BMEN E3500, Fall, 1999 **EFL, revised: 12/14/99**

Practice Problems: Ionic Transport across Cell Membranes. (Ch. 7, Weiss, T. F., *Cellular Biophysics*, V. 1 *(Transport)* M.I.T. Press, Cambridge, 1996).

1. This problem is equivalent to discussion question 7.2, W-I, p. 533. Two compartments, I and 2, contain wel1-stirred solutions of potassium chloride and are separated by a membrane that is permeable to only potassium. The potential between compartment 1 and 2 is V_m. The concentrations of KCl in compartments 1 and 2 are 100 mmol/L and 10 mmol/L, respectively.

    a. Determine the equilibrium value of V_m, and give a physical explanation of the sign of the potential.

    b. A battery is now connected to the solutions, so that V_m = -30mv. In which direction will current flow through the membrane? Explain.

    c. Draw an equivalent electrical network for the condition indicated in part b. Label the nodes that represent compartments 1 and 2, V_m and label I_m, defined as the current that flows through the membrane in the direction from compartment 1 to compartment 2.

(You should be able to answer most of the other discussion questions 7.1 through 7.9--except, perhaps 7.)

2. This problem is a rephrasing of problem 7.11,W-1, p. 538: The ionic concentrations in mol/L of a uniform isolated cell are given as:

	Inside	Outside
Potassium	150	15
Sodium	15	150

An electrode is inserted into the cell and connected to a current source so that the current through the cell membrane is I_m. The steady-state current is as shown in the figure below. Assume that (1) the cell membrane is permeable to only K^+ and Na^+ ions, (2) the Nernst equilibrium potentials are $V_n = (60/z_n) \log_{10}(c_n^o/c_n^i)$, (mv), (3) the ion concentrations are constant, (4) the active transport processes make no contribution to these measurements.

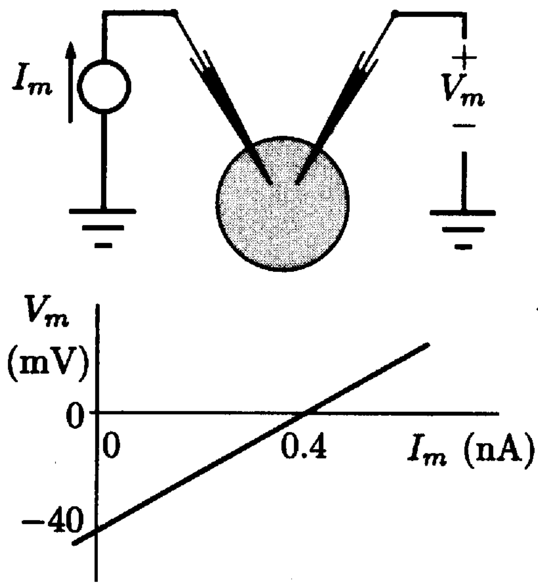
    a. Determine the equilibrium potentials for sodium and potassium ions, V_{Na} and V_K

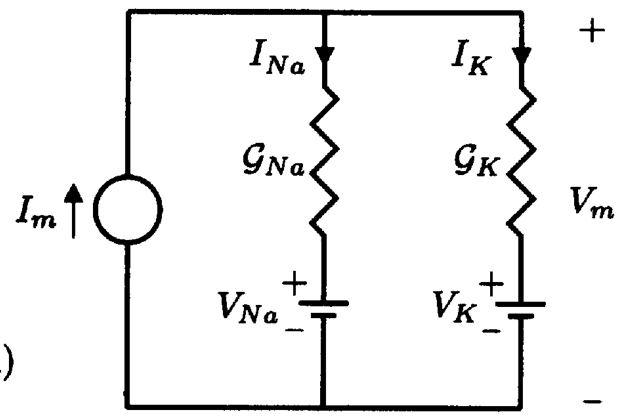
    b. What is the resting potential of the cell with these ionic concentrations?

    c. With the current I_m adjusted so that $V_m = V_K$ what is the ratio of the sodium current to the total membrane current, I_{Na} / I_m?

    d. What is the total conductance of the cell membrane $G_m = G_{Na} + G_K$?

    e. Determine G_{Na} and G_K separately.





3. The following is a paraphrase of problem 7.9, W-1, p. 551. A uniform isolated small cell has a membrane that is permeable only to sodium and potassium ions and contains an active transport mechanism that transports three sodium ions outward and two potassium ions inward for every molecule of ATP split into ADP and phosphate. Summed over the entire membrane of this cell, the active transport system splits 10^{-17} moles of ATP per second. Assume that the cell is at quasi-equilibrium, so that the concentrations of all ions are constant. The cell has a total membrane conductance of 10^{-10} siemens. The temperature is 24 C. The ionic concentrations of sodium and potassium across the membrane are given as:

	Inside	Outside
Potassium	150	3
Sodium	15	106

The potassium conductance exceeds the sodium conductance of this cell.

a. Determine the value of the component of the resting membrane potential, V_m^0 that is directly attributable to active transport.

b. Determine the value of the resting membrane potential, V_m^0.

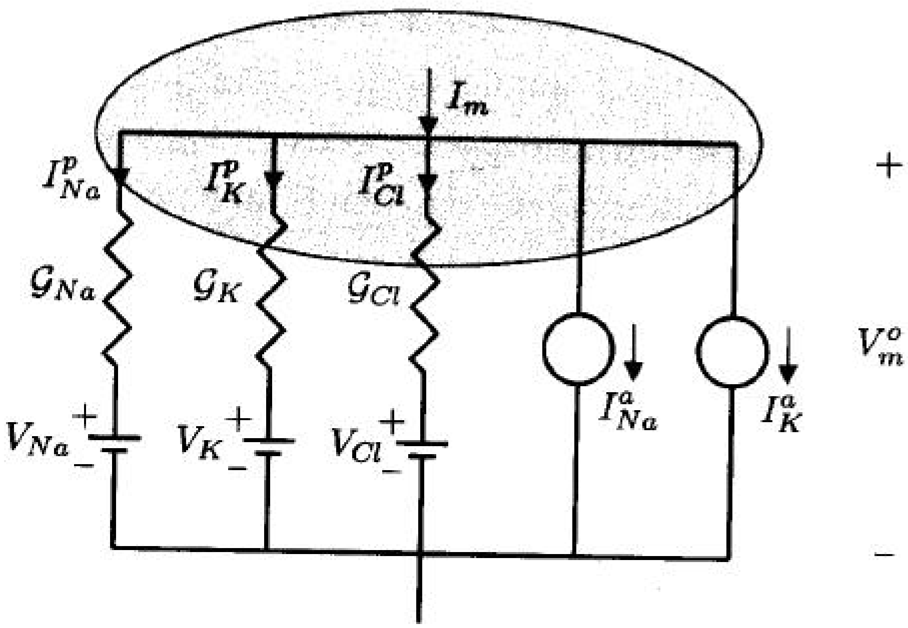
c. Determine the values of the sodium, G_{Na}, and potassium, G_K, conductances of the membrane.

4. The following is a paraphrase of problem 7.9, W-1, p. 551. The pH of extracellular solutions is typically 7.3. Consider a cell with a resting potential of -70 mV.

a. 1f H^+ were transported passively across the membrane, what would be the value of the intracellular pH?

b. Measurements indicate that the intracellular pH is typically in the range of 7.0-7.2. What can you conclude about the transmembrane transport of H^+?

5. The following is a paraphrase of problem 7.19, W-1, p. 561. Consider the model of a cell shown in the figure below. The cell has channels for the passive transport of sodium, potassium, and chloride as well as a pump that actively transports sodium out of the cell and potassium into the cell. The pump ratio is $I^a_{Na}/I^a_K = -1.5$. The intracellular and extracellular concentrations, Nernst potentials, and conductance ratios are given below the figure.



	c^i_n	c^o_n	V_n	G_n/G_K
Na^+	10	140	+68	0.1
K^+	140	10	-68	1
Cl^-	?	150	?	1

The cell also contains impermeant intracellular ions. Assume that the cell is in equilibrium at t = 0, i.e., assume that at t = 0, the cell has reached a condition for which all solute concentrations, the cell volume, and the membrane potential are constant.

a. Choose one of the following statements, and explain why it is true.

i. The cell resting potential depends on G_{Cl}.

ii. The cell resting potential depends on V_{Cl}.

iii. The cell resting potential depends on both G_{Cl} and V_{Cl}.

iv. T e cell resting potential does not depend on G_{Cl}.

v. The cell resting potential does not depend on V_{Cl}.

vi. The cell resting potential does not depend on either G_{Cl} or V_{Cl}.

b. Determine V_m^0.

c. At t = 0, the external concentration of chloride is reduced from 150 mmol/L to 50 mmol/L by substituting an isosmotic quantity of an impermeant anion for chloride. Assume that the concentrations of sodium and potassium both inside and outside the cell remain the same and that the volume of the cell does not change.

i. Determine V_m^0 (0+) , the value of the membrane potential immediately after the change in solution. You may ignore the effect of the membrane capacitance.

ii. Determine V_m^0 (∞) , the value of the membrane potential after the ceIJ has equilibrated.

iii. Determine c^i_{Cl} (∞) , the intracellular chloride concentration after the cell has equilibrated.

iv. Give a physical interpretation of your results in parts i, ii, and iii.

v. Discuss the validity of the assumptions that the sodium and potassium concentrations in the cell are constant and that the volume does not change.

End: W-I-Ch. 7