Subject 15. Coagulation of colloidal solutions

1. Importance

All biological liquids of the organism (blood, intracellular liquid, lymph, urine etc.) are complex dispersion systems. Their stability depends on constancy of pH and electrolyte and protein composition. Their alteration can lead to onset of coagulation of the hydrophobic particles, erythrocytes and proteins.

Coagulation also takes place in blood clotting – a complex of enzymic reactions that ensure minimal blood loss on one hand and formation of clots in blood vessels on the other hand. Blood clotting (coagulation hemostasis) is routinely analyzed in clinical laboratories; the measurement of the rate of sedimentation of erythrocytes is included to the general clinical analysis of blood. Knowledge of characteristics of coagulation processes is important in blood preservation and storage, applications of modern thromboresistant materials.

Colloidal protection is of great importance for the normal functioning of the organism. Proteins, polysaccharides and other natural polymers are adsorbed on the surface of colloidal hydrophobic particles, thus increasing their hydrophilicity. The polymers promote stability of the particles because they protect them from the coagulating action of electrolytes. Particles of lipids, cholesterol, insoluble calcium phosphates, urates and oxalates exist in the body fluids in the protected state. The protective action of proteins increases concentration of insoluble compounds: for instance, proteins of blood plasma increase solubility of calcium carbonate almost fivefold, the high concentration of calcium phosphate in milk is also ensured by the protective action of proteins. Certain pathological processes as well as aging alter concentrations and protective properties of proteins and polysaccharides. It causes formation of cholesterol plagues on the blood vessel walls as well as formation of stones in the kidneys, gallbladder and bladder.

The phenomenon of colloidal protection is used in the manufacturing of medicines. Sols of silver (protargol, collargol), gold, mercury and radioactive isotopes protected with albumins, gelatin, pectins and dextrin are widely applied in medicine.

Competences

Capacity for abstract thinking, analysis and synthesis, capacity to learn.

Ability to apply knowledge in practical situations.

Ability to assess and ensure quality of work.

Ability to communicate in English language both orally and in writing.

Use English language in professional and business communications and preparation of documents.

Ability to choose strategy of communication; ability to work in a team; skills of interpersonal interaction.

Ability to exercise self-control and healthy lifestyle, adaptability and ability to perform in new situations.

Motivation and perseverance in achieving goals.

Skills in using information and communication technologies.

Desire to preserve the environment.

Ability to evaluate results of laboratory and practical studies.

Ability to solve typical problems and practical problems in learning.

2. Concrete aims

Explain physical and chemical basis of coagulation of colloidal solutions and determine the coagulation threshold.

3. Basic knowledge, skills necessary for studying the subject (interdisciplinary integration)

Previous subjects	Obtained skills
1. Chemistry (school course)	Have an understanding of polymers.
2. Medical Biology	Proteins and polysaccharides as natural polymers
3. Foreign language for professional purposes	Know and use English language. Be able to communicate in English language both orally and in writing.
4. Safety, basics of bioethics and biosafety	Strive to preserve the environment

4. Tasks for independent work during preparation for the class and in class.

4.1. The list of key terms, parameters, characteristics that the student is to learn while preparing for classes:

Term	Definition
1. Stability of disperse systems	It is an ability to keep the constant size of particles of the dispersed phase and their uniform distribution in the dispersion medium.
2. Coagulation	It is a process of a decrease of dispersion of a system through aggregation of the dispersed phase.
3. The coagulation	This is the minimum concentration of an electrolyte, that

threshold.	causes evident coagulation of a sol.
4. The Schultze-Hardy rule.	Coagulating action is not pertinent to all ions of an electrolyte but rather to the ions that have charges of opposite sign to the charge of colloidal particles (granules).
5. Heterocoagulation.	This is aggregation of particles of different size or composition.
6. Colloidal protection.	It is an increase in stability of sols upon addition of macromolecular compounds (BMC).
7. The protection number.	It is the weight (in milligrams) of a dry macromolecular substance that can protect 10 mL of sol from coagulation caused by an addition of 1 mL of 10% sodium chloride solution.
8. Coarse dispersions	These are systems in which particles of the dispersed phase have size of $10^{-4} – 10^{-7}$ m.
a) aerosols	These are dispersion systems with a gaseous dispersion medium and a dispersed liquid or solid phase.
b) suspensions	These are coarse dispersions with a solid dispersed phase and a liquid dispersion medium.
c) emulsions	These are coarse dispersions that consist of two immiscible liquids of different polarity.

4.2. Theoretical questions to the lesson:

1. Kinetic and aggregate stability of liosols. Factors of stability.
2. Coagulation. The mechanism of coagulative action of electrolytes.
3. The coagulation threshold, its measurement.
4. The Schultze-Hardy rule.
5. Coagulation processes in purification of drinking water and wastewater.
6. Colloidal protection, its biological role.
7. Coarse dispersions:

a) coarse dispersions with a gaseous dispersion medium. Classification of aerosols, their properties and methods of preparation. Applications of aerosols in clinical practice. Negative impact of industrial aerosols on human health.

b) coarse dispersions with a liquid dispersion medium. Suspensions, their properties and methods of preparation. Pastes, their medical applications.

c) emulsions, their properties and methods of preparation. Types of emulsions. Emulsifiers. Applications of emulsions in clinical practice. The biological role of emulsification.

8. Semicolloid soaps, detergents. Formation of micelles in solutions of semicolloids.

4.3. Practical and calculation tasks done by students in class

1. A sol of silver iodide was obtained in the reaction: KI + $AgNO_3$ → AgI + KNO_3 with KI taken in excess. The sol was coagulated with solutions of potassium sulphate and calcium acetate. The coagulating action of whish electrolyte is stronger?
2. A hydrosol $Al(OH)_3$ is stabilized with excess $AlCl_3$. What volume (in liters) of 0.005 *M* solution of K_2CrO_4 is to be added to 0.05 L of the sol to induce its evident coagulation? Which ion is responsible for the coagulating action of the electrolyte? The coagulation threshold of $Al(OH)_3$ is 0.15 mmol/L.
3. Calculate the coagulation threshold if 4.0 cm^3 of 0.15 *M* solution $A1_2(SO_4)_3$ was used for coagulation of colloidal particles in 230.0 cm^3 wastewater.

Contents of the subject (abstract):

1. The kinetic and aggregate stability of liosols. Factors of stability.

Stability of disperse systems is their ability to keep a constant size of the dispersed particles and their uniform distribution in the dispersion medium.

Kinetic (sedimentation) stability is the ability of a system to resist sedimentation of particles under gravity.

Aggregate stability is the ability of systems to resist adhesion (aggregation) of the particles.

Factors of stability:

1) electrostatic (stipulated by the charge of colloidal particles);

2) solvation (stipulated by formation of solvation layers on the surface);

3) entropic (resulting from the adsorption of a surfactant on the surface of particles);

4) structural and mechanical (resulting from the adsorption of surfactants such as proteins, glycosides, cellulose derivatives, soap).

2. Coagulation. Mechanism of coagulating action of electrolytes.

Coagulation is the process of decrease of dispersion of the system through consolidation of the dispersed phase.

There are two mechanisms of coagulation:

1. **Neutralization** (adsorptive) coagulation of sols is caused by addition of electrolytes. The charge sign of the coagulation ion is opposite to the charge sign of potential determining ions of colloidal particles.

2. **Concentration** coagulation of sols is caused by addition of electrolytes that can not be adsorbed on the particles.

The following phenomena accompany coagulation caused by mixtures of two or more electrolytes:

1) additivity is the sum of coagulating actions of electrolytes;

2) antagonism is a decrease of the coagulating action of an ion in the presence of another;

3) synergy is an increase of the coagulating action of an electrolyte in the presence of another.

3. The coagulation threshold, its measurement.

The coagulation threshold is a minimum concentration of electrolyte that causes evident coagulation of a sol.

The coagulation threshold is calculated with the formula:

$$\mathbf{C_{thr}} = \frac{Vel \cdot C\min \cdot 1000}{Vsol + Vel}, \text{ mmol/L;}$$

where

C_{thr} is the coagulation threshold, mmol/L;

V_{el} is the volume of the electrolyte that caused coagulation, mL;

S_{min} is the normality of the electrolyte mmol/L;

V_{sol} is the volume of the sol, mL.

4. The Schultze-Hardy rule.

The Schultze-Hardy rule: Coagulating action is not pertinent to all ions of an electrolyte but rather to the ions that have charges of opposite sign to the charge of colloidal particles (granules).

5. Coagulation processes in purification of drinking water and wastewater.

Heterocoagulation is aggregation of particles of different size or composition. Heterocoagulation is the basis of water purification. Aluminum sulfate or ferric chloride are added to wastewater at water treatment plants. They are good coagulators.

6. Colloidal protection, its biological role.

Colloidal protection is an increase of stability of sols upon addition of macromolecular compounds. The protective number is a quantitative characteristics of the ability of macromolecular compounds to protect a sol from coagulation.

The protective number is the weight (mg) of a dry macromolecular substance that can protect 10 mL of sol from coagulation caused by an addition of 1 mL of 10% sodium chloride solution.

Proteins (albumin, mucin, gelatin, casein) show the greatest protective effect, polysaccharides (starch, dextrin) show a smaller protective effect.

Biological role of colloidal protection.

Blood and urine are protected colloids. Proteins protect hydrophobic particles of calcium carbonate and calcium phosphate, cholesterol and other fat droplets in water soluble substances from coagulation.

7. Coarse dispersions.

Coarse dispersions are systems in which particles of the dispersed phase have size of $10^{-4} – 10^{-7}$ m.

These are coarse dispersions that consist of two immiscible liquids of different polarity.These include aerosols, suspensions, emulsions.

a) **aerosols** are dispersion systems with a gaseous dispersion medium and a dispersed liquid or solid phase.

According to the aggregative state of the dispersed phase, aerosols are classified as follows: fog is a system in which the dispersed phase is liquid; smoke and dust are systems with a solid dispersed phase.

According to the method of preparation, aerosols are classified as follows: dispergation and condensation aerosols.

For typical aerosol phenomena such as Thermophoresis, photophoresis and thermoprecipitation are phenomena observed in aerosols.

Aerosols are used as a dosage form in pharmacy.

b) **suspensions** are coarse dispersions with a solid dispersed phase and a liquid dispersion medium.

There are dispergation and condensation methods of preparation of suspensions.

Diffusion, osmosis, Brownian motion are not observed in suspensions. Light passing through a suspension is reflected rather than scattered.

Pastes are coarse dispersions with a high concentration of a solid dispersed phase (25 - 75%) in a liquid dispersion medium. Pastes have high viscosity.

Pastes are mainly used topically in dentistry, dermatology, cosmetology.

c) **emulsions** are coarse dispersions that consist of two immiscible liquids of different polarity.

Methods of preparation of emulsions:

- dispergation (stirring, mixing);
- ultrasonication;

- condensation.

Emulsifiers are surface active compounds that are added to emulsions to increase their stability.

Biological role of emulsification.

Salts of bile acids that come from the liver through the bile duct into the intestine emulsify fat droplets in digestion of food.

In medicine, drugs in a form of oil/water emulsions are used orally and for injections, and water/oil emulsions are applied externally.

8. Semicolloid soaps, detergents. Formation of micelles in solutions of semicolloids.

Semicolloid soaps form true solutions at low concentrations and micellar colloidal solution at high concentrations. The process is spontaneous and reversible.

Solubilisation is a process of dissolving of compounds insoluble in a certain solvent in a colloidal micellar system.

Materials for self control:

A. Tasks for self control:

1. Which of the factors ensure stability of colloidal solutions:

1 – the charge sign of the particle; 2 – the charge value of the particle;
3 – the thickness of the diffuse layer; 4 – kind of ions in the diffuse layer;
5 – Brownian motion of colloidal particles;
6 – the value of the electrokinetic potential.

a) 1, 2, 3, 6; b) 2, 3, 5, 6; c) 1, 2, 4, 5; d) 1, 3, 4, 5.

2. Which of the factors cause coagulation of a sol?

1 – a change of temperature; 2 – addition of the solvent;
3 – a change of pressure; 4 – addition of an electrolyte;
5 – addition of dehydrating agents.

a) 1, 2, 3; b) 1, 3, 4; c) 1, 4, 5; d) 2, 3, 5.

3. Which of the factors effect coagulation threshold and coagulating ability of ions?

a) concentration of the ion; b) hydration of the ion;
c) charge of the ion; d) temperature.

4. Choose one best characteristic of antagonism of ions in coagulation:

a) impossibility for ions to exist simultaneously in the same solution because of a reaction between them;

b) a decrease of solubility of ions when they are present at the same time in the same solution;

c) a decrease of coagulation thresholds of ions in mutual coagulation;
d) a decrease of coagulating abilities of ions in mutual coagulation.
5. Choose the substances that have the protective action in the human body:
a) electrolytes; b) cholesterol; c) proteins; d) polysaccharides.
6. When a small amount of a macromolecular compound that is not sufficient to cause a protective effect, is added to a colloidal solution, its stability decreases and the disperse phase eventually sedimentates. How is the phenomenon called?
a) sedimentation; b) flocculation; c) flotation; d) mutual coagulation.

B. Practical tasks for self control:

1. The protective numbers of some macromolecular compounds are as follows: gelatin - 0.1; sodium caseinate - 0.5; starch - 35; dextrin - 20; saponin - 40. Which of the macromolecular substances has the greatest protective effect?
a) gelatin;
b) saponin;
c) dextrin;
d) starch;
e) sodium caseinate.
2. A sol of ferric hydroxide with positively charged particles is coagulate with electrolytes. Which of these electrolytes has the greatest coagulating ability:
a) sodium phosphate;
b) potassium chloride;
c) aluminum carbonate;
d) ferrous sulfate;
e) aluminum nitrate.

Literature

Main:

1. Medical Chemistry: textbook / V.O. Kalibabchuk, V.I. Halynska, V.I. Hryshchenko et al.; edited by Prof. V.O. Kalibabchuk – Kyiv: “Medicine”, 2010 – 224 p. (P. 134 – 168).

Informational resources:

2. www. pdmu, edu.ua
https://med-chemistry.pdmu.edu.ua/

(Web page of Poltava State Medical University).