Students workbook

in Medical Chemistry

for Dentistry faculty

Student___________________

Group____________________

Kharkiv 2013
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Fundamentals of Medical Chemistry: workbook for dentistry faculty students self-work.

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 dentistry faculty.
Dear first-year students!

Team of medical and bioorganic chemistry department congratulates you on successful entrance Kharkiv national medical university.

Complicated and important tasks are set before higher school in conditions of development of sovereign Ukrainian state, which seeks integration into the European and world community. Education reform, particularly Bologna process, provides for search, development and realization of new forms and vocational training methods of specialists for applied medicine.

Chemical sciences are those natural sciences which give possibility for future doctors to capture knowledge and practical skills, which will be necessary in the study of other disciplines both medicobiological and clinical specialization in the preparation system of students-physicians.

Team of department has highly skilled specialists, who help you to master medical chemistry successfully.

We wish you success!

WORK SAFETY

1. The students should work in white gowns with long sleeves in the classes. Long hair should be hidden carefully.
2. During work the students should keep silence and order. Before starting the work it is necessary to learn the technique of the work, all operations must be performed carefully in compliance with description.
3. Watch closely that reagents don’t come in contact with face, hands and clothes. Not be allowed to measure reagents sucking them by mouth in pipette to avoid chemical burn of oral cavity. It is necessary to use cylinder or dropper for these purposes but for pipette it is necessary to use pipette-bulb.
4. Make sure that there are not flammable liquids (alcohol, an ether, gasoline, etc.) near before you turn on the gas burner.
5. It is necessary to watch the gas cocks, it is impossible to leave them unclosed properly, it is impossible to leave burning gas burner unattended.
6. Hold test-tube aperture aside from yourself and others while heating liquid, don’t touch with burning wick, don’t bring the face nearer to vessel in which liquid heats.
7. While odor identification of escaping gas turn air jet with a subtle movement from aperture of vessel to yourself and inhale.
8. Pour alkali and acid into the water but not vice versa while diluting alkalis and concentrated acids. It is forbidden to pour out concentrated acids and alkalis to the sinks.
9. Keep the work place clean after finishing of work, wash used utensil, and shut off water valves and gas. Reagents and utensil must be returned to the duty student or laboratory assistant.
10. Address to the teacher in all cases even trivial traumas or burns. All questions, appearing in process of work, must be found out from the teacher or laboratory assistant.
INFORMATIVE MODULE 1
Theoretical fundamentals of chemical reactions and biochemical processes
(Subjects 1 – 11)

Purposes:
- To analyze correlation between chemical properties of compounds and their structure.
- To explain correlation between biological role of biogenic s-, p- and d-block elements and their form in the organism.
- To analyze correlation between chemical properties of compounds of s-, p- and d-block elements and their application in stomatology.
- To interpret chemical and biochemical processes basing on their heat effects.
- To be able to use thermodynamic functions for evaluating of processes direction, to explain energetic coupling in the living systems.
- To analyze dependence of reaction rate on concentration and temperature.
- To interpret dependence of reaction rate on activation energy.
- To analyze peculiarities of catalysts action and to explain mechanisms of homogenic and heterogenic catalysis.
- To explain mechanisms of enzymes action and to analyze dependence of enzymatic reactions rates on concentrations of enzyme and substrate.
- To analyze chemical equilibrium and explain it from the thermodynamic and kinetic point of view.
- To explain influence of external factors on the chemical equilibrium.
- To be able to characterize quantitative composition of solutions.
- To be able to prepare solutions with the given quantitative composition.
- To analyze principles of titrimetric methods.
- To analyze quantitative content of acids and bases in solutions by means of acid-base titration.
- To make conclusions about acidity of biological liquids basing on pH.
- To explain mechanism of buffer solutions action and their role in the maintenance of acid-base balance in biological systems.
- To analyze correlation between colligative properties and concentration of solutions.
Characteristic of the subject

All living organisms, their tissues and organs contain different quantities of all known chemical elements. 96% of the human body mass consists of four p-block elements – organogens: carbon, oxygen, hydrogen, and nitrogen. There is a great content of sodium, potassium, calcium, phosphorus, sulfur, etc. in the human organism. The purpose of this class is to refresh school knowledge about structure of chemical substances. Studying of atomic structure and nature of chemical bonds allows to predict properties of chemical elements, their role in vital activity which is necessary for a future physician for better understanding the normal and pathological processes taking place in the human organism.

Objectives

1. Atomic structure.
2. Types of hybridization of atomic orbitals.
3. Mechanisms of formation of $\sigma$ and $\pi$-bonds.
4. Conception of s-, p-, d-, and f-block elements (report on chemistry of biogenic elements)

Practical skills

To have the idea about atomic structure, valence, types of hybridization and mechanisms of formation of chemical bond.

Questions for class work and self work

1. General characteristic of groups I and II s-block elements:
   a) Describe electronic structure of outermost level of any s-block element.

   b) Give characteristic valences and oxidation states, supply examples.

   c) Compare oxidation-reduction and acid-base properties of compounds of Na and Cs; K and Ca depending on atomic radii, ionization energy, electron affinity, and electronegativity.

   d) Describe dependence of ions degree of hydration on the position of atom in the Periodic table.
2. General characteristic of groups III - VII p-block elements:
   a) Describe electronic structure of outermost energy level of p-block elements.

   b) Give characteristic valences and oxidation states, supply examples.

   c) Compare oxidation-reduction properties of elements and acid-base properties of their compounds depending on atomic radii, ionization energy, electron affinity, and electronegativity.

3. General characteristic of groups IIIB-VIIB d-block elements:
   a) Describe electronic structure of outermost and next-to-outermost levels of d-block elements:

   b) Give characteristic valences and oxidation states.

   c) Compare oxidation-reduction properties of elements and acid-base properties of their compounds depending on atomic radii, ionization energy, electron affinity, and electronegativity.
SUBJECT. THERMODYNAMIC AND KINETIC REGULARITIES OF CHEMICAL PROCESSES. CHEMICAL EQUILIBRIUM. REACTIONS OF DISSOLUTION AND PRECIPITATION (LESSONS 2-4)

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.

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. First law of thermodynamics. Enthalpy — is a state function of the system. Exothermic and endothermic processes.
2. Hess’s law — is the basic law of thermochemistry.
4. Basic concepts of chemical kinetics: reaction rate, reaction rate constant, homogenic and heterogenic systems, etc.
5. Dependence of reaction rate on the concentration, temperature, nature of reactants and catalysts.
6. Order and molecularity of reaction, reactions of zero, first and second order, half life period.
8. Reversible and irreversible reactions.
10. Shift of chemical equilibrium. Le Chatelier’s principle.

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.
4. To be able to analyze dependence of reaction rate on the temperature, concentration of reactants, their nature and catalyst.
5. To be able to explain mechanism of action of enzyme, peculiarities of catalytic action; to predict direction of chemical reaction.
6. To be able to calculate equilibrium constant and solubility product.
LESSON 2. CHEMICAL THERMODYNAMICS

Questions for class work and self work

1. Basic concepts of chemical thermodynamics.
   What is *the system*? Give definition and examples.

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   Name *thermodynamic parameters*.

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   Name thermodynamic state functions. What is their main property?

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2. Define first law of thermodynamics.

   ______________________________________________________

3. Write reactions equations which heat effects correspond to the enthalpies of combustions of the following substances:
   a) C₂H₅OH ______________________________________________
   b) C₆H₁₂O₆ ______________________________________________

4. Calculate the heat effect of the following reaction:
   \[ \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2 \text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2 \]
   \[ \Delta H^\circ_{\text{comb}}(\text{C}_6\text{H}_{12}\text{O}_6) = -2815 \text{ kJ/mol} \]
   \[ \Delta H^\circ_{\text{comb}}(\text{C}_2\text{H}_5\text{OH}) = -1367 \text{ kJ/mol} \]

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.

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6. Define second law of thermodynamics. What is meant by entropy? What is the change in entropy in the phase transition and in chemical reactions?
7. What is Gibbs free energy? How is it useful for predicting the feasibility of a process?

8. Predict whether the following reaction is spontaneous in the forward direction under standard conditions: 2H₂ + O₂ ↔ 2H₂O. How does the temperature influence the feasibility of reaction?

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

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

<table>
<thead>
<tr>
<th>Substance</th>
<th>Enthalpy of formation ΔH₀, kJ/mol</th>
<th>Entropy S, J/mol K</th>
<th>Gibbs' energy of formation ΔG₀, kJ/mol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose(s)</td>
<td>-1273,0</td>
<td></td>
<td>-393,4</td>
</tr>
<tr>
<td>Sucrose(s)</td>
<td>-2220,9</td>
<td></td>
<td>-228,8</td>
</tr>
<tr>
<td>CO₂(g)</td>
<td>-393,5</td>
<td>213,6</td>
<td>-237,5</td>
</tr>
<tr>
<td>H₂O(g)</td>
<td>-241,8</td>
<td>188,7</td>
<td>-174,8</td>
</tr>
<tr>
<td>H₂O(l)</td>
<td>-285,8</td>
<td>69,96</td>
<td>-392,5</td>
</tr>
<tr>
<td>C₂H₅OH (l)</td>
<td>-277,8</td>
<td>160,7</td>
<td>124,5</td>
</tr>
<tr>
<td>CH₃COOH (l)</td>
<td>-484,8</td>
<td>159,8</td>
<td>-16,5</td>
</tr>
<tr>
<td>C₆H₆(l)</td>
<td>+49,04</td>
<td>173,2</td>
<td>209,2</td>
</tr>
<tr>
<td>NH₃(g)</td>
<td>-46,2</td>
<td>192,5</td>
<td>-137,3</td>
</tr>
<tr>
<td>C₂H₂ (g)</td>
<td>226,7</td>
<td>200,8</td>
<td>-1128,8</td>
</tr>
<tr>
<td>CO(g)</td>
<td>-110,5</td>
<td>197,4</td>
<td>-1147,25</td>
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<tr>
<td>CaCO₃</td>
<td>-1207,0</td>
<td>92,9</td>
<td>-3899,5</td>
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<tr>
<td>H₃PO₄(l)</td>
<td>-1271,9</td>
<td>200,8</td>
<td></td>
</tr>
<tr>
<td>Ca₃(PO₄)₂</td>
<td>-4125,0</td>
<td>240,9</td>
<td></td>
</tr>
<tr>
<td>CH₃COOC₂H₅</td>
<td>-628,7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LESSON 3. KINETICS OF BIOCHEMICAL REACTIONS AND CATALYSIS

Questions for class work and self work

1. What does Chemical kinetics study? What is chemical reaction rate?
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2. Which factors influence reaction rate?
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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. State Van’t Hoff’s rule
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5. Write the rate expressions for forward and reverse reactions:
   \[ \text{N}_2 + \text{O}_2 \leftrightarrow 2\text{NO} \]
   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, \((\gamma = 2)\)?

6. What is meant by reaction rate constant? What does it depend on? _____________________
_____________________________________________________________________________
_____________________________________________________________________________

7. Calculate half life period of:
Zero order reaction, if \(C_0 =0.01\) mol/L, \(k_0=0.005\) mol/L⋅sec

First order reaction, if \(k_1=0.05\) sec\(^{-1}\)

Second order reaction, if \(C_0 =0.01\) mol/L, \(k_2=0.5\) L/mol⋅sec

8. What does Theory of effective collisions postulate? What is activation energy? Write Arrhenius equation.
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9. What are catalysts and catalysis? Give definitions and examples:
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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 to the following steps:

\[ \text{Na}_2\text{S}_2\text{O}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{S}_2\text{O}_3 + \text{Na}_2\text{SO}_4 \text{ (fast)} \]

\[ \text{H}_2\text{S}_2\text{O}_3 \rightarrow \text{S} \downarrow + \text{SO}_2 \uparrow + \text{H}_2\text{O} \text{ (comparatively slow)} \]

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>
<thead>
<tr>
<th>№</th>
<th>Volume, ml</th>
<th>Obtained conc. of Na\textsubscript{2}S\textsubscript{2}O\textsubscript{3} (C), mol/L</th>
<th>Time of turbidity arising ((\tau)), sec</th>
<th>(U = \frac{1}{\tau})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.5</td>
<td>2.0</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.5</td>
<td>1.5</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.5</td>
<td>1.0</td>
<td>1.5</td>
<td></td>
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<tr>
<td>4</td>
<td>2.5</td>
<td>0.5</td>
<td>2.0</td>
<td></td>
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<tr>
<td>5</td>
<td>2.5</td>
<td>0.0</td>
<td>2.5</td>
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</table>

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

The conditional reaction rate \((U)\) is proportional to the value \(\frac{1}{\tau}\), hence \(U_1 = \frac{1}{\tau_1}, U_2 = \frac{1}{\tau_2}, \) etc.

The experimental data processing

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

\[ C = \frac{V(\text{Na}_2\text{S}_2\text{O}_3) \cdot 0.2}{5} \]

2. Calculate values of conditional reaction rates \((U)\).

The results should be noted down to the table.

3. Plot the graph \(U = fC_{\text{salt}}\) and make conclusions about dependence obtained.
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: \( \gamma = \frac{v_{T+10}}{v_T} \)

The date should be noted down to the table 2

<table>
<thead>
<tr>
<th>Temperature, °C</th>
<th>Time ((\tau)), c</th>
<th>Conditional reaction rate ((v = \frac{1}{\tau})), sec(^{-1})</th>
<th>Temperature coefficient ((\gamma))</th>
</tr>
</thead>
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</table>

Calculate the average value of temperature coefficient and make conclusions
LESSON 4. CHEMICAL EQUILIBRIUM. SOLUBILITY PRODUCT

Questions for class work and self work

1. Choose irreversible reactions. What are the conditions of these reactions running?
   a) \( \text{Na}_2\text{CO}_3 + 2\text{HCl} = \text{CO}_2 + \text{H}_2\text{O} + 2\text{NaCl} \)

   b) \( \text{BaCl}_2 + \text{Na}_2\text{SO}_4 = \text{BaSO}_4 + 2\text{NaCl} \)

   c) \( \text{HCl} + \text{NaOH} = \text{H}_2\text{O} + \text{NaCl} \)

   d) \( 2\text{Mg} + \text{O}_2 = 2\text{MgO} + \text{Q} \)

   e) \( 2\text{NaCl(l)} + \text{H}_2\text{SO}_4(l) = \text{Na}_2\text{SO}_4 + 2\text{HCl} \)

2. Write the expression for \( K_{eq} \) for the following reversible reactions:
   a) \( 2\text{NO} + \text{O}_2 \leftrightarrow 2\text{NO}_2 \)

   b) \( \text{CO}_2 + \text{C(s)} \leftrightarrow 2\text{CO} \)

   c) \( \text{Fe}_2\text{O}_3(s) + 3\text{H}_2(g) \leftrightarrow 2\text{Fe(s)} + 3\text{H}_2\text{O(g)} \)

3. Given the system \( \text{H}_2 + \text{I}_2 \leftrightarrow 2\text{HI} \)
   what is \( K_{eq} \) if, at equilibrium, \([\text{H}_2]= 0.164 \text{ mol/L}, [\text{I}_2]=0.164 \text{ mol/L}, \) and \([\text{HI}]=1.21 \text{ mol/L}\)?

4. Determine the direction in which the equilibrium will be shifted by increasing the concentration of carbon monoxide in the following reactions.
   a) \( \text{CO(g)} + \text{Cl}_2(g) \leftrightarrow \text{COCl}_2(g) \)

   b) \( \text{CO}_2 + \text{C(s)} \leftrightarrow 2\text{CO} \)

   c) \( \text{CO}_2(g) + \text{H}_2(g) \leftrightarrow \text{CO(g)} + \text{H}_2\text{O(g)} \)

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) \(H_2 + Cl_2 \leftrightarrow 2HCl; \Delta H<0\)

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

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 = 0.02 mol/L) and \(K_2SO_4\) (C=0.0002 mol/L) are mixed?

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

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 = 0.1 mol/L) and \(NaCl\) (C=0.1 mol/L) are mixed?
SUBJECT. VALUES CHARACTERIZING QUANTITATIVE COMPOSITION OF SOLUTIONS. PREPARATION OF SOLUTIONS
(LESSON 5)

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 other 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

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.

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

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5. Give the definition of molality.

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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 molar concentration of the equivalent.

8. How to determine the equivalence factor for 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. Give formula to converse:
    a) mass percent into molarity

    b) molar concentration into molar concentration of the equivalent

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 formula for mole fraction calculation.

14. Calculate mole fraction of glucose in the 20% solution.
SUBJECT. ACID-BASE EQUILIBRIUM IN THE ORGANISM.

pH OF BIOLOGICAL LIQUIDS

(LESSON 6)

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.

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$_3$COOH, NaOH, Ca(OH)$_2$, NH$_3$OH, H$_2$CO$_3$, Na$_2$SO$_4$, H$_2$O. 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 acids and bases solutions.

4. Give the pH values for biological liquids:
   blood__________ saliva__________ urine______________ gastric juice__________
What is acidosis; alkalosis?

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 CH₃COOH if K(CH₃COOH)=1.8⋅10⁻⁵?

6. What is the pH of a 0.03 M solution of NaOH? What is the pH of a 0.01M solution of NH₄OH if α=0.042?

7. Determine the concentration of hydrogen ions in the blood if pH = 7.35.

8. Determine the concentration of hydroxyl groups in the solution of potassium hydroxide if pH = 12.0.

9. There are two samples of gastric juice. The content of hydrochloric acid in one of the samples is 0.1 %, in the other — 0.2 %. Where will the pH value be higher?
10. There are two solutions of hydrochloric and acetic acids with the identical molar concentrations. Where will the pH value be higher?

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11. Write the hydrolysis reactions for salts which undergo hydrolysis in the ionic and molecular forms: NH₄Cl, K₂CO₃, KCl, CH₃COONH₄. Predict whether aqueous solutions of these salts are acidic, neutral, or basic. Write the formulae for pH calculation in salts solutions.

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12. Calculate the pH value in the solution of sodium acetate, if the concentration of salt C(CH₃COONa) = 0.05 mol/L, and the dissociation constant of acetic acid K(CH₃COOH) = 1.8 · 10⁻⁵.

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SUBJECT. BUFFER SOLUTIONS, CLASSIFICATION
AND MECHANISM OF ACTION. ROLE OF BUFFERS IN BIOLOGICAL SYSTEMS
(LESSON 7)

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.
3. Composition, mechanism of action and importance of the basic buffers of the organism.
4. 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 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.
4. To characterize the mechanism of organism’s buffers action.
5. To calculate the buffer capacity.
6. To prepare buffer solution and determine its pH by means of potentiometry method.

Questions for class work and self work
1. Define buffer solutions.

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2. Composition of buffer systems. Chose mixtures possessing buffer action among the below written ones:
   a) HNO₃; NH₄NO₃
   b) H₂CO₃; KHCO₃
   c) H₂CO₃; (NH₄)₂CO₃
   d) NH₄OH; NH₄HSO₄

3. Illustrate the buffer action of acetic and ammoniacal buffer systems.

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4. What is the Henderson’s equation for the calculation of pH of buffer systems?

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5. Calculate the pH value of buffer solution obtained by mixing 300 ml of NH₄Cl solution where C(NH₄Cl) = 0.1 mol/L with 150 ml of NH₃ · H₂O solution where C(NH₃) = 0.2 mol/L, K(NH₃ · H₂O)= 1.8 · 10⁻⁵.

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6. Calculate the volumes of acetic acid solution with C(CH₃COOH) = 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 where pH = 5.24 if K(CH₃COOH) = 1.8 · 10⁻⁵.

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

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

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9. What is the buffer action of amino acids and proteins? What is isoelectric point (pI) of a protein?

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10. What is buffer capacity? What does it depend on?

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11. 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.
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. CH₃COOH and CH₃COONa) or weak base and its salt of a strong acid (e.g. NH₄OH and NH₄Cl).

Acetate 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 acetate or phosphate buffer solutions:

\[ \text{CH}_3\text{COO}^- + \text{H}^+ \rightarrow \text{CH}_3\text{COOH} \]
\[ \text{HPO}_4^{2-} + \text{H}^+ \rightarrow \text{H}_2\text{PO}_4^- \]
\[ \text{CH}_3\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{COO}^- + \text{H}_2\text{O} \]
\[ \text{H}_2\text{PO}_4^- + \text{OH}^- \rightarrow \text{HPO}_4^{2-} + \text{H}_2\text{O} \]

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 cm³ of ________ buffer solution where pH = __________.
2. Proper volumes of acid (base) solutions and their salts should be measured off with a burette, added to a glass and mixed up carefully.
3. pH of the prepared buffer solutions should be measured with a pH-meter. Don’t pour out the solution.
4. Pipette 5 ml of solution in the 50 ml measuring flask. Adjust the volume to 50 ml with distilled water. Divide the remaining solution into two equal portions. 1 cm³ of HCl solution (the molar concentration of the equivalent is 0.01 mole/dm³) should be added to the first portion with a pipette and 1 cm³ of NaOH solution of the same concentration should be added to the other one.
5. pH of the obtained solutions should be measured with the pH-meter and the data should be noted down to the table:

<table>
<thead>
<tr>
<th>Solution</th>
<th>pH rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calculated data</td>
</tr>
<tr>
<td>Initial buffer solution</td>
<td></td>
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<tr>
<td>Diluted solution</td>
<td></td>
</tr>
<tr>
<td>The solution after the HCl addition</td>
<td></td>
</tr>
<tr>
<td>The solution after the NaOH addition</td>
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</tbody>
</table>

The experimental data processing
1. pH rate calculation after the addition of a strong acid:
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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SUBJECT. COLLIGATIVE PROPERTIES OF SOLUTION
(LESSON 8)

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 laws and its corollary;
   b) Diffusion and osmosis;
   c) Osmotic pressure;
   d) What are the 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 $P_{\text{osm}}$ 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?
2. What is diffusion?

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3. 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.

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4. Give the definition of the osmotic pressure.

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Write the formula for osmotic pressure calculation (Van’t Hoff’s law)

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What is the normal value of the osmotic pressure of blood?

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What is oncotic pressure and what is its normal value?

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5. The osmotic pressure of CaCl$_2$, which molar concentration is 0.04 mol/L at T = 300 K equals 2.493 \cdot 10^5$ Pa. Determine isotonic coefficient of calcium chloride in this solution.

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6. 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).

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7. Compare the values obtained in task 6 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?

8. 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. 46 g of glycerin were dissolved in 100 g of water. What is a freezing point of this solution? 
\[ M(C_3H_5(OH)_3) = 92 \, \text{g/mol}; \; T_f(H_2O) = 273.15 \, \text{K}; \; K_f = 1.86 \, \text{kg} \cdot \text{K/mol}. \]

11. 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 \( t = 17 \, ^\circ\text{C} \). (Osmometry).

12. 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).
SUBJECT. FUNDAMENTALS OF TITRIMETRIC ANALYSIS
(LESSONS 9-11)

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. Measuring utensils used for volumetric analysis.
6. Titration technique and the determination of the equivalence point.

Practical skills
After studying the subject a student should be able:
1. To write down the law of equivalents for every couple of interacting substances.
2. To calculate the mass of weighted portion necessary to prepare a definite volume of operating solution with the given molar concentration of the equivalent.
3. To calculate the molar concentration of the equivalent according to the mass of weighed portion of a substance taken in the definite volume.
4. To calculate the molar concentration of the equivalent and the titer of the investigated solution according to the results of titration.
5. 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.

LESSON 9. FUNDAMENTALS OF TITRIMETRIC ANALYSIS

Questions for class work and self work
1. Give mathematic expression of law of equivalents.

2. Is it possible to prepare a standard solution using accurate portions of NaOH and H₂SO₄?
3. Define the term “operating solution”. How to determine its concentration?

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4. Define the terms “titration curves” and “pH jump”. How to find the equivalence point according to the titration curve?

5. Define indicators. How to choose the indicator?

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6. Why is the pH jump shifted to the acidic or alkaline area, or covers both acidic and alkaline areas in different cases of titration?

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7. Which indicator should be taken during the titration of H_2C_2O_4 \cdot 2H_2O, CH_3COOH, HCl, HNO_3, and H_2SO_4 with caustic soda and why? In what area is the titration jump located during the titration of: a weak acid against a strong base; a strong acid against a strong base; a strong acid against a weak base?

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8. Define the titer. Write the formula for titer calculation.

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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).

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LESSON 10. 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 with a standard solution. As standard solution in this case oxalic acid may be used. **Standardization** — is the determination of the molar concentration of the equivalent and the titer of solution according to the results of titration.

Phenolphthalein can be used as the indicator. Titration process runs according to the reaction equation:

\[
H_2C_2O_4 + 2NaOH \rightarrow Na_2C_2O_4 + 2H_2O
\]

The operation process

1. Rinse a clean burette with the operating alkaline solution and then fill with the same solution - the lower meniscus must be at zero mark.
2. Take 5 cm³ of the standard solution of the oxalic acid and transfer it to the titration flask. Then add two drops of the indicator and rinse the walls of the flask with water.
3. Titrate oxalic acid against NaOH solution adding it from the burette and mixing constantly up to the moment when light-pink coloration will appear. Note down the volume of NaOH solution used for the titration (V(\(NaOH\))).
4. Carry out the titration process till three coincided results will be obtained. Note down the data of the titration to the table:

<table>
<thead>
<tr>
<th>The results of the titration</th>
<th>The results of the calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>V(H₂C₂O₄), cm³</td>
<td>V(NaOH), cm³</td>
</tr>
<tr>
<td>V₁ = 5,00</td>
<td>V₁ =</td>
</tr>
<tr>
<td>V₂ = 5,00</td>
<td>V₂ =</td>
</tr>
<tr>
<td>V₃ = 5,00</td>
<td>V₃ =</td>
</tr>
<tr>
<td>V_{av} =</td>
<td></td>
</tr>
</tbody>
</table>

5. Use an 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 \(V = \)___________ cm³ of solution:
\[
C\left(\frac{1}{2}H_2C_2O_4 \cdot 2H_2O\right) = \frac{m(H_2C_2O_4 \times 2H_2O)}{M\left(\frac{1}{2}H_2C_2O_4 \times 2H_2O\right) V(H_2C_2O_4 \times 2H_2O)} = \text{mol/dm}^3
\]

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

\[
V(\text{NaOH}) \times C(\text{NaOH}) = V(H_2C_2O_4 \cdot 2H_2O) \times C\left(\frac{1}{2}H_2C_2O_4 \cdot 2H_2O\right)
\]

\[
C(\text{NaOH}) = \frac{\tilde{N}\left(\frac{1}{2}H_2C_2O_4 \times 2H_2O\right) \cdot V(H_2C_2O_4 \times 2H_2O)}{V_{av}(\text{NaOH})} = \text{mol/dm}^3
\]

\[
T(\text{NaOH}) = \frac{C(\text{NaOH}) \times M(\text{NaOH})}{1000} = \text{g/cm}^3
\]

Conclusions

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LESSON 11. 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 0.1 M NaOH solution in cm³ 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 gives bright red coloration to the solution 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 hypo acidity.

The operation process

1. Rinse a clean burette with the operating alkaline solution and then fill with the same solution - the lower meniscus must be at zero mark.
2. Take 5 cm³ 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 and rinse the walls of the flask with water.
3. Titrate gastric juice against NaOH solution adding it from the burette and mixing constantly up to the moment when orange coloration will appear. Note down the volume of NaOH solution used for the titration (V1).
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 (V2). Carry out the titration process till three coincided results will be obtained. Note down the data of the titration to the table:

<table>
<thead>
<tr>
<th>Gastric juice V, cm³</th>
<th>V₁ (NaOH), cm³</th>
<th>V₂ (NaOH), cm³</th>
<th>HCl_free (actual acidity) =</th>
<th>The total acidity =</th>
</tr>
</thead>
<tbody>
<tr>
<td>V = 5,00</td>
<td>V₁ =</td>
<td>V₂ =</td>
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<td></td>
<td>V₃ =</td>
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<td>V₃ =</td>
<td>V₃ =</td>
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</tbody>
</table>

An average rate of the volume of NaOH solution used for the titration of the gastric juice sample is used for the determination of its acidity. The results will be expressed in clinical units.
The experimental data processing

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

   \[ K = \frac{0,1}{C(\text{NaOH})} \]

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

   \[ \text{HCl}_{\text{free}} = \frac{V_1(\text{NaOH}) \times 100}{V(\text{of the gastric juice}) \times K} = \text{units} \]

3. The total acidity of gastric juice calculation:

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

**Conclusions**

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Date ______________________                             Signature ____________________________
INFORMATIVE MODULE 2
Heterogeneous equilibria in biological liquids
Acid-base equilibria in biological liquids
(subjects 12-18)

Purposes:
- To explain principles of structure of complex compounds.
- To interpret characteristic features of structure of complex compounds in order to apply in chelatotherapy.
- To explain the mechanism of electrode potentials formation.
- To analyze electrochemical processes in the oral cavity.
- To analyze principles of potentiometry and to make conclusions about its application in medico-biological researchers.
- To be able to measure oxidation-reduction potentials and to predict direction of oxidation-reduction reactions.
- To make conclusions about surface activity of the substances according to their structure.
- To analyze characteristic features of the surface layer of adsorbed molecules of surface active substances (SAS) and to explain structure of biological membranes.
- To analyze adsorption equation and limits of its application, to distinguish between monomolecular and polynuclear adsorption.
- To interpret regularities of adsorption from solutions on the solid surfaces.
- To explain physico-chemical bases of adsorption therapy methods.
- To distinguish between selective adsorption and ion-exchange adsorption of electrolytes.
- To interpret chromatographic methods of and their application in medico-biological researchers.
- To analyze principles of methods of highly dispersed systems obtaining and purification.
- To explain physico-chemical fundamentals of hemodialysis.
- To interpret physico-chemical properties of proteins – structural components of all tissues of the organism.
- To make conclusions about charge of the dissolved biopolymers on the basis of their isoelectric points.

SUBJECT. COMPLEX FORMATION IN BIOLOGICAL SYSTEMS
(LESSON 12)

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. Equilibria 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 and name following substances:

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

   a) $K_4[\text{Ni(CN)}_6]_4$
   and $\text{Na}[\text{Co(NO}_2)_4(\text{NH}_3)_2]$  

   b) $[\text{Zn(NH}_3)_4]_2(\text{NO}_3)_2$  
   and $[\text{Cr(H}_2\text{O})(\text{NH}_3)_4\text{Cl}]\text{Cl}_2$  

   c) $[\text{Pt(NH}_3)_2\text{Cl}_4]$  
   and $[\text{Cu(H}_2\text{O})\text{Br}_3]$  

2. Give the classification of complex compounds. Determine the type of the following compounds and the charge of complex ion:
   $[\text{Cu(NH}_3)_4]\text{SO}_4$
   $\text{Na}_2[\text{Cu(OH)}_4]$
   $[\text{Ni(CO)}_4]$  

3. Give the definition of ligand  

   __________________________________________________________

   a) Which of the following particles can serve as ligands? Classify them:
   $\text{SO}_4^{2-}$, $\text{Co}^{3+}$, $\text{F}^-$, $\text{CO}_3^{2-}$, $\text{Ni}^{2+}$, $\text{Cl}^-$, $\text{H}_2\text{O}$, $\text{Br}^-$, $\text{NH}_3$, $\text{OH}^-$

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   b) Which of the following particles can serve as complexing agents? Define the type of hybridization and write the orbital diagrams of the ions: $\text{Ni}^+$, $\text{Fe}^{3+}$, $\text{Na}^+$, $\text{Cl}^-$, $\text{Fe}^{2+}$, $\text{NO}_2^-$, $\text{F}^-$
4. Indicate the coordination number and oxidation state of the central ion in the following complexes:

\[ \text{[Pt(NH}_3\text{)},{_2}\text{Cl}_4]\]____________________
\[ \text{Na[Ag(CN)$_2$]}\]____________________
\[ \text{[Co(NH}_3\text{)},{_4}\text{Cl}_2]\text{NO}_3\]____________________

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

\[ \text{[Co}^{+3}\text{(NH}_3\text{)},{_4}\text{(NO}_2\text{)},{_2}\text{]}^x\]____________________
\[ \text{[Ti}^{+3}\text{(H}_2\text{O)},{_6]}^x\]____________________
\[ \text{[CoF}_6]^x\]____________________

6. Give cis- and trans-isomers of the following ions:

a) \[ \text{[Pt(NH}_3\text{)},{_2}\text{Cl}_2]\] b) \[ \text{[Co(H}_2\text{O)},{_4}\text{Cl}_2]^+\text{Cl}\]

Cis- Cis-

Trans- Trans-

7. Write the dissociation equation and expression of \(K_{\text{diss}}\) for the compound \(K\text{d}[\text{Fe(CN)},{_6}]:\)

8. Write the expression of the \(K_{\text{inst}}\) for complex ions of the following complexes:

a. \[ \text{Na}_3\text{[Cr(OH)},{_6}]\]

b. \[ \text{[Co(H}_2\text{O)},{_4}\text{Cl}_2]^+\text{Cl}\]

9. What are complexons? What is their application in medicine as antidotes at the poisonings with heavy metals? In which solution the concentration of mercury ions is greatest?

a) sol. of \(K\text{d}[\text{HgCl}_4]; K_{\text{inst}}=10^{-23}\)____________________

b) sol. of \(K\text{d}[\text{HgBr}_4]; K_{\text{inst}}=10^{-11}\)____________________

c) sol. of \(K\text{d}[\text{HgI}_4]; K_{\text{inst}}=10^{-8}\)____________________
SUBJECT. OXIDATION-REDUCTION REACTIONS. 
DETERMINATION OF ELECTRODE POTENTIALS 
(LESSONS 13-14)

Characteristic of the subject
Oxidation-reduction reactions take place in the human organism on different levels including a cell. CO₂ and H₂O 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.

Electrochemical processes are widely used in scientific research. Methods of electrochemistry such as potentiometry, polarography, as well as methods used for the determination of different ions concentration are widely adopted in medical practice and medico-biological studies. Diffuse and membrane potentials play a great role in biological objects. 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. Standard oxidation-reduction potential as a measure of oxidizing and reducing ability of a system.
2. The role of oxidation-reduction reactions in the vital activity of the organism.
3. The use of ORR in analytical practice, clinical analysis and sanitary investigations.
4. Electrode potential formation
5. Nernst’s equation for electrode potential determination.
7. Electrode potentials measuring.
8. Classification of electrodes.
9. E.M.F. calculation for electrochemical cell.

Practical skills
1. To determine the equivalent, the equivalence factor and the molar weight of the equivalent of oxidizing and reducing agents in ORR;
2. To determine the direction of ORR by the values of the standard oxidation-reduction potentials.
3. To know the nature of formation of electrode potentials.
4. To determine the values of electrodes potentials.
5. To make up the schemes of electrodes and galvanic cells.

LESSON 13

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:
   Fe²⁺ → Fe³⁺ ____________________________
   2 Cl⁻ → Cl₂ ____________________________

2. Basing on the oxidation state of phosphorus in the following compounds: PH₃, H₃PO₄, H₃PO₃, determine, which of them can be only reducing agent, only oxidizing agent and which ones can possess both properties.
3. Balance the following reactions:

\[ \text{P} + \text{HIO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4 + \text{HI} \]

\[ \text{H}_2\text{S} + \text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 + \text{HCl} \]

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

b) Is it possible to oxidize bromide ions into elemental bromine \([\text{2Br}^-\text{Br}^-\text{e}^0=1.0652 \text{ V}]\) using the elemental chlorine \([\text{Cl}_2\text{Cl}^-\text{e}^1=1.3595 \text{ V}]\) ?

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

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

6. Write the Nernst’s equation for the different electrodes.
7. Calculate the electrode potential of zinc electrode if the active concentration of zinc ions is 5 mol/L and T = 298 K.

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

9. 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.

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

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

12. Calculate the electromotive force and make up a pattern of the galvanic element consisting
of iron and silver electrodes.
\[ e^0_{Ag^+|Ag}=+0.799 \text{ V}; \ e^0_{Fe^{2+}|Fe}=-0.441 \text{ V}. \]

13. The E.M.F. of the galvanic element composed of calomel and hydrogen electrodes is 0.35 V. Calculate the pH value if \( e_{cal} = +0.248 \text{ V} \).

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

\[
\begin{align*}
&\text{Pt} \left[ \frac{Co^{3+}}{Co^{2+}} \right] \quad \text{and} \quad \text{Pt} \left[ \frac{MnO_4^-}{Mn^{2+}}, H^+ \right], \quad e^0_{Co^{3+}|Co^{2+}}=+1.81 \text{ V}; \ e^0_{MnO_4^-|Mn^{2+}}=+1.52 \text{ V}. \\
\end{align*}
\]

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.

15. 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 0.0001 mol/L correspondingly at \( T = 298 \text{ K} \)?
LESSON 14
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.

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

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

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

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

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SUBJECT. ADSORPTION PROCESSES AND ION EXCHANGE IN BIOLOGICAL SYSTEMS. CHROMATOGRAPHY

LESSON 15

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.

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. Free surface energy and surface tension.
4. Orientation of surfactants molecules in the surface layer.
5. Adsorption on solids. Langmuir’s equation.
7. Physico-chemical fundamentals of adsorption therapy (hemosorption, enterosorption, application therapy).
8. Ion adsorption. Peskov-Fajans rule of selective adsorption. Types of ion exchangers.
10. Adsorption chromatography.
11. Partition chromatography.
12. Ion-exchange chromatography.
15. Thin layer chromatography.

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.
4. To know the factors of selective ion adsorption.
5. To be able to explain particularities of ion exchange in biological structures.
6. To know the essence of chromatographic analysis method.
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_{2}SO_{4}, C_{3}H_{7}OH, HCl, NaOH, C_{3}H_{11}NH_{2}, C_{4}H_{9}SO_{3}H, HSO_{3}Cl.
   a) surface-active agents
   b) surface-inactive agents
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   ____________________________________________

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

3. Point hydrophilic and hydrophobic groups in the molecules of propionic acid (C_{3}H_{5}COOH) and butan-1-ol (CH_{3}CH_{2}CH_{2}CH_{2}-OH). How are these molecules oriented in the surface of a liquid?
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4. Write Gibbs’ equation. What is surface activity?
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   ____________________________________________

5. When the value of surface activity is positive, and when it is negative?
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6. How many times surface activity of valeric acid (CH_{3}CH_{2}CH_{2}CH_{2}COOH) is greater than that of acetic acid (CH_{3}COOH)?
   ____________________________________________

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 \((\text{SiO}_2 \cdot \text{H}_2\text{O})\) from hydrocarbons?

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

11. Name factors of selective ion adsorption

12. What is the selectivity of ions adsorption from solutions on the solid surfaces? Formulate Peskov-Fajans rule of selective adsorption.

13. Which of the following ions will be preferentially adsorbed on AgCl particles: \(\text{Na}^+, \text{Ca}^{2+}, \text{SO}_4^{2-}, \text{Cl}^-, \text{NO}_3^-, \text{Ag}^+?\)

14. Place following ions in the order of increasing of adsorption ability: \(\text{Fe}^{3+}, \text{Ca}^{2+}, \text{K}^+, \text{Th}^{4+}, \text{and I}^-, \text{Br}^-, \text{Cl}^-, \text{CNS}^-\).
15. Explain the process of ion-exchange adsorption using the example of permutite – [Permutite Na₂], which is applied for water softening.

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

_____________________________________________________________________________

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

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18. Give classification of chromatographic methods.

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

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20. Explain the process of gas-liquid chromatography.

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21. Give examples of chromatography application in medicine and biology.

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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 molar concentrations indicated below. Adsorption takes 30 min. The content of flasks should be shaken up periodically. In 30 min decant solutions through paper filters. Pour out 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. Each solution should be titrated 3 times in order to obtain the average value. Note down the data to the table.
Calculate the equilibrium concentrations of acetic acid according to the equation:

$$C_{eq} = \frac{C_{(NaOH)} \cdot V_{(NaOH)}}{V_{(CH_3COOH)}}$$

Calculate the value of absorption according to the equation:

$$\Gamma = \frac{[C_0(CH_3COOH) - C_{eq(CH_3COOH)}] \cdot V(CH_3COOH)}{m_{carbon}}$$

Plot the graph of adsorption isotherm, i.e. adsorption against concentration.

Make conclusions

Date ___________________________ Signature ___________________________
LESSON 16. PREPARATION, PURIFICATION AND PROPERTIES OF COLLOIDAL SOLUTIONS. PHYSICO-CHEMISTRY OF BIOPOLYMERS SOLUTIONS (LESSONS 16 – 18)

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.

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.

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. 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 dispersion medium
   a) molecular-kinetic (diffusion, osmosis, Brownian movement)
   b) optical (the scattering of light)
   c) electro-kinetic (electrophoresis, electroosmosis)
5. Types of colloidal solutions stability and factors determining them.
6. Coagulation under the influence of electrolytes action. Hardy-Schulze rule.
8. Comparative characteristic of HWC, true and colloidal solutions.
9. Swelling and dissolution of polymers, their role in physiological processes.
11. Isoelectric point of proteins.

Practical skills

1. To be able to obtain a colloidal solution and to purify 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.
3. To use Hardy-Schulze rule.
4. To determine in practice the coagulation threshold.
5. To calculate the protective number.
6. 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.
LESSON 16

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) \(5 \times 10^{-7}\) м; b) \(5 \times 10^{-8}\) м; c) \(5 \times 10^{-9}\) м; d) \(5 \times 10^{-10}\) 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) \(\text{H}_2\text{SO}_4 + \text{Fe} \rightarrow \text{FeSO}_4 + \text{H}_2\); 
   b) \(\text{H}_2\text{SO}_4 + \text{BaCl}_2 \rightarrow \text{BaSO}_4 + 2\text{HCl}\); 
   c) \(\text{H}_2\text{SO}_4 + \text{Na}_2\text{SiO}_3 \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{SiO}_3\)?

   What are the conditions for these reactions running?

4. Explain the mechanism of colloidal particles formation during the reaction running

   \(\text{CaCl}_2 + \text{Na}_2\text{SO}_4 \rightarrow \text{CaSO}_4 + 2\text{NaCl}\),

   if a stabilizer is: a) \(\text{CaCl}_2\), b) \(\text{Na}_2\text{SO}_4\).

5. 3 ml of \(\text{Fe(NO}_3)_3\) \((C(\text{Fe(NO}_3)_3 = 0.007 \text{ mol/L})\) solution were mixed with 5 ml of \(\text{Na}_3\text{PO}_4\) \((C(\text{Na}_3\text{PO}_4) = 0.01 \text{ mol/L})\) 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 \(\text{H}_2\text{SO}_4\) solution and in the colloidal solution of
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 \( C(FeCl_3) = 0.005 \text{ mol/L} \) and potassium ferrocyanide (II) solution with \( C(K_4[Fe(CN)_6]) = 0.005 \text{ mol/L} \) 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.
LESSON 17.

Questions for class work and self work

1. What is kinetic stability and what is aggregative stability of sols? What does each of them depend on?

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2. Name factors of stability of colloidal systems.

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

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4. Define the following phenomena: coagulation, sedimentation, hidden and explicit coagulation.

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

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6. Write the formulae of sols micelles: Al(OH)$_3$, stabilized by AlCl$_3$ and SiO$_2$, stabilized by H$_2$SiO$_3$. Which ions cause coagulation of these sols (Hardy-Schulze rule): Na$_2$SO$_4$, KCl, FeBr$_3$, CaI$_2$, Na$_3$PO$_4$? What series are called lyotropic and what do they show?

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

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8. 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 0.01 M solution of Na$_2$SO$_4$ and 3.7 ml of 0.001 M solution of Na$_3$PO$_4$ were added in each case. What charge do the particles of sol have? What is the value of coagulation threshold of each electrolyte? Determine the ratio of ions coagulating power.

9. 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 ion antagonism in the life of living creatures.

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

11. Two sols of silver iodide are obtained: the first one is obtained by the addition of 16 ml of silver nitrate with C(E) = 0.05 mol/L to 20 ml of potassium iodide with C(E) = 0.05 mol/L, the other one — by the addition of 16 ml of potassium iodide with C(E) = 0.05 mol/L to 20 ml of silver nitrate with C(E) = 0.05 mol/L. Will we observe any phenomena when pouring them in a vessel together?

12. What phenomenon do we call tolerance?

13. What phenomena do we call colloidal protection? What is its practical use? What can we define as a measure of protective action?

14. 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.

**Procedure**

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

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

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.

<table>
<thead>
<tr>
<th>Electrolyte</th>
<th>C(E) of electrolyte, mol/L</th>
<th>Volume of electrolyte, V(x), ml</th>
<th>Coagulating ion</th>
<th>Coagulation threshold, C(x) mmol/L</th>
<th>Coagulating power, P(x), L/mmol</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td>1</td>
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<td></td>
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<tr>
<td>K$_2$CrO$_4$</td>
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<tr>
<td>K$_3$[Fe(CN)$_6$]</td>
<td>0.01</td>
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</tbody>
</table>

**The experimental data processing**

1. Calculation of coagulation threshold:

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

2. Calculation of coagulating power of electrolytes:

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

Conclusions _______________________________________________________
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Date________________________________Signature________________________________
LESSON 18

Questions for class work and self work

1. Give classification of high molecular weight compounds:
   - on the basis of origin____________________________________________________
   - on the basis of mode of synthesis________________________________________
   - on the basis of chemical composition_____________________________________
   - on the basis of structure_________________________________________________

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

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?

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

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LABORATORY WORK: “PROTECTIVE ACTION OF BIOPOLYMERS”

Procedure

Fill 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: 

\[
C(\text{Na}_2\text{SO}_4) = \frac{\text{C}(\text{Na}_2\text{SO}_4) \cdot V(\text{Na}_2\text{SO}_4) \cdot 1000}{V(\text{sol}) + V(\text{Na}_2\text{SO}_4)}
\]

Note down the data to the table.

<table>
<thead>
<tr>
<th>№ of test tube</th>
<th>Volume of polymer, ml</th>
<th>Volume of Na(_2)SO(_4), ml</th>
<th>Coagulation threshold ( C ), mmol/L</th>
</tr>
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</table>

Note down the data to the table.

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**

90 hours (3 credits)  
=  
50 hours of class work (10 hours of lectures + 40 hours of practical classes)  
+  
40 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 mark got by a student for the course completion is to be identified according to the scale of ratings. 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**

<table>
<thead>
<tr>
<th>Mark for module in ECTS points</th>
<th>ECTS score</th>
<th>Traditional mark</th>
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</thead>
<tbody>
<tr>
<td>180-200</td>
<td>A</td>
<td>5</td>
</tr>
<tr>
<td>150-179</td>
<td>B, C</td>
<td>4</td>
</tr>
<tr>
<td>120-149</td>
<td>D, E</td>
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<tr>
<td>&lt; 120</td>
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Conversion of traditional marks for each subject into points

<table>
<thead>
<tr>
<th>Marks</th>
<th>Points</th>
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<tr>
<td>5</td>
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<tr>
<td>4</td>
<td>8</td>
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<td>3</td>
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Distribution of points in subjects and modules of Medical Chemistry

<table>
<thead>
<tr>
<th>#</th>
<th>Subject</th>
<th>Number of hours</th>
<th>Number of lessons</th>
<th>Min/max of points</th>
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<tbody>
<tr>
<td>1</td>
<td>Structure of chemical substances. Biogenic elements in medicine and stomatology</td>
<td>2</td>
<td>1</td>
<td>6-10</td>
</tr>
<tr>
<td>2</td>
<td>Thermodynamic and kinetic regularities of chemical processes. Chemical equilibrium. Reactions of dissolution and precipitation</td>
<td>6</td>
<td>3</td>
<td>6-10</td>
</tr>
<tr>
<td>3</td>
<td>Values characterizing quantitative composition of solutions. Preparation of solutions</td>
<td>2</td>
<td>1</td>
<td>6-10</td>
</tr>
<tr>
<td>4</td>
<td>Acid-base equilibrium in the organism. pH of biological liquids</td>
<td>2</td>
<td>1</td>
<td>6-10</td>
</tr>
<tr>
<td>5</td>
<td>Properties of buffer solutions. Role of buffers in biological systems.</td>
<td>2</td>
<td>1</td>
<td>6-10</td>
</tr>
<tr>
<td>6</td>
<td>Colligative properties of solutions</td>
<td>2</td>
<td>1</td>
<td>6-10</td>
</tr>
<tr>
<td>7</td>
<td>Titrimetric analysis. Acid-base titration.</td>
<td>6</td>
<td>3</td>
<td>6-10</td>
</tr>
<tr>
<td>8</td>
<td>Complex formation in biological systems</td>
<td>2</td>
<td>1</td>
<td>6-10</td>
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<tr>
<td>9</td>
<td>Oxidation-reduction reactions. Determination of electrode potentials</td>
<td>4</td>
<td>2</td>
<td>6-10</td>
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<tr>
<td>10</td>
<td>Adsorption processes and ion exchange in biological systems. Chromatography</td>
<td>2</td>
<td>1</td>
<td>6-10</td>
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<td>Preparation, purification and properties of colloidal solutions. Coagulation of colloidal solutions. Physico-chemistry of biopolymers solutions.</td>
<td>6</td>
<td>3</td>
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<td>12</td>
<td>Report “Biogenic elements in medicine and stomatology”</td>
<td>2</td>
<td>1</td>
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<tr>
<td>13</td>
<td>Control of practical skills. Module control “Fundamentals of medical chemistry”</td>
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<td>14</td>
<td>Total:</td>
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<td>120-200</td>
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</table>

**Questionnaire for the final testing in discipline “Medical chemistry”**

7. Prognosis of chemical equilibrium shifting.
8. Rate of a chemical reaction. Law of mass action for rate of a chemical reaction. Rate constant.
14. Enzymes – catalysts of biochemical reactions. Dependence of enzymes action on the concentration of enzyme and substrate, temperature and pH.
15. Role of solutions in life activity. Enthalpy and entropic factors of dissolution and their connection with dissolution mechanism.
17. Solubility of solid substances and liquids. Distribution of substances between to immiscible liquids. Nernst distribution law, its significance for biological membranes permeability.
22. Buffer capacity and factors which it depends on. Buffer systems of blood.
25. Is it possible to calculate osmotic pressure of solution according to the cryoscopy and ebullioscopy data? Give the example of calculations.
26. How to calculate molar mass of the substance according to cryoscopy data? Which solvent should be taken for precise determination of the molar mass – the one with higher or lower value of cryoscopic constant?
28. Solutions of complex compounds. Modern ideas about structure of complex compounds.
29. Complex compounds classification (according to ligands nature and charge of the inner sphere).
32. Standard hydrogen electrode.
35. 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.
37. Potentiometry and its application in medico-biological investigations.
39. Langmuire equation.
40. Adsorption from solutions on the surface of solids. Freundlich equation.
41. Physico-chemical fundamentals of adsorption therapy.
42. Electrolytes adsorption (selective and ion-exchange). Peskov-Fajans rule.
43. Ionites and their application in medicine.
44. Classification of chromatography methods according to mechanism of substances distribution, aggregative state of phases and performance technique. Application of chromatography in medico-biological researches.
46. Molecular-kinetic properties of colloidal solutions (Brownian movement, diffusion, osmotic pressure).
51. 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.
52. Isoelectric point of proteins. Methods of pI determination.
55. Donnan’s membrane equilibrium.
Contents

Introduction........................................................................................................................................................................

Work safety..............................................................................................................................................................................

Informative Module 1
Theoretical fundamentals of chemical reactions and biochemical processes

Subject. Structure of chemical substances. Biogenic elements in medicine and stomatology
(Lesson 1)...............................................................................................................................................................................
Subject. Thermodynamic and kinetic regularities of chemical processes. Chemical equilibrium.
Reactions of dissolution and precipitation. ....................................................
  Lesson 2. Chemical thermodynamics. ....................................................
  Lesson 3. Kinetics of biochemical reactions and Catalysis......................
  Lesson 4. Chemical equilibrium. Solubility product..........................
Subject. Values characterizing quantitative composition of solutions. Preparation of solutions
(Lesson 5)...............................................................................................................................................................................
Subject. Acid-base equilibrium in the organism. pH of biological liquids (Lesson 6)...........
Subject. Buffer solutions, classification and mechanism of action. Role of buffers in biological systems. (Lesson 7)...............................................................................................................................................................................
Subject. Colligative properties of solutions (Lesson 8)..................................................
Subject. Fundamentals of titrimetric analysis..................................................
  (Lesson 9)..................................................................................................................
  (Lesson 10)..................................................................................................................
  (Lesson 11)..................................................................................................................

Informative Module 2
Heterogeneous equilibria in biological liquids
Acid-base equilibria in biological liquids

Subject. Complex formation in biological liquids (Lesson 12).........................
Subject. Oxidation-reduction reactions. Determination of electrode potentials............... 
  (Lesson 13)..................................................................................................................
  (Lesson 14)..................................................................................................................
Subject. Adsorption processes and ion exchange in biological systems. Chromatography (Lesson 15)............................................................
Subject. Preparation, purification and properties of colloidal solutions. Physico-chemistry of biopolymers solutions..............................................................................................................................
  (Lesson 16)..................................................................................................................
  (Lesson 17)..................................................................................................................
  (Lesson 18)..................................................................................................................
System of students’ progress evaluation regarding the course of medical chemistry........
Questionnaire for the final testing in discipline “Medical chemistry” ..................
УТВЕРЖДЕНО УЧЕНЫМ СОВЕТОМ ХНМУ, протокол № от

Сырова А. О. и др.

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