CEE 6570: Biological Processes

Problem Set 1

Due: Wednesday, February 7th

1. *Anammox* refers to anaerobic ammonium oxidation according to the reaction:

$$NH_4^+ + NO_2^- \rightarrow N_2 + 2\ H_2O$$

   a. Identify the electron donor and electron acceptor
   b. What type of catabolic metabolism is this?
   c. What is the $\Delta G°'$ for this process (refer to $\Delta G°'$ half reaction tables in R&M or on blackboard)? Report your answer as kJ/mol e^- eq as well as kJ/mol NH_4^+.

2. Using glucose as an electron donor, calculate the $\Delta G°'$ for the reduction of:

   a. Ferric (Fe^{3+}) to ferrous (Fe^{2+}) iron
   b. Nitrate (NO_3^-) to dinitrogen gas (N_2)
   c. Sulfate (SO_4^{2-}) to sulfide (H_2S/HS^-)

   Comment on how the energetic yields of glucose oxidation vary depending on the terminal electron acceptor available.

3. *Syntrophy* refers to the metabolic interaction between two organisms in which two organisms depend on the metabolic activity of the other one to enable favorable thermodynamic conditions for both. An example is a co-culture of two partner organisms, organism A and organism B, that cooperate in the conversion of ethanol (CH_3CH_2OH) to acetate (CH_3COO^-) and methane (CH_4) by interspecies hydrogen transfer:

   Organism A: $CH_3CH_2OH + H_2O \rightarrow CH_3COO^- + H^+ + 2\ H_2$ (1)
   Organism B: $4\ H_2 + CO_2 \rightarrow CH_4 + 2\ H_2O$ (2)

   The critical feature of this syntrophic cooperation is that reaction 1 is only thermodynamically favorable if the H_2 partial pressure (p_{H2}) is low. At the same time, reaction 2 is only favorable if p_{H2} is above a certain threshold. Therefore, organism B must efficiently remove H_2 from the system if organism A is able to capture energy from reaction 1, while organism A must efficiently produce H_2 if organism B is able to capture energy from reaction 2.

   Calculate the maximum p_{H2} at which organism A can gain energy from catalyzing reaction 1 at pH 7 and 25°C, and assuming that ethanol and acetate both have a concentration of 10^{-4} M. $\Delta G°$ for reaction 1 is +49.6 KJ mol^{-1} ethanol. (Note that the $\Delta G°$ is written per mol ethanol, and not per electron equivalents. Also remember that dissolved gases like H_2 in reaction quotient expressions are given as the partial pressure of the gas species, in the gas phase in equilibrium with the solution; see Equation 2.4.3 in R&M for an example).

4. You isolate a microorganism that reduces nitrate with acetate as an electron donor. You determine that the empirical formula for the biomass of this organism is $C_5H_7O_2N$. Assume that $f_s^0 = 0.5$, a typical value for denitrifiers (Table 3.1 in R&M), and that there is no nitrogen source besides nitrate. If you grow this organism in a 1 L batch culture with 5 mM acetate (assume nitrate is in excess):

    a. How much nitrate do you expect to be consumed? How much of this is due to cell synthesis and how much to energy production?
    b. What is the mass of cellular biomass that you expect to be produced?