Chemistry 301 - FINAL EXAM

Thursday, December 8, 2011, 8:30 am
Only the standard UBC Science calculator (Sharp EL-510R) is permitted.
Show your work and explain your answers whenever possible.

70 points total (52-55% of total marks for course)
(this exam has 42 questions on 8 pages)

Section I: Multiple Choice (30 points – one point each).
Circle your answer on this exam packet.

1. If "total CO_2" = 1.1×10^{-5} M and pH = 11.33, what is the concentration of HCO_3^- (in M)?

   a) 1×10^{-4}
   b) 1×10^{-5}
   c) 1×10^{-6}
   d) 1.1×10^{-5}
   e) 1.1×10^{-6}
   f) 5×10^{-5}
   g) 5×10^{-6}

2. Given $[HCO_3^-]$ = 0.04 mM, $[HPO_4^{2-}]$ = 0.08 mM, $[NH_3]$ = 0.20 mM, and pH = 7, what is the total alkalinity of the system (in meq)?

   a) 0.04
   b) 0.08
   c) 0.12
   d) 0.16
   e) 0.28
   f) 0.32
   g) 0.36
   h) 0.40
   i) 0.44
   j) 0.52

3. Given the same data ($[HCO_3^-]$ = 0.04 mM, $[HPO_4^{2-}]$ = 0.08 mM, $[NH_3]$ = 0.20 mM, and pH = 7), what is the carbonate alkalinity (in meq)?

   a) 0.04
   b) 0.08
   c) 0.12
   d) 0.16
   e) 0.28
   f) 0.32
   g) 0.36
   h) 0.40
   i) 0.44
   j) 0.52

4. What do you expect to happen to $CaCO_3$ sediments at the bottom of a lake if the concentration of CO_2 in the lake increases?

   a) There will be more $CaCO_3$ sediments formed.
   b) The existing $CaCO_3$ sediments will dissolve.
   c) No change since CO_2 does not affect $CaCO_3$.
   d) No change since sediments are not in contact with water.

5. "Scale" is more likely to form in which of the following situations?

   a) Hard water in a hot water tank
   b) Soft water in a hot water tank
   c) Hard water in cold water pipes
   d) Soft water in cold water pipes
   e) Using soap with hard water
   f) Using soap with soft water

6. Initially, a solution of CrO_4^{2-} dissolved in neutral pH water has a wonderful yellow color. At a later time, the yellow color has faded and the pH is lower than at the start. What hydrolysis reaction do you think has occurred?

   a) aqua to hydroxo
   b) aqua to oxo
   c) hydroxo to aqua
   d) hydroxo to oxo
   e) oxo to aqua
   f) oxo to hydroxo

7. Why is humin less important than fulvic acids as a metal transporter in the environment?

   a) humin is smaller and has fewer functional groups
   b) humin is naturally removed from basic environments
   c) formation constants favor reactants more with humin
   d) humin isn't as soluble
   e) humin decompose less readily

8. Given the oxidation of ammonia:

   $1/8\ NH_4^+ + ¼\ O_2 \rightleftharpoons 1/8\ NO_3^- + ¼\ H^+ + 1/8\ H_2O \quad p\varepsilon^\circ = 6.00$

   When the partial pressure of oxygen of O_2 = 1 atm and pH = 8, calculate the pε if $100[NH_4^+] = [NO_3^-]$

   a) 3.75
   b) 4.00
   c) 4.25
   d) 6.00
   e) 7.75
   f) 8.25
   g) 10.0
   h) 14.0

9. On the Fe pε/pH diagram we created in class, what will happen to the line between Fe^{2+} and $Fe(OH)_2$ if the total dissolved Fe is decreased (from 1×10^{-5} to 1×10^{-8}, for example)?

   a) The line will move to the right (higher pH)
   b) The line will move to the left (lower pH)
   c) The line will move up (higher pε)
   d) The line will move down (lower pε)
   e) The line will not move position

10. Out of the size classes of sediments, what is the best at adsorbing particles to its surface?

a) silt
b) sand
c) clay
d) large organic matter
e) rocks

11. Given the mineral formula : $(Ca^{2+}nH_2O)Mg_3(Si_{4-x}\text{-}Al_x)(OH)_2O_{10}$, this mineral is a:

a) 1:1 mineral, with charge generation from the Si^{4+} sheet and a charge balancing cation of Mg^{2+}
b) 1:1 mineral, with charge generation from the Mg^{2+} sheet and a charge balancing cation of Ca^{2+}
c) 1:1 mineral, with charge generation from the Si^{4+} sheet and a charge balancing cation of Ca^{2+}
d) 1:1 mineral, with charge generation from the Ca^{2+} sheet and a charge balancing cation of Mg^{2+}
e) 2:1 mineral, with charge generation from the Si^{4+} sheet and a charge balancing cation of Mg^{2+}
f) 2:1 mineral, with charge generation from the Si^{4+} sheet and a charge balancing cation of Ca^{2+}
g) 2:1 mineral, with charge generation from the Ca^{2+} sheet and a charge balancing cation of Mg^{2+}
h) 2:1 mineral, with charge generation from the Mg^{2+} sheet and a charge balancing cation of Ca^{2+}

12. Increasing temperature speeds up the rate of microbially mediated reactions:

a) at all temperatures
b) at temperatures below the optimum temperature for the microbe
c) at temperatures above the optimum temperature for the microbe
d) only at the optimum temperature for the microbe

13. Why aren't MnO_2 and FeOOH typically important oxidants in aqueous systems?

a) MnO_2 and FeOOH are not very strong oxidants
b) CO_2 is more energetically favorable, and it never runs out
c) MnO_2 and FeOOH exist at low concentrations
d) MnO_2 and FeOOH react with H_2S to make solids, so they can't react with organic matter
e) NO_3^- is supplied by decomposition of organic matter and it is a better oxidant than MnO_2 and FeOOH

14. During denitrification, ____ is converted into ____.

a) nitrate to nitrogen gas
b) nitrate to ammonium
c) nitrite to ammomium
d) organic N to nitrogen gas
e) nitrogen gas to ammonium

15. At the surface of a lake, which of the following processes from the nitrogen cycle is NOT likely to be occurring?

a) ammonification
b) nitrification
c) nitrate assimilation
d) denitrification
e) nitrogen fixation

For questions 16 and 17 below: In the treatment for the acid mine drainage (AMD) at Britannia Mine, the AMD is treated with a "lime slurry" (water with $Ca(OH)_2$). Afterward a precipitate forms and a customized, manmade polymer is added.

16. The lime is added to ____ and the precipitate is____.

a) raise the pH, metal hydroxides
b) lower the pH, metal hydroxides
c) raise the pH, metal sulphides
d) lower the pH, metal sulphides
e) raise the pε, metal hydroxides
f) lower the pε, metal hydroxides
g) raise the pε, metal sulphides
h) lower the pε, metal sulphides

17. Continuing from question 16, the manmade polymer is ____ and is added to ____.

a) a ligand, complex toxic metals
b) "peat", complex toxic metals
c) a polyelectrolyte, aggregate colloids
d) a disinfectant, kill bacteria

18. Which of the following statements best describes the toxicity of metals to plankton?

a) All plankton will experience a toxic response if metals levels are above a specific toxic threshold, regardless of ligands present.
b) Adding a ligand will increase metal toxicity since more metals will dissolve
c) Adding a ligand will decrease metal toxicity since more metals will precipitate
d) Adding a ligand will increase metal toxicity since complexation raises free metal concentrations
e) Adding a ligand will decrease metal toxicity since complexation lowers free metal concentrations

19. Which two of the metals we studied in this class form organometallic complexes?

a) Cd and Pb
b) Cd and Hg
c) Cd and As
d) Pb and Hg
e) Pb and As
f) Hg and As

20. Which two species **primarily** cause acid rain?

a) NO_x and CO_2
b) SO_2 and CO_2
c) SO_2 and O_2
d) NO_x and SO_2
e) H_2 and CO_2

21. In which of the following zones of decomposition is O_2 at its minimum?

a) clean zone
b) decomposition zone
c) septic zone
d) recovery zone

22. Which of the following statements is true about the organic pollutants, PCB's, dioxins and DDT?

a) PCB's are a byproduct produced during dioxin degradation.
b) DDT is a common byproduct of the pulp and paper industry in BC.
c) Dioxins are produced for use as coolants and insulators.
d) Dioxins are a byproduct produced during degradation of PCB's.
e) all of the above

23. Fill in the blank:
$^{14}C \rightarrow {}^{14}N + \_\_\_$

a) β^-
b) β^+
c) α
d) γ
e) p^+

24. An alpha particle, once it leaves the nucleus, is the same as:

a) a neutron
b) an electron
c) a positron
d) a hydrogen nucleus
e) a deuterium nucleus
f) a helium nucleus

25. If a parent element has a biological half-life of 24 hours and a nuclear half-life of 12 hours, what percentage of the total concentration will be the daughter element inside of a person's body after 24 hours?

a) 0%
b) 12.5%
c) 33%
d) 50%
e) 67%
f) 87.5%
g) 100%

26. Why is chlorine often added in water treatment even if it is not the primary treatment method?

a) It is the most effective at killing bacteria and viruses.
b) It is cheaper than other methods, so it is often combined with others.
c) It is less likely to react with organic molecules in the water than treatments such as ozone.
d) It stays in the water longer and continues to kill pathogens.
e) It is less toxic than other methods.

27. Why is desalination not a commonly used method of water treatment?

a) The water is still high in salt content and is very hard compared to normal water.
b) It does not remove bacteria, so other methods have to be used in conjunction.
c) It is very energy inefficient compared to other processes.
d) Heavy metals can seep in more easily than with other methods.
e) It removes needed minerals along with removing the salt content.

28. Given the following information on the conversions between the different forms of total active chlorine:

pKa1 = 0.75
PKa2 = 7.52

At which pH is chlorine disinfectant the most effective?

a) 4.5
b) 6.5
c) 7.5
d) 8.5
e) 10.5

29. What is the primary reason why chlorination is no longer the most common method of drinking water treatment in developed countries?

a) it cannot be stored
b) it causes the pH to decrease
c) it can make organic molecules more toxic
d) it kills off good bacteria as well as bad bacteria
e) it needs to be combined with another secondary disinfectant

30. What is sewage sludge?

a) a biosolid which is used for fertilizer
b) solids collected from primary treatment
c) runoff from a storm drain in a city
d) the total of suspended solids in sewage
e) all water that is in the sewer system

Section II: Short Answer Questions (24 points).
Answer the short answer questions in the exam booklet.

31. (2 pts) Why are the winters in Vancouver milder than at the same latitude in other parts of Canada?

32. (3 pts) Why don't nutrients get trapped in the bottom of temperate lakes as they can in tropical lakes?

33. (3 points) "A high $p\varepsilon$ indicates an oxidizing environment, while a high $p\varepsilon^0$ indicates a reaction that is likely to go to reduced products". Is this statement true? Is it a contradiction? Explain your logic, and include a definition of $p\varepsilon$, $p\varepsilon^0$, "oxidizing environment" and "reduced products" as part of your answer.

34. (3 pts) Why might toxic metals be released into the environment when bottom sediments are disturbed (such as by dredging)?

35. (3 pts) Your friend is concerned that there is some lead in his drinking water. What do you tell him? Is this a problem he should be concerned about? What are the potential sources of Pb? What information do you need to make a recommendation on what he should do?

36. (3 pts) You find that your drinking water is more radioactive than desired. What isotope (element) is this most likely due to? Where does this isotope come from? What kind of treatment would best be used to remove the radioactivity?

37. (3 pts) What is the primary reason that soils can become salty when used for agriculture in dry regions? Describe this process.

38. (4 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 need to make this estimate *before* you add any chlorine to the water. 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 measured properties that characterize their water. You have a small budget, and can only measure two things 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 two things do you want to know about your water to help you with your job? Why? What difference do these parameters make? Under what circumstances would you recommend a higher or lower dose?

Section III: Calculation Questions (16 points).
Answer the calculation questions in the exam booklet. If you are not using a calculator, please feel free to round off all numbers

39. (4 pts) If a solution containing 30 mg/L Na_3NTA (MW = 257 g/mole) is equilibrated with $Fe(OH)_3(s)$, and is then measured to have a pH of 6.0, what is the equilibrium ratio of $[Fe(NTA)]/[HNTA^{-2}]$?

40. At pH 7.3 and pε -4, in a solution with a carbonate alkalinity of 1.5 meq,:
    a) (2 pts) What is the predicted Mn^{+2} concentration in equilibrium with $MnCO_3(s)$?
    b) (2 pts) What is the predicted Mn^{+2} concentration in equilibrium with $MnO_2(s)$?
    c) (1 pt) What form of manganese (Mn) do you expect to dominate if total Mn is in the micromolar (10^{-6} moles/litre) range?
    d) (1 pt) What is the actual dissolved Mn^{2+} concentration at equilibrium under the conditions *(incl. the total Mn given in part c)*?

41. (2 pts) What is the pε of a suboxic environment at pH = 6, when $[NO_3^-] = [NH_4^+]$

42. (4 pts) Filter alum, $Al_2(SO_4)_3$, is often used to remove phosphate ions from waste water. A wastewater of pH 5.0 containing 0.20 mM total phosphate is treated with alum until the equilibrium concentration of Al^{3+} is 1.0×10^{-7} M. What percent of the total phosphate is precipitated as $AlPO_4(s)$? Consider only the equilibia below:

$AlPO_4(s) \rightleftharpoons Al^{+3} + PO_4^{-3}$	$K_{sp} = 1.0 \times 10^{-21}$	$pK_{sp} = 21$
$H_2PO_4^- \rightleftharpoons HPO_4^{-2} + H^+$	$K_a = 6.2 \times 10^{-8}$	$pK_a = 7.2$
$HPO_4^{-2} \rightleftharpoons PO_4^{-3} + H^+$	$K_a = 4.8 \times 10^{-13}$	$pK_a = 12.3$