Chemistry 301 - FINAL EXAM

Wednesday, December 12, 2007, 12:00 pm

Only the standard UBC Science calculator (Sharp 510B) is permitted.
Explain your answers whenever possible.

55 points total (55% of total marks for course)

1) (4 pts) Explain how a lake can be freezing on the top while the water below the surface is warmer (above the freezing point). Can this happen in a saltwater lake? Why?

2) (6 pts) What does it mean when we say that water is "hard"? What visible effects are found when hard water is boiled? What is this due to? Why?

3) You have calculated the equilibrium concentration of a metal "M^{+n}" in the presence of each of several different solid forms MX (s), MY (s) and MZ (s). Next you collect some water from an aqueous environment, and measure the total concentration of M in this sample. Assume that the measurement includes small suspended particulate forms of M. The results of your calculations and measurements are:

M^{+n} in equilibrium with MX (s)	10^{-5} moles/litre
M^{+n} in equilibrium with MY (s)	10^{-10} moles/litre
M^{+n} in equilibrium with MZ (s)	10^{-15} moles/litre
Measured concentration of M	10^{-8} moles/litre

a) (2 pt) Show how you would set up the equations for the calculation of M^{+n} in equilibrium with MX (s). What information would you have needed to make the above calculation?
b) (1 pt) What form of the metal (M) do you expect to dominate in the real sample?
c) (1 pt) What is the actual dissolved M^{+n} concentration at equilibrium in the real sample?

4) (2 pts) What are two primary processes by which sediments are formed? What kind of sediments is formed by each of these processes?

5) The pE-pH diagram below shows an alternate look at Fe speciation, compared to the one we saw in class, where the presence of carbon (in the +4 oxidation state) is also considered, as well as multiple forms of the iron hydroxides. It is also unlike others we have seen in that the lines are extended beyond the region of water stability, and hatch marks are drawn around the regions that show the dominance of a solid form. Take a minute to look at the diagram carefully, and read the caption, then answer the following questions:

a) (1pt) What form of iron do you expect to dominate under oxic conditions at pH 8.5?
b) (1pt) What form of iron do you expect to dominate under oxic conditions at pH 2.5?
c) (1pt) What form of iron to you expect dominate under anoxic conditions (controlled by the CO_2/CH_4 couple) at pH 8.5?
d) (1pt) What form of iron do you expect to dominate under anoxic conditions (controlled by the CO_2/CH_4 couple) at pH 2.5?
e) (1pt) In the real environment, for which of the above conditions would you be least confident that your prediction would prove to be correct? Why?
f) (1pt) Under what conditions to you expect to find $Fe(OH)_4^-$?
g) (2 pts) Explain why iron is easily corroded in aqueous environments (and define corrosion as part of your answer)
h) (1pt) The equation for the line between Fe^{+2} and $FeCO_3(s)$ comes from what chemical reaction?

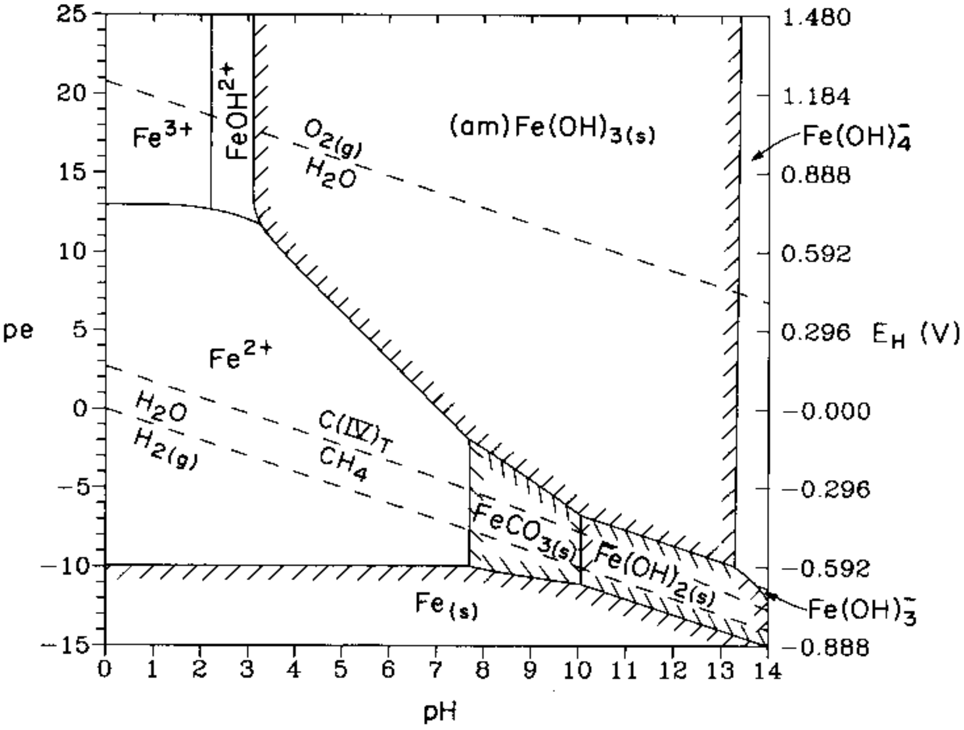

Figure 23.19 pe-pH diagram for aqueous iron for $Fe_T = 10^{-5}$ M, $C_T = 10^{-3}$ M, and 25°C/1 atm. Activity corrections are neglected. Only the pertinent portions of the various lines are shown. The $C(IV)_T/CH_4$ line (Eq. (23.27)) is included in the diagram. Below that line, at full equilibrium, there will be significant error in all of the pe-pH lines involving $FeCO_{3(s)}$. Indeed, as drawn here, the lines involving $FeCO_{3(s)}$ assume that C(IV) carbon (i.e., carbonate carbon) is present at a constant level of 10^{-3} M.

6) (6 pts) For each of the follow N conversions, give the name of the process, and state the conditions under which you expect it to occur:

   a) Nitrate → Nitrogen gas
   b) Ammonium → Nitrate
   c) Nitrogen gas → Organic N

7) (6 pts) Describe (with <u>words</u>) why mining results in acid mine drainage (AMD). What are the two biggest problems associated with AMD? Describe one method for the passive treatment of AMD and describe how it addresses both of these problems.

8) (5 pts) You are given the job of estimating the amount (per litre) of chlorine to add to the drinking water for a small town. You do a bit of research, and discover the amount (per litre) that a nearby city has determined to be optimal. They also have made available to you a long list of test results from their water. You have a small budget, and can only run 2 tests on your water to determine if the same level of chlorine is also optimal for your town, or whether you should recommend a higher or lower dose. What tests do you choose to run? Why? What difference do these parameters make? Under what circumstances would you recommend a higher or lower dose?

9) (4 pts) When an organic pollutant, such as sewage, is introduced into the aquatic environment, 4 zones can be defined. What are they called? What are the relative concentrations of oxygen and the organic pollutant in each zone, and are they changing (if so, how)?

10) (2 pts) Why is sulfur dioxide a bigger contributor to acid rain than carbon dioxide, even though carbon dioxide is typically present at much higher levels?

11) (3 pts) A water quality inspector discovers that the water in a region is high in radium ($^{226}_{88}\mathrm{Ra}$). What is the likely source of this radionuclide? What can be done to fix this problem? If $^{226}_{88}\mathrm{Ra}$ decays by alpha decay, what is its daughter?

12) (4 pts) What are the four main steps common to most drinking water treatment processes? Briefly describe the purpose of each step, and a common procedure used.