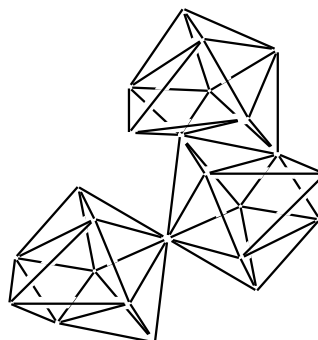
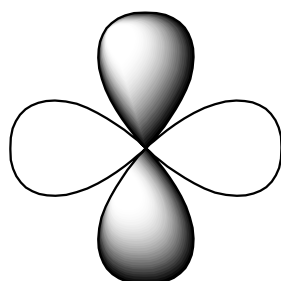


**Vinnitsia National Pirogov Memorial Medical University**  
Biological and General Chemistry Department  
Medical chemistry course



**SYSTEMATIC COURSE**  
practical lessons of medical chemistry for foreign students

**Module 2. Equilibrium in biological systems at the interfaces**



**Vinnitsia 2017**

A work sheet and methodical developments (Methodical of recommendation for practical classes from Medical chemistry for 1-st year foreign students) are made by the employees of department of biological and general chemistry of VNMMU Pirogov in accordance with a curriculum, worked out on principles of the European credit-transfer system (ECTS) for higher medical establishments of Ukraine III - IV levels of accreditation for specialities of “Medical Affairs” direction of the preparation “Medicine” is in accordance with education qualification descriptions (EQD) and scientific professional programs (SPP) of the preparation of specialists, approved by an order MES Ukraine from 16.04.03 № 239.

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It is discussed and approved on a meeting of the department of biological and general chemistry, protocol № 1 from 28.08.2017y.

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## CONTENT

TOPIC 1	Thermal effects of the chemical direction of the processes	6
TOPIC 2	Kinetics of biochemical reactions	8
TOPIC 3	Chemical equilibrium. Solubility equilibrium	11
TOPIC 4	Potentiometric method of analysis	14
TOPIC 5	Determination of oxidation-reduction (redox) potential	15
TOPIC 6	Surface tension	17
TOPIC 7	Sorbition of biological active compounds on the layer liquid – gas	19
TOPIC 8	Sorption of biological active compounds at the interface solid-liquid	20
TOPIC 9	Ion exchange. Chromatography	22
TOPIC10	Colloidal solutions. Synthesis, purification and properties	24
TOPIC 11	Coagulation of colloids. Colloidal stability	26
TOPIC 12	Properties of biopolymers. Isoelectric point	28

## SAFETY IN THE CHEMICAL LABORATORY AND FIRST AID RULES.

1. The chemical laboratory must be always extremely clean and kept the order and silence. It should not be present unnecessary staff and the roles of safety must be performed.
2. The student has to wear the laboratory coat and special medical hat in the laboratory.
3. Every student have to know where the fire-preventing means and the first-aid kit are placed in the laboratory.
4. It is forbidden to smoke, eat and drink in the laboratory.
5. It is not allowed to start the laboratory work without knowing the technique of the experiments.
6. Experiments must be carried out only in the clean laboratory dishes. After laboratory work finishing the dishes have to be washed.
7. The students must carefully perform the experiments and avoid getting the chemicals in eyes, on face and hands skin.
8. Do not taste the chemicals. To smell the substances is necessary to move the hand in the direction of face carefully.
9. Do not use the chemicals without the identified label on the flask or vessel.
10. Do not direct the test-tube towards the front of your face or near standing person during heating of solid or liquid substance. Do not have a look in the test-tube during such procedure.
11. Switch off gas, water, and electricity before leaving the laboratory.
12. It is forbidden to pour out the concentrated acid or base. The students have to use the special glasses, the gas mask working with the poisoning compounds, concentrated acid and base, phenol and others.
13. The experiments with the inflammable compounds (ether, acetone, benzene, alcohol) must be carried out far from fire and switched off instruments.
14. If fire starts, gas must be closed immediately. All inflammable compounds must be shifted far a way from fire and used the antifire stuffs (a fire-extinguisher, sand, antifire coating). Wrap person in fire blanket. **DO NOT USE WATER TO PUT OUT FIRE.**
15. The below given table is helpfull in an accident situation. Read and remember them.

<i>Situation</i>	<i>Safe Response</i>
Burns	Flush with ethanol solution or diluted solution of $\text{KMnO}_4$ .
Cuts and Bruises	Treat as directed by instructions included with first aid kit
Fainting or collapse	Provide person with fresh air, have him recline in a position so that his head is lower than their body
Foreign Matter in Eyes	Flush about 15 min with plenty of water, then go to the doctor
Severe bleeding	Apply pressure or a compress directly to the wound and get medical attention immediately
1. Spills, general 2. Acid burns 3. Base burns	1. Wash area with plenty of water, use safety shower if needed 2. Use sodium hydrogen carbonate (baking soda) 3. Use 3 % of boric acid or acetic acid

Short methodical directions for practical lesson:

Practical lesson is started from the general questions (5 min).

Explanation of unclear questions (25 min)

Writing of control test (15 min)

Carrying out a laboratory work, filling a laboratory notebook, signing the laboratory notebook by a teacher, announcing of student marks (45 min).

***Technological map of practical lesson:***

<i>N</i>	<i>Steps</i>	<i>Time (min)</i>	<i>Educational handout</i>	<i>Residence</i>
1	General questions	5		Faculty
2	Correction of theoretical student knowledge	20	Tables, task	
3	Control test	15	Test, questions	
4	Performing of laboratory work	40	Chemicals, chemical dishes, equipments.	
5	Analysis and conclusion of a practical lesson	10		

## ***TOPIC 1: Thermal effects of the chemical direction of the processes.***

**1. Actuality of the topic:** knowledge of chemical thermodynamics is necessary to understand the energetics of biochemical processes. Calculation of thermal effect is used in dietology for determination of food energy.

**2. General aim:** is to interpret the base thermodynamics laws for biological process characterization.

**3. Actual aims and abilities:**

- to know thermodynamics laws;

- to be able to calculate thermodynamic equations and to use them for determination of food energy.

**4. Literature:**

4.1. Lecture materials;

**5. The main questions of the seminar:**

5.1. Chemical thermodynamics as a branch of the physical chemistry. Thermodynamic system, types and the examples of the thermodynamic systems, intensive and extensive parameters of the system.

5.2. The first law of thermodynamics. Internal energy of system. Enthalpy.

5.3. Thermochemical equations. The standard enthalpy of formation and combustion.

5.4. Hess's law. Calorimetry.

5.5. The energetic characteristics of biochemical processes. Thermochemical calculations for the estimation of the calorie content in foodstuff and the dietotherapy.

**6. The questions for individual learning:**

6.1. The second law of thermodynamics. Entropy. Gibbs free energy.

6.2. Thermodynamic processes (reversible and irreversible). Thermodynamic equilibrium. Irreversibility of the processes in vital activity.

6.3. ATP as the source of the biochemical processes. Exergonic and endergonic processes in the human organism.

**7. The examples of the task:**

7.1. Calculation of  $\Delta H$ .

Calculate  $\Delta H^\circ$  of the reaction  $\text{CO}_{\text{gas}} + \text{H}_2_{\text{gas}} = \text{CH}_4_{\text{gas}} + \text{H}_2\text{O}_{\text{gas}}$  knowing that the standard enthalpy of formation for  $\text{CO} = -110 \text{ kJ/mol}$ ,  $\text{CH}_4 = -74.9 \text{ kJ/mol}$ ,  $\text{H}_2\text{O} = -241.8 \text{ kJ/mol}$ .

The answer:

$$\Delta H^\circ_f = \sum \Delta H^\circ_{\text{PRODUCTS}} - \sum \Delta H^\circ_{\text{REACTANTS}}$$

$$\Delta H^\circ_f = (\Delta H^\circ_f(\text{CH}_4) + \Delta H^\circ_f(\text{H}_2\text{O})) - \Delta H^\circ_f(\text{CO}) = -74,9 + (-241,8) - (-110,5) = -206,2 \text{ kJ/mol.}$$

7.2. Calculations for the estimation of the calorie content in foodstuff

100 g of cod (fish) contain 11.6 g of proteins. The calorie content of 1 g of proteins is 4.1 kcal.

Calculate the calorie content of cod.

The answer:

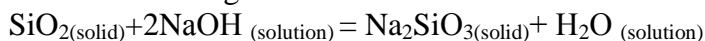
1 g of protein contains 4.1 kcal

11.6 g of protein contain X kcal

$$X = 11.6 \cdot 4.1 = 47.56 \text{ kcal.}$$

### 7.3. Detect the spontaneity of the process.

Can the following reaction



Occurs spontaneously when Gibbs energy of  $\text{SiO}_{2(\text{solid})} = -803,75 \text{ kJ/mol}$ ,

$\text{NaOH}_{(\text{sol})} = -419,5 \text{ kJ/mol}$ ,

$\text{Na}_2\text{SiO}_{3(\text{solid.})} = -1427,8 \text{ kJ/mol}$ ,

$\text{H}_2\text{O}_{(\text{sol})} = -237,5 \text{ kJ/mol}$ ?

The answer:

$$\Delta G = \sum \Delta G^{\circ}_{\text{PRODUCTS}} - \sum \Delta G^{\circ}_{\text{REACTANTS}} = (-1427,8 - 237,5) - (-803,75 - 2 \cdot 419,5) = -22,5 \text{ kJ/mol.}$$

Since  $\Delta G < 0$ , it is spontaneous.

### 8. **Homework (must be performed in the laboratory notebook):**

8.1. Calculate  $\Delta H$  of the reaction:



$\Delta H^{\circ}_f(\text{H}_2\text{C}_2\text{O}_4) = -60,10 \text{ kJ/mol}$ ;

$\Delta H^{\circ}_f(\text{CH}_3\text{OH}) = -173,65 \text{ kJ/mol}$ ;

$\Delta H^{\circ}_f(\text{H}_3\text{COOC} - \text{COOCH}_3) = -401,0 \text{ kJ/mol}$ ;

$\Delta H^{\circ}_f \text{H}_2\text{O} = -241,8 \text{ kJ/mol}$ .

8.2. Energy of the fat formation in human organism contains 9.3 kcal/g. Daily necessity of the male organism is 106 g of fat. Calculate the daily energy of fat for the male organism.

8.3. Can the reaction of glucose oxidation follow spontaneously at room temperature if the standard Gibbs energies of glucose, water, carbon oxide (IV) equal -910 kJ/mol; -237 kJ/mol; -394 kJ/mol.

### 9. **The control test**

**for instance :**

1. Choose the correct answer. The extensive parameters of the system are:

- volume, mass;
- pressure, temperature;
- concentration, potential.

2. Choose the correct answer. Exergonic systems in the human organism is

- glucose;
- ATP;
- glycogen.

3. Energy of the carbohydrates formation in human organism contains 4.1 kcal/g. Daily necessity of the female-student organism is 135 g of carbohydrates. Calculate the daily energy of carbohydrates for the female-student organism

### 10. **The algorithm of the experiments:**

10.1. Determination of thermal effect of neutralization reaction.

### 11. **The detailed explanation of the following experiment:**

#### 11.1. Determination of thermal effect of neutralization reaction.

Thermal effect of a chemical reaction is determined in calorimeter. The calorimeter with known mass is filled by 150 ml of NaOH solution with  $C_n = 1 \text{ mol/L}$ . The temperature of the solution must be measured. In the glass put 150 ml of 1 M HCl solution and the temperature of the second solution must be measured too. The solution of HCl is added to the solution of the NaOH *constantly mixing*. The temperature of the final solution is measured.

The experimental data are filled in the table.

<i>Mass of the calorimeter (<math>m_1</math>)/g</i>	
<i>Concentration of the acid and base (C)</i>	1 M
<i>Volume of the solutions (V)</i>	150 ml
<i>Temperature of NaOH solution (<math>t_{\text{NaOH}}</math>)/°C</i>	
<i>Temperature of HCl solution (<math>t_{\text{HCl}}</math>)/°C</i>	
<i>The initial temperature of the resulting solution <math>t_1 = 1/2 (t_{\text{NaOH}} + t_{\text{HCl}})</math>/°C</i>	
<i>The temperature of the resulting solution after neutralization <math>t_2</math>/°C</i>	
<i>The total mass of the solutions <math>m_2 = 2 V \rho</math></i>	

Calculate the heat of the neutralization reaction using :

$$C_x = \frac{w\% \cdot \rho \cdot 10}{M_x} = \underline{\hspace{2cm}},$$

where  $\Delta t = t_2 - t_1$ ;  $C = m_1 c_1 + m_2 c_2$ ;

$c_1$  (specific heat of the glass) = 0,753 J/g°C,

$c_2$  (specific heat of the solution) = 4,184 J/g°C.

$\text{NaOH} + \text{HCl} = \text{NaCl} + \text{H}_2\text{O}$ ;  $\Delta H = - \underline{\hspace{2cm}}$ .

## **TOPIC 2: Kinetics of biochemical reactions.**

**1. Actuality of the topic:** knowledge and understanding of the kinetic laws is essential to study the mechanism of the organic reactions, the enzymatic processes, the formation of metabolite, the suction and transmutation of the drugs.

**2. General aim:** is to interpret the base kinetics laws for biological process characterization.

**3. Actual aims and abilities:**

- to have an idea about the main meanings of the chemical kinetics;
- to know the laws and rules of kinetics;
- to be able to reveal and explain the influence of the various factors on the rate of the chemical reactions, to determine the order and molecularity of the chemical reaction as well as the biological one.

**4. Literature:**

4.1. Lecture materials;

**5. The main questions of the seminar:**

5.1. The rate of the homogeneous and heterogeneous reactions and its dependence on concentration. The law of mass action states. The rate constants.

5.2. The rate of the reaction. The kinetic equations of zero-, first- and second-orders.

5.3. Conception of the reaction mechanism. Molecularity of the reaction.

5.4. The dependence of the reaction rate on the temperature. Van't Hoff's rule. The characteristic properties of the temperature coefficient for the biological processes.

5.5. Collision theory. Activation energy. Arrhenius equation. Transition states.

5.6. Enzyme kinetics.

**6. The questions for individual learning:**

6.1. Half-life.



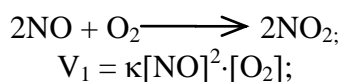
- 6.2. The parallel, consecutive, conjugate, reversible and chain reactions. Photochemical reactions.
- 6.3. Free radical reactions in the living organism. Antioxidants.
- 6.4. Catalysis and the catalysts. Homogeneous and heterogeneous catalysis. Acid-base catalysis. The mechanism action of the catalysts. Autocatalysis. The promoters and inhibitors.

**7. The examples of the task:**

7.1. The influence of the concentration on the reaction rate.

How does the reaction rate of the oxidation nitrogen (II) to nitrogen (IV) change if the system pressure is raised in 3 times?

The answer:



When the pressure is increased in 3 times, the volume of the system is decreased in 3 times. Consequently the concentration of the components is increased in 3 times.

Then,  $V_2 = \kappa[3\text{NO}]^2 \cdot [3\text{O}_2] = 27 \kappa[\text{NO}]^2 \cdot [\text{O}_2];$

$$\frac{V_2}{V_1} = \frac{27\kappa[\text{NO}]^2 \cdot [\text{O}_2]}{\kappa[\text{NO}] \cdot [\text{O}_2]} = 27 \text{ thus, the reaction rate is increased in 27 times.}$$

7.2. The influence of the temperature on the reaction rate.

The reaction time is 2 min 15 sec at 50 °C. Calculate the reaction time at 70 °C knowing the temperature coefficient ( $\gamma$ ) is 3.

The answer:

$$\frac{r_2}{r_1} = \gamma^{\frac{t_2 - t_1}{10}} = 3^{\frac{70 - 50}{10}} = 3^2 = 9$$

$$r_1 = \frac{\Delta C}{\Delta t_1}$$

$$r_2 = \frac{\Delta C}{\Delta t_2}$$

$$\frac{r_2}{r_1} = \frac{\Delta C \Delta t_1}{\Delta t_2 \Delta C}$$

Since  $\Delta C$  is constant follows

$$\frac{r_2}{r_1} = \frac{\Delta t_1}{\Delta t_2} = \gamma^{\frac{t_2 - t_1}{10}}$$

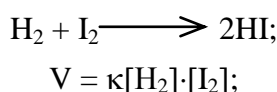
Where,

$$\Delta t_2 = \frac{\Delta t_1}{\gamma^{\frac{t_2 - t_1}{10}}} = \frac{135}{9} = 15 \text{ sec}$$

7.3. Determination of the reaction order.

Determine the reaction order of the interaction of hydrogen with iodine.

The answer:



The reaction rate depends on the concentration of two components and the sum of the exponents is 2. The reaction is the second order.

**8. Homework (must be performed in the laboratory notebook):**

- 8.1. How does the reaction rate of ammonia synthesis change if the volumes of molecular hydrogen and nitrogen are enlarged in 3 times?  
8.2. The reaction time are 25 min at 30°C and 4 min at 50°C. Calculate the temperature coefficient ( $\gamma$ ) of the reaction rate for the given temperature range.  
8.3. Determine the reaction order of the hydrolysis.

**9. The control test:**

*for instance:*

- 9.1. The reaction rate is affected by:  
a) the volume  
b) the concentration  
c) the density  
9.2. How does the reaction rate change if the temperature is increased by in 3 times at 30 °?

**10. The algorithm of the experiments:**

- 10.1. Dependence of the reaction rate on the concentration of the reactants.  
10.2. Dependence of the reaction rate on the temperature.

**11. The detailed explanation of the following experiment:**

11.1. Dependence of the reaction rate on the concentration of the reactants.

Prepare the sodium thiosulphate solution of different concentrations.

	<u>1 test-tube</u>	<u>2 test-tube</u>	<u>3 test-tube</u>
$Na_2S_2O_3$	5 drops	10 drops	15 drops
$H_2O$	10 drops	5 drops	-

Add 1 drop of  $H_2SO_4$  solution in the first test-tube and fix the end of the reaction (time when the dimness of the solution occurs). Analogous perform the same procedure for the last two test- tubes. Fill the table.

No of the test-tube	Number of $Na_2S_2O_3$ drops	Number of $H_2O$ drops	Reaction time / sec.	Relative rate, 1/sec
1				
2				
3				

Depict the graph of the reaction rate vs the concentration of the reactants where the abscise is the concentration data and the ordinate axis is the reaction rate. Write the reaction equation and make a conclusion.

11.2. Dependence of the reaction rate on the temperature.

In the first test-tube add 10 drops of  $Na_2S_2O_3$  solution and measure the room temperature, then add 1 drop  $H_2SO_4$  solution and fix time (sec) when the solution becomes to be muddy. The second test-tube must be filled by 10 drops of  $Na_2S_2O_3$  solution and heat the test-tube to a higher room temperature by 10 °C, add 1 drop of sulphuric acid and fix time (sec) when the solution becomes to be muddy.

The third test-tube must be filled by 10 drops of  $Na_2S_2O_3$  solution and heat the test-tube to a higher room temperature by 20 °C, add 1 drop of sulphuric acid and fix time (sec) when the solution becomes to be muddy.

Fill the table. Is Van't Hoff rule valid for the given experiments?

<i>Nº of the test-tube</i>	<i>Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub></i>	<i>t</i>	<i>H<sub>2</sub>SO<sub>4</sub></i>	<i>Time/sec</i>
<i>1 test-tube</i>	10 drops	room	1 drop	
<i>2 test-tube</i>	10 drops	room + 10 °C	1 drop	
<i>3 test-tube</i>	10 drops	room + 20 °C	1 drop	

### **TOPIC 3: Chemical equilibrium. Solubility equilibrium.**

**1. Actuality of the topic:** the knowledge of the chemical equilibrium principles is necessary to study the direction of the chemical and enzymatic processes as a result of the action of the various factors.

**2. General aim:** is to interpret the basic chemical equilibrium for biological process characterization.

**3. Actual aims and abilities:**

- to have an idea about the main meanings of the chemical equilibrium;
- to know the Le Chatelier's principle;
- to be able to reveal and explain the influence of the various factors on the chemical equilibrium.

**4. Literature:**

4.1. Lecture materials;

**5. The main questions of the seminar:**

- 5.1. Reversible and irreversible chemical reactions.
- 5.2. Chemical equilibrium.
- 5.3. Thermodynamic conditions of equilibrium.
- 5.4. The constant of the chemical equilibrium and its expression.
- 5.5. The shift of chemical equilibrium changing temperature, pressure and concentration. Le Chatelier's principle.

**6. The questions for individual learning:**

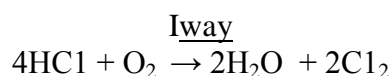
- 6.1. Solubility and precipitation reactions.
- 6.2. The conditions of solubility and precipitation.
- 6.3. Solubility product.
- 6.4. The role of the heterogeneous equilibrium (in the presence of the salts) in the general homeostasis of human organism.

**7. The examples of the task:**

7.1. The shift of chemical equilibrium changing with the concentration.

What is the direction of the chemical reaction  $\text{HCl} + \text{O}_2 \rightarrow \text{H}_2\text{O} + \text{Cl}_2$  if the concentration of all substances is accelerated in 2 times?

The answer:



1) Accordingly the mass action law:

$$V_{\text{forward}} = K_1 \cdot [\text{HCl}]^4 \cdot [\text{O}_2]$$

$$V_{\text{reverse}} = K_2 \cdot [\text{H}_2\text{O}]^2 \cdot [\text{Cl}_2]^2$$

2) After the increase the concentrations twice:

$$V_{\text{forward}} = K_1 \cdot [2\text{HCl}]^4 \cdot [2\text{O}_2] = 32 \cdot K_1 \cdot [\text{HCl}]^4 \cdot [\text{O}_2]$$

$$V_{\text{reverse}} = K_2 \cdot [2\text{H}_2\text{O}]^2 \cdot [2\text{Cl}_2]^2 = 16 \cdot K_2 \cdot [\text{H}_2\text{O}]^2 \cdot [\text{Cl}_2]^2$$

3)

$$\frac{V_{\text{forward}}}{V_{\text{reverse}}} = \frac{32}{16} = 2$$

The chemical equilibrium is shifted in the side of the direct reaction.

#### II way

1) The equilibrium constant before the increase of concentrations.

$$K_{P_1} = \frac{[\text{H}_2\text{O}]^2 \cdot [\text{Cl}_2]^2}{[\text{HCl}]^4 \cdot [\text{O}_2]}$$

2) The equilibrium constant after the increase of concentrations.

$$K_{P_1} = \frac{[2\text{H}_2\text{O}]^2 [2\text{Cl}_2]^2}{[2\text{HCl}]^4 [2\text{O}_2]}$$

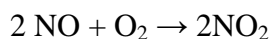
1) 
$$\frac{K_{P_1}}{K_{P_2}} = 2$$

The chemical equilibrium is shifted in the side of the direct reaction.

### 7.2. The shift of chemical equilibrium changing the pressure.

The equilibrium of the reaction  $\text{NO} + \text{O}_2 \rightarrow \text{NO}_2$  is stated at  $[\text{NO}] = 0.5 \text{ mol/l}$ ,  $[\text{NO}_2] = 2.1 \text{ mol/l}$ ,  $[\text{O}_2] = 0.7 \text{ mol/l}$ . What is the direction of the reaction if the pressure in the system is lowered in 2 times?

The answer:



#### I way.

$$K_{\text{equil.}} = \frac{[\text{NO}_2]^2}{[\text{NO}]^2 \cdot [\text{O}_2]}$$

1)  $V_{\text{forward}} = K_1 \cdot [\text{NO}]^2 \cdot [\text{O}_2] = K_1 \cdot (0.5)^2 \cdot (0.7) = K_1 \cdot 0.175$

2)  $V_{\text{reverse}} = K_2 \cdot [\text{NO}_2]^2 = K_2 \cdot (2.1)^2 = K_2 \cdot 4.41$

3) After decreasing of the pressure in 2 times:

$$V_{\text{forward}} = K_1 \cdot \left(\frac{0.5}{2}\right)^2 \cdot \frac{0.7}{2}$$

$$V_{\text{reverse}} = K_2 \cdot \left(\frac{2.1}{2}\right)^2 = K_2 \cdot 1.101$$

4)

$$\frac{V_{\text{forward}}}{V_{\text{forward}'}} = \frac{K_1 \cdot 0.175}{K_1 \cdot 0.0219} = 8 \text{ times}$$

(it is decreased);

$$\frac{V_{\text{reverse}}}{V_{\text{reverse}'}} = \frac{K_2 \cdot 4.41}{K_2 \cdot 1.101} = 4 \text{ times}$$

(it is decreased).

The chemical equilibrium is shifted in the indirect side.

#### II way

1) The equilibrium constant before the pressure changes:

$$K_{\text{equil}_1} = \frac{[2.1 \text{NO}_2]^2}{[0.5 \text{NO}]^2 \cdot [0.7 \text{O}_2]} = \frac{4.41}{0.175} = 25.2$$

2) The equilibrium constant after the pressure changes:

$$K_{\text{equil}_2} = \frac{[2.1/2]^2}{[0.5/2]^2 \cdot [0.7/2]} = \frac{1.1025}{0.022} = 50.4$$

3)

$$\frac{K_{P_1}}{K_{P_2}} = \frac{50.4}{25.2} = 2$$

The chemical equilibrium is shifted in the indirect side.

### 7.3. Calculation of solubility product (SP) of the low soluble compounds.

Calculate SP of silver chromate if the solubility is  $6,5 \cdot 10^{-5}$ .

The answer:

1. Silver chromate is dissociated as



2. The concentration is calculated as

$$[\text{Ag}^+] = 2 \cdot 6,5 \cdot 10^{-5} = 1,3 \cdot 10^{-4} \text{ mol/l}$$

$$[\text{CrO}_4^{2-}] = 6,5 \cdot 10^{-5} \text{ mol/l}$$

3.  $\text{Ag}_2\text{CrO}_4 = [\text{Ag}^+]^2 \cdot [\text{CrO}_4^{2-}] = (1,3 \cdot 10^{-4}) \cdot 6,5 \cdot 10^{-5} = 1,1 \cdot 10^{-12}$

### **8. Homework (must be performed in the laboratory notebook):**

8.1. The equilibrium constant of the thermal reaction  $\text{N}_2\text{O}_4 \rightarrow 2\text{NO}_2$  is 0.26. The equilibrium concentration of  $\text{NO}_2$  is 0,28 mol/l. Calculate the equilibrium concentration of  $\text{N}_2\text{O}_4$ .

8.2. What is the equilibrium direction of the reaction  $\text{CH}_4 + \text{H}_2\text{O} = \text{CO} + \text{H}_2$  if the volumes are lowered thrice?

8.3. Calculate SP of barium sulphate if solubility is  $1.05 \cdot 10^{-5}$ .

### **9. The control test:**

*for instance:*

9.1. The chemical equilibrium of the reaction  $\text{SO}_3 \leftrightarrow \text{SO}_2 + \text{O}_2$  as the result of pressure decrease shifts in:

- a) left side
- b) right side
- c) does not shift

9.2. Calculate SP of calcium oxalate if its solubility is  $5.07 \cdot 10^{-5}$  mol/l.

### **10. The algorithm of the experiments:**

10.1. Influence of the reactant concentration on the equilibrium shift.

10.2. Influence of temperature on the equilibrium shift.

### **11. The detailed explanation of the following experiment:**

11.1. Influence of the reactant concentration on the equilibrium shift.

Add 1 drop of saturated  $\text{FeCl}_3$  solution and 1 drop of  $\text{NH}_4\text{SCN}$  solution to 50 mls of water. The solution is mixed and divided in 4 test-tubes.

- 1) add 2 drops of saturated  $\text{FeCl}_3$  solution;
- 2) add 2 drops of saturated  $\text{NH}_4\text{SCN}$  solution;
- 3) add some crystals of  $\text{NH}_4\text{Cl}$ ;

Give data in table. Write the chemical equations, the equilibrium constants, make the conclusions.

<i>Nº test-tube</i>	<i>Added component</i>	<i>Color change</i>	<i>Conclusion (equilibrium shift)</i>
<i>1</i>	FeCl <sub>3</sub>		
<i>2</i>	NH <sub>4</sub> SCN		
<i>3</i>	NH <sub>4</sub> Cl		

### 11.2. Influence of temperature on the equilibrium shift.

In two test-tubes add 5 ml of starch solution and 1 drop of iodine solution. Heat one of them and then cool it. The second one is the blank test-tube. Make a conclusion.

## ***TOPIC 4: Potentiometric method of analysis.***

**1. Actuality of the topic:** electrochemical phenomena are observed in human organism. The muscles movements, heartbeat, spreading of nerve impulses are accompanied by electrochemical phenomena. Electrochemical analysis is widely used in medicine for determination of pH, biological liquids, for determination of the concentration of acids and bases that can not be detected by visual titration.

**2. General aim:** is to detect the active and potential acidity of biological liquid and organs by potentiometry.

### **3. Actual aims and abilities:**

- use the knowledge about the mechanism of creation of electrode potential to estimate the character of biochemical processes in wide pH range.
- to be able to measure the pH, the total acidity of biological liquids and organs for the diagnostic, prediction and medical treatment.

### **4. Literature:**

4.1. Lecture materials;

### **5. The main questions of the seminar:**

- 5.1. Galvanic cell. Determination, its structure, the schema.
- 5.2. Electrode potential. The half-cells.
- 5.3. Nernst equation, Standard electrode potential.
- 5.4. Reference electrodes: hydrogen electrode, saturated calomel electrode. Structure and their standard electrode potentials. Electrodes for pH measurements: hydrogen, glass electrodes, their structure, scheme of the electrodes.
- 5.6. Electro motive force.
- 5.7. Concentrated galvanic cell, the principle, the schema, the equation.
- 5.8. Determination of pH using hydrogen-hydrogen, saturated calomel-hydrogen, saturated calomel-glass galvanic cells, the scheme, equation of pH calculation.
- 5.9. Measurement of pH using the pH meter.

### **6. The questions for individual learning:**

- 6.1. Potentiometric titration.
- 6.2. Ion-selective electrodes.

### **7. The examples of the task:**

#### 7.1. pH calculation using emf.

The cell contains hydrogen electrode immersed in the solution with unknown concentration of H<sup>+</sup> and saturated calomel electrode. EMF equals 0.51 V. Write down the scheme of the given

cell and calculate the pH at 18 °C.

The answer:  $(-) \text{Pt} (\text{H}_2) \mid \text{H}^+ \parallel \text{Hg}_2\text{Cl}_2, \text{KCl} \mid \text{Hg}^{(+)}$

$$\text{pH} = \frac{\text{emf} - e_{\text{SCE}}}{0,058} = \frac{0,51 - 0,25}{0,058} = 4$$

### 7.2. Calculation of pH according to the compensation method.

Objective 2. Element consists of a hydrogen electrode immersed in a solution of unknown concentration of  $\text{H}^+$  and calomel electrode. Weston element off set in the interval of rheochord  $\text{AU}=500\text{mm}$ , and a galvanic cell-in the interval reohord  $\text{AC}_1=250\text{mm}$ . Calculate the pH and the concentration of hydrogen ions.

### **8. Homework (must be performed in the laboratory notebook):**

8.1. The cell contains the hydrogen electrode immersed in gastric juices and the saturated calomel electrode. Write scheme of the cell; calculate pH and Cn of gastric juices knowing that emf equals 0.33 at 18 °C.

8.2. The cell contains two hydrogen electrodes. One of them is immersed in the solution with  $\text{pH}= 4$  and other in solution with  $\text{pH} = 1$ . Calculate emf at 25 °C.

### **9. The control test:**

*for instance:*

9.1. Choose the correct answer. Nernst equation is

a)  $e = e_0 + \frac{0,058}{nF} \ln a_{\text{Me}^+}$     б)  $e = e_0 + \frac{0,058}{n} \ln a_{\text{Me}^+}$     в)  $e = e_0 + \frac{RT}{nF} \ln a_{\text{Me}^+}$

9.2. Immersing an electrode in the solution of its salt:

- a) the electrode is positively charged;
- b) the electrode is negatively charged;
- c) the electrode does not charge.

9.3. The cell contains two electrodes. One of them is immersed in the solution with  $\text{pH} = 4$  and an other in solution with  $\text{pH} = 2$ . Calculate emf at 18 °C.

### **10. The algorithm of the experiments:**

10.1. Measurement of pH using pH meter.

### **11. The detailed explanation of the following experiment:**

#### 11.1. Measurement of pH using pH meter.

Detect pH of the solutions №1, №2, №3 using pH meter. Write the schema of the saturated calomel-glass cell, make a conclusion.

## **TOPIC 5: Determination of oxidation-reduction (redox) potential.**

1. **Actuality of the topic:** biological oxidation is a net reaction of the redox reactions. The particular redox system possessing the corresponding potential is in charge for every unit of biological net oxidation. Having knowledge of the topic is essential for studying biochemistry, physiology and other related subjects.

2. **General aim:** is to have an idea about the redox potentials for explanation of the biological oxidation in living organisms.

### **3. Actual aims and abilities:**

- to use the physical and chemical characteristics of the redox systems to estimate and

- predict biological oxidation in tissues;
- to interpret the biological oxidation as a main source of energy in the organism;
- to use the redox elements for studying redox processes in living organisms with the aim of diagnostics, predictions and treatment.

#### 4. Literature:

4.1. Lecture materials;

#### 5. The main questions of the seminar:

- 5.1. Redox systems (determination, examples).
- 5.2. Mechanism of redox potential appearing.
- 5.3. Nernst equation, the depending factors of redox potential, the standard redox potential.
- 5.4. Biological importance of the redox system.
- 5.5. Diffusion and membrane potentials.

#### 6. The questions for individual learning:

6.1. Explain the appearance of the redox potential during lactate acid oxidation to pyruvic acid. Write formula of electrode potential.

#### 7. The examples of the task:

##### 7.1. Calculation of the component ratio in the redox system.

The redox potential of FeCl<sub>3</sub>/ FeCl<sub>2</sub> system is +0.888 V. The standard redox potential of the given system is +0.77 V. Calculate the ratio of oxidized and reduced forms at 25 °C.

The answer:

$$e_{\text{red}} = e^{\circ}_{\text{red}} + \frac{0.058}{n} \lg \frac{[\text{oxidized form}]}{[\text{reducing form}]}$$

$$n = 1$$

$$0.888 = 0.77 + 0.059 \cdot \lg \frac{[\text{Fe}^{+3}]}{[\text{Fe}^{+2}]}$$

$$\lg \frac{[\text{Fe}^{+3}]}{[\text{Fe}^{+2}]} = \frac{0.888 - 0.77}{0.059} = 2$$

$$\frac{[\text{Fe}^{+3}]}{[\text{Fe}^{+2}]} = 100$$

#### 8. Homework (must be performed in the laboratory notebook):

- 8.1. The redox potential and the standard redox potential of Cr<sup>3+</sup>/ Cr<sup>2+</sup> system are +0.468 V and +0.41 V correspondently. Calculate the ratio of oxidized and reduced form at 18 °C.
- 8.2. Calculate the standard redox potential of a system if redox potential is -0.15 V, the mass fractions of oxidized form is 20 % and reduced form is 80 % (n=1).

#### 9. The control test:

*for instance:*

9.1. Immersing the electrode in the redox system solution where the concentration of oxidized form is predominant, the electrode is charged:

a) negatively;      b) positively;    c) no change.

9.2. The transformation of FeSO<sub>4</sub> → Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> is:

a) oxidation;      b) reduction;    c) no change.

9.3. How many electrons take place in the redox reaction if E<sub>red</sub>=0.169 V, E<sup>o</sup><sub>red</sub>=0.110 V and the concentration of the oxidizing agent is lower in 10 times than the reducing agent?



### **10. The algorithm of the experiments:**

10.1. Determination of the redox potential and its dependence on the ratio of oxidized and reduced forms.

### **11. The detailed explanation of the following experiment:**

#### **11.1. Determination of the redox potential and its dependence on the ratio of oxidized and reduced forms.**

##### **11.1.1. Make a galvanic cell.**

A half-cell - a platinum electrode immersed in a solution containing 1 ml of 0.01 M solution of  $K_3[Fe(CN)_6]$  and 10 ml of 0.01 M solution of  $K_4[Fe(CN)_6]$ ;

II half-cell - hydrogen reference electrode whose potential is 0.669 V.

Element of Weston compensated on a segment 43 cm, and compiled a galvanic cell - the segment 12.7 cm.

Calculate the redox potential -  $e_{red}^1$ . Decision:  $EMF = e_{ox} - e_{red}$ ;  $e_{red} = EMF - e_{ox}$ ;  
 $e_{red} = 0.669 - 0.283 = 0.386$  V.

##### **11.1.2. Make a galvanic cell.**

A half-cell - a platinum electrode immersed in a solution containing 10 mL of 0.01 M solution of  $K_3[Fe(CN)_6]$  and 1 ml of 0.01 M solution  $K_4[Fe(CN)_6]$ ;

II half-cell - hydrogen reference electrode whose potential is 0.669 V.

Element of Weston compensated on a segment of 43 cm, and compiled a galvanic cell - to 9-cm segment.

Calculate the redox potential -  $e_{red}^2$  (analogous to the experience 11.1.1.).

##### **11.1.3. Make a galvanic cell.**

A half-cell - a platinum electrode immersed in a solution containing 5 ml of 0.01 M solution of  $K_3[Fe(CN)_6]$  and 5 ml of 0.01 M solution of  $K_4[Fe(CN)_6]$ ;

II half-cell - hydrogen reference electrode whose potential is 0.669 V.

Element of Weston compensated on a segment of 43 cm, and compiled a galvanic cell - on a segment of 11 cm

Calculate the normal redox potential -  $e_{red}^0$  (similar to the experience in 11.1.1.).

## **TOPIC 6: SURFACE TENSION**

**1. Actuality of the topic:** studying of surface tension at the interface in the biological systems of normal and pathological metabolism under the action of the medicines, toxic compounds is widely used in medical and biological investigations. The surface tension value can be used to measure the activity of the surfactant of the lungs and to identify the liquids.

**2. General aim:** is to understand the sorption processes at the interface liquid-gas.

### **3. Actual aims and abilities:**

- ✓ to measure the surface tension of the biological liquids;
- ✓ to be able to use the main principles of the surface tension theory explaining the biological processes in human organism;
- ✓ to have an idea about the structure of biological membrane.

### **4. Literature:**

4.1. Lecture materials;

## 5. The main questions of the seminar:

- 5.1. Surface tension and surface energy.
- 5.2. Surface phenomena at the interface liquid-gas: the structure of the surface layer, surface tension.
- 5.3. Gibbs equation, surface activity.
- 5.4. Surface active and inactive agents.
- 5.5. Duclo-Traube rule.
- 5.6. Methods of surface tension determination.
- 5.7. Surface tension of biological systems

## 6. The questions for individual learning:

- 6.1. The structure of the biological membrane.

## 7. The examples of the task:

- 7.1. How does the surface tension of water change after adding of butyric acid  $\text{CH}_3\text{-(CH}_2\text{)}_2\text{-COOH}$ .

Answer:

Butyric acid is diphilic acid possessing the low solubility in water. It is characterized by the concentration at the surface of water lowering the surface tension of it.

- 7.2. How does the emulsification of fat take place in human organism?

Answer:

Bile acids are the surface active agents adsorbing at the surface of the fat layer causing to the lowering of the surface tension of fat destroying the big fat drops to lower ones.

## 8. Homework (must be performed in the laboratory notebook):

- 8.1. Why does the surface tension of water have the higher value than benzene?
- 8.2. Why does a drop of a liquid have the sphere form?

## 9. The control test:

*for instance:*

- 9.1. Increasing the polarity, the surface tension at the interface liquid-gas is:  
a) lowered;                      b) accelerated;                      c) the surface tension does not depend on the polarity.
- 9.2. The Gibbs equation for the adsorption is:  
a)  $\Gamma = \frac{C}{RT} \cdot \frac{dC}{d\sigma}$                       б)  $\Gamma = -\frac{C}{RT} \cdot \frac{d\sigma}{dC}$                       в)  $\Gamma = -\frac{C}{RT} \cdot \frac{d\sigma}{dC}$
- 9.3. What is the surface tension?

## 10. The algorithm of the experiments:

- 10.1. Detection of liquid surface tension.
- 10.2. The surfactant influence on the surface tension of water.

## 11. The detailed explanation of the following experiment:

### 11.1. Detection of liquid surface tension.

Stalagmometer is filled by the certain volume of water and calculate the number of drops. Analogous perform with propanol. Knowing the number of water and propanol drops detect the surface tension of the liquid. Surface tension of water is  $\delta = 72.75 \cdot 10^{-3} \text{ H/M}$ .

$$\delta = \delta_0 \cdot \frac{n_0}{n_x} \rho$$

11.2. The surfactant influence on the surface tension of water.

Detect the surface tension of bile by stalagmometric method. Make a conclusion.

***TOPIC 7: Sorption of biological active compounds on the layer liquid – gas***

**1. Actuality of the topic:** The surface phenomena at the of solid-liquid and solid-gas interface are widely occurred in nature. The absorption process in human organism and the interaction of a substrate with an enzyme take place as a result of the adsorption processes. Adsorption therapy is used in the treatment process.

**2. General aim:** is to understand the sorption processes at the solid-liquid and solid-gas interface.

**3. Actual aims and abilities:**

- to have an idea about of the processes occurring at the interface solid-liquid;
- to characterize the adsorption processes using the isotherms of Langmur, BET, Freundlich;
- to explain the living processes on the basis of the adsorption phenomena.

**4. Literature:**

4.1. Lecture materials;

**5. The main questions of the seminar:**

- 5.1. Basic aspects of adsorption. Determinations: sorption, physical and chemical adsorption, absorption, the adsorbents and adsorbates.
- 5.2. Adsorption at the surface of the solid. Isotherms and equation of Langmur, BET, Freundlich.  
The value of sorption.
- 5.3. Hemosorption. Enterosorption.
- 5.4. Adsorption significance for the living organisms.

**6. The questions for individual learning:**

6.1. Immunosorbents. Plasmosorption. Application therapy.

**7. The examples of the task:**

7.1. What is the difference between adsorption and absorption.

The answer:

Adsorption is the process of adsorbate accumulation into the surface of the adsorbent and absorption is the distribution of the adsorbate in the bulk of the adsorbent.

**8. Homework (must be performed in the laboratory notebook):**

- 8.1. Write the example of the selective absorption.
- 8.2. Write the examples of the adsorption therapy application.

**9. The control test:**

**for instance:**

- 9.1. How does the adsorption of gases change under temperature changing?
- 9.2. Adsorption theory of narcosis.

9.3. The basis of the ionic adsorption.

**10. The algorithm of the experiments:**

10.1. Adsorption of acetic acid by activated carbon.

10.2. Adsorption of the colored substances by activated carbon.

10.3. Dependence of the adsorption on the nature of the adsorbents.

**11. The detailed explanation of the following experiment:**

11.1.. Adsorption of acetic acid by activated carbon.

Prepare the solutions according to the table data.

<i>N<sub>2</sub></i>	<i>C<sub>0</sub></i> <i>CH<sub>3</sub>COOH</i>	<i>ml of 0.1N</i> <i>NaOH for</i> <i>10 ml of acid</i>	<i>ml of 0.1N</i> <i>NaOH for 25</i> <i>ml of acid V<sub>0</sub></i>	<i>ml of 0.1N</i> <i>NaOH for</i> <i>10 ml of</i> <i>filtrate</i>	<i>ml of 0.1N</i> <i>NaOH for</i> <i>25 ml of</i> <i>acid V<sub>1</sub></i>	<i>Relative</i> <i>adsorption</i> <i>value</i> <i>ΔV=V<sub>0</sub>-V<sub>1</sub></i>
<b>1</b>	0.03 N					
<b>2</b>	0.07 N					
<b>3</b>	0.12 N					

In three test-tubes are put 1g of activated carbon and filled by 25 ml of acetic acid solution with C<sub>N</sub>= 0.03, 0.07 and 0.12 mol/l. The test-tubes are closed and periodically stirred for 20 min.

During 20 min 10 ml of 0.03, 0.07 and 0.12 mol/l acetic acid are titrated –V<sub>0</sub>.

The mixtures must be filtrated from the activated carbon 20 min later. 10 ml of the filtrate are titrated by 0.1 N NaOH in the presence of phenolphthalein -V<sub>1</sub>.

Calculate the relative adsorption value:  $\Delta V=V_0-V_1$ . The table is filled. Depict the graphical dependence of  $\Delta V$  on C<sub>0</sub>. Make a conclusion.

11.2. Adsorption of the colored substances by activated carbon.

In the test tube add 1 ml of mixture of fuchsin and fluorescein, next add 0.2 g of activated carbon and stir it for 3 min. Filtrate the mixture. Write the observations and make the conclusions.

11.3. Dependence of the adsorption on the nature of the adsorbents.

<i>Prepare three test-tubes:</i>		
<i>1 test-tube</i>	<i>2 test-tube</i>	<i>3 test-tube</i>
5 ml Pb(NO <sub>3</sub> ) <sub>2</sub>	5 ml Pb(NO <sub>3</sub> ) <sub>2</sub>	5 ml Pb(NO <sub>3</sub> ) <sub>2</sub>
0.2 g Al <sub>2</sub> O <sub>3</sub>	0.2 g activated carbon	—

The test-tubes must be shaken for 2 min and filtrated in the clean test-tubes. In every filtrate add 2 drops of KI solution. Write the observations and make the conclusions.

**TOPIC 8: SORPTION OF BIOLOGICAL ACTIVE COMPOUNDS AT THE INTERFACE SOLID-LIQUID**

**1. Actuality of the topic:** the surface phenomena at the interface of solid-liquid and solid-gas are widely occurred in nature. The absorption process in human organism and the interaction of a substrate with an enzyme take place as a result of the adsorption processes. Adsorption therapy is used in the treatment process.

2. **General aim:** is to understand the sorption processes at the interface solid-liquid and solid-gas.

3. **Actual aims and abilities:**

- ✓ to have an idea about of the processes occurring at the interface solid-liquid;
- ✓ to characterize the adsorption processes using the isotherms of Langmur, BET, Freundlich;
- ✓ to explain the living processes on the basis of the adsorption phenomena.

4. **Literature:**

4.1. Lecture materials;

5. **The main questions of the seminar:**

- 5.1. Basic aspects of adsorption. Determinations: sorption, physical and chemical adsorption, absorption, the adsorbents and adsorbates.
- 5.2. Adsorption at the surface of the solid. Isotherms and equation of Langmur, BET, Freundlich. The value of sorption.
- 5.3. Hemosorption. Enterosorption.
- 5.4. Adsorption significance for the living organisms.

6. **The questions for individual learning:**

6.1. Immunosorbents. Plasmosorption. Application therapy.

7. **The examples of the task:**

7.1. What is the difference between adsorption and absorption..

Answer:

Adsorption is the process of adsorbate accumulation into the surface of the adsorbent and absorption is the distribution the adsorbate in the bulk of the adsorbent.

8. **Homework (must be performed in the laboratory notebook):**

- 8.1. Write the example of the selective absorption.
- 8.2. Write the examples of the adsorption therapy application.

9. **The control test:**

*for instance:*

- 9.1. How does the adsorption of gases change under temperature changing?
- 9.2. Adsorption theory of narcosis.
- 9.3. The basis of the ionic adsorption.

10. **The algorithm of the experiments:**

- 10.1. Adsorption of acetic acid by activated carbon.
- 10.2. Adsorption of the colored substances by activated carbon.
- 10.3. Dependence of the adsorption on the nature of the adsorbents.

11. **The detailed explanation of the following experiment:**

11.1. . Adsorption of acetic acid by activated carbon.

Prepare the solutions according to the table data.

Nº	C <sub>0</sub> CH <sub>3</sub> COOH	ml of 0.1 N NaOH for	ml of 0.1 N NaOH for 25	ml of 0.1 N NaOH for	ml of 0.1 N NaOH for 25	Relative adsorption
----	-------------------------------------	----------------------	-------------------------	----------------------	-------------------------	---------------------

		10 ml of acid	ml of acid $V_0$	10 ml of filtrate	ml of acid $V_1$	value $\Delta V = V_0 - V_1$
1	0.03 N					
2	0.07 N					
3	0.12 N					

Three test-tubes are put 1gram of activated carbon and filled by 25 ml of acetic acid solution with  $C_N = 0.03, 0.07$  and  $0.12$  mol/L. The test-tubes are closed and periodically stirred for 20 min.

During 20 min 10 ml of 0.03, 0.07 and 0.12 mol/L acetic acid are titrated  $-V_0$ .

The mixtures must be filtrated from the activated carbon 20 min later. 10 ml of the filtrate are titrated by 0.1 N NaOH in the presence of phenolphthalein  $-V_1$ .

Calculate the relative adsorption value:  $\Delta V = V_0 - V_1$ . The table is filled. Depict the graphical dependence of  $\Delta V$  on  $C_0$ . Make a conclusion.

### 11.2. Adsorption of the colored substances by activated carbon.

In the test tube add 1 ml of mixture of fuchsin and fluorescein, next add 0.2 g of activated carbon and stir it for 3 min. Filtrate the mixture. Write the observations and make the conclusions.

### 11.3. Dependence of the adsorption on the nature of the adsorbents.

Prepare three test-tubes:

1 test-tube	2 test-tube	3 test-tube
5 ml $Pb(NO_3)_2$	5 ml $Pb(NO_3)_2$	5 ml $Pb(NO_3)_2$
0.2 g $Al_2O_3$	0.2 g activated carbon	—

The test-tubes must be shake 2 min and filtrated in the clean test-tubes. In every filtrate add 2 drops of KI solution. Write the observations and make the conclusions.

## TOPIC 9: ION EXCHANGE. CHROMATOGRAPHY

1. **Actuality of the topic:** the selective adsorption is widely extended in human organisms. Chromatographic analysis, adsorption therapy, the lowering of water hardness are grounded on the adsorption phenomenon. Ionic exchange plays the crucial role in the transportation of the ions through the biological membrane.

2. **General aim:** is to formulate the theoretical knowledge of adsorption and ionic exchange for the following application in the medical practice.

3. **Actual aims and abilities:**

- ✓ to have an idea about of ionic exchange and its application in medical practice;
- ✓ to study the adsorption of the electrolytes (selective and ion exchange);
- ✓ to praxis in the separation and identification of the mixture using chromatography analysis

4. **Literature:**

4.1. Lecture materials;

5. **The main questions of the seminar:**

5.1. The adsorption of the electrolytes (selective and ion exchange).

- 5.2. Panet- Phayance rule.
- 5.3. The natural and synthetic ion-exchanger.
- 5.4. The role of ionic exchange in the processes of vital functions. Adsorption therapy.

**6. The questions for individual learning:**

- 6.1. Chromatography. The principles of the method.
- 6.2. Classification of the chromatographic analysis:
  - a) by the phase stage;
  - b) by techniques;
  - c) by distribution mechanism.
- 6.3. Adsorption chromatography, ion-exchange chromatography and partition chromatography.
- 6.4. Application of chromatography in biology and medicine.

**7. The examples of the task:**

7.1. *Adsorption of electrolytes.*

How are the ionites called on the surface of which the exchange of cations takes place?

Answer:

Ionites are called the cationic exchanger.

7.2. *Calculation of  $R_f$  of the components in the mixture.*

Calculate  $R_f$  of monosaccharides if the distance moved by solvent is 21 cm, the distance moved by glucose (1) is 13 cm and the distance moved by fructose (2) is 17 cm.

Answer:

$$R_{f\ 1} = \frac{13}{21} = 0,62; \quad R_{f\ 2} = \frac{17}{21} = 0,81.$$

**8. Homework (must be performed in the laboratory notebook):**

- 8.1. Write the example of the adsorption phenomena in human organism.
- 8.2. The distance moved by solvent is 17 cm, the distance moved by amino acid is 13 cm. What is the amino acid if  $R_f$  of the following amino acids corresponds 0.84 for leucine; 0.76 for alanine; 0.91 for glycine.

**9. The control test:**

*for instance:*

- 9.1. What is the stationary phase?
- 9.2. The distance moved by solvent is 43 cm, the distance moved by a substance is 28 cm. What is the carbohydrate under analysing if  $R_f$  of the following carbohydrates corresponds 0.88 for sucrose; 0.05 for fructose; 0.41 for ribose and 0.65 for glucose.

**10. The algorithm of the experiments:**

- 10.1. Paper chromatography of amino acids.
- 10.2. Circular paper chromatography.

**11. The detailed explanation of the following experiment:**

11.1. . Paper chromatography of amino acids.

Put a drop of the mixture of amino acids at the strip of the chromatographic paper about 1 cm from the base. Beside put a drop of the solution of the known amino acids at the chromatographic paper about 1 cm from the base. The strip must be dried and dipped in the solvent (ethanol:water=7:3) and leave for 4-5 hours. Then the chromatogram is dried and revealed by and again must be dried. Calculate  $R_f$  of amino acids and make a conclusion.

### 11.2. Circular paper chromatography.

At the middle of the circular chromatographic paper drop of the mixture ( $\text{CuSO}_4$ ,  $\text{FeCl}_3$ ,  $\text{Co}(\text{NO}_3)_2$ ). The cut and immerse in the water and seal the container. 10-15 min later paper draw out and filled by  $\text{K}_4[\text{Fe}(\text{CN})_6]$ . Write the chemical equations. Classify the cations in the line of adsorption increasing.

## ***TOPIC 10: COLLOIDAL SOLUTIONS. SYNTHESIS, PURIFICATION AND PROPERTIES.***

**1. Actuality of the topic:** the theory of biological systems, the creation and development of life on the Earth are based on the knowledge of the dispersive systems. Therefore the study of the properties, synthesis and purification of colloids have a great meaning for understanding of many technological and vital processes, for studying of many subjects as namely biochemistry, pharmacy and other and for practice of physician.

**2. General aim:** is to interpret the formation of colloids in medical practice.

### **3. Actual aims and abilities:**

- ✓ to use the physico-chemical properties of colloids to estimate the properties of biological liquids, drugs;
- ✓ to interpret the properties of biological colloidal liquids;
- ✓ to be able to write the structure of the micelles.

### **4. Literature:**

4.1. Lecture materials;

### **5. The main questions of the seminar:**

- 5.1. Colloids (determination)
- 5.2. Synthesis of the colloidal systems.
- 5.3. Purification of colloids. Artificial kidney.
- 5.4. Micelle structure. Panet-Phayance rule.
- 5.5. Colloidal solutions in medicine.

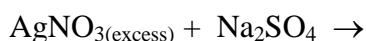
### **6. The questions for individual learning:**

- 6.1. Classification of the colloids: by particle size, dispersed and dispersing phases, interfacing interaction.
- 6.2. Molecular-kinetic properties of colloids (Brownian movements, diffusion in sols, osmotic pressure)
- 6.3. Optical property of colloids. Tyndall effect.
- 6.4. Electrophoresis and its application in medical practice.

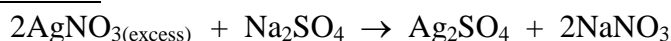
### **7. The examples of the task:**

7.1. *Micelle structure.*

Write the micelle formula of sol obtained in the below given reaction.



Answer:





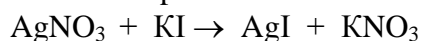
Sol of silver (I) is obtained. As the solution of  $\text{AgNO}_3$  is taken in excess due to the Panet-Payance rule the potential-determining ions are  $\text{Ag}^+$ . The particle has positive charge.

**7.2. Electro-kinetic property of sol particles.**

Sol of  $\text{AgI}$  is obtained adding 20 ml 0.01 mol/L of  $\text{KI}$  solution to 10 ml of 0.2 %  $\text{AgNO}_3$  ( $\rho = 1$ ) solution. What is the charge of the particles? Write the structure of the micelle. How do the particles move in electric field?

Answer:

To find the potential-determining ions, it needs to detect what the reactant is in excess.



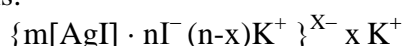
$$m(\text{AgNO}_3) = \frac{10 \cdot 0,2}{100} = 0,02 \text{ g}$$

$$n(\text{AgNO}_3) = \frac{0,02\text{r}}{170\text{r/МОЛЪ}} = 0,00013 \text{ mol}$$

$$m(\text{KI}) = \frac{20 \cdot 0,01}{1000} \cdot 166 = 0,033 \text{ g}$$

$$n(\text{KI}) = \frac{0,033}{166} = 0,0002 \text{ mol}$$

Calculations show that  $\text{KI}$  ions are in excess. Therefore potential-determining ions are iodide ions.



The charge of the particles is negative and the movement of the last is directed to the anode.

**8. Homework (must be performed in the laboratory notebook):**

8.1. Write the structure of  $\text{PbI}_2$  micelle obtained after mixing of  $\text{KI}$  и  $\text{Pb}(\text{NO}_3)_2$  solutions if

- a)  $\text{KI}$  solution is in excess;
- b)  $\text{Pb}(\text{NO}_3)_2$  solution is in excess.

How do the particles move in electric field?

**9. The control test:**

**for instance:**

9.1. Write the micelle structure after reaction of silver nitrate and calcium bromide solutions at the condition:

- a) when silver nitrate is in excess;
- b) when calcium bromide is in excess.

9.2. Write the classification of the dispersive systems by particle size. Write the examples.

**10. The algorithm of the experiments:**

- 10.1. Synthesis of  $\text{Fe}(\text{OH})_3$  sol by hydrolysis.
- 10.2. Synthesis of  $\text{Fe}(\text{OH})_3$  sol by peptization.
- 10.3. Synthesis of sulfur sol by the solvent exchange method.
- 10.4. Synthesis of sulfur sol by chemical reaction.

**11. The detailed explanation of the following experiment:**

11.1. Synthesis of  $\text{Fe}(\text{OH})_3$  sol by hydrolysis.

Fill the chemical glass by 20 ml of water and heat to 100 °C. Add 1 ml of diluted FeCl<sub>3</sub> solution. Note the colour, write the micelle structure.

#### 11.2. Synthesis of Fe(OH)<sub>3</sub> sol by peptization.

In the test-tube add 1 drop of the saturated FeCl<sub>3</sub> solution, 1 drop of NH<sub>4</sub>OH solution and 2 ml of water. The resulting solution divide in 3 test-tubes. In the first test-tube add HCl solution until dissolving occurs, in second one add saturated FeCl<sub>3</sub> solution until dissolving occurs, the last one is the blank experiment. Write observations and chemical reactions. Make conclusions.

#### 11.3. Synthesis of sulfur sol by the solvent exchange method.

In test tube add 5 ml of water and ethanolic solution of sulphur dropwisely under permanent mixing. Write observations and explain the formation of colloidal solution.

#### 11.4. Synthesis of sulfur sol by chemical reaction.

In test tube add 5 ml of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> solution and 1 ml of phosphoric acid under permanent mixing. Write observations. Make conclusions.

### ***TOPIC 11: COAGULATION OF COLLOIDS. COLLOIDAL STABILITY.***

**1. Actuality of the topic:** the biological liquids as namely blood, serum, lymph present the colloidal systems where proteins, cholesterol and glycogen are in colloidal state. Destruction the colloidal state leads to the illnesses and pathology. A great number of drugs are manufactured in the state of high dispersive suspension.

**2. General aim:** is to study the theoretical bases of coagulation and protection of colloidal systems.

#### **3. Actual aims and abilities:**

- ✓ to know the stability factors of dispersive systems;
- ✓ to know the factors influenced on stability and coagulation of dispersive systems;
- ✓ to learn the synthesis and properties of aerosols, emulsions, the low dispersive systems;
- ✓ to be capable determining of coagulation concentration.

#### **4. Literature:**

4.1. Lecture materials;

#### **5. The main questions of the seminar:**

- 5.1. Kinetic and aggregative stability of sols, the stability factors.
- 5.2. Coagulation and the factors influenced on the coagulation.
- 5.3. Coagulation mechanism. Schulz-Hardy rule.
- 5.4. Coagulation ability of electrolytes. Reciprocal coagulation.
- 5.5. Coagulation concentration.
- 5.6. Colloidal stability.
- 5.7. Coagulation in the water purification process.

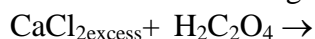
#### **6. The questions for individual learning:**

- 6.1. Aerosols: the preparation methods, properties, application in medicine. Poisonous action.
- 6.2. Suspensions: the preparation methods and properties.
- 6.3. Emulsion: the preparation methods and properties. Types. Emulsifying agent. Application in clinical practices. Biological role of emulsification.

## 7. The examples of the task:

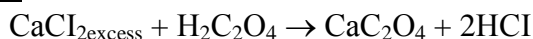
### 7.1. Sol coagulation by electrolytes.

Sol can be form after adsorbing of oxalic acid by kidneys from gastrointestinal tract

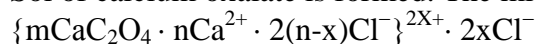


- What is the charge of the particle?
- Which kind of the following ions  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{NO}_3^-$ ,  $\text{PO}_4^{3-}$ ,  $\text{Al}^{3+}$  exhibits the coagulation action for the particles of the given sol?

Answer:



Sol of calcium oxalate is formed. The micelle structure is



When the particle has a positive charge the coagulating ions are  $\text{NO}_3^-$ ,  $\text{PO}_4^{3-}$  according to Schulze-Hardy law.

### 7.2. Determination of coagulation concentration.

The coagulation concentration of  $\text{Fe}(\text{OH})_3$  sol for KI and  $\text{K}_2\text{Cr}_2\text{O}_7$  electrolytes are 10.0 and 0.095 mmol/L respectively. In how many times the coagulation ability of  $\text{K}_2\text{Cr}_2\text{O}_7$  is higher than KI?

Answer.

The coagulation ability of the electrolyte is the reverse value to the coagulation concentration.

$$P = \frac{1}{C}$$

$$P_{\text{KI}} = \frac{1}{10} = 0,1$$

$$P_{\text{K}_2\text{Cr}_2\text{O}_7} = \frac{1}{0,195} = 5,1$$

$$P_{\text{KI}} : P_{\text{K}_2\text{Cr}_2\text{O}_7} = 0.1 : 5.1 = 1 : 51$$

For  $\text{Fe}(\text{OH})_3$  sol the coagulation ability of  $\text{K}_2\text{Cr}_2\text{O}_7$  is higher in 51 times than of KI.

## 8 Homework (must be performed in the laboratory notebook):

8.1. The coagulation concentrations of a sol by electrolytes are  $C(\text{NaNO}_3) = 250.0$ ;  $C(\text{Mg}(\text{NO}_3)_2) = 20$ ;  $C(\text{Fe}(\text{NO}_3)_3) = 0.5$  (mg-eq/L). What are the coagulating ions? What is the charge of the sol particles?

## 9. The control test:

*for instance:*

- Write the structure of AgI micelle if the excess of KI was added to  $\text{AgNO}_3$  solution.
- Select the ions ( $\text{Na}^+$ ,  $\text{Li}^+$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cr}^{3+}$ ,  $\text{Pb}^{2+}$ ,  $\text{CH}_3\text{COO}^-$ ,  $\text{PO}_4^{3-}$ ,  $\text{OH}^-$ ,  $\text{Cs}^+$ ,  $\text{Sr}^{2+}$ ,  $\text{Br}^-$ ,  $\text{Mg}^{2+}$ ) that are able to cause the coagulation of the colloidal particles described in question 1.

## 10. The algorithm of the experiments:

- Conformation of Schulze-Hardy rule.
- Dependence of the coagulation concentration on the charge of coagulating ion.
- Synthesis of emulsion.

## 11. The detailed explanation of the following experiment:

### 11.1. Conformation of Schulze-Hardy rule.

Three test-tubes are filled:

1 test-tube	2 test-tube	3 test-tube
5ml Fe(OH) <sub>3</sub> sol	5ml Fe(OH) <sub>3</sub> sol	5ml Fe(OH) <sub>3</sub> sol
1 ml of KCl solution	1 ml of K <sub>2</sub> SO <sub>4</sub> solution	1 ml of K <sub>3</sub> [Fe(CN) <sub>6</sub> ] solution

The solutions are mixed and the coagulation consecution is observed. Write the micelle structure of Fe(OH)<sub>3</sub> sol and arrange the coagulating ions in liotropic row.

11.2. Dependence of the coagulation concentration on the charge of coagulating ion.

Prepare the ammonium sulfate solutions of different concentrations:

In the first test-tube add 10 ml of ammonium sulfate (C<sub>N</sub>=1 mol/L).

In the second test-tube add 9 ml of water and 1ml of ammonium sulfate from the first test tube.

In the third test-tube add 9 ml of water and 1ml of ammonium sulfate from the second test tube.

Analogous prepare the fourth, fifth and sixth test-tube.

Then add 2 ml of iron (III) hydroxide sol to every test-tube. Fill the below given table marking by “+” and “-”.

Analogous perform the experiments with ammonium chloride. Make the conclusions.

<i>Electrolytes</i>	<i>Coagulating ion</i>	<i>Concentration of the electrolyte in the test-tube, mol/L</i>							<i>Coagulation concentration n</i>
		1	10 <sup>-1</sup>	10 <sup>-2</sup>	10 <sup>-3</sup>	10 <sup>-4</sup>	10 <sup>-5</sup>	10 <sup>-6</sup>	
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	SO <sub>4</sub> <sup>2-</sup>								
NH <sub>4</sub> Cl	Cl <sup>-</sup>								

11.3. Synthesis of emulsion.

The test-tube is filled by 5 ml of water and 5 drops of vegetable oil. Mix intensively. For emulsion stabilization add 5 drops of NaOH. Again shake the test-tube. Note the observation and make a conclusions.

**TOPIC 12: PROPERTIES OF BIOPOLYMERS. ISOELECTRIC POINT.**

1. **Actuality of the topic:** Biopolymers (proteins, polysaccharides, nucleic acids) are included in the structure of the cells performing the function of the accumulation of nutrients and energy. Nucleic acids together with proteins are the source of hereditary information, glycol proteins occasion the blood group.
2. **General aim:** is to estimate the polymer's property based on the chemical nature and characteristics of macromolecules.
3. **Actual aims and abilities:**
  - ✓ to classify the polymers by type of monomers and spatial structure;
  - ✓ to forecast the swelling process and the polymer's solubility on the base of thermodynamic laws.
4. **Literature:**
  - 4.1. Lecture materials;

**5. The main questions of the seminar:**

- 5.1. What are the polymers?
- 5.2. Isoelectric state and isoelectric point of the proteins.
- 5.3. Protection action of proteins, protection number, biological meaning.
- 5.4. Swelling of polymers (the determination, mechanism, the factors). The fixed water, the properties and biological meaning.
- 5.5. The stability of polymers. Factors of stability.
- 5.6. Gelatinization of polymer solution, mechanism, factors, biological meaning.
- 5.7. Galantines, reaction in galantines, biological meaning.

**6. The questions for individual learning:**

- 6.1. Classification of polymers.
- 6.2. Salting out of the polymers, mechanism, factors, biological meaning.
- 6.3. Thixotropy, syneresis, coacervation, their biological meaning.

**7. The examples of the task:**

- 7.1. What is the influence of pH on gelatinization of proteins.

Answer:

The highest stage of gelatinization takes place at isoelectric point due to the neutrality of the proteins and the loss of stability is observed.

**8. Homework (must be performed in the laboratory notebook):**

- 8.1. Biological meaning of fixed water.
- 8.2. What are the substances extracted from blood by using salting out.

**10. The algorithm of the experiments:**

- 10.1. Determination of isoelectric point.
- 10.2. Determination of coagulation concentration of protected sol.
- 10.3. Swelling.
- 10.4. Influence of pH on swelling.
- 10.5. Influence of electrolytes on swelling.

**11. The detailed explanation of the following experiment:**

**11.1. . Determination of isoelectric point.**

Concurrently 2 ml of acetate buffer with pH according to the table are added in 4 test-tubes. Then add 1 ml of 0.5% gelatine solution and mix them. Carefully add 3 ml of ethanol. Five min later estimate the dimness of every solutions and determine the isoelectric point of gelatine.

<i>Nº</i>	<i>pH of the system</i>	<i>0,5% gelatine solution, ml</i>	<i>Ethanol, ml</i>	<i>Dimness stage</i>
1	3,8	1	3	
2	4,4	1	3	
3	4,7	1	3	
4	5,1	1	3	

### 11.2. Determination of coagulation concentration of protected sol.

Prepare the ammonium sulfate solutions of different concentrations:

In the first test-tube add 10 ml of ammonium sulfate ( $C_N=1$  mol/L).

In the second test-tube add 9 ml of water and 1ml of ammonium sulfate from the first test tube.

In the third test-tube add 9 ml of water and 1ml of ammonium sulfate from the second test tube.

Analogous prepare the fourth, fifth and sixth test-tube.

Then add 2 ml of iron (III) hydroxide sol. Determine the coagulation concentration. Prepare again the ammonium sulfate solutions of different concentrations and add 1 ml gelatine then 2 ml of iron (III) hydroxide sol. Determine the coagulation concentration for both cases and compare the data. Make a conclusion.

### 11.3. Swelling..

A piece of rubber immerse in the benzene, the second piece of rubber in water. Explain the observations.

### 11.4. Influence of pH on swelling.

1 test-tube dry gelatine 5 ml of HCl	II test-tube dry gelatine 5 ml of acetate buffer	III test-tube dry gelatine 5 ml of NaOH with pH = 4,7
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15 min later note the results. Make a conclusion.

### 11.5. Influence of electrolytes on swelling.

1 test-tube dry gelatine 5 ml of $K_2SO_4$	II test-tube dry gelatine 5 ml of KCl	III test-tube dry gelatine 5 ml of KSCN
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15 min later note the results. Make a conclusion.