Subject 16. Physical chemistry of biopolymer solutions

1. Importance

Such high-molecular compounds as proteins, polysaccharides and nucleic acids are vital for functioning of the living organism. Biopolymers perform important functions in the body. They catalyze biochemical processes, preserve and transfer genetic information, perform protective and structural functions, take part in blood coagulation, are storage forms of nutrients, maintain oncotic pressure of blood plasma.

pH alterations of the blood make proteins lose their charge (isoelectric state) thus impairing their structure and functioning.

Proteins do not come with the diet at starvation; synthesis of blood plasma proteins is deficient in liver diseases; proteins are lost with urine in kidney diseases. It causes decrease of protein concentration in blood and lowering of oncotic pressure of blood plasma. Therefore the water from the blood vessels moves to the tissues causing edema.

Artificial and synthetic polymers are of great importance in medicine and pharmaceutics. They are used in production of artificial blood vessels, prosthetic teeth and bones. They are also used in the "artificial kidney" apparatus etc. Polymers are used in production of modern medicines, prolongation of action of medicines in the organism.

2. Concrete aims

Explain physical and chemical characteristics of proteins as structure components of all tissues of the organism.

Make conclusions about the charge of dissolved biopolymers from their isoelectric point.

3. Basic knowledge and skills necessary to study the subject

To know high molecular compounds (polymers).

To know the structure of proteins.

To be able to explain formation of charge of the protein as an amphoteric polyelectrolyte.

4. Tasks for self-preparation for the lesson

4.1. Theoretical questions for the lesson:

1. Characteristics of solutions of high molecular compounds.
2. Mechanism of turgescence and solubility of high molecular compounds. Effect of various factors on turgescence and solubility of high molecular compounds. Role of turgescence in physiology of organisms.
3. Isoelectric point of the protein (pI) and methods of its measurement.
4. Jellification of solutions of high molecular compounds. Properties of jellies.
5. Anomalous viscosity of solutions of high molecular compounds. Viscosity of blood.
6. Osmotic pressure of solutions of biopolymers. The Galler equation. Oncotic pressure of blood plasma.

4.2. Practical work (task) done by students in class

Measurement of the isoelectric point of gelatin with the maximum precipitation.

Add such amounts of acetic acid (CH_3COOH) and sodium acetate (CH_3COONa) to five test tubes, that make 10 mL buffer solution with certain pH in each test tube (see Table 22). Add 0.5 mL 1% gelatin solution to each test tube, mix. Then add 2 mL ethanol to each test tube, mixing vigorously. Leave the tubes for ten minutes. Mark the test tube and the pH, where the solution is the most turbid. The pH will correspond to the isoelectric point of gelatin. Fill in Table 22 with the results.

Table 22

№	Volumes of solutions, mL		pH	№ test tube with the maximum turbidity	pH of the solution with the maximum turbidity	pI
	0.2 *M* CH_3COOH	0.2 *M* CH_3COONa				
1	9.75	0.25	3.17			
2	8.90	1.10	3.85			
3	5.35	4.65	4.70			
4	1.70	8.30	5.45			
5	0.25	9.75	6.35			

Materials for self-control

1. Choose the correct characteristics of solutions of high molecular compounds:
   1 – homogeneous,
   2 – heterogeneous,
   3 – real,
   4 – coarse dispersion,
   5 – have molecular structure,
   6 – have micellar structure.
   a) 1, 3, 5;
   b) 2, 4, 6;
   c) 1, 3,6;
   d) 2, 4, 5.
2. Choose one best description of the isoelectric point (pI) of the protein:
   a) it is the state of the protein macromolecule, when it is not charged;
   b) it is the pH of the solution when the protein molecule is positively charged;
   c) it is the pH of the solution when the resulting charge of the protein molecule equals zero;
   d) it is the pH of the solution when the protein molecule is negatively charged.
3. How do the volume of a polymer sample and the general volume of the polymer-solvent system change in turgescence?
   a) the volume of the sample and the general volume of the system decrease;
   b) the volume of the sample and the general volume of the system increase;

c) the volume of the sample increases, the general volume of the system decreases;
d) the volume of the sample decreases, the general volume of the system increases.

4. Which pH values of the solution cause the smallest turgescence of the protein.
a) pH > pI;
b) pH < pI;
c) pH = pI;
d) pH = 7.

Correct answers

1. The correct answer is a).
From the contemporary point of view solutions of polymers are mostly homogeneous systems, where the disperse phase is made by polymer macromolecules. The molecules have large size, but their surface does not make interface between phases. The solutions belong to real solutions.

2. The correct answer is c).

3. The correct answer is c).
At the first stage of the turgescence molecules of the solvent penetrate the polymer structure. The polymer does not change its dimensions, and the general volume of the solution does not change much. At the second stage of turgescence the volume of the polymer greatly increases (the distance between polymer molecules grows), and the general volume of the system greatly decreases ("contraction").

4. The correct answer is c).
Protein molecules are amphoteric polyelectrolytes, that can obtain a greater or smaller number of positive ($-NH_3^+$) or negative ($-COO^-$) charges depending on pH of the solution. If pH< pI, the resulting charge of the protein molecule is positive. If pH > pI, the resulting charge is negative. When pH = pI, the resulting charge of all charged qroups in the protein molecule is zero. Charged molecules are hydrated better, therefore hydration and, respectively, turgescence are the smallest in a solution where pH = pI.

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. 62 – 73).

Informational resources:

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

(Web page of Poltava State Medical University).