12.007 Geobiology
Spring 2009

PS 4 3/5/09

1. For sulfate reducers that oxidize formate to CO_2, reducing sulfate to sulfide, express these reactions assuming the appropriate species at pH=9.4. (Hint: use Table 4.2 to figure out the form of sulfidic and carbonic acid at this pH).

Acid-base reactions (Mixed acidity constants)

Reactions	-log K I = 0	-log K I = 0.5 M
$H_2O = H^+ + OH^-$	14.00	13.89
$CO_2(g) + H_2O = H_2CO_3^*$	1.46	1.51
$H_2CO_3^* = HCO_3^- + H^+$	6.35	6.30
$H_2CO_3^- = CO_3^{2-} + H^+$	10.33	10.15
$H_2SiO_3 = HSiO_3^- + H^+$	9.86	9.61
$HSiO_3^- = SiO_3^{2-} + H^+$	13.1	12.71
$H_3PO_4 = H_2PO_4^- + H^+$	2.15	1.87
$H_2PO_4^- = HPO_4^{2-} + H^+$	7.20	6.72
$HPO_4^{2-} = PO_4^{3-} + H^+$	12.35	11.89
$NH_3(g) = NH_3(aq)$	-1.76	-1.64
$NH_4^+ = NH_3(aq) + H^+$	9.24	9.47
$H_2S(g) = H_2S(aq)$	0.99	0.99
$H_2S(aq) = HS^- + H^+$	7.02	6.98
$HS^- = S^{2-} + H^+$	13.9	13.45
$B(OH)_3 + H_2O = B(OH)_4^- + H^+$	9.24	8.97
$SO_2(g) = SO_2(aq)$	-0.1	–
$SO_2(aq) + H_2O = HSO_3^- + H^+$	1.9	–
$HSO_3^- = SO_3^{2-} + H^+$	7.2	–

a) Calculate the ΔG^0 of the reaction (using Table 7.1).
b) Discuss how ΔG would change over the pH range 1-14. State your assumptions about the concentrations of other relevant species.
c) Would these organisms be heterotrophic or autotrophic?

2. Repeat 1a-c, but this time assuming that the organism oxidizes H_2 to H^+.

3. Read the attached paper.
    a) Which electron donors and acceptors are most likely used by *D. audaxviator*?
    b) How did this organism acquire archaeal-type genes responsible for sulfate reduction?
    c) Could this organism live heterotrophically? Why?
    d) Could this organism fix carbon?
    e) How does this organism acquire its nitrogen?
    f) How could it survive long periods without nutrients?

4. Would you expect chemolithotrophs such as *Thiobacillus* to make a living by oxidizing thiosulfate to sulfate coupled to:

a) Reduction of nitrate to ammonia?
b) Reduction of nitrate to nitrite?

Justify your answer by solving for the ΔG of these reactions.

5. In sub-oxic waters MnO_2 is reduced to Mn^{2+}. Pore water from a sub-oxic sediment is carefully collected and analyzed for $[Mn^{2+}]$ and $[O_2(aq)]$. The measured concentrations are [Mn2+] = 10^{-6}M and $[O_2(aq)] = 2.4 \times 10^{-5}$ M. If the sample were in equilibrium, what would the pH of the sample have to be? (Assume that all soluble manganese is there as Mn2+).

6. Oxidized P680, the chlorophyll complex in the reaction center of photosystem II (PSII), has a reduction potential of ~ +1.2V. Oxidized P700, the chlorophyll complex in the reaction center of photosystem I, has a reduction potential ~ +0.4. Could P700 accept electrons from water? Could P700 accept electrons from sulfide? How would you test whether some cyanobacteria can use sulfide as an electron donor?