Name:_____

Biology 3820
Physical Principles in Biology
Fall Semester 2015

Quiz 3
6 November 2015

Please write your name on each page.
Be sure to show your work and include correct units in all of your answers!
25 points total.

Some possibly useful constants:
The Boltzmann constant: $1.3806\times10^{-23}\,\mathrm{J\cdot K^{-1}}$
The gas constant: $8.314\,\mathrm{J\cdot mol^{-1}K^{-1}} = 0.08206\,\mathrm{L\cdot atm\cdot K^{-1}mol^{-1}}$
Avogadro's number: 6.02×10^{23}

1. (6 pts) Most animal cells contain specialized compartments called lysosomes, in which a variety of proteins and other molecules are degraded when they are no longer needed. One of the things that distinguishes the lysosome from its surroundings in the cell, the cytoplasm, is that the pH in the lysosome is about 5, whereas the pH of the cytoplasm is about 7.2. The number of lysosomes in a cell and their sizes can vary in different cell types, but for this problem, consider a typical lysosome with a diameter of 200 nm and a volume of $3.3\times10^{-17}\,\mathrm{L}$.

   (a) Calculate the number of moles of free H^+ ions in the lysosome.

   (b) Calculate the number of moles of free H^+ ions that would be in the lysosome if its pH were the same as that of the surrounding cytoplasm.

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2. (19 pts) The energy required to establish and maintain the pH of a lysosome depends on many factors, including the electrical potential created by the pH difference relative to the cytoplasm, but one important factor is the reduction in entropy associated with increasing the H^+ ion concentration. For the following, consider only this factor.

   (a) Calculate the change in (system) entropy for decreasing the pH of a solution from pH 7.2 to pH 5, for one mole of H^+ ions. This amounts to reducing the volume of a solution large enough to contain one mole of H^+ ions at pH 7.2 to the volume where the pH is 5. *But*, you shouldn't need to calculate these volumes!

   (b) Calculate the entropy change for decreasing the pH in a single lysosome from 7.2 to 5.

(c) Calculate the free energy change at 37°C for decreasing the pH of a solution from pH 7.2 to pH 5, for one mole of H^+ ions.

(d) Calculate the free energy change at 37°C for decreasing the pH in a single lysosome from 7.2 to 5.