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 15: Physico-chemistry of dispersed systems

Time: 2 hours

2023

THE TRAINING AND EDUCATIONAL GOALS, MOTIVATION TO STUDY THE TOPIC

The purpose of the class:

To acquaint students of the Faculty of Medicine with the structure, methods of preparation and physico-chemical properties of dispersed systems, paying special attention to the biological significance of colloidal solutions *in vivo*.

The tasks of the class:

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

1) the concept of dispersed systems, their classification;
2) methods of obtaining and purifying colloidal solutions;
3) thermodynamics of the formation of lyophilic and lyophobic sols;
4) structure of micelles of lyophobic sols stabilized by electrolytes;
5) molecular kinetic and optical properties of colloidal systems;
6) electrokinetic phenomena, in particular, electrophoresis and electroosmosis, and their application and significance in biology and medicine.

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

1) characterize colloidal systems by comparing their properties with the properties of coarse and true solutions;
2) make formulas of micelles of lyophobic sols;
3) determine the direction of movement of colloidal particles during electrophoresis.

Motivation to study the topic:

Dispersed systems are widespread in nature and play an important practical role. Natural waters, clouds, smoke, soil, clays are examples of natural dispersed systems. Biological fluids (blood, plasma, lymph, cerebrospinal fluid) are also dispersed systems in which phosphates, urates, oxalates, carbonates, proteins, lipids and other substances can be in a colloidal degree of dispersity. Knowledge of the physico-chemical processes occurring in dispersed systems and the factors determining their stability makes it possible to explain such pathological conditions of the human body as the deposition of salts (formation of stones) in the kidneys, liver, urinary tract.

Many medicines produced by the pharmaceutical industry in the form of pastes, ointments, suspensions and emulsions, aerosols are also dispersed systems.

NECESSARY EQUIPMENT

1. Methodological manual for students on the topic "Physico-chemistry of 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. Dispersed systems. Methods of classification of dispersed systems.
2. Methods of preparation and purification of sols.
3. Structure of colloidal particles of lyophobic sols.
4. Physical properties of sols.

COURSE OF THE CLASS

The theoretical part

1. DISPERSED SYSTEMS. METHODS OF CLASSIFICATION OF DISPERSED SYSTEMS

Dispersed system is a micro heterogeneous system composed of microscopic particles of a dispersed phase distributed in a dispersion medium. A model of a dispersed system is given in Figure 1.

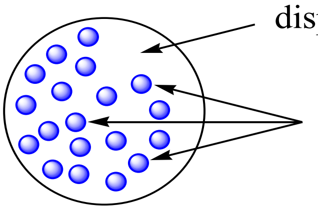

Figure 1 – A model of a dispersed system

Classification of dispersed systems:

1) according to the degree of dispersity:

▪ colloidal dispersed $10^{-9} < \alpha < 10^{-7}$ m;

▪ coarse dispersed $10^{-7} < \alpha < 10^{-5}$ m;   *α is a diameter of a dispersed phase particle.*

2) according to the degree of solvation:

▪ lyophilic: dispersed particles are solvated; they are stable, their formation is spontaneous (dispersions of surfactants and high-molecular compounds);

▪ lyophobic: dispersed particles are not solvated therefore they are unstable; their formation is nonspontaneous (dispersions of metals and insoluble salts).

3) according to interaction between dispersed particles:

▪ freely-dispersed systems are free from interaction between dispersed particles and, therefore, are mobile (aerosols, lyosols);

▪ in binding-dispersed systems dispersed particles are bound by intermolecular forces and, therefore, non-mobile (foams, jells):

4) according to the aggregate state of dispersed phase and dispersion medium (Table 1):

Table 1 – Classification of dispersed systems according to the aggregate state of dispersed phase and dispersion medium

Dispersion medium	System	Examples
▪ Gas: **aerosols**	• Liquid in Gas	Fog, clouds, liquid sprays
	• Solid in Gas	Smoke, dust
▪ Liquid: **lyosols**	• Gas in Liquid	Liquid foams
	• Liquid in Liquid	Emulsions: milk, mayonnaise
	• Solid in Liquid	Colloidal solutions, suspensions
▪ Solid: **solidosols**	• Gas in Solid	Solid foams: bread, activated carbon, expanded polystyrene
	• Liquid in Solid	Soil, opal, pearls
	• Solid in Solid	Pigmented plastics, black diamonds

A special place among of dispersed systems belongs to colloidal solutions (sols).

Colloidal solutions do not form spontaneously. Conditions for obtaining stable lyophobic sols are:

1) low solubility of the dispersed phase in the dispersion medium;

2) colloidal degree of dispersity: size of particle of dispersed phase is 10^{-9}–10^{-7} m;

3) the presence of a stabilizer in the system that will ensure the stability of the colloidal system (an excess of one of the reagents; surfactants or high-molecular compounds) [1-3].

2. METHODS OF PREPARATION AND PURIFICATION OF SOLS

Preparation methods are:

▪ *Dispersion (degradation) methods* in which larger particles are broken down to particles of colloidal degree of dispersity.

Dispersion methods are:

– mechanical dispersion with the help of a colloidal mills;

– ultrasonic dispersion;

– electrodispersion is used to prepare sols of metals such as copper, silver, gold or platinum;

– peptization.

Peptization method is a process that involves the conversion of a freshly prepared precipitate into a colloidal solution by the addition of a suitable electrolyte. The added electrolyte is called peptizing agent. Selective adsorption of electrolyte ions on the surface of solid particles makes them all positively or negatively charged. Repulsion of charged particles results in their migration into a liquid phase.

▪ *Condensation (aggregation) methods* in which colloidal particles are produced by aggregation of atoms or molecules.

Condensation (aggregation) methods may be physical and chemical.

Physical aggregation includes:

– cooling and pressure elevating of gases and vapors. For example, formation of fogs and clouds in nature;

– substitution of solvents in solutions. For example, a solution of sulfur in alcohol mixed with excess of water results in a colloidal sol of sulfur.

Chemical aggregation is based on chemical reactions running in solutions with the formation of insoluble substances.

Purification methods are:

▪ *Dialysis* is the process of removing low-molecular impurities and electrolyte ions (crystalloids) from colloidal solutions by diffusion them through a semipermeable membrane. Molecules or ions smaller than the pores of the membrane can pass from solution to water, while colloidal particles cannot pass through the pores of the membrane.

▪ *Electrodialysis:* to accelerate the purification process, dialysis is carried out by applying electric field. The cations and anions of the electrolyte will be attracted towards the oppositely charged electrodes.

▪ *Ultrafiltration* is a separation of dispersed phase particles from dispersion medium particles with the help of highly porous membrane at high pressure. Ultra-filters permit the separation of colloidal particles of different sizes from one another [1-3].

Both dialysis and ultrafiltration are involved in **hemodialysis** which is the most common method used to treat advanced and permanent kidney failure (applied in medicine since the 1960_s). Hemodialysis means «cleaning the blood» – and that is exactly what this treatment does. Blood is circulated through a machine which contains a *dialyzer* also called an artificial kidney. Blood passes on one side of the membrane and dialysis fluid passes on the other. The wastes and excess water pass from the blood through a membrane into the dialysis fluid, which is then discarded. The cleaned blood is returned to a bloodstream (Fig. 2).

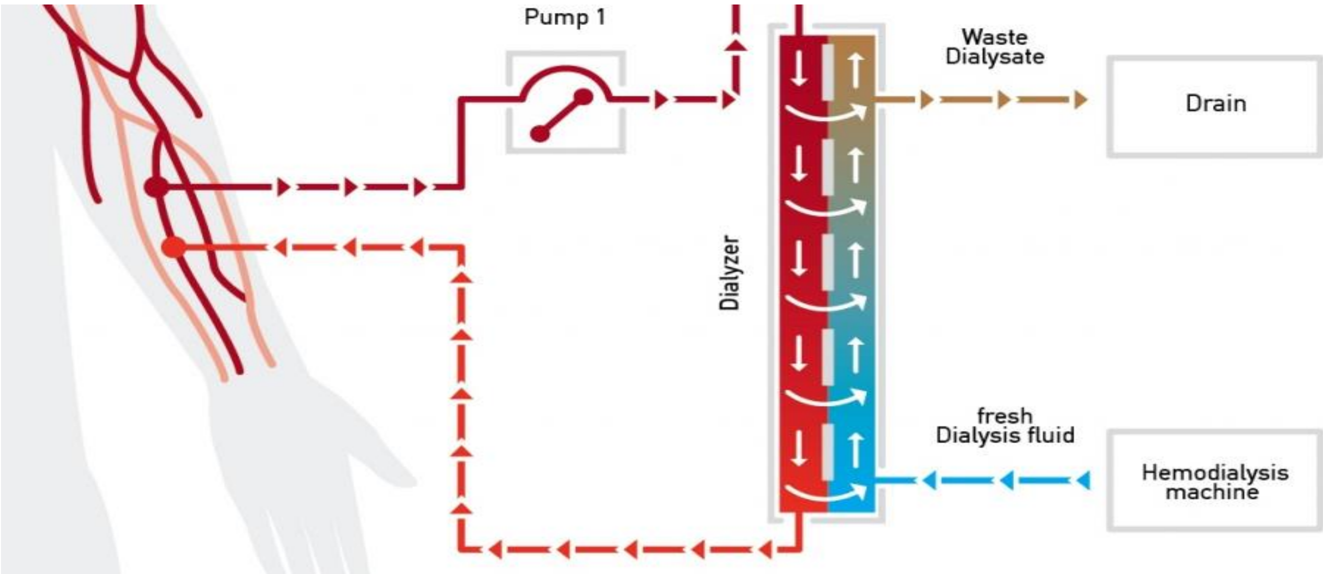

Figure 2 – Hemodialysis process

3. STRUCTURE OF COLLOIDAL PARTICLES OF LYOPHOBIC SOLS

Lyophobic sols are composed of micelles distributed in a dispersion medium.

Micelle is a neutral solid particle surrounded by a double electric layer composed of ions of an electrolyte-stabilizer.

Aggregate is the main compartment of a micelle. It consists of microcrystals formed as a result of the aggregation process — clustering of molecules of an insoluble product into larger and larger particles. Under suitable conditions, at a certain stage of their growth, aggregates begin to adsorb ions contained in the solution.

Ions adsorption obeys the *Panet-Phayans' Rules:*

Rule 1. Solid surfaces adsorb those ions that are included into their composition. These ions are defined ***as potential determining ions*** or ***PDI***.

*Rule 2. A charged surface adsorbs only oppositely charged ions (**counter ions).***

Potential determining ions (PDI) are ions which are adsorbed at the surface of aggregates. Their electric charge determines a charge of a colloidal particle. An aggregate and a layer of PDI form **a nucleus.**

Counter ions are ions which are adsorbed on the surface of nucleus; they are involved in adsorption and diffusion layers separately.

Colloidal particle is a compartment of a micelle, composed of an aggregate and an adsorption layer.

Adsorption layer is built up of potential determining ions and counter ions involved into a colloidal particle.

Diffusion layer involves counter ions that are outside the colloidal particle. As a result of ions adsorption, colloidal particles acquire a certain electric charge. The appearance of the charge significantly retards the further growth of particles, thereby stabilizing the sol.

A double electric layer (DEL*)* is responsible for generation of an electric potential at the boundary between adsorption and diffusion layers. This electrokinetic potential (ξ) is an important characteristic of sols. ξ – Potential defines stability of a colloidal particle and a distance between cells *in vivo* [3].

Example 1. Let's examine a structure of AgI micelle when sol is prepared by a reaction: $AgNO_{3(excess)} + KI \rightarrow AgI + KNO_3$

The electrolyte in excess ($AgNO_3$) is responsible for a sol's stability, since it contributes its ions into formation of a double electric layer around an aggregate:

$$AgNO_3 \rightarrow Ag^+ + NO_3^-$$

The formula of the silver iodide micelle stabilized with silver nitrate is shown in Figure 3:

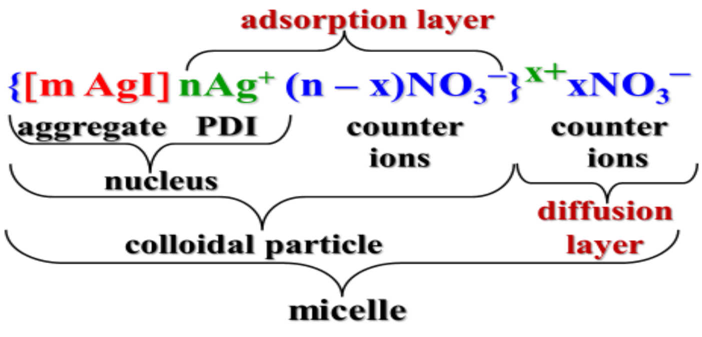

Figure 3 – The formula of the silver iodide micelle stabilized with silver nitrate

4. PHYSICAL PROPERTIES OF SOLS

Three types of physical properties of sols can be distinguished:

1) Molecular kinetic properties:

▪ *Brownian motion* is a random chaotic movement of particles in colloidal dispersion caused by the collision between the dispersed particles and the molecules of a dispersion medium.

▪ *Diffusion* is the tendency for molecules to migrate from a region of higher concentration to a region of lower concentration and is a direct result of Brownian motion.

▪ *Sedimentation* is the settling of suspended particles under the action of gravity.

2) Optical properties dispersed systems exhibit due to the equal size of dispersed particles and wavelength of visual spectrum. When a beam of light passes through a colloidal solution, each dispersed particle scatters the light rays that falling on it and looks like a luminous point. The entire path of a beam becomes visible, having the appearance of a bright cone, if viewed in darkness. This phenomenon is known as the Tyndall effect.

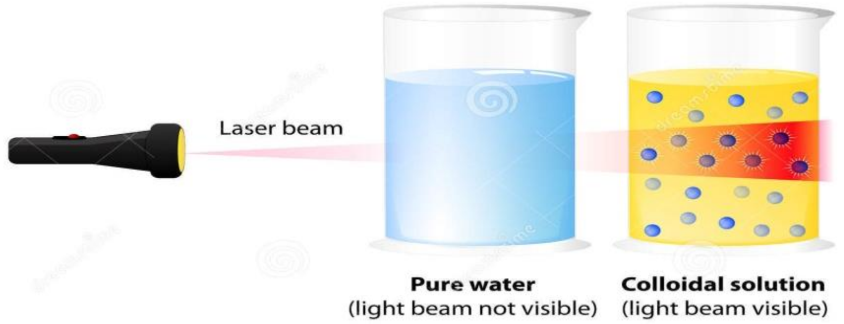

Figure 4 – The Tyndall effect

3) Electro kinetic properties of sols appear when electric current is passed through a colloidal solution. The most important among them are:

▪ *Electrophoresis* is the motion of electrically charged dispersed particles under the influence of an electric field. It is used to diagnose and monitor the disease, and for drug administration into the affected organs.

▪ *Electroosmosis* is an electrical transfer of dispersion medium across semipermeable membrane. It is applied in medicine for therapeutic sulfur purification [1-3].

The practical part

Safety instructions before laboratory work.

LABORATORY WORK No. 1

Preparation of colloidal solutions by condensation method

Test 1. *Preparation of silver iodide sol*

Pour (approximately half) of the KI solution into a test tube and add the $AgNO_3$ solution to it drop by drop when shaking to get opalescent sol of AgI:

$$KI_{(excess)} + AgNO_3 \rightarrow AgI + KNO_3$$

Report form:

1. Write down the equation of reaction for obtaining AgI sol.
2. Write the formula of the micelle of silver iodide sol stabilized by an excess of KI solution.

Test 2. *Preparation of copper (II) hexacyanoferrate (II) sol*

Pour (approximately half) of the $K_4[Fe(CN)_6]$ solution into a test tube and add a solution of $CuSO_4$ to it drop by drop when shaking until a red-brick sol is formed:

$$K_4[Fe(CN)_6]_{(excess)} + 2CuSO_4 \rightarrow Cu_2[Fe(CN)_6] + 2K_2SO_4$$

Report form:

1. Write down the equation of reaction for obtaining copper (II) hexacyanoferrate (II) sol.

2. Write the formula of the copper (II) hexacyanoferrate (II) sol micelle stabilized by excess $K_4[Fe(CN)_6]$ solution.

Test 3. *Preparation of sulfur sol*

Pour (approximately half) of the sodium thiosulfate solution into a test tube and add 3-4 drops of sulfuric acid solution to it when shaking. After some time, an opalescent sulfur sol is slowly formed in the resulting solution:

$$Na_2S_2O_{3(excess)} + H_2SO_4 \rightarrow S + Na_2SO_4 + SO_2 + H_2O$$

Report form:

1. Write down the equation of reaction for obtaining sulfur sol.

2. Write the formula of the sulfur sol micelle stabilized by an excess of sodium thiosulfate solution.

Control over the assimilation of the topic

It is conducted in the form of an oral conversation with students.

QUESTIONS FOR SELF-CONTROL OF KNOWLEDGE

1. Dispersed systems. Methods of classification of dispersed systems. What is the difference between colloidal dispersed and coarse dispersed systems? lyophilic and lyophobic systems?

2. Methods of preparation and purification of sols. What is the difference between degradation and condensation methods of sols preparing? Define the following terms:

a) dialysis; b) electrodialysis; c) ultrafiltration.

3. Structure of colloidal particles of lyophobic sols.

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

Exercises for the self – control

1. Lead (II) chloride sol was prepared according to the reaction:

$Pb(NO_3)_2 + 2KCl \rightarrow PbCl_2 + 2KNO_3$

Write the formula for the micelle of the prepared sol when $Pb(NO_3)_2$ is the excess. Give names to all compartments of the micelle.

2. $Al(OH)_3$ sol was prepared according to the reaction:

$3Ba(OH)_2 + 2AlCl_3 \rightarrow 2Al(OH)_3 + 3BaCl_2$

Write the formula for the micelle of the prepared sol when $AlCl_3$ is the excess.

Towards what electrode (anode or cathode) is the particle of the prepared sol moved when passing current through the solution?

3. Magnesium (II) hydroxide sol was prepared by interaction of magnesium (II) chloride dilute solution and slight excess of sodium hydroxide according to the equation:

$MgCl_2 + 2NaOH \rightarrow Mg(OH)_2 + 2NaCl$

Write the formula for the micelle of the prepared sol and answer the following questions:

a. What is the charge of a colloidal particle?

b. Towards what electrode is this particle moved when passing current through the solution?

4. AgBr sol was obtained by mixing 25 ml of 0.008 M KBr solution and 18 ml of 0.0096 M $AgNO_3$ solution. Determine the sign of charge of the particle and write the formula for the micelle of the prepared sol. Give names to all compartments of the micelle.

Answer: negative charge

QUESTIONS FOR INDEPENDENT WORK OF STUDENTS (IWS)

1. Aerosols. Fogs, dust, smog. Features of molecular kinetic and electrical properties of aerosols. The use of aerosols in medicine. Negative effects of industrial aerosols on human health (anthracosis, silicosis, asbestos, allergoses, etc.).

2. Suspensions and emulsions, their preparation and properties. The use of suspensions and emulsions in medicine.

LIST OF SOURCES USED

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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. 157-160. – 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 parts. 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.