Please make sure to do the reading prior to completing the problem set.

Equilibrium Potentials I Lab Notebook

Reading: Equilibrium Potentials I

Name:
Date:
Purpose of Lab:

Problem Set 1

a. If you have not already done so, download the Nernst Potential Simulator using the links in Canvas.

b. Double click the program icon to open the simulator. Under the File menu, choose Load Initial Conditions, and then select *Problem1.init*. This file should be in the same folder as the one in which you found the Nernst Potential Simulator program. Note that the **permeability**, which is a measure of the number of channels that will allow a particular kind of ion to cross the membrane, has been set to zero for all of the ions. When the permeability is set to 1, the maximum number of channels are available to those ions. Also note that the **Electrostatics** box is unchecked. This means that the ions will be treated as uncharged particles. Consequently, **ignore the Membrane Potential plot** on the right side of the window. It is only applicable when Electrostatics is turned on, which will only happen during part (f) of this problem.

c. Start the simulation (press Start). Click on one of the red ions, which will enlarge it. *Describe what you observe about the motion of the single ion, as well as the movements of all of the ions in the intracellular compartment. Predict the long term behavior of the system, record your prediction, and observe the system for at least 2,000 iterations to see if your long term prediction is likely to be correct* (the iteration number is updated on the lower left-hand corner of the window).

d. Pause the simulation (press Pause). Change the permeability for the K+ ions from 0 to 1 (either by moving the slider, or typing 1 into the box). Also change the permeability of the Na+ and Cl− ions to 1. Note that the Selective Permeability box is unchecked. Thus, increasing the permeability to Na+ and Cl− under these conditions will provide many opportunities for potassium ions to move through the membrane. You can see the many channels shown in the zoom window at the bottom middle of the simulation. ***Before continuing, take a screenshot of the simulation for your lab notebook.***

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Paste screenshot here. Make sure to label the figure, you can do this by right clicking the image and clicking “Insert Caption”

Now continue the simulation (press Continue). Observe what happens to the individual ion that you have selected, and to all of the ions over time. Also observe the change in the intracellular and extracellular concentrations of K+ listed in the table under the graph to the right. Predict the final intracellular and extracellular concentrations of K+ ions. Note that in this exercise the "ions" in the simulation have no charge (the Electrostatics setting is disabled), and so they will behave like electrically-neutral particles, such as glucose. Run the system for up to another 5,000 iterations to see if your long term prediction is likely to be correct. ***Take another screenshot of the simulation for your lab notebook.***

Paste screenshot here. Make sure to label the figure, you can do this by right clicking the image and clicking “Insert Caption”

e. Take the simulation back to the initial conditions loaded from the file by pressing the "Reset with Loaded Initial Conditions" button. Now switch the intracellular concentration of K+ from 2000 to 0, and the extracellular concentration of K+ from 0 to 2000, so that the K+ ions are all in the extracellular compartment. Change the permeability of all the ions from 0 to 1. **Before starting the simulation, take another screenshot for your lab notebook.**

Paste screenshot here. Make sure to label the figure, you can do this by right clicking the image and clicking “Insert Caption”

Start the simulation, and again click on one of the red ions. *Predict the long term intracellular and extracellular concentrations of K+ ions, and observe the system for about 5,000 iterations to see if your long term prediction is correct.* Note to the careful student: the extracellular and intracellular compartments have slightly different volumes in this simulation, but you may treat them as identical volumes for these questions. ***Take another screenshot of the simulation after at least 5,000 iterations have passed.***

Paste screenshot here. Make sure to label the figure, you can do this by right clicking the image and clicking “Insert Caption”

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f. Use these results to *describe the long term behavior of any system in which a single particle species has different concentrations in the intracellular and extracellular spaces, and is allowed to freely diffuse across a permeable membrane.* First answer this assuming that the particle is uncharged (as in the exercises above). Then, discuss what will happen if the particle has a charge (e.g., is an ion) and is associated with a second ion of opposite and equal charge (e.g., sodium and chloride ions, or potassium and chloride ions); assume the second ion has the same initial concentrations as the first on the same side of the membrane and is equally permeable. *Test your prediction by running the simulation and see what happens.* You can give the particles charge in the simulation by checking the Electrostatics box. **Take screenshots before and after allowing the two ionic species to diffuse and include these in your lab notebook.**

Paste screenshot here. Make sure to label the figure, you can do this by right clicking the image and clicking “Insert Caption”

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Question 2: What about osmotic balance?

You must follow the instruction in the reading for this problem. By the first rule, water should move from the side that has more water molecules (the left side) to the side that has less (the right side), shrinking the size of the cell. Using **Equation 3**, and assuming for simplicity that each volume is 1 liter initially, it is easy to show that that the volume change is 9/11 liter. ***Please do the calculation to make sure you see that this is true! Please include your work and the results of your calculation in your notebook.*** Using this result in **Equation 2**, it is easy to show that the total concentration of particles on each side of the membrane will now be equal.

Question 3: What happens to the Nernst potential for chloride under those circumstances?

You must follow the instruction in the reading for this problem. Examine **Equation 5**. The concentration of the chloride ion will now be the same inside and out. What will the resulting voltage be? ***Please do this calculation. Please include your work and the results of your calculation in your notebook.*** If you don't find it easy, please review your understanding of logarithms.

Question 4: Calculate the concentrations of ions and equilibrium across the membrane.

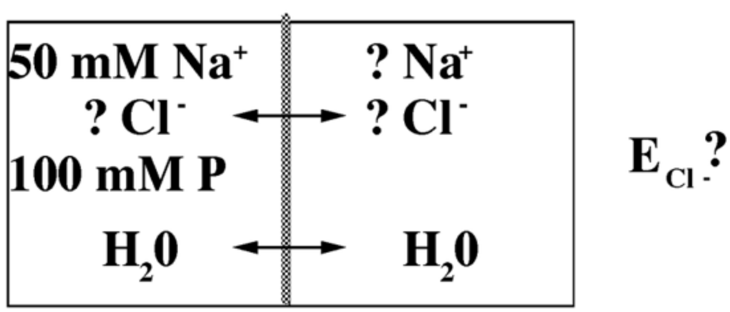

Figure 6: Balancing osmotic pressure, bulk electroneutrality, and concentration and electrical gradients

You must follow the instruction in the reading for this problem. We need to ensure bulk electroneutrality within the cell, that is, there have to be as many positive as negative charges inside. *What is the internal concentration of chloride ions based on this rule* (i.e., the concentration of chloride ions on the left side of Figure 6)?

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Since we've filled in the concentrations of all components within the cell, ***what is the total concentration of solute particles inside the cell*** (left side of Figure 6)?

We have to maintain bulk electroneutrality outside of the cell as well; additionally, to guarantee osmotic balance, we have to ensure that the concentration of solute particles outside the cell equals the concentration of solute particles inside the cell. Given this information, ***what are the concentrations of the sodium and chloride ions outside the cell*** (right side of Figure 6)?

Now that you have the concentrations of chloride ions both outside and inside the cell, what is the equilibrium or Nernst potential across the cell membrane, i.e., please calculate E_{Cl^-} using Equation 5.

Once you've tried the calculations, you can check the results in the reading.

Discussion:

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