KHARKOV NATIONAL MEDICAL UNIVERSITY
DEPARTMENT OF MEDICAL AND BIOORGANIC CHEMISTRY

STUDENTS WORKBOOK

In Medical Chemistry

Student______________________________

Group_______________________________

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The Workbook is composed strictly in accordance with the prescribed syllabus. It includes questions and laboratory works in all basic topics in Medical Chemistry according to ECTS: chemistry of biogenic elements, complex compounds, properties of solutions, fundamentals of titrimetric analysis, electrochemistry, bioenergetics and kinetics of biochemical processes, surface phenomena, properties of colloidal solutions, and solutions of high-molecular-weight compounds. The workbook is for students of the medical faculty.

INTRODUCTION

Dear students,

Future specialists-physicians training starts with studying such fundamental sciences as biology, physics, chemistry and others. These disciplines studying forms theoretical basis for mastering modern methods of investigations in biology and medicine, which will help future doctors to solve successfully the tasks of practical care of public health and to prevent diseases rather than to treat them.

The course of medical chemistry acquaints students with physico-chemical laws on the basis of which a number of processes taking place in the living organism can be investigated, for example, stability of osmotic pressure, blood pH, the causes of bio-potentials formation, factors of stability of dispersed systems of the organism, etc.

The course of medical chemistry consists of lectures and laboratory practical classes as well as of students self-work. The latter is the most important way to get knowledge. The given textbook will help you to organize your self-work the most effectively. We wish you success!

WORK SAFETY

1. The students are not allowed to wear overcoats at the department.
2. The students should wear white gowns in the classes.
3. During the work the students should keep silence, be neat, accurate, they shouldn’t be hasty.
4. The students working in the laboratory should not be admitted by outsiders.
5. The students are forbidden to perform the work, which is not connected with the subject of the lesson.
6. Before starting the work it is necessary to learn the technique of the work, to check if the equipment is fitted properly and the substances taken correspond to those in the description of the work.
7. When a solution is heated in a tube take care to direct the opening away from the working student and from those standing nearby.
8. Do not stoop over the liquid being heated to avoid splashes to the face.
9. When determining the odor of the substance direct the air current from the vessel with a light movement of the hand. Carefully breath in a small amount of the air.
10. Diluting alkali and concentrated acid, add the alkali or acid to the water, not vice versa.
11. After finishing the work, wash the chemical utensils, turn of the water, gas, electric appliances and tidy your working place.
12. After finishing the work in the laboratory, wash your hands carefully.

MODULE 1
ACID-BASE EQUILIBRIA AND COMPLEX FORMATION IN BIOLOGICAL LIQUIDS
(SUBJECTS 1 – 11)

INFORMATIVE MODULE 1
CHEMISTRY OF BIOGENIC ELEMENTS
COMPLEX FORMATION IN BIOLOGICAL LIQUIDS
(SUBJECTS 1-2)

Purposes:
- To explain correlation between biological role of biogenic s-, p- and d-block elements and their form in the organism;
- To explain principles of complex compounds structure;
- To interpret peculiarities of complex compounds structure as a basis for use in chelatotherapy.

SUBJECT 1. STRUCTURE OF CHEMICAL SUBSTANCES

Characteristic of the subject

Functions of compounds in the living organisms depend on their composition and structure. Chemical processes in the organism proceed in water medium, that’s why it is necessary to be able to predict behavior of compounds upon dissolution in water. The aim of the subject is to recall atomic structure, nature of chemical bond and to consider some questions needed for the following subjects of the Medical chemistry course.

Objectives

1. Structure of atom.
2. Mechanism of formation of covalent bonds.
3. Valence and oxidation state.
4. Ionic bond
5. Electrolytic dissociation. Strong and weak electrolytes.
6. Activity of ions.
7. Degree of dissociation and dissociation constant.
8. Ionic strength of solution.

Practical skills

1. To be able to write electronic formulae of atoms and to explain mechanism of formation of covalent bond.
2. To be able to determine valence and oxidation state of elements in the compounds.
3. To be able to show the mechanism of formation of ionic bond.
4. To be able to explain mechanism of electrolytic dissociation.
5. To know about activity of ions in strong electrolytes solutions.
6. To understand the relation between degree of dissociation and dissociation constant.
7. To be able to calculate ionic strength of solution.

Questions for class work and self work

1. Write the electronic configurations of atoms of the following elements:

Hydrogen____
Nitrogen ____
Sodium____
Chlorine____

2. Show the mechanism of formation of chemical bond in compounds:

Cl_2____
N_2____
HCl____
NH_4^+____

3. Determine valence and oxidation state of elements in compounds given in question 2.

4. Show the mechanism of bond formation in sodium chloride. Write electronic configurations of Na^+ and Cl^- ions.

5. Show the mechanism of electrolytic dissociation of NaCl, HCl and CH_3COOH.

6. What is degree of dissociation? What are the values of degree of dissociation for strong and weak electrolytes?

7. On example of acetic acid show the relation between degree of dissociation and dissociation constant (Ostwald`s dilution law).

8. What is activity of ions? How does it relate with concentration of ions?

SUBJECT 2. COMPLEX FORMATION IN BIOLOGICAL SYSTEMS

Characteristic of the subject

Coordination compounds (complexes) are widely present in the minerals, plants and animals and play many important functions. Many biologically important compounds are coordination compounds in which complicated organic species are bound to metal ions. The common examples are: haemoglobin which is coordination compound of iron, chlorophyll which is coordination compound of magnesium, etc.

Objectives

1. Fundamentals of the A. Werner's coordination theory.
2. Classification and nomenclature of complex compounds.
3. Theory of the chemical bond in complex compounds.
4. Geometry of the complex ion.
5. Equilibriums in water solutions of complex compounds.
6. Constant of instability.
7. Polynuclear complexes.
8. Biocomplex compounds
9. Metal-ligand homeostasis.
10. Complex compounds in nature and in medicine.

Practical skills

1. To be able to determine the type of the complex compound.
2. To be able to name the complex compound.
3. To be able to write the equation of the complex ion dissociation.
4. To be able to write the equation of the constant of instability of the complex ion.
5. To be able to determine the oxidation state of the complexing agent (central ion), the charge of complex ion, coordination number.
6. To know the application of complexons in medicine.

Questions for class work and self work

1. Give the definition of complex compounds. Define the terms: compexing agent, ligands, inner coordination sphere and outer coordination sphere. Explain the structure of complex compounds on example of $K_3[Fe(CN)_6]$ and $[Pt(NH_3)_2Cl_2]$

2. a) Which of the following particles can serve as ligands? Classify them:
SO_4^{2-}, Co^{3+}, F^-, CO_3^{2-} , Ni^{2+}, Cl^-, H_2O, Br^-, NH_3, OH^-

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b) Which of the following particles can serve as complexing agents? Ni^{+}, Fe^{3+}, Na^{+}, Cl^{-}, Fe^{2+}, NO_2^{-}, F^{-}

3. Show the mechanism of formation of bond between complexing agent and ligands in the complex ion $[Ag(NH_3)_2]^{+}$.

4. Give the classification of complex compounds. Determine the type of the following compounds and the charge of complex ion:

$[Cu(NH_3)_4]SO_4$____

$Na_2[Cu(OH)_4]$____

$[Ni(CO)_4]$____

5. What is the charge of complex ion in the following compounds?

$[Co^{+3} (NH_3)_4 (NO_2)_2]^{x}$____
$[Ti^{+3}(H_2O)_6]^{x}$____
$[CoF_6]^{x}$____

6. Indicate the coordination number and oxidation state of the central ion in the following complexes:

$[Pt(NH_3)_2Cl_4]$____
$Na[Ag(CN)_2]$____
$[Co(NH_3)_4Cl_2]NO_3$____

7. Name following substances:

a) $K_4[Ni(CN)_6]$____
and $Na[Co(NO_2)_4(NH_3)_2]$ ____

b) $[Zn(NH_3)_4](NO_3)_2$____
and $[Cr(H_2O)(NH3)_4Cl]Cl_2$____

c) $[Pt(NH_3)_2Cl_4]$____
and $[Cu(H_2O)Br_3]$____

8. Write the dissociation equation and expression of K_{diss} for the compound $K_4[Fe(CN)_6]$:

9. Write the expression of the K_{inst} for complex ions of the following complexes:

a. $Na_3[Cr(OH)_6]$

b. $[Co(H_2O)_4Cl_2]Cl$

10. In which solution the concentration of mercury ions is greatest?
a) sol. of $K_2[HgCl_4]$; $K_{inst}=10^{-23}$ ____
b) sol. of $K_2[HgBr_4]$; $K_{inst}=10^{-11}$ ____
c) sol. of $K_2[HgI_4]$; $K_{inst}=10^{-8}$ ____

11. What are chelates? What are intracomplex compounds? Characterize complexons which are used in medicine as antidotes.

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INFORMATIVE MODULE 2
ACID-BASE EQUILIBRIA IN BIOLOGICAL LIQUIDS
(SUBJECTS 3-11)

Purposes:
- To be able to characterize quantitative composition of solutions;
- To be able to prepare solutions of given composition;
- To analyze principles of titrimetric methods;
- To analyze quantitative content of acids and bases in solutions by means of acid-base titration methods;
- To make conclusions about acidity of biological liquids on the basis of pH
- To explain the mechanism of buffer action and ability of buffers to maintain acid-base equilibrium;
- To analyze correlation between colligative properties and solutions concentration.

SUBJECT 3. VALUES CHARACTERIZING QUANTITATIVE COMPOSITION OF SOLUTIONS. PREPARATION OF SOLUTIONS

Characteristic of the subject

Solutions concentration is their quantitative characteristic. Ability to estimate the concentration includes several methods of expression and is very important in the study of pharmacology, normal and pathological physiology and clinical subjects.

Objectives

Studying the subject it is necessary to get acquainted with the following concepts:
– Mass percent
– Molarity
– Molality
– Molar concentration of the equivalent (normality)
– Titer of solutions
– Mole fraction

Practical skills

To be able to calculate and prepare solutions of different concentrations.

Questions for class work and self work

1. Give the definition of mass percent (percent concentration).

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2. Calculate the masses of water and iodine needed to prepare iodine solution where $\omega(I_2) = 10\%$. The mass of the solution is 500 g.

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3. Give the definition of molar concentration.

4. 200 ml of a solution were prepared with 21.1 g of sodium carbonate. Calculate the molar concentration.

5. Give the definition of molality.

6. 36 g of glucose were dissolved in 500 ml of water. Find the molality of glucose in the solution.

7. Give the formula used for the determination of the equivalent molar concentration.

8. How to determine the equivalence factor of acids, bases, salts and their molar mass of the equivalent?

9. 500 ml of a solution contains 4.9 g of sulfuric acid. Calculate the molar concentration of the sulfuric acid equivalent (normality).

10. What is titer? Calculate the titer of sulfuric acid solution using the data from previous task.

11. Calculate the molar concentration of a solution where the mass percent of calcium chloride is 20 % and the density of the solution is 1.178 g/ml.

12. Calculate molar concentration of the equivalent of sulfuric acid solution if molarity is 0.5 mol/L.

13. Give the definition and formula for mole fraction calculation.

14. Calculate mole fraction of glucose in the 20% solution.

SUBJECT 4. COLLIGATIVE PROPERTIES OF SOLUTIONS

Characteristic of the subject

Human organism is a complex system where ions, molecules and colloidal particles of various substances are present in the dissolved state. A large number of solutions properties depend not on the nature of the dissolved substances but on the thermal movement of particles, i.e. are determined by the quantity of the kinetic units of the system. Such qualities are called colligative. Diffusion and osmosis being colligative properties play a great part in the physiological processes of an organism. Food assimilation and metabolism are closely connected with the permeability of cellular membranes for water and dissolved substances.

Osmotic pressure is a mechanism supplying cells with nutrients and water. Osmotic pressure in the different organs and tissues of higher animals is almost identical and equals 700—800 kPa. Some deviation is quickly eliminated by regulating mechanisms such as changes in quality and composition of the exerted saliva and urine. To have a good knowledge in this subject is necessary for a future doctor for better understanding a large number of processes taking place in a human organism as well as to understand what physiological and hypertonic solutions should be used for.

Osmometry, ebulliometry, and cryometry allow determining molar masses of different substances which cannot be determined by other methods.

Objectives

1. The role of water and water solutions in the vital activity of the living organisms.
2. Colligative properties of solutions:

a) Raoult’s law and its corollaries;
b) Diffusion and osmosis;
c) Osmotic pressure;
d) Causes of the divergence from van’t Hoff’s and Raoult’s laws in the electrolyte solutions;
e) Theoretical basis of osmometry, cryometry, ebulliometry.
f) The peculiarities of osmosis in the living organism.

Practical skills

After studying the subject students are to be able
– To calculate osmotic pressure, solution depression and molar weights of physiologically active substances on the base of P_{osm} and depression.
– To classify solutions according to the values of their osmotic pressure.
– To make a prognosis of the processes taking place in a cell when placing it to the hypotonic, isotonic or hypertonic solution.

Questions for class work and self work

1. What are colligative properties? Name them.

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2. State Raoult’s law. Give its mathematical expression. Explain phenomena of change of boiling and freezing points of solutions in comparison with the pure solvent.

3. 46 g of glycerin were dissolved in 100 g of water. What is a freezing point of this solution? $M(C_3H_5(OH)_3) = 92$ g/mol; $T_f(H_2O) = 273.15$ K; $K_f = 1.86$ kg·K/mol.

4. Depression in freezing point of non-electrolyte solution containing 29.5 g of a substance in 100 g of water is 1.6 K. Determine the molar weight of the substance. (Cryometry).

5. **Osmosis.** 10 % solution of sodium chloride is on the first side of the semipermeable membrane separating the vessel and 2 % solution of sodium chloride is on its other side. Describe the process taking place there.

6. Give the definition of the osmotic pressure.

How to calculate the value of osmotic pressure (Van`t Hoff`s law)?

What is the value of normal osmotic pressure of blood?

What is oncotic pressure?

7. Calculate the osmotic pressure of 5 % glucose solution and the osmotic pressure of 0.2 %, 0.9 % and 10 % sodium chloride solutions on the base of Van’t Hoff’s law (d = 1.1 g/ml for 10 % NaCl).

8. Compare the values obtained in task 7 with Posm. of the blood. How do we call solutions where the values of osmotic pressure are higher or lower than the standard one or are equal to it?

9. An erythrocyte is placed into the following solutions: a) 0.5 % NaCl solution; b) 0.9 % NaCl; c) 5 % glucose solution; d) 10 % NaCl solution. Name the phenomena taking place in a cell and describe them.

10. Calculate the molar weight of hemoglobin, if the osmotic pressure of hemoglobin in water containing 124 g/L of a substance equals 4.40 kPa at t = 17 °C. (Osmometry).

Demonstration experiment
The rise of Traube’s «artificial cell»

Pour 5 ml of 5 % $CuSO_4$ solution into the flask and carefully place there a small crystal of potassium ferrocyanide (don’t shake). Make a sketch of the new formation, which looks like an alga in an hour. Explain the phenomenon.

SUBJECT 5. ACID-BASE EQUILIBRIUM IN THE ORGANISM.
pH OF BIOLOGICAL LIQUIDS

Characteristic of the subject

All biological liquids are water solution with a given rate of pH. Studying of pH of biological liquids enables to determine pathological phenomena taking place in an organism and to prevent diseases.

Objectives

1. Ion product of water.
2. pH is a measure of the medium active acidity.
3. Calculation of pH in solutions of strong and weak acids and bases.
4. Calculation of pH in solutions of salts.

Practical skills

– to make the pH calculation in the solutions of acids, bases and salts;
– to determine the concentration of hydrogen ions according to the pH value;
– to use the knowledge of this subject for the estimation of medium acidity of biological fluids (blood, gastric juice, urine, etc.).

Questions for class work and self work

1. Write the dissociation equations of the following substances: HNO_3, CH_3COOH, NaOH, $Ca(OH)_2$, NH_4OH, H_2CO_3, Na_2SO_4, H_2O. What is the strength of these electrolytes? Give definition of degree of dissociation and dissociation constant.

2. What does it mean «active acidity»? Are active and total acidities the same in the solution of:

a) a strong acid ____
b) a weak acid ____

3. What is pH? Write formulae for pH calculation in strong and weak acids and bases solutions.

4. What is the pH value of:
blood________________; saliva________________;urine___________; gastric juice_________?
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What is acidosis; what is alkalosis?
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Indicate the pH of gastric juice for the following cases:
«hypoacidity» ____
«zero acidity» ____
«hyperacidity» ____

5. What is the pH of a 0.05 M solution of HCl? What is the pH of a 1M solution of CH_3COOH if $K(CH_3COOH)=1.8\cdot10^{-5}$?

6. What is the pH of a 0.03 M solution of NaOH? What is the pH of a 0.01M solution of NH_4OH if $\alpha=0.042$?

7. Determine the concentration of hydrogen ions in the blood if pH = 7.35.
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8. Determine the concentration of hydroxyl groups in the solution of potassium hydroxide if pH = 12.0.
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9. There are two samples of gastric juice. The content of hydrochloric acid in one of the samples is 0.1 %, in the other is 0.2 %. In which solution the pH value is higher?
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10. There are two solutions of hydrochloric and acetic acids with the identical molar concentrations. In which solution the pH value is higher?

11. Write the hydrolysis reactions for salts which undergo hydrolysis in the ionic and molecular forms: NH_4Cl, K_2CO_3, KCl, CH_3COONH_4. Predict whether aqueous solutions of these salts are acidic, neutral, or basic. Write the formulae for pH calculation in salts solutions.

SUBJECT 6. BUFFER SOLUTIONS, CLASSIFICATION AND MECHANISM OF ACTION

Characteristic of the subject

The pH value of the internal media of the organism is characterized by a significant constancy and stability. For example, blood pH of the human being is constant in the interval 7.35—7.45. A small change of the pH value causes significant changes in the activity of the organism. Stability of the organism's pH systems is a pledge of its normal vital activity. In many cases monitoring of this value enables to find out different pathologies and to make a right diagnosis. Working properly the organism keeps the acid-base equilibrium (pH) of the internal media due to the physiological (kidneys, liver, lungs, bowels) and physico-chemical (buffer systems of the organism) mechanisms of compensation.

Objectives

1. Buffer systems, mechanism of action.
2. pH calculation of buffer systems.

Practical skills

After studying the subject the student is to be able:

1. To characterize the mechanism of buffer action.
2. To calculate the pH value of buffer solution by its composition and the buffer solution composition using the given pH value.
3. To determine the change in pH of buffer system after addition of strong acid or base.

Questions for class work and self work

1. Define buffer solutions.

2. Composition of buffer systems. Which of the following mixtures posses buffer activity?

a) HNO_3; NH_4NO_3 ____________________
b) H_2CO_3; $KHCO_3$ ____________________
c) H_2CO_3; $(NH_4)_2CO_3$ ____________________
d) NH_4OH; NH_4HSO_4 ____________________.

3. Illustrate the buffering action of acetic and ammonium buffer systems.

4. Write the Henderson's equation for the calculation of pH of buffer systems.

5. Calculate the pH value of buffer solution obtained by mixing 300 ml of NH_4Cl solution where $C(NH_4Cl) = 0.1$ mol/L with 150 ml of $NH_3 \cdot H_2O$ solution where $C(NH_3) = 0.2$ mol/L, $K(NH_3 \cdot H_2O) = 1.8 \cdot 10^{-5}$.

6. Determine the pH value of buffer solution prepared of 150 ml of CH_3COOH solution where $C(CH_3COOH) = 0.1$ mol/L and 250 ml of CH_3COONa solution where $C(CH_3COONa) = 0.2$ mol/L. $K(CH_3COOH) = 1.8 \cdot 10^{-5}$.

What will be the change of the pH value of this buffer after addition of 6 ml of NaOH solution where $C(NaOH) = 0.1$ mol/L.

7. Calculate the volumes of acetic acid solution with $C(CH_3COOH) = 0.2$ mol/L and sodium acetate solution with $C = 0.2$ mol/L which ought to be mixed in order to obtain 400 ml of buffer solution with pH = 5.24. $K(CH_3COOH) = 1.8 \cdot 10^{-5}$.

8. There are two acetic buffer solutions. The pH value of one of them is 4.2, of the other one is 5.2. Which of the above solutions is more stable when acids are added; which one is stable when bases are added?

Laboratory work

«The investigation of the properties of buffer solutions by means of potentiometry»

The essence of the method

A buffer solution is one that resists a change in its pH even when a strong acid or a base is added to it. Buffer solution contains weak acid and its salt of a strong base (e.g. CH_3COOH and CH_3COONa) or weak base and its salt of a strong acid (e.g. NH_4OH and NH_4Cl).

Acetic buffer consists of acetic acid and sodium acetate, phosphate buffer consists of sodium dihydrogen phosphate (acid) and sodium hydrogen phosphate (salt). The following reactions take place if HCl or NaOH solutions are added to the acetic or phosphate buffer solutions:

$$CH_3COO^- + H^+ \rightarrow CH_3COOH \qquad HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-$$

$$CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O \qquad H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O$$

Buffer solutions are made of the equimolar solutions of corresponding acid (base) and its salt. pH of buffer solutions is measured with a pH-meter before and after the addition of acid and base solution.

The operation process

1. Calculate the volume of ______________ and volume of _______________ in order to prepare 20 cm^3 of _________________ buffer solution whith pH = ____________.
2. Measure proper volumes of solutions by means of burette, add to a glass and mix up carefully.
3. Measure pH of the prepared buffer solutions by means of pH-meter. Don't pour out the solution.
4. Pour 5 ml of the buffer solution to the measuring flask and add distilled water up to 50 ml. (dilution). Divide the remaining solution into two equal portions. Pipette 1 cm^3 of HCl solution (the molar concentration of the equivalent is 0.01 mol/dm^3) to the first portion and 1 cm^3 of NaOH solution of the same concentration to the other one.
5. Measure pH of the obtained solutions with the pH-meter and note down the data to the table:

Solution	pH rates	
	Calculated data	Measured data
Initial buffer solution		
Diluted solution		
The solution after the HCl addition		
The solution after the NaOH addition		

The experimental data processing

1. pH rate calculation after the addition of a strong acid:

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2. pH rate calculation after the addition of a strong base:

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3. pH rate calculation after dilution:

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Conclusions

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Date ______________________ Signature_____________________

SUBJECT 7. ROLE OF BUFFERS IN BIOLOGICAL SYSTEMS, BUFFER CAPACITY DETERMINATION

Characteristic of the subject

Buffer systems of the organism maintain acid-base equilibrium of the blood on the constant level which is necessary for normal vital activity. Buffer solutions are widely used in biomedical researches as the constant pH level is very important in the course of many reactions. Buffer capacity being a quantitative measure of buffer action is an important parameter of the organism status.

Objectives

1. Composition, mechanism of action and importance of the basic buffers of the organism.
2. Buffer capacity and factors which it depends on.

Practical skills

After studying the subject the student is to be able:

1. To characterize the mechanism of organism's buffers action.
2. To calculate the buffer capacity.
3. To prepare buffer solution and determine its pH by means of potentiometry method.

Questions for class work and self work

1. Write the composition of the most important buffer systems of the organism.

2. Show the mechanism of buffering action of phosphate and carbonic acid-bicarbonate buffer systems.

3. What is the buffering action of aminoacids and proteins? Describe the concept of isoelectric point (pI).

4. What is the pI value of ribonuclease enzyme if the protein contained in the ammonium buffer solution prepared of 63.3 ml of NH_4Cl where $C = 0.1$ mol/L and 100 ml of NH_4OH where $C = 0.4$ mol/L ($C_{bas} = 1.8 \cdot 10^{-5}$) doesn't move to any poles during the electrophoresis?

5. What is buffer capacity? Which factors does it depend on?

6. To change the pH value from 7.36 to 7.00 it is necessary to add 36 ml of HCl with C(HCl) = = 0.05 mol/L to 100 ml of blood. Calculate the buffer capacity of blood.

7. Phosphate buffer systems contain 0.02 M solutions of Na_2HPO_4 and NaH_2PO_4 taken in the following proportions:
1) 10 ml of $Na_2HPO_4$and 20 ml of Na_2HPO_4
2) 20 ml of Na_2HPO_4 and 30 ml of Na_2HPO_4
3) 40 ml of Na_2HPO_4 and 40 ml of Na_2HPO_4
Which of these solutions has the highest value of buffer capacity?

SUBJECT 8. FUNDAMENTALS OF TITRIMETRIC ANALYSIS

Characteristic of the subject

The purpose of titrimetric analysis is to determine the quantitative composition of the investigated substance. Methods of titrimetric analysis are widely used in medico-biological and hygienic investigations to make the analysis of biological liquids, drinking water and sewage, food, medicines, etc. To know the subject is necessary for a future doctor in order to solve a large number of scientific and practical questions.

Objectives

1. Law of equivalents.
2. The main concepts of volumetric analysis.
1) Operating solution (or titrant).
2) Investigated solution.
3) Titration.
4) Equivalence point.
5) Indicators.
3. The requirements for the reactions used in the process of volumetric analysis.
4. Classification of the methods of volumetric analysis.
1) Neutralization method.
2) Oxidimetry method.
3) Precipitation method.
4) Chelatometric analysis method.
5. Operating solutions (standard and standardized solutions).
6. The requirements for a standard substance.
7. Measuring vessels used for volumetric analysis.
8. Titration technique and the determination of the equivalence point.

Practical skills

After studying the subject a student should be able (using the law of equivalents for making calculations during volumetric analysis):

1. To determine the molar weight of the equivalents.
2. To write down the law of equivalents for every couple of interacting substances.
3. To calculate the mass of weighted portion necessary to prepare a definite volume of operating solution with the given molar concentration of the equivalent.
4. To calculate the molar concentration of the equivalent according to the mass of weighed portion of a substance taken in the definite volume.
5. To calculate the molar concentration of the equivalent and the titer of the investigated solution according to the results of titration.
6. To determine the purity of preparation i.e. the mass fraction of the main substance in the initial weighed portion or in the solution according to the results of titration.

Questions for class work and self work

1. Give mathematical expression of law of equivalents.

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2. Define fundamental terms of titrimetric analysis:

- titration ____

- investigated solution____

- operating solution____

a) standard solution ____

b) standardized solution ____

- equivalence point ____

3. Is it possible to prepare a standard solution using accurate portions of NaOH and H_2SO_4?

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4. What is the essence of neutralization method (acid-base titration)?

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5. What is the meaning of the terms: titration curves, titration jump? How to determine the equivalence point according to the titration curve?

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6. Why the titration jump for different cases of titration is shifted to the acidic or alkaline area, or covers both acidic and alkaline areas? What is the medium for titration jump when
a) a strong acid is titrated against a strong base;
b) a weak acid is titrated against a strong base;
c) a strong acid is titrated against a weak base?

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7. Define indicators used in neutralization method. How to choose the indicator?

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8. Which indicator should be taken during the titration of $H_2C_2O_4 \cdot 2H_2O$, CH_3COOH, HCl, HNO_3, H_2SO_4 with caustic soda and why?

9. 8 ml of NaOH solution were used to titrate 10 ml of $H_2C_2O_4 \cdot 2H_2O$, $C(1/2\ H_2C_2O_4 \cdot 2H_2O) = 0.05$ mol/L. Calculate C(NaOH) and T(NaOH).

SUBJECT 9. NEUTRALIZATION METHOD

Laboratory work
«Standardization of the operating solution of NaOH»

The essence of the method

Acid-base titration method — is one of the methods of volumetric analysis. As NaOH doesn't meet the requirements for standard substances (it's hygroscopic, has admixtures), a prepared solution should be titrated against standard solution. As standard solution in this case oxalic acid may be used.

$$H_2C_2O_4 + 2NaOH \rightarrow Na_2C_2O_4 + 2H_2O$$

The molar concentration of the equivalent and the titer can be estimated according to the results of titration, i.e. this is the **standardization of the operating solution.**

Phenolphthalein can be used as the indicator.

The operation process

1. Rinse a clean burette with the operating alkaline solution and then fill it in with the same solution - the lower meniscus must be at zero mark.
2. Pipette 5cm^3 of the standard solution of the oxalic acid to the titration flask. Add two drops of the indicator and rinse the walls of the flask with water.
3. Titrate it against NaOH solution adding it from the burette and mixing constantly up to the moment when light-pink coloration will appear. The volume of NaOH solution used for the titration (V(NaOH)) should be noted down then.
4. The titration process should be carried out till three coincided results will be obtained. The data of the titration should be noted down to the table:

The results of the titration		The results of the calculation
V($H_2C_2O_4$), cm^3	V(NaOH), cm^3	
V1 = 5,00	V1 =	C($1/2H_2C_2O_4 \cdot 2H_2O$) =
V2 = 5,00	V2 =	C(NaOH) =
V3 = 5,00	V3 =	T(NaOH) =
	Vav =	

Take the average rate of the volume of NaOH solution used for the titration for the determination of molar concentration of equivalent of NaOH solution.

The experimental data processing

1. The calculation of the molar concentration of equivalent of standard solution of oxalic acid, if there is m = ___________ g in V = ____________ cm^3 of solution:

$$C(\frac{1}{2}H_2C_2O_4 \cdot 2H_2O) = \frac{m(H_2C_2O_4 \times 2H_2O)}{M(\frac{1}{2}H_2C_2O_4 \times 2H_2O)\quad V(H_2C_2O_4 \times 2H_2O)} = \quad mol/dm^3$$

2. The calculation of the molar concentration of equivalent and the titer of NaOH solution:

$$V(NaOH) \times C(NaOH) = V(H_2C_2O_4 \cdot 2H_2O) \times C(1/2H_2C_2O_4 \cdot 2H_2O)$$

$$C(NaOH) = \frac{\tilde{N}(\frac{1}{2}H_2C_2O_4 \times 2H_2O) \cdot V(H_2C_2O_4 \times 2H_2O)}{V_{av}(NaOH)} = \qquad mol/dm^3$$

$$T(NaOH) = \frac{C(NaOH) \times M(NaOH)}{1000} = \qquad g/cm^3$$

Conclusions

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Date ____________________ Signature ____________________

SUBJECT 10. GASTRIC JUICE ACIDITY DETERMINATION

Laboratory work
«Gastric juice acidity determination»

The essence of the method

Gastric juice contains hydrochloric acid, organic acids, acid salts and enzymes. The acidity of gastric juice can be expressed in titrimetric (clinical) units: the quantity of NaOH solution in cm3 with 0,1 mol/cm3 of the molar concentration used up to titrate 100 cm3 of gastric juice.

The content of free hydrochloric acid and the total acidity of gastric juice are determined during the clinical analysis. In order to do this, two indicators - methyl orange and phenolphthalein should be added to the gastric juice volume we are going to determine. Methyl orange colored the solution in bright red in the presence of HCl. The sample is being titrated by NaOH solution till it becomes orange. The amount of the alkali used up is equal to the hydrochloric acid content in the gastric juice sample. Then the titration with the same solution is going on till the coloration will change from yellow to crimson due to the phenolphthalein presence. The total volume of NaOH solution determines the total acidity of gastric juice.

A standard **total acidity** of gastric juice equals 40—60 titrimetric units and the content of free hydrochloric acid (**actual acidity**) is 20—40 units. If the result exceeds the normal value it is called a **hyper acidity**, if the result is less than a normal value it is called a **hypo acidity.**

The operation process

1. Rinse a clean burette with the operating alkaline solution and then fill it in with the same solution — the lower meniscus must be at zero mark.
2. Take 5 cm^3 of the investigated solution of gastric juice and transfer it to the titration flask. Then add two drops of the indicators: methyl orange and phenolphthalein.
3. Titrate it against NaOH solution adding it from the burette and mixing constantly up to the moment when orange coloration will appear. The volume of NaOH solution used for the titration (V_1) should be noted down then.
4. Continue the titration of this sample up to the color change through yellow to crimson and then note down the rate of NaOH solution volume used for the titration (V_2). The titration process should be carried out till three coincided results will be obtained. The data of the titration should be noted down to the table:

The results of the titration			**The results of the calculation**
Gastric juice V, cm^3	**V_1 (NaOH), cm^3**	**V_2 (NaOH), cm^3**	
V = 5,00	V_1 =	V_1 =	HCl_{free} (actual acidity) = The total acidity =
	V_2 =	V_2 =	
	V_3 =	V_3 =	
	V_{av} =	V_{av} =	

Take the average rate of the volume of NaOH solution used for the titration of the gastric juice sample for the determination of its acidity. The results will be expressed in **clinical units.**

The experimental data processing

1. As the molar concentration of NaOH operating solution equivalent doesn't correspond precisely to 0,1 mol/dm^3 value, the correction factor (K) should be calculated:

$$K = \frac{0,1}{C(NaOH)} =$$

2. The calculation of the gastric juice **actual acidity** (according to the free HCl content):

$$HCl_{free} = \frac{V_1(NaOH) \times 100}{V(\text{of the gustric juice}) \times K} = \qquad \text{units}$$

3. The total acidity of gastric juice calculation:

The total acidity = $\frac{V_2(NaOH) \times 100}{V(\text{of the gustric juice}) \times K} =$ units

Conclusions

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Date ________________________ Signature ______________________________

SUBJECT 11. TAP WATER HARDNESS DETERMINATION

Laboratory work
«Tap water hardness determination»

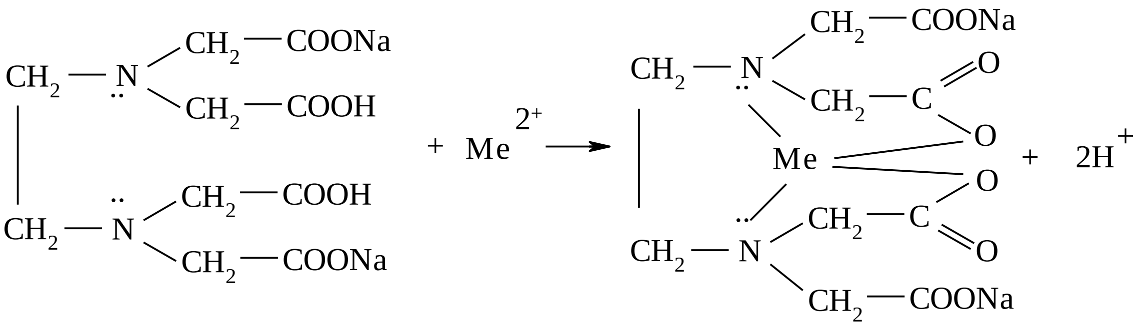
The essence of the method

The total water hardness (H) depends on the content of calcium and magnesium ions in water. The complexometric method of analysis is used to determine the quantity of these ions. It is based on the formation of complex compounds of various metals with the so-called chelates (complexones). Ethylenediaminetetraacetate should be referred to them and is used in the volumetric analysis as the operating solution. The ethylenediaminetetraacetate is often called **B trilon**. The reaction takes place in the presence of indicators - chromogen black or murexide. Ions of metals (Ca^{2+} and Mg^{2+}) form a complex with the indicator, which is less stable then a complex formed with B trilon. The complex of metal ion with the indicator is broken down in the process of titration, a new complex with B trilon is formed and the indicator is segregated in a free state. The indicator in the free state and the indicator combined with the metal ion are colored differently.

$$Me^{2+}+\underset{\text{blue}}{H_2Ind} \rightleftarrows \underset{\text{red}}{MeInd}+2H^+;\ \underset{\text{red}}{MeInd}+Na_2H_2Y \rightleftarrows Na_2MeY+\underset{\text{blue}}{H_2Ind}$$

As pH (pH = 8—10) influences the equilibrium of the reaction, the process of titration should be carried out in the ammonium buffer solution.

The interaction of B trilon with cations can be expressed by the following equation:



The water used for everyday necessities of life is suitable if its hardness is not more than 8 mmoles per dm^3.

The operation process

1. Fill the burette with the B trilon operating solution.
2. Transfer 5 cm^3 of fresh water used for the analysis to the titration flask. Add 2.5 cm^3 of ammonia buffer solution and two drops of the indicator.
3. Titrate the water against B trilon solution until the coloration changes from red to blue.

The titration process should last until tree coincided results (values) are obtained. Note down the data into the table.

The results of the titration		The results of the calculation
$V(H_2O)$, cm^3	V(B Trilon), cm^3	
V_1 = 5,00	V_1 =	$Ñ(1/2Na_2H_2Y)$ =
V_1 = 5,00	V_1 =	$H(H_2O)$ =
V_1 = 5,00	V_1 =	
	$V_{av.}$ =	

The experimental data processing

1. The calculation of the molar concentration of equivalent of standard solution of B trilon, if $M(Na_2H_2Y)$ = ______ and there are *m* = _____ g in *V* =_ ____ cm^3 of solution:

$$Ñ(1/2Na_2H_2Y) = \frac{m(Na_2H_2Y)}{M(1/2Na_2H_2Y) \times V(Na_2H_2Y)}$$

2. The calculation of water total hardness (the total sum of mmol equivalents of Ca^{2+} and Mg^{2+} ions per one liter of water):

$$H(H_2O) = \frac{C(1/2Na_2H_2Y)\text{mol/L} \times V_{av}(Na_2H_2Y)\text{ml}}{V(H_2O)\text{ml}} \times 1000 \qquad \text{mmol/dm}^3$$

Conclusions

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Date ________________________ Signature ______________________________

MODULE 2
EQUILIBRIA IN BIOLOGICAL SYSTEMS AT A PHASE INTERFACE
(SUBJECTS 14—24)

INFORMATIVE MODULE 3
THERMODYNAMIC AND KINETIC REGULARITIES OF PROCESSES AND ELECTROKINETIC PHENOMENA IN BIOLOGICAL SYSTEMS
(SUBJECTS 14-19)

Purposes:

– To be able to explain chemical and biochemical processes form the point of view of their heat effects;
– To be able to use thermodynamic functions for the estimation of processes direction, to explain energetic coupling in living systems;
– To analyze the dependence of reactions rate on concentration and temperature;
– To interpret the dependence of reaction rate on activation energy;
– To analyze peculiarities of catalysts action and to explain the mechanism of homogeneous and heterogeneous catalysis;
– To explain the mechanism of enzymes action and to analyze the dependence of enzymatic processes rates on enzyme and substrate concentrations;
– To analyze chemical equilibrium and to explain its conditions from thermodynamic and kinetic positions;
– To explain the influence of external factors on the chemical equilibrium;
– To analyze conditions of precipitates formation and dissolution, to explain the role of heterogeneous equilibria with participation of salts in the organism general homeostasis;
– To explain the mechanism of electrode potentials formation;
– To analyze principles of potentiometry method and to make conclusions as for use of this method in medico-biological researches;
– To know how to measure oxidation-reduction potentials and to predict direction of oxidation-reduction reactions.

SUBJECT 14. CHEMICAL THERMODYNAMICS. DIRECTION OF CHEMICAL REACTIONS. HEAT EFFECTS OF CHEMICAL REACTIONS

Characteristic of the subject

Metabolism is the sum total of the chemical and physical processes involving both the conversion of matter and energy within the living organism and the exchange of matter and energy between the organism and its environment. The most important property of life is perpetual metabolism. To gain a deeper insight into the essence of energy metabolism processes, one stands in need of referring to certain general aspects of thermodynamics.

Objectives

1. Basic concepts of chemical thermodynamics.
2. First law of thermodynamics. Enthalpy — is a state function of the system. Exothermic and endothermic processes.
3. Hess’s law — is the basic law of thermochemistry.
4. Second law of thermodynamics. Entropy, thermodynamic potentials.
5. Physico-chemical principles of homeostasis.

Practical skills

1. To be able to calculate the heat effect of chemical reaction by using enthalpies of combustion of reactants and products.
2. To be able to calculate caloricity of foodstuffs.
3. To be able to use thermodynamic functions for estimating the processes directions and explain energetic coupling in living systems.

Questions for class work and self work

1. Basic concepts of chemical thermodynamics.

What is *the system*? Describe types of systems and give examples.

Name *thermodynamic parameters*.

Name thermodynamic state functions. What is their main property?

2. State first law of thermodynamics.

3. Write reactions equations which heat effects correspond to the enthalpies of combustions of the following substances:

a) C_2H_5OH ____

b) $C_6H_{12}O_6$ ____

4. Calculate the heat effect of the following reaction:

$$C_6H_{12}O_6(s) \rightarrow 2\,C_2H_5OH(l) + 2CO_2(g)$$

$\Delta H°comb(C_6H_{12}O_6) = –2815$ kJ/mol

$\Delta H°comb(C_2H_5OH) = –1367$ kJ/mol

5. Calculate caloricity of 100g of nuts containing 16% of proteins, 67% of fats, and 10% of carbohydrates. Caloricity of proteins is 17 kJ/g, fats — 38 kJ/g, carbohydrates — 17 kJ/g.

6. State second law of thermodynamics. What is meant by entropy? What is the change in entropy during phase transition and in chemical reactions?

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7. What is Gibbs free energy? How it can be used for predicting the feasibility of a process?

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8. Predict whether the following reaction is spontaneous in the forward direction under standard conditions:
$2H_2 + O_2 \leftrightarrow 2H_2O$. How does the temperature influence the feasibility of reaction?

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9. What is the stationary state and homeostasis of biological system?

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10. Describe the mechanism of energetic coupling in biological systems.

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Table 1. Reference values of thermodynamic functions at T=298,15 K

Substance	Enthalpy of formation ΔH^0_f, kJ/mol	Entropy S, J/mol·K	Gibbs’ energy of formation ΔG^0, kJ/mol
Glucose$_{(s)}$	–1273,0		
Sucrose$_{(s)}$	-2220,9		
$CO_{2(g)}$	–393,5	213,6	–393,4
$H_2O_{(g)}$	–241,8	188,7	–228,8
$H_2O_{(l)}$	–285,8	69,96	–237,5
C_2H_5OH (l)	–277,8	160,7	-174,8
CH_3COOH (l)	-484,8	159,8	-392,5
C_6H_6 (l)	+49,04	173,2	124,5
$NH_{3(g)}$	–46,2	192,5	–16,5
C_2H_2 (g)	226,7	200,8	209,2
$CO_{(g)}$	–110,5	197,4	–137,3
$CaCO_3$	-1207,0	92,9	-1128,8
$H_3PO_{4(l)}$	–1271,9	200,8	-1147.25
$Ca_3(PO_4)_2$	-4125,0	240,9	-3899,5
$CH_3COOC_2H_5$	-628.7		

SUBJECT 15. KINETICS OF BIOCHEMICAL REACTIONS AND CATALYSIS

Characteristic of the subject

Sometimes it is very important to chose from a great number of medicinal preparations the doctor has got in his disposal that one the effectiveness of which is determined by the rate of chemical reactions occurring in the organism under the influence of this medicine. Biochemical reactions run in the organism under the influence of biological catalysts i.e. enzymes. Carefully studying of the subject will enable a future specialist to be well oriented in the variety of medicinal preparations.

Objectives

1. Basic concepts of chemical kinetics: reaction rate, reaction rate constant, etc.
2. Dependence of reaction rate on the concentration, temperature, nature of reactants and catalysts.
3. Order and molecularity of reaction, half life period.
4. Catalysis and catalysts. Kinetics and peculiarities of enzymatic reactions.

Practical skills

1. To be able to analyze dependence of reaction rate on the temperature, concentration of reactants and activation energy.
2. To be able to explain peculiarities of catalytic action.
3. To be able to describe action of enzymes and peculiarities of enzymatic reactions.

Questions for class work and self work

1. What does Chemical kinetics study?

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2. Which factors influence the rate of chemical reaction?

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3. State the Law of mass action. What are molecularity and order of a reaction? What is the difference between them? Give examples.

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4. What is meant by reaction rate constant? What does it depend on? ______________________

5. What is the dependence of reaction rate on temperature? State Van`t Hoff`s rule.

6. Write the rate expressions for forward and reverse reactions:

$$N_2 + O_2 \leftrightarrow 2NO$$

What will be the change in rates of reactions if:
a) concentration of nitrogen is doubled;
b) pressure is three times decreased;
c) temperature is increased by 30 degrees, ($\gamma = 2$)?

7. What does Theory of effective collisions postulate? What is activation energy? What is the relation between activation energy and nature of reacting substances? Write the Arrhenius equation.

8. Catalysis and catalysts. Give definitions and examples.

9. Describe peculiarities of enzymatic reactions. Which factors influence the rate of enzymatic reaction? Write the Michaelis-Menten equation.

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Laboratory work
«Study of chemical reaction kinetics»

Test 1. Influence of sodium thiosulfate concentration on the rate of thiosulfuric acid decomposition.

The essence of the method

Sulfuric acid reacts with sodium thiosulfate with formation of thiosulfuric acid according following steps:

$$Na_2S_2O_3 + H_2SO_4 \rightarrow H_2S_2O_3 + Na_2SO_4 \text{ (fast)}$$

$$H_2S_2O_3 \rightarrow S\downarrow + SO_2\uparrow + H_2O \text{ (comparatively slow)}$$

According to the chemical kinetics, in case of multi-step reactions, each step will occur at its own distinctive rate. If one step takes place much more slowly than all other steps, it will definitely control the overall reaction rate. The slowest step is called rate determining step. Sulfuric acid concentration remains constant in all experiments, so estimation of conditional reaction rate should be done according to the change in sodium thiosulfate concentration.

The operation process

1. Fill three burettes with solutions of sodium thiosulfate, sulfuric acid, and water.
2. Take two test tubes; pour sodium thiosulfate and water from burettes into one test tube, and sulfuric acid into another one. Then pour together the contents of the test tubes and note the time when the turbidity arises (formation of opalescent ppt of sulfur) by means of the stopwatch. This procedure should be done five times varying the volumes of reagents according to the table 1

Table 1

№	Volume, ml			Obtained conc. of $Na_2S_2O_3$ (C), mol/L	Time of turbidity arising (τ), sec	$\upsilon = \frac{1}{\tau}$
	H_2SO_4	H_2O	$Na_2S_2O_3$			
1	2.5	2.0	0.5			
2	2.5	1.5	1.0			
3	2.5	1.0	1.5			
4	2.5	0.5	2.0			
5	2.5	0.0	2.5			

The initial concentration of sodium thiosulfate is 0.2 mol/L.

The conditional reaction rate (υ) is proportional to the value $\frac{1}{\tau}$, hence $\upsilon_1 = \frac{1}{\tau_1}$, $\upsilon_2 = \frac{1}{\tau_2}$, etc.

The experimental data processing

1. Calculate salt concentration obtained after dilution according to the following formula:

$$C = \frac{V(Na_2S_2O_3) \cdot 0.2}{5}$$

2. Calculate values of conditional reaction rates (υ).
The results should be noted down to the table.

3. Plot the graph $\upsilon = fC_{salt}$ and make conclusions about dependence obtained.

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Test 2. Determination of temperature coefficient for reaction of thiosulfuric acid decomposition.

The operation process

1. Pour from burettes 2 ml of sodium thiosulfate into one test tube and 2 ml of sulfuric acid into another one. Place the test tubes in the beaker filled with tap water and measure the temperature by the thermometer in 2-3 min. Then pour reagents together in the one test tube keeping it in the beaker and note by the stopwatch the time when the turbidity arises.
2. The experiment should be carried out 4 times using the same volumes of reagents but the temperature should be increased by 10 degrees each time. In order to increase the temperature, pour hot water into the beaker and note the temperature by the thermometer.

Calculate temperature coefficient according to the formula: $\gamma = \frac{\upsilon_{T+10}}{\upsilon_T}$

The date should be noted down to the table 2

Table 2

Temperature, °C	Time (τ), c	Conditional reaction rate ($\upsilon = \frac{1}{\tau}$), sec^{-1}	Temperature coefficient (γ)

Calculate the average value of temperature coefficient and make conclusions

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SUBJECT 16. CHEMICAL EQUILIBRIUM. SOLUBILITY PRODUCT

Characteristic of the subject

Any chemical reaction in nature can proceed spontaneously in direction which allows reaching the state of equilibrium. Metabolism in the living systems provides continuous entering and excretion of different metabolites. In the living organism many reactions do not reach the point of dynamic equilibrium and proceed continuously.

Objectives

1. Reversible and irreversible reactions.
2. Chemical equilibrium. Equilibrium constant.
3. Shift of chemical equilibrium. Le Chatelier's principle.
4. Solubility product ($K_{sp)}$. Formation and dissolution of precipitates.

Practical skills

1. To be able to determine the direction of chemical reaction.
2. To be able to calculate the equilibrium constant and solubility product.

Questions for class work and self work

1. Choose irreversible reactions.

a) $Na_2CO_3 + 2HCl = CO_2 + H_2O + 2NaCl$____

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b) $BaCl_2 + Na_2SO_4 = BaSO_4 + 2NaCl$____

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c) $HCl + NaOH = H_2O + NaCl$____

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d) $2Mg + O_2 = 2MgO + Q$____

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e) $2NaCl(l) + H_2SO_4(l) = Na_2SO_4 + 2HCl$____

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2. Write the expression for K_{eq} for the following reversible reactions:

a) $2NO(g) + O_2(g) \leftrightarrow 2NO_2(g)$

b) $CO_2(g) + C(s) \leftrightarrow 2CO(g)$

c) $Fe_2O_3(s) + 3H_2(g) \leftrightarrow 2Fe(s) + 3H_2O(g)$

3. Given the system $H_2(g) + I_2(g) \leftrightarrow 2HI(g)$
what is K_{eq} if, at equilibrium, $[H_2]= 0.164$ mol/L, $[I_2]=0.164$ mol/L, and $[HI]=1.21$ mol/L?

4. Determine the direction in which the equilibrium will be shifted by increasing the concentration of carbon monoxide in the following reactions?

a) $CO(g) + Cl_2(g) \leftrightarrow COCl_2(g)$____

b) $CO_2 + C(s) \leftrightarrow 2CO(g)$____

c) $CO_2(g) + H_2(g) \leftrightarrow CO(g) + H_2O(g)$__________________________________

5. Determine the direction in which the equilibrium will be shifted by increasing the pressure in the following reactions?

a) $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$____

b) $C(s) + CO_2(g) \leftrightarrow 2CO(g)$____

c) $N_2(g) + O_2(g) \leftrightarrow 2NO(g)$____

6. Determine the direction in which the equilibrium will be shifted by increasing the temperature in the following reactions?

a) $H_2(g) + Cl_2(g) \leftrightarrow 2HCl(g)$; $\Delta H<0$___________________________________

b) $H_2(g) + I_2(g) \leftrightarrow 2HI(g)$; $\Delta H>0$_____________________________________

7. Calculate solubility of AgCl using the solubility product constant $K_{sp}(AgCl)=1.7 \cdot 10^{-10}$.

8. $K_{sp}(CaSO_4)=2.4 \cdot 10^{-5}$.Will the precipitate of $CaSO_4$ be formed, if:

a) equal volumes of $CaCl_2$ (C = 0.02mol/L) and K_2SO_4 (C=0.0002 mol/L) are mixed?

b) equal volumes of $CaCl_2$ (C = 0.02mol/L) and K_2SO_4 (C=0.02 mol/L) are mixed?

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9. $K_{sp}(PbCl_2)=2.4 \cdot 10^{-4}$.Will the precipitate of $PbCl_2$ be formed, if equal volumes of $Pb(NO_3)_2$ (C = 0.1mol/L) and NaCl (C=0.1 mol/L) are mixed?

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SUBJECT 17. OXIDATION-REDUCTION REACTIONS. PERMANGANATOMETRY

Characteristic of the subject

Oxidation-reduction reactions take place in the human organism on different levels including a cell. CO_2 and H_2O are products of biological oxidation. They form the basis of some volumetric analysis methods (oxidimetry), which enable to determine the content of oxidizing and reducing agents in solutions including biological fluids.

Knowledge of this subject is necessary for a future physician for the successful studying of such disciplines as bioorganic and biological chemistry, normal and pathological physiology, pharmacology and others.

Objectives

1. Types of oxidation-reduction reactions.
2. Standard oxidation-reduction potential as a measure of oxidizing and reducing capacity of a system.
3. The role of oxidation-reduction reactions in the vital activity of the organism.
4. The use of ORR in analytical practice, clinical analysis and sanitary investigations.

Practical skills

1. To be able to make up ORR equations using ion-electron method (the half-reaction method);
2. To determine the equivalent, the equivalence factor and the molar weight of the equivalent of oxidizing and reducing agents in ORR;
3. To determine the direction of ORR by the values of the standard oxidation-reduction potentials.

Questions for class work and self work

1. Make up electron equations and indicate which of the processes — oxidation or reduction takes place during the following conversions:

$Fe^{2+} \rightarrow Fe^{3+}$ ____

$2\,Cl^{-} \rightarrow Cl_2$ ____

2. Basing on the oxidation state of phosphorus in the following compounds: PH_3, H_3PO_4, H_3PO_3, determine, which of them can be only reducing agent, only oxidizing agent and which ones can possess both properties. Explain.

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3. Define the type of the following oxidation-reduction reactions:

$$KClO_3 \rightarrow KCl + O_2$$

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$$Cl_2 + Ca(OH)_2 \rightarrow Ca(OCl)_2 + CaCl_2 + H_2O$$

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$$KMnO_4 + KNO_2 + H_2SO_4 \rightarrow MnSO_4 + KNO_3 + H_2O + K_2SO_4$$

4. Balance the following oxidation-reduction reactions using half-reaction method. What is the equivalence factor and molar mass of equivalent of potassium permanganate in the first reaction?

$$Na_2SO_3 + KMnO_4 + H_2SO_4 \rightarrow Na_2SO_4 + MnSO_4 + K_2SO_4 + H_2O$$

$$Na_2SO_3 + KMnO_4 + KOH \rightarrow Na_2SO_4 + K_2MnO_4 + H_2O$$

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

$$P + HIO_3 + H_2O \rightarrow H_3PO_4 + HI$$

$$H_2S + Cl_2 + H_2O \rightarrow H_2SO_4 + HCl$$

5. a) When the reaction between two Red-Ox systems is possible?

b) Is it possible to oxidize bromide ions into elemental bromine [$Br_2^0|2Br^-$ e^0=1,0652 V] using the elemental chlorine [$Cl_2|2Cl^-$ e^0=1,3595 V] ?

SUBJECT 18. ELECTRODE POTENTIALS

AND MECHANISM OF THEIR ORIGIN

Characteristic of the subject

Electrochemistry studies chemical reactions which take place under the influence of electric current and the processes of the electric energy generation occurring due to the chemical reactions. Electrochemical processes are widely used in scientific research. Methods of electrochemistry such as potentiometry, polarography, as well as methods used for the determination тof different ions concentration are widely adopted in medical practice and medico biological studies.

Diffusive and membrane potentials play a great role in biological objects. Diffusive potential develops if only some mechanical damage of a cell takes place. Membrane potential is very similar by its nature to the diffusive one.

Biopotentials are very sensitive to the physiological changes in cells and organs. The use of electrocardiography and encephalography methods is based on this sensitivity.

Objectives

1. Electrode potential formation
2. Nernst's equation for electrode potential determination.
3. Standard hydrogen electrode.
4. Electrode potentials measuring.
5. Classification of electrodes.
6. E.M.F. calculation for electrochemical cell.

Practical skills

1. To make up the patterns of electrodes and galvanic elements.
2. To determine the values of electrodes potentials and electromotive force.
3. To know the nature of formation of diffusive, membranous and biological potentials.

Questions for class work and self work

1. What is the mechanism of formation of potential on the border metal-solution?

2. What is electrode? Where does electrode potential arise?

3. Write the Nernst's equation for the different electrodes.

4. Calculate the electrode potential of zinc electrode if the active concentration of zinc ions is 5 mol/L and T = 298 K.

5. Give the classification of electrodes depending on structure and electrode reaction; write the schemes and formulae for electrode potential calculation.

6. Calculate the pH value of formic acid solution if the potential of the quinhydrone electrode placed into this solution is 0.48 V at T = 298 K, $e^0_{quin}=0,7$V.

7. Calculate the potential of oxidation-reduction electrode in which the following reaction takes place: $Cr^{3+} + e = Cr^{2+}$, if T = 298 K, $\alpha\ Cr^{2+} = 0.01$ mol/L; $\alpha\ Cr^{3+} = 0.001$ mol/L, $e^0 = -0.41$ V.

8. How to write the scheme of galvanic cell correctly? Write the formula for E.M.F. calculation.

9. Calculate the electromotive force and make up a pattern of the galvanic element consisting of iron and silver electrodes.
$e^0_{Ag^+|Ag}=+0,799$ V; $e^0_{Fe^{2+}|Fe}=-0,441$ V.

10. The E.M.F. of the galvanic element composed of calomel and hydrogen electrodes is 0.35 V.

Calculate the pH value if e_{cal} = +0.248 V.

11. Write down the scheme of galvanic cell composed of the following electrodes

$\mathrm{Pt}\left|\dfrac{\mathrm{Co}^{3+}}{\mathrm{Co}^{2+}}\right.$ and $\mathrm{Pt}\left|\dfrac{\mathrm{MnO}^{-}4}{\mathrm{Mn}^{2+}}\right., H^{+}$, $e^{0}_{\mathrm{Co}^{3+}\,|\,\mathrm{Co}^{2+}}$=+1,81 V; $e^{0}_{\mathrm{MnO4}^{-}\,|\,\mathrm{Mn}^{2+}}$=+1,52 V.

What processes take place in each electrode and in the galvanic element itself? Calculate the E.M.F. of the element under the standard conditions.

12. What is the value of E.M.F. of the concentrating cell composed of two hydrogen electrodes placed into the solution with hydrogen ions concentration 0.01 mol/L and 0.001 mol/L correspondingly at T = 298 K?

SUBJECT 19. ROLE OF ELECTROCHEMICAL PHENOMENA IN BIOLOGICAL PROCESSES

Characteristic of the subject

Biological liquids and tissues contain a lot of electrolytes, hence they posses high electrical conductivity. Electrolytes participate in the processes of acid-base equilibrium maintenance, water-salt metabolism, and osmotic pressure. Studying of electrolytic disturbances and their correction is important for successful treatment of many diseases.

Objectives

1. Definition of standard electrode potential.
2. Oxidation-reduction cells.
3. Electrodes for pH measuring.
4. Role of ORR in biological processes.

Practical skills

To be able:

1. to calculate electrode potentials.
2. to determine pH of biological liquids by means of potentiometry.
3. to balance ORR by half-reaction method.
4. to explain the role of ORR in living organisms.

Questions for class work and self work

1. Which electrodes are used as indicating ones in galvanic cells for measuring of pH in biological liquids? Write the schemes of such electrodes and formulae for electrode potential calculation.

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2. Which electrodes are used as reference ones in galvanic cells for measuring of pH in biological liquids? Write the schemes of galvanic cell used in the Linar probe. What is Linar probe used for?

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3. Quinone is the constituent part of coenzyme Q which participates in the electron transport chain of mitochondria. Being a carrier of electrons, quinone can be transformed into hydroquinone. Write equation of this oxidation-reduction reaction.

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4. Oxidation of organic substances includes transfer of electrons and protons form reduced substrate to NAD^+ and cytochromes. Write the reaction equations of reduction of NAD^+ and cytochromes containing iron and copper ions.

5. What is the name of the potential formed on the border cellular membrane — electrolyte solution?

6. What are biopotentials? Explain the mechanisms of rest potential and action potential arising.

7. Which potential occurs on the border solution-solution?

8. In orthopedic stomatology different metals are used, but they can not be applied together. Why?

INFORMATIVE MODULE 4
PHYSICO-CHEMISTRY OF SURFACE PHENOMENA. LYOPHOBIC AND LYOPHILIC DISPERSED SYSTEMS.
(SUBJECTS 20-24)

Purposes:

- To be able to make conclusions about surface activity of substances on the basis of their structure;
- To analyze peculiarities of structure of surface layer formed by SAS adsorbed molecules, to explain principles of biological membranes structure;
- To analyze adsorption equation, to differentiate mono- and poly-molecular adsorption;
- To interpret adsorption of substances from solutions on a solid surface regularities;
- To understand physico-chemical fundamentals of adsorption therapy methods;
- To differentiate selective and ion-exchange adsorption of electrolytes;
- To interpret methods of chromatography and their role in medico-biological researches;
- To analyze principles of methods of dispersed systems obtaining and purification; to explain physico-chemical fundamentals of hemodialysis;
- To interpret physico-chemical properties of proteins which are structural components of all tissues of an organism;
- To be able to make conclusions about proteins charges on the basis of isoelectric point value.

SUBJECT 20. SORPTION OF BIOLOGICALLY-ACTIVE SUBSTANCES AT THE PHASE INTERFACE

Characteristic of the subject

Biological systems are heterogeneous, i.e. consist of some phases separated by interfaces. There are a lot of processes which occur at the phase interface. The rate of these processes is determined by the surface area. Among the processes taking place at the phase interface in heterogeneous systems, sorption phenomena are of great importance. The processes of adsorption are a part of mechanism of absorption of nutrients and medicinal compounds. Hemosorption method is used for the detoxication of blood. Phenomena of adsorption are the base of chromatography – method of analysis and separation of mixtures of biologically active substances.

Objectives

1. Free surface energy and surface tension.
2. Surface-active and surface inactive agents. Surface activity. Traube’s rule.
3. Adsorption at the interface liquid-gas and liquid-liquid. Gibbs’ equation. Surface tension and adsorption isotherms.
4. Orientation of surfactants molecules in the surface layer.
5. Adsorption on solids. Langmuir’s equation.
6. Structure of biological membranes.
7. Physico-chemical fundamentals of adsorption therapy (hemosorption, enterosorption, application therapy).

Practical skills

1. To know the structure of surfactants and to be able to calculate surface activity.
2. To be able to apply Gibbs’ equation for adsorption phenomena.
3. To formulate basic propositions of Langmuir’s theory.

Questions for class work and self work

1. Give the definition of surface-active and surface inactive agents. Which of the following substances are surface-active and which are surface inactive agents? $C_{17}H_{35}COONa$, K_2SO_4, C_3H_7OH, HCl, NaOH, $C_5H_{11}NH_2$, $C_4H_9SO_3H$, HSO_3Cl.

a) surface-active agents b) surface-inactive agents

2. What is the characteristic feature of SAS molecule structure? How to depict the molecule of SAS?

3. Point hydrophilic and hydrophobic groups in the molecules of propionic acid (C_2H_5COOH) and butan-1-ol ($CH_3CH_2CH_2CH_2$-OH). How are these molecules oriented in the surface of a liquid?

4. Write Gibbs' equation. What is surface activity?

5. When the value of surface activity is positive, and when it is negative?

6. How many times surface activity of valeric acid ($CH_3CH_2CH_2CH_2COOH$) is greater than that of acetic acid (CH_3COOH)?

7. Formulate basic propositions of Langmuir's theory. In which cases Langmuir's and Freundlich's equations can be used?

8. Explain the structure of biological membrane.

9. Why does charcoal adsorb surfactants from water solutions and silica gel ($SiO_2 \cdot H_2O$) from hydrocarbons?

10. Hemosorption, enterosorption, application therapy are widely used in medicine. What is the essence of these methods? ____

Laboratory work
«Adsorption of acetic acid on charcoal»

Purpose of the work

To study dependence of acetic acid adsorption from solution on concentration.

The operation process

Place 0.5 g of charcoal in each flask and add 25 ml of acetic acid solutions of the different molar concentrations. Adsorption takes 30 min. Shake up the content of flasks periodically. In 30 min filter solutions through paper filters. Pour away first 2-3 ml of filtrate. Determine the concentration of acetic acid after adsorption by titration against NaOH (C_{NaOH} = 0.1 mol/L), $V_{CH3COOH}$=5ml. Titrate each solution 3 times in order to obtain the average value. Note down the data to the table.

$C_o(CH_3COOH)$, mol/L	V(NaOH),ml	$C_{eq}(CH_3COOH)$, mol/L	Γ, mol/g
0.2 0.1 0.05 0.025			

Calculate equilibrium concentrations of acetic acid according to the equation:

$$Ceq = \frac{C(NaOH)\cdot V(NaOH)}{V\ (CH_3COOH)} =$$

Calculate the value of absorption according to the equation:

$$\Gamma = \frac{[C_o(CH_3COOH) - Ceq(CH_3COOH)]\cdot V(CH_3COOH)}{m_{carbon}} =$$

Plot the graph of adsorption isotherm

Make conclusions

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Date__________________________________Signature____________________________________

SUBJECT 21. ION EXCHANGE. CHROMATOGRAPHY

Characteristic of the subject

Chromatography is used for determination of amino acid composition of hydrolysates and primary structure of proteins, in studying of amino acid composition of plasma and other biological fluids, in quantitative detection of vitamins, hormones and other biologically active compounds. Due to high sensitivity chromatography is used for separation in pure form and identification of different compounds. Nowadays chromatographic analysis is applied as very effective tool for diagnostics of many diseases.

Objectives

1. Ion adsorption. Peskov-Fajans rule of selective adsorption. Types of ion exchangers.
2. Biological significance of selective adsorption.
3. Adsorption chromatography.
4. Partition chromatography.
5. Ion-exchange chromatography.
6. Gas chromatography (gas-liquid chromatography).
7. Paper chromatography.
8. Thin layer chromatography.
9. Application of chromatography in medicine.

Practical skills

1. To know the factors of selective ion adsorption.
2. To be able to explain particularities of ion exchange in biological structure.
3. To know the essence of chromatographic analysis method.

Questions for class work and self work

1. Name factors of selective ion adsorption.____

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2. Formulate Peskov-Fajans rule of selective adsorption.______________________________

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3. Which of the following ions will be preferentially adsorbed on AgCl particles: Na^+, Ca^{2+}, SO_4^{2-}, Cl^-, NO_3^-, Ag^+?____

4. Place following ions in the order of increasing of adsorption ability: Fe^{3+}, Ca^{2+}, K^+, Th^{4+}, and I^-, Br^-, Cl^-, CNS^-.

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5. Explain the process of ion-exchange adsorption using the example of permutite – [Permutite Na_2], which is applied for water softening.

6. Give examples of synthetic ion-exchangers (anion and cation exchangers).

7. What is the role of ion exchange in biological systems?

8. Give classification of chromatographic methods.

9. What is the essence of adsorption, partition and ion-exchange chromatography?

10. Explain the process of gas-liquid chromatography. ____________________________________

11. Give examples of chromatography application in medicine and biology.__________________

SUBJECT 22. PREPARATION AND PROPERTIES OF COLLOIDAL SOLUTIONS

Characteristic of the subject

The most important biological fluids such as blood, urine and spinal fluid contain slightly soluble substances in colloid state: cholesterol, carbonates, phosphates, urates, and salts of other acids. Break of their stability causes their precipitation resulting in arteriosclerosis, holelithiasis, urolithiasis, etc.

Objectives

1. Dispersed system (definition and components)
2. Classification of dispersed systems.
a) according to the degree of dispersion;
b) according to the aggregative state of dispersed phase and dispersing medium
c) according to the degree of interaction between dispersed phase and dispersing medium
3. Methods of colloidal solutions obtaining.
4. Methods of colloidal solutions purification.
5. Mechanism of colloidal particles formation. Their structure.
6. Properties of colloidal solutions.
a) molecular-kinetic (diffusion, osmosis, Brownian movement)
b) optical (the scattering of light)
c) electro-kinetic (electrophoresis, electroosmosis)
7. Electrodynamic and electrokinetic potentials.

Practical skills

1. To be able to obtain a colloidal solution and to refine it from low-molecular admixtures.
2. To be able to distinguish colloidal and true solutions basing on the differences in their molecular-kinetic and optical properties.

Questions for class work and self work

1. Define dispersed system. Give the classification of dispersed systems. Give the examples of substances, which are present in the human organism in colloidal state.

2. Which group of the dispersed systems a substance with the following size of the particles of the dispersed phase belongs to: a) $5 \cdot 10^{-7}$ м; b) $5 \cdot 10^{-8}$ м; c) $5 \cdot 10^{-9}$ м; d) $5 \cdot 10^{-10}$ м?

3. Describe the methods of preparation of colloidal solutions. What is the difference between them? In which of the below written reactions can colloidal solutions be obtained:
a) $H_2SO_4 + Fe \rightarrow FeSO_4 + H_2$;

b) $H_2SO_4 + BaCl_2 \rightarrow BaSO_4 + 2HCl$;

c) $H_2SO_4 + Na_2SiO_3 \rightarrow Na_2SO_4 + H_2SiO_3$?

What are the conditions for these reactions running?

4. Explain the mechanism of colloidal particles formation in the reaction:

$$CaCl_2 + Na_2SO_4 \rightarrow CaSO_4 + 2NaCl,$$

if a stabilizer is: a) $CaCl_2$, b) Na_2SO_4.

5. 3 ml of $Fe(NO_3)_3$ ($C(Fe(NO_3)_3$ = 0.007 mol/L) solution were mixed with 5 ml of Na_3PO_4 ($C(Na_3PO_4)$ = 0.01 mol/L solution. Write the structure of the obtained micelle.

6. Compare molecular-kinetic properties of colloidal and true solutions. Compare the value of osmotic pressure in H_2SO_4 solution and in the colloidal solution of H_2SiO_3 if their molar concentrations are identical. Explain the answer.

7. What qualities of the dispersed phase and the dispersion medium are the basis of colloidal solutions purification by the following methods: a) dialysis; b) electrodialysis?

8. How can we distinguish a colloidal solution from a true one if running a light ray through it?

9. Determine the direction of movement of colloidal particles obtained in q.4 during electrophoresis.

Demonstration experiment
«Determination of colloidal particles charge by capillary method»

Capillary method is based on the following phenomenon: cellulosic cells of the capillaries of filter paper are charged negatively while water soaking the paper is charged positively.

Procedure: A drop of Berlin blue solutions obtained earlier from ferric chloride (III) solution with C($FeCl_3$) = 0.005 mol/L and potassium ferrocyanide (II) solution with C($K_4[Fe(CN)_6]$) = 0.005 mol/L taken in the following proportions is placed on the filter paper: a) 3 ml of $FeCl_3$ solution and 1 ml of $K_4[Fe(CN)_6]$; b) 3 ml of $K_4[Fe(CN)_6]$ solution and 1 ml of $FeCl_3$ solution.

After the absorption of the drop a positive sol is adsorbed by the paper and produces a spot colored in the center and having colorless edges; negative sol isn't adsorbed by the paper and produces evenly colored spot. Describe the results of the observation. Write the formulae of micelles of sols used in this experiment.

SUBJECT 23. COAGULATION OF COLLOIDAL SOLUTIONS. COLLOIDAL PROTECTION

Characteristic of the subject

Knowledge of coagulation and stability of the dispersed systems is necessary to understand processes taking place in the human organism because a large number of biological fluids in the organism are colloidal systems. So, one of the most important characteristics of blood is erythrocyte sedimentation rate (ESR) which increases if some kind of pathology takes place. Coagulation phenomena become clearly seen in the process of blood coagulation. The nature of blood coagulation must be taken into account during the blood conservation as well as in the process of creation of new medicinal materials possessing antithrombotic properties.

Objectives

1. Types of colloidal solutions stability and factors determining them.
2. Phenomenon of coagulation. Coagulation under the influence of electrolytes action. Hardy-Schulze rule.
3. Phenomena which accompany coagulation.
4. Coagulation kinetics. DLFO theory.
5. Coagulation in biological systems.
6. Colloidal protection.

Practical skills

Studying the subject the student is to be able

1. To use Hardy-Schulze rule.
2. To determine in practice the coagulation threshold.
3. To calculate the protective value.

Questions for class work and self work

1. Define kinetic and aggregative stability of sols. What factors does each of them depend on?

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2. What are coagulation and sedimentation?

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3. Name factors, which cause the coagulation of sols.

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4. What is electrokinetic potential? How does its value influence the properties of colloidal particles?

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5. Write the formulae of sols micelles: $Al(OH)_3$, stabilized by $AlCl_3$ and SiO_2, stabilized by H_2SiO_3. Which ions cause coagulation of these sols (Hardy-Schulze rule): Na_2SO_4, KCl, $FeBr_3$, CaI_2, Na_3PO_4? What series are called lyotropic and what do they show?

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6. What is critical potential? At what value of critical potential the coagulation of sols is the greatest? Write the structure of micelle in isoelectric state.

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7. To cause the coagulation of 10 ml of ferric hydroxide (III) sol 1.05 ml of 0.01 M solution of KCl; 6.25 ml of 0.001 M solution of Na_2SO_4 and 3.7 ml of 0.001 M solution of Na_3PO_4 were added in each case. What is the charge of sol particles? What is the value of coagulation threshold of each electrolyte? Determine the ratio of ions coagulating power.

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8. What is the peculiarity of sols coagulation under the influence of the mixture of electrolytes? What does it mean: additivity, synergism and antagonism of ions? Show the role of ions antagonism in the organism.

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9. What is mutual coagulation? What is the practical use of this phenomenon?

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10. What is colloidal protection? What is its practical use? What is the measure of protective action?

11. 3 ml of 4 % starch solution protect 50 ml of $Fe(OH)_3$ sol from coagulation at the addition of 1 ml of 10 % NaCl solution. Calculate the protective value (gold number) of starch.

Laboratory work
«Determination of coagulation threshold of iron(III) hydroxide sol»

Essence of method

According to the Hardy – Schulze rule, coagulation threshold decreases with increasing of the charge of ion causing coagulation. The least molar concentration of equivalent of the coagulating electrolyte can be determined by the arising of turbidity in the sol.

The operation process

1. Fill in burettes: 1 – with solution of potassium chloride, C(KCl)=1mol/L; 2 – with solution of potassium chromate $C(\frac{1}{2}\ K_2CrO_4) = 0.1$ mol/L;

3 – With solution of potassium hexacyanoferrate(III) $C(\frac{1}{3}\ K_3[Fe(CN)_6])=0.01$mol/l.

2. Take three test tubes and place 5 ml of iron(III) chloride sol in each one.
3. Add potassium chloride dropwise to the first sol, potassium chromate – to the second, and potassium hexacyanoferrate(III) – to the third one until turbidity arises (coagulation). Note down the data into the table.

Electrolyte	**C(E) of electrolyte, mol/L**	**Volume of electrolyte, V(x), ml**	**Coagulating ion**	**Coagulation threshold, C(x) mmol/L**	**Coagulating power, P(x), L/mmol**
KCl	1				
K_2CrO_4	0.1				
$K_3[Fe(CN)_6]$	0.01				

The experimental data processing

1. Calculation of coagulation threshold:

$$C(x)=\frac{\tilde{N}(E)\cdot V(x)\cdot 1000}{V(sol)+V(x)} = \qquad \text{mmol/L}$$

2. Calculation of coagulating power of electrolytes:

$P(x) = \frac{1}{C(x)} =$ L/mmol

Conclusions ____

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Date________________________________Signature__________________________________

SUBJECT 24. PROPERTIES OF BIOPOLYMERS SOLUTIONS. ISOELECTRIC POINT OF PROTEINS

Characteristic of the subject

High-molecular-weight compounds have a great influence on the life activity of the organism. These are natural polymers – proteins, nucleic acids, polysaccharides, and synthetic polymers obtained in laboratory by condensation or addition reactions. Cells of all tissues in the organisms consist of natural polymers. Good knowledge of peculiarities of biopolymers solutions enables to understand better processes taking place in the organism (inflammations, edemas, etc.), and to apply different polymers in medical practice (prostheses, component parts of apparatuses "artificial kidney", "heart-lungs", etc.)

Objectives

1. Comparative characteristic of polymers solutions, true and colloidal solutions.
2. Swelling and dissolution of polymers, their role in physiological processes.
3. Stability of polymers solutions and methods of proteins precipitation. Coacervation.
4. Properties of gels and jellies.
5. Abnormal viscosity of polymers solutions, viscosity of blood.
6. Isoelectric point of proteins.

Practical skills

To be able to determine isoelectric point of proteins, degree of swelling, stability of polymers solutions in respect with electrolytes, and protective action of polymers.

Questions for class work and self work

1. Give classification of high molecular compounds:
   - on the basis of origin____

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   - on the basis of mode of synthesis__________________________________

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   - on the basis of chemical composition______________________________

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   - on the basis of structure____

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2. What is swelling? Describe the types of swelling and factors which influence this process. Give examples of swelling in physiology.

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3. 10 g of protein has been placed in water. In some time the mass of protein became 16 g. What is the degree of swelling?

4. Which factors determine thermodynamic stability of polymers solutions? What is salting out and what does it depend on?____

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5. Describe ways of gels obtaining and specific properties of gels (thixotropy, syneresis).

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6. Describe ionic state of biopolymers in water solutions. How to determine isoelectric point of protein? Give Donnan’s equation.

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Laboratory work
«Protective action of biopolymers»

The operation process

Fill in 6 test tubes with 5 ml of iron (III) hydroxide or Berlin blue positively charged sol. Add 0.2 ml of 0.1% gelatin solution or 0.5% starch solution to the sol in the first test tube, 0.4 ml – in the second test tube, 0.6 ml– in the third test tube, 0.8 ml– in the fourth test tube, 1.0 ml –in the fifth one. Don’t add polymer solution to the sixth test tube which serves as a control.

In 2-3 min add 0.05 M sodium sulfate solution dropwise from burette to each test sol until coagulation occurs.

Calculate coagulation threshold (C), mmol/L, using the formula:

$$C(Na_2SO_4)=\frac{C(Na_2SO_4)\cdot V(Na_2SO_4)\cdot 1000}{V(sol)+V(Na_2SO_4)}$$

Note down the data to the table.

№ of test tube	Volume of polymer, ml	Volume of Na_2SO_4, ml	Coagulation threshold (C), mmol/L

Compare data obtained and make conclusions about the influence of polymers on a sol stability. Write the formula of sol micelle.

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Date______________________________Signature________________________________

SYSTEM OF STUDENTS' PROGRESS EVALUATION REGARDING THE COURSE OF MEDICAL CHEMISTRY

Organization of medical chemistry studies as a course is based on a credit-module system which meets the requirements of Bologna process. All the educational material is structurally divided into units/modules where the defined amount of credits (in compliance with European Credit Transfer System) stands for the work load of the particular module/unit for a successful completion.

Medical chemistry course structure

120 hours (4 credits)
=
70 hours of class work (20 hours of lectures + 50 hours of practical classes)
+
50 hours of self work

Current monitoring of students' progress is carried out in the course of every practical work in the class by means of standardized tests and cards for individual control. The final rating mark includes mark for the subject got by a student after oral answer (the number of the lesson is asterisked in the plan). The maximal number of current points is 120, minimal – 70.

When the study of all subjects of the module is completed the final testing (module control) is carried out. The maximal number of points for module control is 80, minimal – 50. The maximal number of points for the whole module is 200, minimal – 120. The mark got by a student for the Medical Chemistry course completion is to be identified according to the scale of ratings and comprises an average score granted for the completion of two modules. It is to be defined according to European Credit Transfer System (ECTS) and local evaluation system accepted in Ukraine.

The minimum number of points for laboratory practical classes needed by a student to be allowed to pass the module control is 70!

A unified grading scale

Mark for module in ECTS points	ECTS score	Traditional mark
180-200	A	5
150-179	B, C	4
120-149	D, E	3
< 120	Fx, F	2

Conversion of traditional marks for each subject into points

Marks	Points
5	15
4	12
3	9
2	0

Plan of practical classes in Medical chemistry

# subj.	Subject	Mark	Hours	Min/max of points
MODULE I				
1*	Introduction: Structure of chemical substances			9-15
2*	Complex formation in biological systems			9-15
3*	Values characterizing quantitative composition of solutions. Preparation of solutions			9-15
4*	Colligative properties of solutions			9-15
5*	Acid-base equilibrium in the organism.			9-15
6	Buffer systems of the organism			
7*	Buffer solutions preparation			9-15
8	Fundamentals of titrimetric analysis			
9	Neutralization method. Standardization of NaOH			
10	Gastric juice acidity determination (lab)			
11*	Tap water hardness determination (lab)			9-15
12*	Report on chemistry of biogenic elements			9-15
	Total for current study			72-120
13	**Module control “Acid-base equilibrium and complex formation in biological liquids”**			50-80
	TOTAL FOR MODULE I			**120-200**
MODULE II				
14*	Chemical thermodynamics. Heat effects of chemical reactions			9-15
15*	Kinetics. Catalysis			9-15
16*	Chemical equilibrium.			9-15
17*	Oxidation-reduction reactions.			9-15
18	Electrode potentials and mechanism of their origin			
19*	Role of electrochemical phenomena in biological processes			9-15
20	Sorption of biologically active substances at a phase interface			
21*	Ion exchange. Chromatography			9-15
22	Preparation and properties of colloidal solutions			
23*	Coagulation of colloidal solutions. Colloidal protection			9-15
24*	Properties of biopolymers solutions.			9-15
25	**Module control “Equilibrium in biological systems at a phase interface”**			50-80
	Total for current study			72-120
	TOTAL FOR MODULE II			**120-200**
	TOTAL FOR THE COURSE (average for module I and module II)			**120-200**

Questionnaire for the final testing in discipline “Medical chemistry”

Module I

1. Electronic structure of biogenic elements. Typical chemical properties of the elements and their compounds (reactions without change of oxidation states, reactions in which elements change their oxidation states, complex formation). Relation between location of s-, p-, and d-block elements in the periodic table and their content in the organism.
2. Solutions of complex compounds. Modern ideas about structure of complex compounds. Complex compounds classification (according to ligands nature and charge of the inner sphere).
3. Instability and stability constants of complex ions. Fundamentals of complexometry.
4. Intracomplex compounds. Polynuclear complexes. Complex compounds in biological systems. Structure of hemoglobin.
5. Role of solutions in life activity. Enthalpy and entropic factors of dissolution and their connection with dissolution mechanism.
6. Solubility of gases in liquids. Dependence of gases solubility on different factors. Henry’s and Dalton’s laws. Influence of electrolytes on gases solubility. Solubility of gases in blood.
7. Solubility of solid substances and liquids. Distribution of substances between to immiscible liquids. Nernst distribution law, its significance for biological membranes permeability.
8. Equilibrium in electrolytes solutions. Ostwald’s dilution law.
9. Water dissociation. Ionic product of water. pH of biological liquids.
10. Solubility product. Conditions of formation and dissolving of precipitates.
11. Types of proteolytic reactions. Neutralization, hydrolysis and ionization reactions.
12. Hydrolysis of salts. Degree of hydrolysis. Dependence of hydrolysis on concentration and temperature. Hydrolysis constant.
13. Fundamentals of titrimetric analysis. Methods of acid-base titration. Acid-base indicators and principles of their selection.
14. Buffer systems and their classification. pH of buffer solutions.
15. Mechanism of buffer systems action.
16. Buffer capacity and factors which it depends on. Buffer systems of blood.
17. Colligative properties of diluted solutions: freezing point lowering, boiling point elevation. Raoult’s law. Cryometry and ebulliometry.
18. Colligative properties of diluted solutions – osmosis. Osmotic pressure. Van’t-Hoff’s law. Plasmolysis and hemolysis.
19. Colligative properties of diluted solutions of electrolytes. Isotonic coefficient. Hypo-, hyper- and isotonic solutions in medical practice. Role of osmosis in biological systems.

Module II

1. ATP as universal source of energy for biochemical reactions. Characteristic of anhydride bonds of ATP.
2. First law of thermodynamics. Internal energy. Enthalpy. Heat of isobaric and isochoric processes. Standard heat of formation and standard heat of combustion of the compound.
3. Thermochemistry. Hess’s law. Thermochemical conversions.
4. Thermochemical calculations and their application for energetic characteristic of biochemical processes.
5. Second law of thermodynamics. Entropy. Gibbs energy.
6. Chemical equilibrium. Thermodynamic conditions of equilibrium. Prognosis of direction of spontaneous processes. Exergonic and endergonic processes in the organism.
7. Law of mass action. Chemical equilibrium constant. The ways of expression of chemical equilibrium constant. Le Chatelier’s principle. Prognosis of chemical equilibrium displacement.
8. Rate of a chemical reaction. Law of mass action for rate of a chemical reaction. Rate constant.

9. Simple and complicated reactions (serial, simultaneous, conjugated, reversible, chain). Photochemical reactions and their role in life activity.
10. Order of reaction. Reactions of I-st and II-nd order. Zero order reactions. Half-reaction period.
11. Dependence of on the temperature. Temperature coefficient. Van't-Hoff's rule. Peculiarities of reaction rate temperature coefficient for biochemical reactions.
12. Arrhenius equation. Activation energy. Concept of effective collisions and activated state theory.
13. Homogeneous and heterogeneous catalysis. Peculiarities of catalysts action. Mechanism of catalysis. Role of catalysis in metabolism.
14. Enzymes – catalysts of biochemical reactions. Dependence of enzymes action on the concentration of enzyme and substrate, temperature and pH.
15. Electrode potentials and mechanisms of their origin. Nernst equation. Standard electrode potential.
16. Standard hydrogen electrode.
17. Measurement of electrode potentials. Indicating electrodes. Reference electrodes.
18. Oxidation – reduction electrode potentials. Mechanism of their origin, biological significance. Peters equation.
19. Oxidation – reduction reactions in the organism. Prognosis of red-ox reactions direction according to standard values of Gibbs energy and values of oxidation – reduction potentials.
20. Oxidation – reduction titration (oxidimetry). Permanganatometry.
21. Iodimetry.
22. Potentiometry and its application in medico-biological investigations.
23. Diffusive and membrane potentials, their role in genesis of biological potentials. Ion-selective electrodes, their use for measurement of H^+ ions concentration (glass electrode), K^+, Na^+, Ca^{2+} ions concentrations in biological liquids.
24. Peculiarities of high-molecular compounds solutions. Mechanism of swelling and dissolving of high-molecular compounds (HMC). Dependence of high-molecular compounds swelling and dissolving on different factors. Role of swelling in physiology.
25.Isoelectric point of proteins. Methods of IEP determination.
26. Jellification of HMC solutions. Properties of jellies.
27. Abnormal viscosity of HMC solutions. Viscosity of blood and other biological liquids. Osmotic pressure of biopolymers solutions. Galler equation. Oncotic pressure of blood plasma and serum.
28. Donnan's membrane equilibrium.
29. Surface activity. Duclo-Traube rule. Gibbs equation. Orientation of molecules in surface layer and structure of biological membranes.
30. Langmuire equation.
31. Adsorption from solutions on the surface of solids. Freundlich equation.
32. Physico-chemical fundamentals of adsorption therapy.
33. Electrolytes adsorption (selective and ion-exchange). Panet-Faience rule.
34. Ionites and their application in medicine.
35. Classification of chromatography methods according to mechanism of substances distribution, aggregative state of phases and performance technique. Application of chromatography in medico-biological researches.
36. Dispersed systems and their classification. Methods of obtaining and purification of colloidal solutions. Dialysis, electrodialysis, ultra-filtration. "Artificial kidney".
37. Molecular-kinetic properties of colloidal solutions (Brownian movement, diffusion, osmotic pressure). Optical properties of colloidal solutions. Ultramicroscopy.
38. Structure of colloidal particles.
39. Electrokinetic potential of colloidal particles. Electrophoresis, its application in medicine and medico-biological researches. Helmholtz-Smoluchowski equation.

40. Kinetic and aggregative stability of lyosols. Factors of stability. Mechanism of coagulating action of electrolytes.
41. Coagulation threshold, its determination. Hardy Schulze rule. Coagulation processes in purification of drinking water and sewage disposal. Colloidal protection, its biological role.
42. Coarsely dispersed systems (aerosols, suspensions, emulsions). Preparation and properties.

Contents

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Chemistry of biogenic elements
Complex formation in biological liquids (subjects 1 – 2)

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Module 2. Equilibria in biological systems at a phase interface (subjects 14—24)

Informative Module 3. Thermodynamic and kinetic regularities of processes and electrokinetic phenomena in biological systems (subjects 14-19)

Informative module 4. Physico-chemistry of surface phenomena. Lyophobic and lyophilic dispersed systems. (subjects 20-24)

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