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
in the academic discipline "Medical chemistry"
for students
the first-year of the Faculty of International Students (FIS),
studying in the specialty 7-07-0911-01 "General medicine"

Topic 15: Physico-chemistry of dispersed systems

Time: 2 hours

Approved at the meeting of the Department
of General and Bioorganic Chemistry
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2026

THE TRAINING AND EDUCATIONAL GOAL, TASKS, MOTIVATION TO STUDY THE TOPIC

Training purpose:

– formation of students' basic professional competence for solving diagnostic, research and other tasks of professional activity based on knowledge about physico-chemistry of dispersed systems with special attention to the biological significance of colloidal solutions *in vivo*;

– familiarization with the surface processes occurring at the interface of the two phases, with special attention to the adsorption processes and their biological significance;

– to give an idea of adsorption therapy (hemo-, lymph-, plasmasorption and enterosorption), as well as the use of surfactants in modern medicine.

Educational goal:

– to develop your personal, spiritual potential;

– to form the qualities of a patriot and a citizen who is ready to actively participate in the economic, industrial, socio-cultural and social life of the country;

– learn to observe academic and labor discipline, the norms of medical ethics and deontology;

– to realize the social significance of their future professional activities.

Tasks:

As a result of the training session, the student should

know:

– the concept of dispersed systems, their classification;

– methods of obtaining and purifying colloidal solutions;

– thermodynamics of the formation of lyophilic and lyophobic sols;

– structure of micelles of lyophobic sols stabilized by electrolytes;

– molecular kinetic and optical properties of colloidal systems;

– electrokinetic phenomena, in particular, electrophoresis and electroosmosis, and their application and significance in biology and medicine;

be able to:

– characterize colloidal systems by comparing their properties with the properties of coarse and true solutions;

– make formulas of micelles of lyophobic sols;

– determine the direction of movement of colloidal particles during electrophoresis;

possess:

– skills in preparation of colloidal solutions by chemical condensation methods.

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. Training tables:
a) Periodic Table of chemical elements by D.I. Mendeleev;
b) table of solubility of acids, bases and salts.
3. Reference materials of basic physico-chemical constants.
4. Chemical reagents and equipment necessary for laboratory work.

CONTROL QUESTIONS ON THE TOPIC OF THE CLASS

1. Dispersed systems, their classification.
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, THEIR CLASSIFICATION

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.

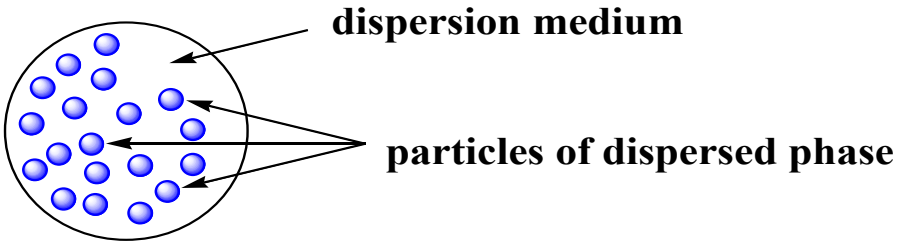


Figure 1 – A model of a dispersed system

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).

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.

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).

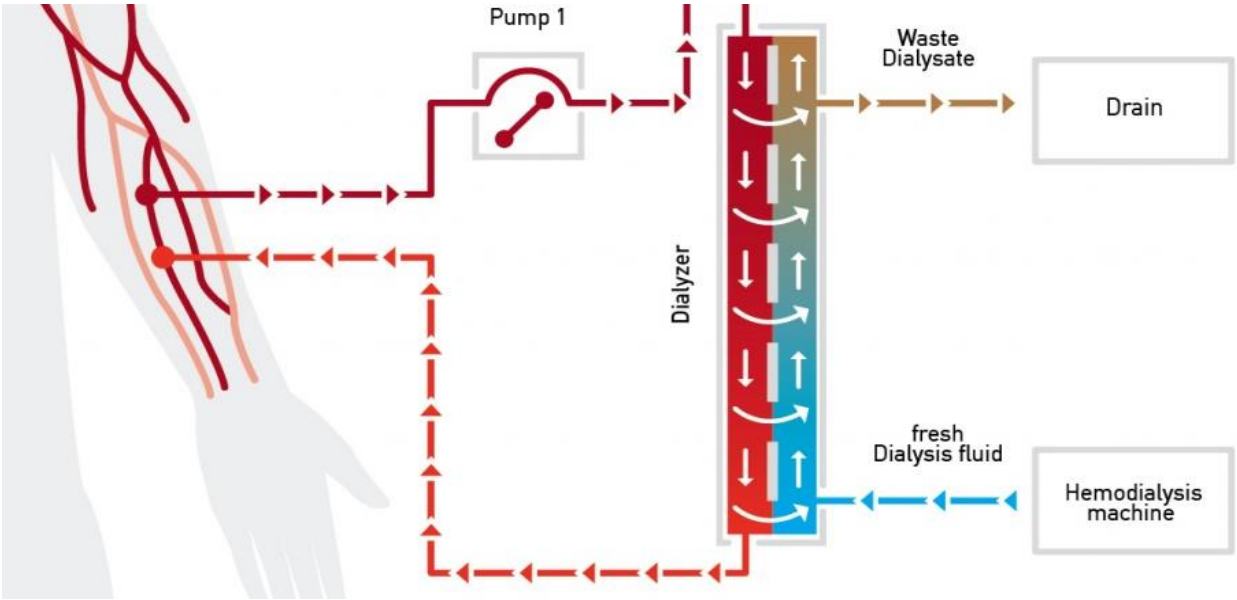


Figure 2 – Hemodialysis process

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***.

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*.

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 silver iodide micelle stabilized with silver nitrate is shown in Figure 4:

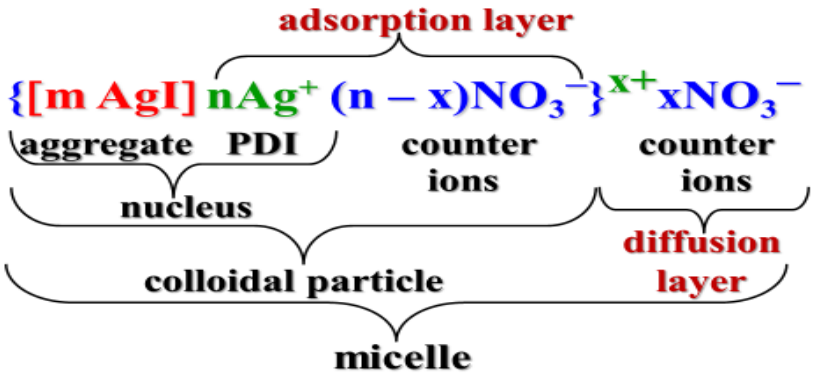


Figure 4 – The formula of the silver iodide micelle stabilized with silver nitrate

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's effect.*

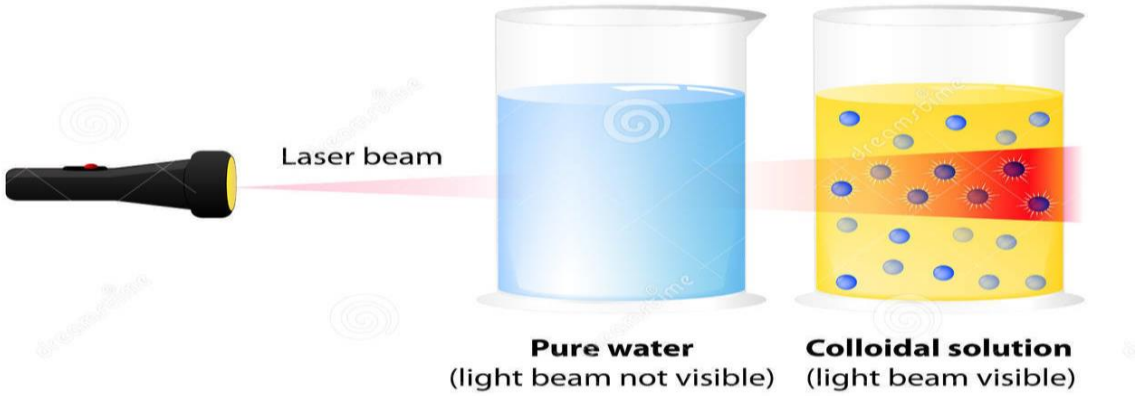


Figure 3 – the Tyndall's effect

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.

The practical part

Safety instructions before laboratory work.

LABORATORY WORK

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.

METHODOLOGICAL RECOMMENDATIONS FOR THE ORGANIZATION AND PERFORMING OF INDEPENDENT WORK OF STUDENT (IWS)

The time allotted for independent work can be used by students for:

– preparation for laboratory classes;
– taking notes of educational literature;
– performing tasks for self-control of knowledge;
– preparation of thematic reports, abstracts, presentations.

The main methods of organizing independent work:

– studying topics and problems that are not covered in the classroom;
– writing an abstract and making a presentation;
– performing tasks for self-control of knowledge.

List of tasks of IWS:

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 $Ba(OH)_2$ 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 hydroxide sol was prepared by interaction of magnesium 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?

The control of the IWS is carried out in the form of:

– evaluation of an oral answer to a question, message, report or presentation;

– individual conversation.

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. 134-151.

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