Name:_____

Biology 3550
Physical Principles in Biology
Fall Semester 2017

Quiz 4
17 November 2017

25 points total.
Please write your name on each page.

In your answers you should:

- Show your work or provide an explanation for an answer.
- Use correct units and the correct number of significant figures (One extra significant figure is allowable.)
- Express numerical answers as decimal values, using scientific notation for numbers outside of the range from 0.01 to 1,000 or -0.01 to -1,000.

Some possibly useful constants:

The Boltzmann constant: $1.3806 \times 10^{-23}\,\mathrm{J \cdot K^{-1}}$
The gas constant: $8.314\,\mathrm{J \cdot mol^{-1}K^{-1}} = 0.082\,06\,\mathrm{L \cdot atm \cdot K^{-1}mol^{-1}}$
Avogadro's number: 6.02×10^{23}

1. Consider two adjacent cells of an animal connected by gap junctions (regulated pores, as introduced in the mid-term exam). Initially the gap junctions are closed, and there is a hormone present in one of the cells at a concentration of $50\,\mu\mathrm{M}$, whereas there is no hormone in the other cell. Both cells are roughly spherical, but the cell containing the hormone has a volume of $1 \times 10^{-13}\,\mathrm{m^3}$, whereas the other cell has a volume of $5 \times 10^{-13}\,\mathrm{m^3}$. Then, the gap junctions open, and the hormone concentration equilibrates between the two cells. For the purposes of this problem, assume that the hormone behaves ideally in dilute solution.

   (a) (3 pts) Calculate the number of moles of hormone initially present in the smaller cell.

(b) (7 pts) Calculate the change in entropy of the hormone molecules between the initial state and the state after the molecules have fully equilibrated between the two cells.

(c) (4 pts) The temperature of the cell *in vivo* is 37°C. Calculate the minimum amount of work that would be required to return all of the hormone molecules to the smaller cell.

Name:_____

2. Suppose that there were an ATP-coupled pump that could pump the hormone from one cell to the adjacent one. (I'm not aware of such a pump, but there could be one!)

   (a) (7 pts) The ATP, ADP and inorganic phosphate (P_i) concentrations in the cells are, 4.0 mM, 0.01 mM and 1.0 mM, respectively. The standard-free energy change, ΔG°, for ATP hydrolysis is -30 kJ/mole. Calculate the free energy change, ΔG, under the *in vivo* conditions.

(b) (4 pts) Assuming that the pump could operate with 100% efficiency, calculate the number of ATP molecules that would be required to return all (or almost all) of the hormone molecules to the smaller cell.