Amylose is a linear polymer consisting of over 1000 monomer units with D-glycopyranose residues linked by α-1,4-glycosidic bonds.


фрагмент молекулы амилозы

Amylopectin is a branched polymer with approximately 600-5000 D-glucose residues per molecule. Its molecular weight ranges from 1-6 million. All polysaccharide chains—the backbone and side chain monosaccharide residues—are linked by a single type of bond, an α-1,4-glycosidic bond. Between two adjacent branch points in the backbone, there are 20-25 monosaccharide residues.



фрагмент молекулы амилопектина

Due to its extensive branching, the amylopectin molecule lacks a helical conformation, binds only a small amount of iodine, and is colored red.

Starch is the main source of carbohydrates in the human diet. The enzyme amylase, present in saliva in the mouth, breaks down starch into dextrin and partially maltose, and then breaks it down into glucose in the intestine. In pharmaceuticals, starch is used to make tablets, as well as to prepare powders and pastes.

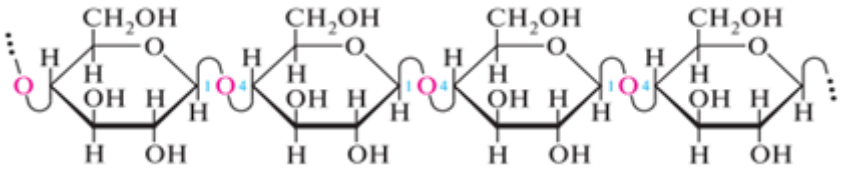
Glycogen (animal starch). While many plants contain starch as a source of polysaccharides, glycogen performs this function in animals. This polysaccharide provides the body with glucose during intense physical activity and during meals.

Glycogen is similar in structure to amylopectin, but has a more branched structure. Glucopyranose residues in the main and side chains are linked by α-1,4, and in the branches by α-1,6, glycosidic bonds. Between two adjacent branch points in the main chain, there are 10-12, rarely 2-4, monosaccharide residues. The molecular weight of glycogen reaches 100 million. Glycogen is more soluble in water than other storage polysaccharides.


гликоген

Glycogen is abundant in the liver and muscles.

Cellulose. Cellulose is one of the most common polysaccharides in nature, forming the membrane of plant cells. Wood contains 50-70% cellulose, and cotton 98%. The D-glycopyranose residue of the cellulose molecule is a linear polymer consisting of over 1000 monomeric bonds linked by a β-1,4-glycosidic bond:



The molecular weight of cellulose ranges from 250,000 to 1,000,000.
Cellulose is insoluble in water and common organic solvents, but is soluble in an ammoniacal solution of copper(II) hydroxide (Schweitzer's reagent) and a concentrated solution of zinc chloride.
Cellulose hydrolysis is carried out by heating in the presence of sulfuric acid.
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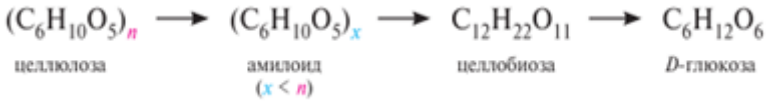

Humans and higher animals lack enzymes that break down β-glycosidic bonds, but it is added to food as a digestive aid.
In pharmaceuticals, sodium carboxymethylcellulose is used in the manufacture of medicines.
Pectin substances are found in fruits and vegetables. It consists primarily of pectic acid, which is a polygalacturonic acid.

4. **Illustrative material**: presented as a presentation using multimedia, and tables are also used during the lecture.

5. Literature:

In Kazakh:

Main:

1. Қ. Н.Дәуренбеков, Қ. М.Серімбетова, А.Ш. Өміркұлов Химия : оқу құралы/. - Шымкент: Әлем баспаханасы, 2019. - 272 бет.
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Additional:

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5. Зурабян С.Э. Органическая химия . Учебник. М: ГЕОТАР-Медиа, 2014

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1.Патсаев, А. К. "Функциональные производные углеводородов" [Текст] : учеб. пособие / 2. А. К. Патсаев ; М-во здравоохранения РК. - Алматы : Эверо, 2014. - 404 с

In English:

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2.Tukibayeva, A. Chemistry of functional derivatives of organic molecules [: study book. - Almaty : "Evero" , 2015. - 180 p

Electronic resources:

1. SKMA Electronic Library - https://e-lib.skma.edu.kz/genres
2. Republican Interuniversity Electronic Library (RIEL) - http://rmebrk.kz/
3. Aknurpress Digital Library - https://www.aknurpress.kz/
4. Epigraph Electronic Library - http://www.elib.kz/
5. Epigraph - Multimedia Textbook Portal https://mbook.kz/ru/index
6. IPR SMART Electronic Library System https://www.iprbookshop.ru/auth
7. Zan Legal Information System - https://zan.kz/ru
8. Medline Ultimate EBSCO
9. eBook Medical Collection EBSCO
10. Scopus - https://www.scopus.com/

Lecture № 8

1. Topic: Biologically Important Heterocyclic Compounds. Nucleic Acids. DNA and RNA.

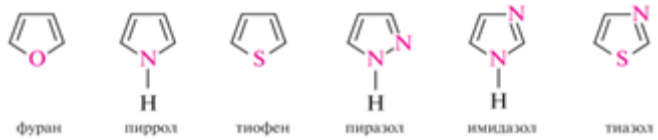
2. Objective: To develop knowledge about the structure and biological significance of heterocyclic compounds, alkaloids, and nucleic acids.

3. Lecture Abstracts

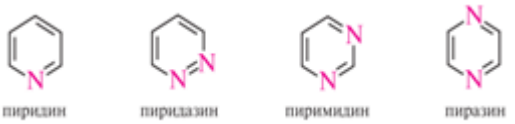
Heterocyclic compounds are substances whose molecules are cyclic and contain, in addition to carbon atoms, one or two non-carbon atoms—heteroatoms—in the ring.

This paper examines heterocycles with O, N, and S heteroatoms with aromatic properties from a large group of five- and six-membered heterocyclic compounds with one or two heteroatoms. These substances often resemble benzene in their stability and chemical properties and are therefore called "heterocyclic aromatic" or "heteroaromatic" compounds.

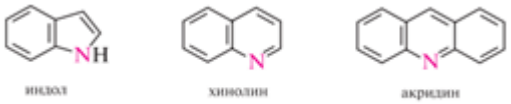
Important representatives of this group of compounds include: five-membered heterocycles



Six-membered heterocycles



Condensed heterocyclic systems

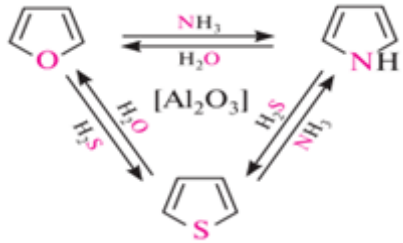


Heterocycles that donate a pair of electrons not shared by a heteroatom in the molecule and increase the electron density of the carbon atoms of the aromatic ring are called π-excessive. These include five-membered heterocyclic compounds containing pyrrole heteroatoms (furan, pyrrole, thiophene, etc.).

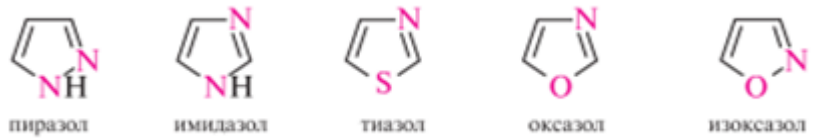
Heterocycles that reduce the electron density of the carbon atoms of the aromatic ring in the molecule by a heteroatom are called π-deficient.

π-deficient heterocyclic systems include heterocycles containing pyridine heteroatoms (pyridine, pyrimidine, pyrazine, etc.).

Heterocyclic compounds containing nitrogen atoms of pyrrole and pyridine exhibit amphoteric properties (pyrazole, imidazole, purine, etc.). The interaction of furan, pyrrole and thiophene was discovered in 1936 by the Russian organic chemist Yuri Konstantinovich Yuryev.



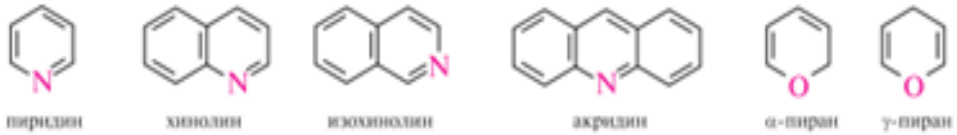
The most common of the two heteroatomic five-membered heterocycles are pyrazole, imidazole, thiazole, oxazole, and isoxazole



These compounds are called "azoles" because one of the two heteroatoms is necessarily nitrogen. The ring consists of at least two heteroatoms, one of which is the pyridine nitrogen atom. Five-membered heteroaromatic compounds with bi- and polycyclic systems based on the azole ring are called azoles.

All of these heterocycles have an aroma.

The main representatives of this group of compounds are heterocycles containing nitrogen atoms—pyridine, quinoline, isoquinoline, and acridine—as well as heterocycles containing oxygen atoms—α-pyran and γ-pyran:



Pyridine-specific reactions can be divided into three groups:
- Reactions involving heteroatoms;
- Reactions of substitution of hydrogen atoms in the pyridine ring;
- Oxidation and reduction reactions.

Diazines are a six-membered heteroaromatic system containing two pyridine nitrogen atoms, as well as bi- and polycyclic compounds with a diazine ring.
Diazine occurs as three isomers: pyridazine (1,2-diazine), pyrimidine (1,3-diazine), and pyrazine (1,4-diazine).

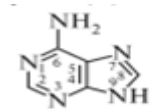
The vast majority of nitrogen-containing organic compounds with basic properties and high biological activity are called alkaloids.
The name "alkaloid" comes from the Arabic word "alkaly" (alkali). Chemically, most alkaloids are heterocyclic compounds.
To date, more than 5,000 alkaloids have been isolated. Renowned chemists such as Alexander Pavlovich Orekhov, Vladimir Mikhailovich Rodionov, Nikolai Alekseevich Preobrazhensky, and Alexander Abramovich have made significant contributions to the study of alkaloids.
Alkaloids are divided into groups for ease of study. Initially, the chemical structure of many alkaloids was not determined, so they were classified based on botanical characteristics. Therefore, alkaloids were grouped by plant type, for example, alkaloids from poppy, calendula, nightshade, and others.
Currently, a general form of chemical classification is used, based on the nature of the heterocycle that makes up the alkaloid structure. According to this classification, alkaloids are divided into the following main groups: pyridine and piperidine, quinoline, isoquinoline, indole, tropane, purine, and others.
Biopolymers that are directly involved in protein biosynthesis and ensure the storage and transmission of genetic information in all living organisms are called nucleic acids (polynucleotides).
Nucleic acids (from the Latin "nucleus") were first discovered in 1868. Swiss chemist Johann Friedrich Miescher discovered the cell nucleus. Similar substances were later discovered in cellular protoplasm.
These are nucleoproteins, found in the cells of humans, plants, bacteria, and viruses. The nucleic acid content of various nucleoproteins, excluding viruses, ranges from 40 to 65%. Nucleic acids, like proteins, are essentially high-molecular-weight organic compounds. However, unlike

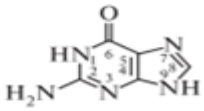
proteins, which yield α-amino acids upon hydrolysis, the monomer units of nucleic acids are nucleotides. Therefore, nucleic acids are also called polynucleotides.

The monomers of nucleic acids—nucleotides—also have a very complex structure. Hydrolysis of nucleotides produces a hydrocarbon, orthophosphoric acid, and a heterocyclic base.

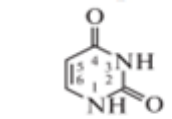
A chemical structure consisting of a hydrocarbon and a heterocyclic base is called a nucleoside.

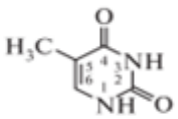
The heterocyclic bases found in nucleic acids are derivatives of purines and pyrimidines. The bases of the purine group are adenine (A) and guanine (G):

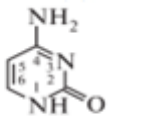

аденин (A);
6-аминопурин


гуанин (G);
2-амино-6-оксопурин

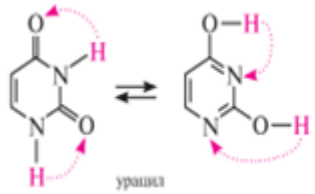
The bases of the pyrimidine group are uracil (U), thymine (T), cytosine (C):

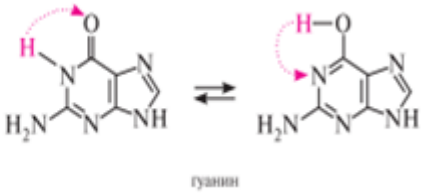

урацил (U);
2,4-диоксопиримидин


тимин (T);
5-метил-2,4-диоксопиримидин

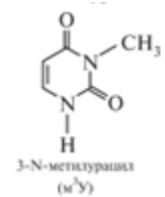

цитозин (C);
4-амино-2-оксопиримидин

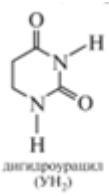
DNA contains adenine, guanine, cytosine, and thymine, while RNA contains adenine, guanine, cytosine, and uracil. The phenomenon of lactam-lactim tautomerism is characteristic of guanine, uracil, thymine, and cytosine.

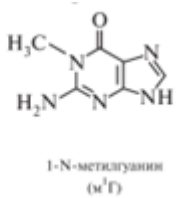

урацил

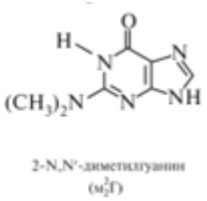

гуанин

Nucleic acids include hypoxanthine, methyl derivatives of uracil and guanine, hydrogenated derivatives of uracil, etc. may also be included.


3-N-метилурацил
($м^3У$)


дигидроурацил
($УH_2$)

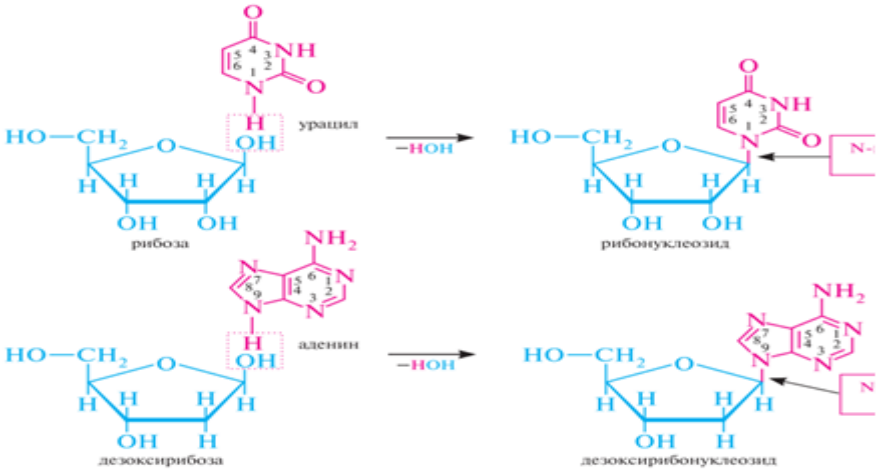

1-N-метилгуанин
($м^1Г$)


2-N,N'-диметилгуанин
($м_2^2Г$)

Organic bases in nucleic acids are linked by N-glycosidic bonds to a D-ribose or 2-deoxy-D-ribose residue.

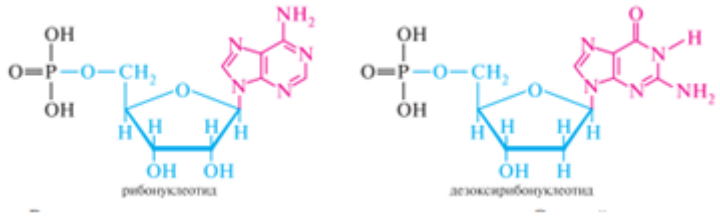
N-glycosides, consisting of nucleic base residues and D-ribose or 2-deoxy-D-ribose, are called nucleosides.

Depending on the nature of the carbohydrate residue, they are divided into ribonucleosides and deoxyribonucleosides.



The structural units of nucleic acids, consisting of nucleoside and phosphoric acid residues, are called nucleotides.

Depending on their nature, pentoses are divided into ribonucleotides and deoxyribonucleotides.



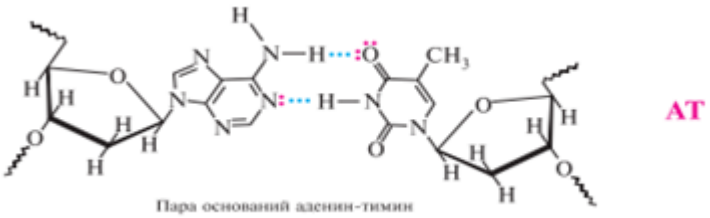
There are two approaches to the nomenclature of nucleotides. On the one hand, they are considered esters, i.e., monophosphates, and on the other, as acids.

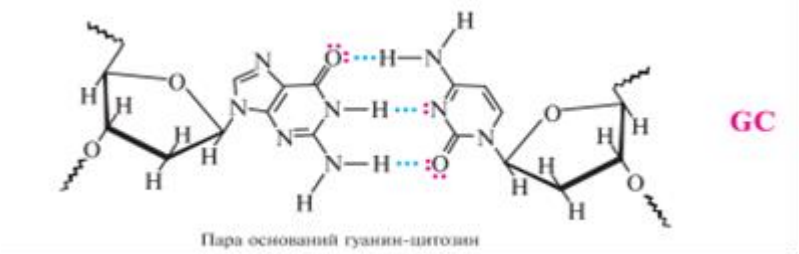
The arrangement of nucleotide units in a specific sequence in a polynucleotide chain is called the primary structure of nucleic acids.

The spatial orientation of polynucleotide chains within a molecule is called the secondary structure of nucleic acids.

The American biochemist James Watson and the British biochemist Francis Crick (1953) were the first to describe the secondary structure of DNA as a double helix.

Hydrogen bonds are formed between the pyrimidine and purine nucleic acids of the parallel branches of the DNA double strand: adenine bonds with thymine, and guanine with cytosine. This is why they are called complementary pairs:





Пара оснований гуанин-цитозин

4. **Illustrative material**: presented as a presentation using multimedia, and tables are also used during the lecture.

5. Literature:

In Kazakh:

Main:

1. Қ. Н.Дәуренбеков, Қ. М.Серімбетова, А.Ш. Өміркұлов Химия : оқу құралы/. - Шымкент: Әлем баспаханасы, 2019. - 272 бет.
2. Химия: оқу құралы / Қ. Н. Дәуренбеков, Қ. М. Серімбетова, А. Ш. Өміркұлов . - Алматы: ЭСПИ, 2023. - 304 бет.
3. Органикалық химия. Т. 1: оқу / Қ.Н. Дәуренбеков. - Алматы: жаңа кітап, 2022. - 320 бет. с. (Шифр 547/Д 22-174053)
4. Органикалық химия. Т. 2: оқу / Қ.Н. Дәуренбеков. - Алматы: жаңа кітап, 2022. - 388 бет. с. (Шифр 547/Д 22-897971)

Additional:

1.Тюкавкина Н. А., Бауков Ю. И., Зурабян С. Е., қазақ тіліне аударған ж/е жауапты редакторлары С.Т.Сейтембетов.Биоорганикалық химия:оқу/-М:ГЕОТАР-Медиа,2014 – 400б
2. Патсаев Ә. Қ. Химия пәні бойынша тестілері. 1-бөлім. Бейорганикалық, физколлоидтық химия пәні бойынша тестілері. II-билим. Биоорганикалық химия пән бойынша тестилер: тестилер. - Шымкент: Б. ж., 2010.

In Russian:

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1.Зурабян, С. Э. Органическая химия [Текст] : учеб. для мед.вузов/ С. Э. Зурабян, А. П. Луизин ; под ред. Н. А. Тюкавкиной. - М. : ГЭОТАР - Медиа, 2013. - 384 с. : ил
6. Зурабян С.Э. Органическая химия . Учебник. М: ГЕОТАР-Медиа, 2014

Additional:

1.Патсаев, А. К. "Функциональные производные углеводородов" [Текст] : учеб. пособие / 2. А. К. Патсаев ; М-во здравоохранения РК. - Алматы : Эверо, 2014. - 404 с

In English:

1.Azimbayeva, G. T. Organic chemistry : textbook / G. T. Azimbayeva. - Almaty : [s. n.], 2016. - 313 p.
2.Tukibayeva, A. Chemistry of functional derivatives of organic molecules [: study book. - Almaty : "Evero" , 2015. - 180 p

Electronic resources:

1. SKMA Electronic Library - https://e-lib.skma.edu.kz/genres
2. Republican Interuniversity Electronic Library (RIEL) - http://rmebrk.kz/
3. Aknurpress Digital Library - https://www.aknurpress.kz/
4. Epigraph Electronic Library - http://www.elib.kz/

5. Epigraph - Multimedia Textbook Portal https://mbook.kz/ru/index
6. IPR SMART Electronic Library System https://www.iprbookshop.ru/auth
7. Zan Legal Information System - https://zan.kz/ru
8. Medline Ultimate EBSCO
9. eBook Medical Collection EBSCO
10. Scopus - https://www.scopus.com/

6. Review questions (feedback):

1. Name the structural features due to the aromatic character of furan, pyrrole, and thiophene.
2. Acidophobicity. Name heterocycles exhibiting acidophobicity.
3. Write the reaction schemes for the nitration and sulfonation of furan and indole.
4. Write the tautomeric forms of pyrazolone-5. Name the drugs consisting of the pyrazolone-5 structure.
5. Note the similarities and differences in the structure and properties of pyridine and benzene. Give reaction examples.
6. Name and write the formulas of the structural components of nucleic acids.
7. Give the primary structure of nucleic acids. Explain their hydrolysis.
8. Write the secondary formulas of nucleic acids. Explain the complementarity of polynucleotide chains in the double helix
9. Explain the biological role of nucleotide polyphosphates in biochemical processes.