Ministry of Health of the Republic of Belarus
Educational institution
"Gomel State Medical University"

Department of General and Bioorganic Chemistry

Author:
A.K. Dovnar, senior lecturer of the Department
of General and Bioorganic Chemistry

# METHODOLOGICAL MANUAL

for conducting the laboratory class with the first-year students
of the Faculty of International Students
studying in the specialty 7-07-0911-01 "Medical business" (FIS)
English-speaking students
in the discipline "Medical chemistry"

## Topic 18: The final class "Fundamentals of medical chemistry"

Time: 2 hours

2023

## THE TRAINING AND EDUCATIONAL GOALS, MOTIVATION TO STUDY THE TOPIC

**The purpose of the class:**

To analyze the knowledge, skills and abilities acquired during the study of the discipline "Medical Chemistry", and to certify students in this academic discipline.

**The tasks of the class:**

The student ***must know:***

1) fundamentals of acid-base balance of blood (blood pH, acidosis, alkalosis); mechanism of action of the hydrocarbonate buffer system of blood plasma and hemoglobin buffer system of erythrocytes;

2) hypo-, hyper-, isotonic solutions and their application in biology and medicine; the main components determining the value of osmotic and oncotic pressure of blood plasma; distribution of water between cells and extracellular fluid (hemolysis, plasmolysis); distribution of water between the vascular bed and the intercellular space;

3) solubility of gases in the blood: features of the dissolution of oxygen, carbon dioxide and nitrogen in the blood (hyperbaric oxygenation, caisson disease);

4) chemical bases of mineralization and prevention of demineralization of bone tissue in calcium-, phosphate-deficient conditions of the human body (rickets, pregnancy);

5) chemical bases of formation and dissolution of concretions in urolithiasis and cholelithiasis;

6) physico-chemical bases of the use of porous adsorbents for hemo-, plasma-, lymphosorption and enterosorbents for the extraction of radionuclides from the human body, for poisoning;

The student ***must be able to:***

1) predict the direction and depth of biochemical processes using thermodynamic calculations;

2) plan the preparation of solutions of a given composition;

3) analyze the composition and physico-chemical properties of biological fluids;

4) for laboratory studies, it is necessary to choose a buffer solution with the required pH value and buffer capacity.

**Motivation to study the topic:**

Medical chemistry plays an important role in the training of a modern doctor. Medical chemistry is an academic discipline that includes knowledge of the basic concepts and laws of chemical thermodynamics, kinetics, physical chemistry of surface phenomena, dispersed systems and high-molecular compounds, types of chemical equilibria (protolytic, heterogeneous, ligand-exchange, redox) necessary for the subsequent study of biological chemistry, physiology, pharmacology.

At the molecular level, medical chemistry provides the basis for understanding physicochemical processes in biological systems. Terms such as bioenergetics, pharmacokinetics, biogenic elements, electrophoresis, osmolarity and osmolality, osmotic and oncotic pressure, hemosorption and hemodialysis are already becoming familiar in medicine. Chemical methods are widely used in the practice of research laboratories and are the fundamental basis for the development of new methods of diagnosis and treatment in the clinic. Knowledge of the theoretical and practical foundations of chemistry helps to form the scientific thinking of a doctor.

## NECESSARY EQUIPMENT

1. Methodological manual for students on the topic "The final class "Fundamentals of medical chemistry".

2. Reference materials of physico-chemical constants for the 1st year education international students.

## CONTROL QUESTIONS ON THE TOPIC OF THE CLASS

### List of questions for the current certification

**1.** Basic terms and definitions of Thermodynamics: energy, heat, work; thermodynamic systems and types of systems (isolated, closed, open); thermodynamic parameters and thermodynamic functions (state functions and path functions); internal energy of system. The First Law of Thermodynamics and its mathematical description for all types of systems. Enthalpy.

**2.** Thermochemistry. Heat effects of chemical reactions. Hess' Law. Calculations of a heat of chemical reactions using: a) standard heats of formation of individual substances; b) standard heats of combustion of individual substances. Thermochemistry as the basis of dietology.

**3.** The Second Law of Thermodynamics: formulations and its mathematical description (Clausius' inequality and Boltzmann's equation). Entropy. Thermodynamic and statistical interpretation of entropy. Calculations of entropy changes for any chemical reactions.

**4.** Gibbs' Free Energy. Gibbs' Free Energy change as a criterion of equilibrium and the possibility of spontaneous processes in isobaric-isothermal conditions. Methods for calculation the change in Gibbs' Free Energy. The concept of bioenergetics; exergonic and endergonic reactions, coupled reactions.

**5.** The subject of chemical kinetics. The rate and mechanism of chemical reactions. Kinetic curves. Factors affecting the reaction rate. Molecularity. The Rate Law. Rate constant. Reaction order.

**6.** Kinetics of irreversible zero-order, first-order, and second-order reactions. The half-life of a reaction. Kinetics of complex reactions.

**7.** Temperature dependence of the reaction rate. Temperature coefficient. Activation energy. The Arrhenius' equation. Theory of the activated complex.

**8.** Catalysis and catalysts. Kinetics of enzymatic reactions.

**9.** The concept of a chemical equivalent. The equivalence factor. The Equivalent Law.

**10.** Concentration units used for expressing the composition of solutions: percent by mass (mass percent, mass fraction); mole fraction (mole percent); molarity (molar concentration); molality; normality (molar concentration of the equivalent); titer.

**11.** Fundamentals of volumetric analysis: principles of volumetric analysis; requirements for chemical reactions used in titration analysis; basic terms of titration analysis (analyte, titrant, types of titrants and methods for their preparing, endpoint (equivalence point) of titration); classification of titration methods of analysis; calculations in titration analysis.

**12.** The theoretical bases for acid-base titration: the essence of acid-base titration; types of acid-base titration; primary and secondary standards; analysts in acid-base titration; acid-base indicators, their characteristics, rules for the correct choice of an indicator for a specific analysis.

**13.** Fundamentals of redox reactions. The most important oxidizing and reducing agents. Types of redox reactions. Balancing redox reactions by the ion-electron (half reaction) method. Influence of the pH of the medium on the oxidizing ability of substances (oxidizing properties of $KMnO_4$ in various media).

**14.** Theoretical basis of the permanganatometric titration method: the essence of permanganatometric titration; fixing the equivalence point; working solution (features of its preparation); standard solutions; standardization of $KMnO_4$ solution using oxalic acid solution as primary standard, autocatalytic nature of the reaction.

**15.** The reduction potential is a measure of the strength of oxidants and reductants. Calculation of reduction potential under conditions other than standard: Nernst's equation. Calculation of EMF and equilibrium constant for redox reactions and prediction of their direction.

**16.** The structure and operation of galvanic cells (using the example of the Daniel's cell). Galvanic cell diagrams. Electrode and diffusion potentials. Calculation of the EMF of a galvanic cell. Membranes (biopotentials), their calculation.

**17.** Potentiometry: direct (ionometry) and indirect (potentiometric titration). Types of electrodes used in potentiometry: metal electrodes, gas electrodes, metal-insoluble salt electrodes, ion-selective electrodes.

**18**. Elements of the theory of weak electrolytes. The Ostwald's Dilution Law. Acidity and basicity constants.

**19.** Elements of the Debye-Hückel's theory of strong electrolytes. Ionic strength of solutions. Activity of ions, activity coefficient.

**20.** Acid-base equilibrium in solutions. Dissociation of water. Water ionization constant. pH of aqueous solutions and calculations of pH in solutions of weak and strong acids and bases.

**21.** Buffer solutions: definition, classification and mechanism of action. Buffer capacity. Calculation of pH of buffer systems. Buffer systems of blood: hydrocarbonate, hydrophosphate buffer systems, hemoglobin – oxyhemoglobin and protein buffers.

**22.** Solutions, types of solutions, thermodynamics of dissolution, solubility.

**23.** Solubility of gases in water. The effect of temperature, pressure and dissolved electrolytes on the solubility of gases. Solubility of liquids in each other. The Nernst-Shilov's distribution Law as a theoretical basis for extraction.

**24.** Solubility of solids in water. Heterogeneous equilibrium "hardly soluble electrolyte – its ions in saturated solution". Solubility-product constant. Conditions for the formation of a precipitate of a difficult-to-dissolve electrolyte. Heterogeneous equilibria in the formation of bone tissue.

**25.** Colligative properties of solutions of electrolytes and nonelectrolytes. Vapor pressure lowering is the First Raoult's Law.

**26.** Ebullioscopic and cryoscopic Raoult's Laws.

**27.** Osmosis and osmotic pressure. Osmotic pressure of blood plasma. Isotonic, hypertonic and hypotonic solutions; their application in medicine.

**28.** Structure of complex compounds: Werner's theory. The basic terms and definitions. Classification and nomenclature of complex compounds. Structure of molecules of intracomplex compounds.

**29.** Equilibria in solutions of the complex compounds. Instability and stability constants. The complexing ability of ions of s-, p- and d-elements. Methods of obtaining complex compounds. Biological role of coordination compounds.

**30.** Surface phenomena. The concept of Free Surface energy and Surface Tension. Adsorption and its types (physical and chemisorption).

**31.** SAS, SIS, SNS. Structure of surfactants, their classification, surface activity, Ducklo-Traube's rule. Biologically active surfactants. Surfactants' adsorption on gas/liquid interface surfaces. Gibbs', Shishkovsky's and Gibbs-Shishkovsky's equations. Application of surfactants. The structure of biomembranes.

**32.** Solid adsorbents and their classification. Food fibers and their role for human health. Types of adsorption on solid adsorbents. Theories of molecular adsorption of nonelectrolytes and weak electrolytes on solid sorbents from gaseous and liquid phases.

**33.** Adsorption of electrolytes on solid adsorbents: selective (Panet-Phayans' rules) and ion exchange adsorption. Application of adsorbents in medicine: hemo-, plasma-and lymphosorption; enterosorbents.

**34.** Dispersed systems. Methods of classification of dispersed systems. Methods of preparation and purification of sols.

**35.** Structure of colloidal particles of lyophobic sols.

**36.** Physical properties of sols: molecular kinetic, optical, and electro kinetic properties.

**37.** Types of stability of colloidal-dispersed systems. The main regularities of coagulation of lyophobic sols under the action of electrolytes. Critical coagulation concentration (CCC) of electrolytes. The Schulze-Hardy's rule.

**38.** Coagulation rate. Kinetic coagulation curves.

**39.** General characteristic of high molecular compounds (HMC) and their classification. Methods of obtaining of HMC. Dissolution of HMC, swelling. The influence of various factors on swelling.

**40.** Polyelectrolytes. Isoelectric point and methods of its determination.

## Examples of practical tasks

**1.** Balance the following redox reactions using the half-reaction method:

a) $KMnO_4 + FeSO_4 + H_2SO_4 \rightarrow MnSO_4 + Fe_2(SO_4)_3 + K_2SO_4 + H_2O$

b) $KMnO_4 + K_2SO_3 + KOH \rightarrow K_2MnO_4 + Na_2SO_4 + H_2O$

c) $KMnO_4 + KNO_2 + H_2O \rightarrow MnO_2 + KNO_3 + KOH$

d) $KMnO_4 + KNO_2 + KOH \rightarrow K_2MnO_4 + KNO_3 + H_2O$

e) $KMnO_4 + H_2S + H_2SO_4 \rightarrow MnSO_4 + S + K_2SO_4 + H_2O$

f) $K_2Cr_2O_7 + Na_2SO_3 + H_2SO_4 \rightarrow Cr_2(SO_4)_3 + Na_2SO_4 + K_2SO_4 + H_2O$

g) $Cr_2O_3 + NaNO_3 + KOH \rightarrow K_2CrO_4 + NaNO_2 + H_2O$

i) $K_2Cr_2O_7 + H_3PO_2 + H_2SO_4 \rightarrow Cr_2(SO_4)_3 + H_3PO_4 + K_2SO_4 + H_2O$

j) $Bi_2O_3 + Br_2 + KOH \rightarrow KBiO_3 + KBr + H_2O$

k) $K_2Cr_2O_7 + NaClO + HNO_3 \rightarrow Cr(NO_3)_3 + NaClO_3 + KNO_3 + H_2O$

**2.** Balance the following redox reactions using the half-reaction method. Calculate the standard EMF and indicate whether spontaneous redox reactions are possible under standard conditions:

a) $KMnO_4 + KBr + H_2SO_4 \rightarrow MnSO_4 + Br_2 + K_2SO_4 + H_2O$

b) $K_2Cr_2O_7 + K_2S + H_2SO_4 \rightarrow Cr_2(SO_4)_3 + S + K_2SO_4 + H_2O$

c) $KMnO_4 + FeSO_4 + H_2SO_4 \rightarrow MnSO_4 + Fe_2(SO_4)_3 + K_2SO_4 + H_2O$

d) $K_2Cr_2O_7 + NaI + H_2SO_4 \rightarrow Cr_2(SO_4)_3 + I_2 + Na_2SO_4 + K_2SO_4 + H_2O$

**3.** Write formulas for micelles of prepared sols according to the following reactions:

a) $Pb(NO_3)_2 + 2NaCl \rightarrow PbCl_2 + 2NaNO_3$ ($Pb(NO_3)_2$ is the excess)

b) $Pb(NO_3)_2 + 2NaCl \rightarrow PbCl_2 + 2NaNO_3$ (NaCl is the excess)

c) $Ba(NO_3)_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaNO_3$ ($Na_2SO_4$ is the excess)

d) $Ba(NO_3)_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaNO_3$ ($Ba(NO_3)_2$ is the excess)

e) $H_2S + ZnCl_2 \rightarrow ZnS + 2HCl$ ($H_2S$ is the excess)

f) $H_2S + ZnCl_2 \rightarrow ZnS + 2HCl$ ($ZnCl_2$ is the excess)

g) $FeCl_3 + 3NaOH \rightarrow Fe(OH)_3 + 3NaCl$ ($FeCl_3$ is the excess)

h) $FeCl_3 + 3NaOH \rightarrow Fe(OH)_3 + 3NaCl$ (NaOH is the excess)

i) $2AsCl_3 + 3Na_2S \rightarrow As_2S_3 + 6NaCl$ ($AsCl_3$ is the excess)

j) $2AsCl_3 + 3Na_2S \rightarrow As_2S_3 + 6NaCl$ ($Na_2S$ is the excess)

**4.** Write formulas for the following complex compounds:

a) potassium bromopentanitroplatinate (IV);

b) tetraamineaquadichlorocobalt (III) chloride;

c) sodium hexacyanochromate (III);

d) diamminetetrachloroplatinum (IV);

e) sodium tetrahydroxoplumbate (II);

f) potassium tetracyanoaurate (III).

Write equations for primary and secondary dissociation of the following coordination compounds. Write expressions for $K_{ins}$ of their complex ions.

## LIST OF SOURCES USED

1. Medical chemistry : textbook for students of higher education establishments – med. univ., inst. and acad. / V.O. Kalibabchuk, V.I. Halynska, L.I. Hryshchenko et al. ; ed. by V.O. Kalibabchuk. – 6th ed., corr. – Kyiv : AUS Medicine Publishing, 2018. – 224 p.

2. Основы химии для иностранных студентов = Essential chemistry for foreign students : учебно-методическое пособие / С. В. Ткачёв [и др.]. – 5-е изд. – Минск : БГМУ, 2018. – 168 с. – Режим доступа: http://rep.bsmu.by:8080/handle/BSMU/21054.

3. Филиппова, В. А. Общая химия : учеб. пособие для студентов лечеб. факта, обуч. на англ. яз. : в 2 ч. = General Chemistry : Educational guaidance for students medical department in English medium / В. А. Филиппова, А. В. Лысенкова, Л. В. Чернышева. – Гомель : ГомГМУ, 2009. – Ч. 1. – 192 с. URI: https://elib.gsmu.by/handle/GomSMU/2679.

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А. Филиппова, А. В. Лысенкова, Л. В. Чернышева. – Гомель : УО «Гомельский государственный медицинский университет», 2013. – 180 с. – URI: http://elib.gsmu.by/handle/GomSMU/10939.

5. Methodological manuals for conducting classes with the first-year students of the Faculty of International Students in Medical Chemistry – No. 1−17. – Gomel, 2023.