

2. Барановський М. М. Трипси Лісостепу України: [монографія] / М. М. Барановський – К.: квітц, 2002. – 228 с.
3. Варфоломеева Е. А. биоценологическое обоснование применения энтомофагов в оранжереях ботанических садов Северо-Запада России: Автореф. дис. к-та биол. наук: 06.01.11 / Е. А. Варфоломеева. – СПб: ВНИИ защиты растений, 2009. – 19 с.
4. Kirk W. D. J. Thrips / W. D. J. Kirk – Department of Biological sciences. England, 1996. – 70 p.
5. Дульгерова В. А. Мониторинг трипсов в теплицах с помощью клеевых ловушек / В. А. Дульгерова, Н. А. Демьянец // Интегрированный захист рослин на початку ХХІ ст. – К.: Колообіг. 2004. – С. 545-548.
6. Дульгерова В. О. Новый для Украины карантинный шкідник – західний квітковий трипс *Frankliniella occidentalis* (Thysanoptera, Thripidae) / В. О. Дульгерова, В. П. Омелюта // Вест. зоол. – 1998. – № 9. – С. 51-52.
7. Mound L. A. The insect Oder Thysanoptera: Classification versus Systematics / L. A. Mound, D. C. Morriz // Zootaxa. – 2007. – № 1668. – P. 395 – 411.
8. http://ipm.ncsu.edu/AG295/html/western_flower_thrips.htm

Gordiyenko O.I.

*Doctor of Science in Biophysics,
Head of department for Low Temperature Preservation,
Institute for Problems of Cryobiology and Cryomedicine NAS of Ukraine*

Barannyk M.O.

*Lecturer,
National University of Pharmacy*

ESTIMATION OF THE SURFACE POTENTIAL OF ERYTHROCYTES AND DEBYE LENGTH IN SOLUTIONS WITH DIFFERENT CONCENTRATION OF NaCl

The Poisson-Boltzmann equation determines the potential Ψ , electric field $E = \frac{\partial \Psi}{\partial x}$ and counterions density ρ at any point x in the gap between the two surfaces [1, p. 294]:

$$\frac{d^2 \Psi}{dx^2} = -\frac{ze\rho}{\varepsilon_0} = -\left(\frac{ze\rho_0}{\varepsilon_0}\right) e^{\frac{ze\Psi}{kT}} \quad (1)$$

where Ψ is the electrostatic potential, ρ is the number density of ions of valency z at any point x between two surfaces, ε_0 is the vacuum permittivity, ε is the relative permittivity, k is the Boltzmann constant, T is the absolute temperature.

The counterion density at the surface determined by the formula [1, p.295]:

$$\rho_0 = \rho_\infty + \frac{\sigma^2}{2\varepsilon_0 kT} \quad (2)$$

where ρ_0 is the counterion density at the surface, and ρ_∞ is the ionic concentration of ions in the bulk.

Consider the distribution of ions near the insulated surface in contact with an electrolyte solution. If a full charge density at any point x can be written as $\sum_i z_i e \rho_{xi}$ and a total concentration of ions (numerical density) can be written as $\sum_i \rho_{xi}$ that the Boltzmann distribution (1) of ions i at x now becomes

$$\rho_{xi} = \rho_{\infty i} e^{\frac{z_i e \Psi_x}{kT}}, \quad (3)$$

while at the surface, at $x=0$, the contact values of ρ and Ψ are related by

$$\rho_{0i} = \rho_{\infty i} e^{\frac{z_i e \Psi_0}{kT}}, \quad (4)$$

where $\rho_{\infty i}$ – is the ionic concentration of ions i in the bulk (at $x = \infty$), where $\Psi_\infty = 0$.

The total concentration of ions at an isolated surface of charge density σ by the formula (2) is:

$$\sum_i \rho_{0i} = \sum_i \rho_{\infty i} + \frac{\sigma^2}{2\epsilon_0 kT} \quad (6)$$

Where can be obtained the relation between the surface charge density σ and the surface potential Ψ_0 .

$$\sigma^2 = 2\epsilon_0 kT \left(\sum_i \rho_{0i} - \sum_i \rho_{\infty i} \right) \quad (7)$$

For erythrocyte the surface charge density $\sigma = -1.31 \cdot 10^{-2} \text{ C/m}^2$ [2, p.19]. Or $1.31 \cdot 10^{-2} \text{ C} \cdot \text{m}^{-2} / 1,602 \cdot 10^{-19} \text{ C} = 0.82 \cdot 10^{17} \text{ charge/m}^2 = 0,082 \text{ charge /nm}^2$, that is 1 elementary charge to 12.2 nm^2 . Considering that the erythrocyte surface area $\sim 140 \cdot 10^{-12} \text{ m}^2$ (or $14 \cdot 10^7 \text{ nm}^2$) we have ~ 107 charges on the surface of red blood cells.

Substituting equation (4) to (6) we obtain the equation for calculation the surface potential of erythrocytes in solutions of varying concentrations of sodium chloride:

$$\cosh \frac{\Psi_0}{26.7} = \frac{1.7161 + 73.04 \times [\text{NaCl}]}{73.04 \times [\text{NaCl}]} \quad (8)$$

For small potential quantities approximately less than 25 mV, which is justified in the case of red blood cells, Grahame equation (7) is simplified to the form

$$\sigma = \epsilon_0 \kappa \Psi_0 \quad (9)$$

where

$$\kappa = \left(\frac{\sum_i \rho_{\infty i} e^2 z_i^2}{\epsilon_0 kT} \right)^{\frac{1}{2}} \text{ M}^{-1} \quad (10)$$

Thus, the potential is proportional to the surface charge density.

The Debye length of NaCl aqueous solutions is:

$$\frac{1}{\kappa} = \frac{(\epsilon_0 kT)^{\frac{1}{2}}}{\left\{ (\rho_{Na} e^2 z_{Na}^2 + \rho_{Cl} e^2 z_{Cl}^2) \times N_A \times 10^3 \right\}^{\frac{1}{2}}} \quad (11)$$

where ρ_i – density of ions pc/m^3 ; z_i – charge of an i^{th} ion (for NaCl $z_i = \pm 1$); e is the elementary charge; N_A – Avogadro constant. Multiplication on $N_A \cdot 10^3$ done for the transition of concentration from pc/m^3 to mol/l .

Then, in the 1: 1 electrolyte, such as NaCl:

$$\frac{1}{\kappa} = \frac{\{80 \times 8.854 \times 10^{-12} \times 1.381 \times 10^{-23} \times 298(310)\}^{\frac{1}{2}}}{1.602 \times 10^{-19} \times (2\rho_{Na})^{\frac{1}{2}} \times 6.022 \times 10^{23} \times 10^3}$$

For temperature $t=37^\circ\text{C}$ (310 K):

$$\frac{1}{\kappa} = \frac{0.313}{([NaCl])^{\frac{1}{2}}} \quad (12)$$

Calculated by the formula (12) values of the Debye length and the formula (8) surface potential of erythrocytes in solutions with different concentration of sodium chloride are given in Table 1.

Table 1

Surface potential of erythrocytes and Debye lengths in solutions with different concentration of NaCl

The concentration of NaCl, M	0,15	0,1	0,05	0,025
Surface potential, mV	-14,7	-18,4	-25,4	-34,4
The Debye length at 37°C , nm	0,81	0,99	1,40	1,98

Theoretical calculation showed that the surface potential of erythrocytes is the largest in the solution with the highest concentration of NaCl, and decreased with decreasing concentration of sodium chloride in solution, while the Debye length, by contrast, is the largest in the solution with the lowest concentration of NaCl, and increased with decreasing concentration of sodium chloride in solution. Obtained results can be used to estimate the electrostatic interactions in cell-cell adhesion processes.

References:

1. Israelachvili J. Intermolecular and Surface forces / J. Israelachvili // 3rd ed. – Burlington: Academic Press, 2011. – 674 p.
2. Petelska A. D. The effect of contrast medium SonoVue on the electric charge density of blood cells / A. D. Petelska, J. R. Janica, J. Kotynska, U. Lebkowska, Z. A. Figaszewski // J. Membrane Biol. – 2012. – V. 245. – P.15–22.