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

Department of General and Bioorganic Chemistry

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

Topic 16: Stability of colloidal-dispersed systems

Time: 2 hours

2023

THE TRAINING AND EDUCATIONAL GOALS, MOTIVATION TO STUDY THE TOPIC

The purpose of the class:

To familiarize medical students with the factors affecting the kinetic and aggregative stability of colloidal-dispersed systems, paying special attention to the general regularities of coagulation of sols by electrolytes.

The tasks of the class:

As a result of the class, the student ***must know:***

1) theoretical bases of the stability of lyophobic sols;
2) factors affecting the stability of lyophobic sols;
3) the main regularities of coagulation of sols under the action of electrolytes;
4) the mechanism of action of electrolytes on the stability of sols;
5) the concept about the critical coagulation concentration (CCC), the Schulze-Hardy's rule;
6) coagulation of sols with a mixture of electrolytes;
7) mutual coagulation of sols;
8) theoretical bases of coagulation kinetics.

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

1) analyze the factors of the stability of dispersed systems;
2) calculate the critical coagulation concentration (CCC) of electrolytes;
3) determine which ion of the electrolyte will have a coagulating effect on sol, taking in account Schulze-Hardy's rule; compare the coagulating ability of electrolytes;
4) prepare colloidal solution of iron (III) hydroxide by hydrolysis reaction;
5) coagulate the resulting sol under the action of electrolytes.

Motivation to study the topic:

The phenomenon of coagulation plays an essential role in a living organism, since colloidal solutions of cells are in contact with electrolytes contained in biological fluids. The solution of many problems in medicine (for example, prosthetics of blood vessels, heart valves, etc.) is associated with the problem of blood clotting. In surgery, anticoagulants (heparin) are injected into the blood during operations, and after operations – to increase coagulation – protamine sulfate. Doctors constantly deal with the phenomenon of erythrocyte coagulation in clinical laboratories.

NECESSARY EQUIPMENT

1. Methodological manual for students on the topic "Stability of colloidal-dispersed systems".
2. Reference materials of physico-chemical constants for the 1st year education international students.
3. Chemical reagents and equipment necessary for laboratory work.

CONTROL QUESTIONS ON THE TOPIC OF THE CLASS

1. Coagulation of sols.
2. Kinetics of coagulation.

COURSE OF THE CLASS

The theoretical part

1. COAGULATION OF SOLS

Colloidal stability means that particles do not aggregate at a significant rate. The main factors of sol's stability are:

▪ kinetic;

▪ aggregative.

Brownian motion is responsible for kinetic stability of sols, and electric charge of dispersed particles is responsible for aggregative stability of sols. The destruction of aggregative stability of soils leads to their coagulation.

Coagulation is the irreversible aggregation of dispersed particles into large particles followed by rapid precipitation. Sol coagulates under heating or mechanical disturbance, but the main reason for their coagulation is addition of electrolytes.

Coagulation by electrolytes plays an essential role *in vivo*, since colloidal solutions of cells are in contact with electrolytes contained in biological fluids.

The introduction of an electrolyte into the solution increases the total concentration of ions in it, creating favorable conditions for the charged colloidal particles to absorb ions of the opposite sign. The initial charge of particles decreases or is completely neutralized, after which coagulation of sol begins.

Critical coagulation concentration (γ) is a minimum amount of electrolyte that starts coagulation in 1 liter of sol. It is calculated by the following equation:

$$\gamma = \frac{C_M \times V}{V_S + V},$$

C_M – volar concentration of an electrolyte, mol/l;
V – a volume of an electrolyte solution, ml;
V_S – a volume of a sol, l.

Schulze-Hardy's rule: *coagulation of sol is caused by the electrolyte's ion whose charge is opposite to the charge of the colloidal particle, and the coagulating ability of the ion, which causes coagulation, increases with the increase in its charge.*

The Nobel Prize Winners B. Derjaguin and L. Landau proved that critical coagulation concentrations of ions that initiate coagulation of lyophobic sols relate to each other as their reverse charges raised into the power six:

$$\gamma_1 : \gamma_2 : \gamma_3 = \frac{1}{1^6} : \frac{1}{2^6} : \frac{1}{3^6} = 730 : 11 : 1$$

The Schulze-Hardy's rule does not give an accurate description of coagulation, since it doesn't take in account the influence of ion radii on coagulating activity of ions. Ions of the same charge but of different ionic radii are arranged in a lyotropic series:

Li^+ Na^+ K^+ Rb^+ Cs^+
→

Increase in radius gives increase in coagulating activity of ions

2. KINETICS OF COAGULATION

The process of sol's coagulation is characterized by **coagulation rate,** which can be defined as a change in the number of colloidal particles in one liter of a colloidal solution per unit time. The rate of coagulation depends upon both electrolyte's concentration and sol's concentration. The kinetic curve of sol's coagulation is given in Figure 1:

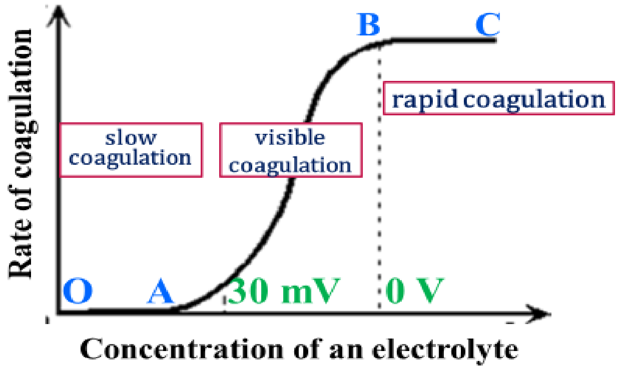

Figure 1 – The kinetic curve of sol's coagulation

The **OA** segment corresponds to a period of slow and latent coagulation when sol is sufficiently stable. The segment **AB** corresponds to the period of visible coagulation (visible changes in sol are detected: turbidity, discoloration), which starts when ξ-potential of a sol becomes 30 mV. Coagulation rate in the segment increases sharply with increasing electrolyte concentration. The segment **BC** corresponds to the period of a rapid coagulation (ζ-potential of a sol is zero), an increase in the electrolyte's concentration does not change the coagulation rate (V_c = const).

When sol is coagulated with a mixture of electrolytes, the following phenomena may occur:

a) additivity – summing of the coagulating action of ions;

b) antagonism – decreasing of the coagulating action of one ion in the presence of another;

c) synergism (from the Greek «*synergos*», meaning working together) – increasing of the coagulating action of one ion in the presence of another.

Before injecting an electrolytes' mixture, a doctor must know that they are not synergists in order to avoid a harmful coagulation of blood.

Before electrolytes application as a drug a doctor must take into consideration not only their concentration but the electric charge of their ions. For example, physiological NaCl solution can't be changed by $MgCl_2$ solution because Mg^{2+} exhibits high coagulating activity.

Mutual coagulation is a coagulation that occurs when two colloidal solutions are mixed with an opposite charge of colloidal particles. This type of coagulation is used in sanitary and hygienic practice in the purification of drinking water when cleaning water from suspended colloidal particles.

The solution of many problems in medicine (prosthetics of blood vessels, heart valves, etc.) is associated with the problem of blood coagulation.

Anticoagulants are substances that suppress blood clotting; they are used to prevent the occurrence of blood clots, as well as to quickly stop their development and growth.

The most widespread is heparin. The mechanism of its action is based on the ability to inhibit the activity of the enzyme thrombin, which causes the conversion of plasma-soluble fibrinogen to insoluble fibrin and leads to aggregation of thrombocytes [1-3].

The practical part

Safety instructions before laboratory work.

LABORATORY WORK

Test 1. Preparing of $Fe(OH)_3$ sol by $FeCl_3$ hydrolysis

Pour 150 ml of distilled water into a flask and heat it up to the boiling point. Add 5 ml of concentrated $FeCl_3$ solution into boiling water. At the result, a dark-brown $Fe(OH)_3$ sol is obtained. Cool the prepared sol with tap water.

Write the equations of reactions for preparing of $Fe(OH)_3$ sol:

$$FeCl_3 + 3H_2O \xrightarrow{t^o} \underset{\text{solid phase}}{Fe(OH)_3} + 3HCl$$

$$Fe(OH)_3 + HCl \rightarrow Fe(OH)_2Cl + H_2O$$

$$Fe(OH)_2Cl \rightarrow \underset{\text{iron (III) oxochloride (ferryl chloride)}}{FeOCl} + H_2O$$

$$FeOCl \rightarrow FeO^+ + Cl^-$$

Write the formula for the micelle of the prepared sol. Give names to all compartments of the micelle.

Test 2. Coagulation of $Fe(OH)_3$ sol

Take three sets of test tubes, each containing six test tubes. Fill each test tube with water and electrolyte solution according to the Table 1. After that, add 5 ml of $Fe(OH)_3$ sol to each test tube. Time of exposition is 20 minutes. Examine the solutions in the test tubes and mark presence or absence of coagulation in them by signs «+» or «–».

Table 1 – $Fe(OH)_3$ coagulation under the influence of electrolytes

A set of test tubes	Coagulator		CCC, mmol/l	Number of a test tube					
	Electrolyte	Ion		1	2	3	4	5	6
1	3.0 M KCl	Cl^-							
2	0.005 M K_2SO_4	SO_4^{2-}							
3	0.0005 M $K_3[Fe(CN)_6]$	$[Fe(CN)_6]^{3-}$							
Volume, ml	Distilled water			0	1	2	3	4	4.5
	Electrolyte solution			5	4	3	2	1	0.5
	$Fe(OH)_3$ sol			5	5	5	5	5	5

Calculate the critical coagulation concentrations of KCl, K_2SO_4 and $K_3[Fe(CN)_6]$ according to the equation:

$$\gamma = C_M \times V \times 100$$

C_M – molar concentration of electrolyte, mol/l;
V – the minimum volume of electrolyte that initiates the coagulation of sol, ml.

Compare the results of your calculations with the Schulze-Hardy's rule.

Control over the assimilation of the topic

It is conducted in the form of written independent work of students.

QUESTIONS FOR SELF-CONTROL OF KNOWLEDGE

1. Types of stability of colloidal-dispersed systems.
2. The main regularities of coagulation of lyophobic sols under the action of electrolytes.
3. Critical coagulation concentration (CCC) of electrolytes. The Schulze-Hardy's rule.
4. Coagulation rate. Kinetic coagulation curves.

Exercises for the self – control

1. Iron (III) hydroxide sol was prepared by interaction of iron (III) nitrate dilute solution and a small excess of potassium hydroxide according to the equation:

$$Fe(NO_3)_3 + 3KOH \rightarrow Fe(OH)_3 + 3KNO_3$$

Write the formula for a micelle and answer the following questions:

a. What is the charge of a colloidal particle?

b. Towards what electrode does this particle move when passing current through the solution ion?

c. What electrolyte $FeCl_3$ or Li_3PO_4 exhibits smaller value of critical coagulation concentration for this sol?

2. Write the equations of reactions for obtaining iron (III) hydroxide sol by hydrolysis. Which ions of electrolytes Na_2SO_4 and $K_3[Fe(CN)_6]$ will cause coagulation of this sol?

Answer: SO_4^{2-}, $[Fe(CN)_6]_3^-$

3. Specify which of the electrolytes, $Ba(NO_3)_2$ or Na_2SO_4, should be taken in excess to obtain barium sulfate sol with positively charged colloidal particles. Write the equation of reaction for obtaining the specified sol and the micelle formula.

Answer: $Ba(NO_3)_2$

4. Specify which of the electrolytes will have the lowest value of the critical coagulation concentration with respect to $Fe(OH)_3$ sol with positively charged colloidal particles: KNO_3, $MgSO_4$, $AlCl_3$, K_3PO_4.

Answer: K_3PO_4

5. Coagulation of 10 ml of iron (III) hydroxide sol occurred when 2 ml of Na_2SO_4 solution with a molar concentration of 0.0025 mol/l was added to it. Calculate the CCC of this electrolyte.

Answer: 5×10^{-4} mol/l

6. $CaCO_3$ sol can be prepared according to the reaction:

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$$

Write formulas for micelles of sols prepared:

a. when $CaCl_2$ is excess;

b. when Na_2CO_3 is excess.

Which ions will coagulate the prepared sol: K^+, Ca^{2+}, Cl^-, Al^{3+}, $[Fe(CN)_6]^{3-}$, $[Fe(CN)_6]^{4-}$? Arrange the ions in a serious of increasing ability to initiate a coagulation process.

7. Small radioactive particles are contained in drinking water. It was decided to purify water by adding electrolytes. What electrolyte: $AlCl_3$ or Na_3PO_4 is preferable? It was found that particles migrate to the cathode in an electric field.

Answer: Na_3PO_4

QUESTIONS FOR INDEPENDENT WORK OF STUDENTS (IWS)

1. Coagulation in biological systems.
2. Colloidal protection. «Protective number» as a quantitative characteristic of the protective action of surfactants and polymers.

LIST OF SOURCES USED

1. Medical chemistry : textbook for students of higher education establishments – med. univ., inst. and acad. / V.O. Kalibabchuk, V.I. Halynska, L.I. Hryshchenko et al. ; ed. by V.O. Kalibabchuk. – 6th ed., corr. – Kyiv : AUS Medicine Publishing, 2018. – P. 151-167.

2. Основы химии для иностранных студентов = Essential chemistry for foreign students : учебно-методическое пособие / С. В. Ткачёв [и др.]. – 5-е изд. – Минск : БГМУ, 2018. – С. 160-163. – Режим доступа: http://rep.bsmu.by:8080/handle/BSMU/21054.

3. Общая химия : учеб. пособие для студентов лечебного факультета, обучающихся на английском языке. В двух частях. Часть 2. = General Chemistry : Educational guidance for students medical department in English medium. In two part. Part 2. – В. А. Филиппова, А. В. Лысенкова, Л. В. Чернышева. – Гомель : УО «Гомельский государственный медицинский университет», 2013. – 180 с. – URI: http://elib.gsmu.by/handle/GomSMU/10939.