GOLDMAN-HODGKIN-KATZ EQUATION CALCULATOR

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Introduction. Equations of Membrane Biophysics provides an introduction to the relevant principles of thermodynamics, kinetics, electricity, surface chemistry, electrochemistry, and other mathematical theorems so that the quantitative aspects of membrane phenomena in model and biological systems could be described.

Purpose. The objective of this work is to know how to calculate the potential of membrane enclosing several "conductances". (depending on the different types of ions).

Materials and methods. The GHK equations apply when one or more ion species exist on both sides of a membrane permeable to them. The electrical and diffusive influences on each ion are not necessarily at equilibrium.

Definition. There are two Goldman-Hodgkin-Katz (GHK) equations: the GHK voltage equation and the GHK current equation. The GHK voltage equation gives the membrane potential expected to result from multiple ion species at differing concentrations on either side of the membrane. The GHK current equation gives the transmembrane current of an ion species expected at a given membrane potential for a given concentration of the ion on either side of the membrane.

The Goldman-Hodgkin-Katz equation :

$$V_{\mathrm{m}} = \frac{RT}{F} \ln\left(\frac{p_{\mathrm{K}}[\mathrm{K}^+]_{\mathrm{o}} + p_{\mathrm{Na}}[\mathrm{Na}^+]_{\mathrm{o}} + p_{\mathrm{Cl}}[\mathrm{Cl}^-]_{\mathrm{i}}}{p_{\mathrm{K}}[\mathrm{K}^+]_{\mathrm{i}} + p_{\mathrm{Na}}[\mathrm{Na}^+]_{\mathrm{i}} + p_{\mathrm{Cl}}[\mathrm{Cl}^-]_{\mathrm{o}}} \right)$$

Vm is the membrane potential. This equation is used to determine the resting membrane potential in real cells, in which K+, Na+, and Cl-are the major contributors to the membrane potential. Note that the unit of Vm is the Volt. However, the membrane potential is typically reported in millivolts (mV). If the channels for a given ion (Na+, K+, or Cl-) are closed, then the corresponding relative permeability values can be set to zero. For example, if all Na+ channels are closed, pNa = 0.

R is the universal gas constant (8.314 J.K-1.mol-1).

T is the temperature in Kelvin (K = °C + 273.15).

F is the Faraday's constant (96485 C.mol^{-1}).

p_K is the membrane permeability for K^+. Normally, permeability values are reported as relative permeabilities with p_K having the reference value of one (because in most cells at rest p_K is larger than p_{Na} and p_{Cl}). For a typical neuron at rest, $p_K : p_{Na} : p_{Cl} = 1 : 0.05 : 0.45$. Note that because relative permeability values are reported, permeability values are unitless.

p_{Na} is the relative membrane permeability for Na^+.

p_{Cl} is the relative membrane permeability for Cl^-.

$[K^+]_o$ is the concentration of K^+ in the extracellular fluid. Note that the concentration units for all the ions must match.

$[K^+]_i$ is the concentration of K^+ in the intracellular fluid. Note that the concentration units for all the ions must match.

$[Na^+]_o$ is the concentration of Na^+ in the extracellular fluid. Note that the concentration units for all the ions must match.

$[Na^+]_i$ is the concentration of Na^+ in the intracellular fluid. Note that the concentration units for all the ions must match.

$[Cl^-]_o$ is the concentration of Cl^- in the extracellular fluid. Note that the concentration units for all the ions must match.

$[Cl^-]_i$ is the concentration of Cl^- in the intracellular fluid. Note that the concentration units for all the ions must match.

Constant terms in the Goldman-Hodgkin-Katz equation: Universal Gas Constant (R) = 8.314 J.K^{-1}.mol^{-1} (Joules per Kelvin per mole). Faraday's Constant (F) = 96485 C.mol^{-1} (Coulombs per mole).

Goldman-Hodgkin-Katz equation calculator. Each calculator cell shown below corresponds to a term in the formula presented above. Enter appropriate values in all cells except the one you wish to calculate. Therefore, at least ten cells must have values, and no more than one cell may be blank.

Please note that the unit of temperature used in the Goldman-Hodgkin-Katz equation is the Kelvin.

Interpretation. As mentioned above and as can be seen from the GHK equation shown above, the value of the membrane potential is determined by the concentration gradients and the relative permeability values of ions for which there are open channels in the plasma membrane. The physiological concentration gradients are homeostatically maintained within a very narrow range. The magnitude of the permeability (i.e., how many open channels in the plasma membrane) for any given ion can, in fact, be regulated physiologically, and determines the relative contribution of that ion to V_m. It is important to remember that the movement of any ion down its own electrochemical gradient will tend to move the membrane potential toward the equilibrium potential for that ion. The larger the permeability of a given ion, the larger the contribution of that ion will be in setting the membrane potential.

Conclusion. Thanks to the determination of different channels and transporter structures, the mechanisms that determine ion selectivity and transport in them is much better understood at present. However, the elegance, simplicity, and usefulness of the GHK equation are something difficult to beat.

APPLICATION OF THE QUEUING THEORY IN THE PHARMACY

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Introduction. Queuing theory is part of process control theory. It describes any system where queues and / or denials of service are possible. Such systems are called queuing systems; in the following we will denote them as QS. The use of this theory allows us to formalize the process and find a cost-effective solution to the problem of the ratio of the costs of eliminating queues and the danger of losing profits due to the loss of customers. The queuing theory has found wide application in various fields of activity: sales management, communication networks, aircraft landing systems and passenger traffic regulation in other types of transport, etc.

Aim. The aim of the work is to study the features of using the queuing theory to solve the problems of the pharmaceutical business, including to analyze the quality of functioning of a pharmaceutical company and to develop recommendations for improving their work.

Materials and methods. Queuing theory includes the development and analysis of mathematical models that describe the service process as a flow that forms a queue at the entrance to the QS. The main elements of a QS are: incoming flow of requests, service channels, queue of requests waiting for service, coming out served requests, coming out unserved requests.

The incoming flow of requests is a requirement requiring service. For the pharmaceutical business, these are customers in a pharmacy, customers of drugs, equipment, etc. Typically, the flow of requests obeys the Poisson law, in which the time intervals between requests are distributed according to the exponential law with density λ.

Channels are used to service requests. Under the service can be understood as the implementation of the necessary customer actions. In our case, the service is the appeal of the pharmacy visitor to the pharmacist and the issuance of necessary medications. It is usually considered that the time of request servicing is random and obeys the exponential distribution law with the parameter μ.

Requests to the system are received under the stochastic law and service channels may not always cope with their «processing». This leads to the formation of a queue of requests waiting for service. Waiting time is subject to exponential law with the parameter ν.

Depending on the type of QS chosen, two outgoing flows can be realized – served and unserved requests.

The queuing theory considers the following types of QS.