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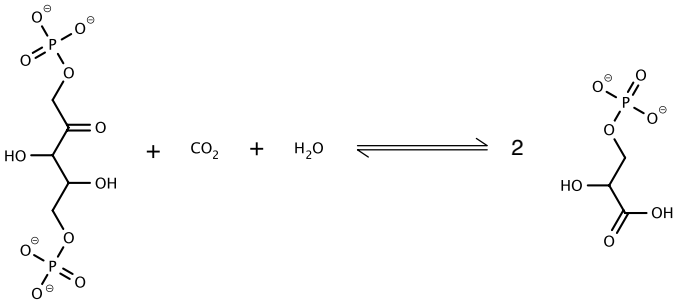
# Biology 3550
# Physical Principles in Biology
Fall Semester 2016

Quiz 4
18 November 2016

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: $6.02\times10^{23}$

1. One of the most important biochemical reactions on our planet is catalyzed by the enzyme ribulose 1,5-bisphosphate carboxylase, commonly called Rubisco. This is the primary reaction in which $CO_2$ is "fixed" to form reduced carbon compounds, which are then used by nearly all organisms. The Rubisco reaction is drawn below.




Ribulose 1,5-bisphosphate (RubP) — 3-phosphoglycerate (3PG)

(a) Write the expression for the reaction quotient, $Q$, for this reaction. As is customary for biochemical reactions, the water molecule that is consumed in the reaction should be ignored.

(b) The equilibrium constant for the reaction as written above is $1.3\times10^9$ at 298 K, with all of the concentrations expressed in molar units. (In this context, $CO_2$ is a solute, not a gas.) Calculate the standard free energy change, $\Delta G^\circ$, for the reaction.

(c) The enthalpy change for the Rubisco reaction has been measured to be -21 kJ/mole. Calculate the entropy change ($\Delta S_{\text{sys}}$) for the reaction at 298 K and standard-state concentrations.

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2. In the chloroplasts of plants, the concentrations of the reactants and products of the Rubisco reaction are approximately:

   $[3PG] = 1\,mM$
   $[RubP] = 1\,mM$
   $[CO_2] = 8\,\mu M$

   (a) Calculate the free energy change, $\Delta G$, for the reaction at these concentrations and $298\,K$.

   (b) In the Martian atmosphere, the *in vivo* concentrations of $CO_2$ would be about $120\,\mu M$. Assume for this problem that the other concentrations are the same as on Earth and that the temperature is the same. Also assume that there is no volume change associated for the reaction in solution. Without doing any calculations, describe how you would expect $\Delta G$, $\Delta H$ and $\Delta S_{sys}$ to differ at the higher $CO_2$ concentration. For each, briefly explain your reasoning.

   - $\Delta G$

   - $\Delta H$

   - $\Delta S_{sys}$