

Chemistry 301 - FINAL EXAM

Tuesday, December 14, 2010, 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 (55% of total marks for course) (*this exam has 31 questions on 6 pages*)

Section I: Multiple Choice (20 points – one point each).

Answer the multiple choice questions on the scantron sheet using a pencil. Ensure your name and student number are entered on the scantron sheet. There is only one best answer for each question. Don't leave any questions unanswered (if you don't know an answer, then guess).

- Hydrogen bonding *is NOT* the reason for which of the following:
 - the high specific heat capacity of water
 - the high boiling point of water
 - the high heat of vapourization of water
 - the maximum density of fresh water at 4°C
 - the ability of water to dissolve ions
- If you move a parcel of water which is saturated with CO₂ from the bottom of a lake to the top without any gas exchange:
 - CO₂ become less soluble and supersaturated
 - CO₂ become less soluble and undersaturated
 - CO₂ become less soluble with no change in saturation
 - CO₂ become more soluble and supersaturated
 - CO₂ become more soluble and undersaturated
- The buffering capacity of natural waters is higher where _____, due to _____:
 - Alkalinity is high, contact with granitic minerals
 - Alkalinity is high, contact with carbonate minerals
 - Alkalinity is high, high CO₂ in the atmosphere
 - Alkalinity is low, contact with granitic minerals
 - Alkalinity is low, contact with carbonate minerals
- Metals are more likely to form oxo complexes when:
 - pH is high and the metal charge is high
 - pH is high and the metal charge is low
 - pH is high, regard less of metal charge
 - pH is low and the metal charge is high
 - pH is low and the metal charge is low
- In natural *oxygenated* waters, Cd is most likely to form complexes with _____, while Ca is most likely to form complexes with _____:
 - sulphide, sulphate
 - sulphate, sulphide
 - chloride, sulphide
 - chloride, carbonate
 - carbonate, chloride

6. The fraction of organic matter isolated from river water which stays soluble at both low and high pH is called:
- humic acid
 - fulvic acid
 - dioxin
 - BOD
7. When $p\epsilon$ is controlled by the $\text{Fe}^{3+}/\text{Fe}^{2+}$ redox couple, and $[\text{Fe}^{3+}] = 10[\text{Fe}^{2+}]$, the $p\epsilon$ is:
- <10
 - 12.2
 - 13.2
 - 14.2
 - > 15
8. Which of the following reactions involves an electron transfer?
- $\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{CH}_2\text{O} + \text{O}_2$
 - $\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{H}^+$
 - $\text{FeS}_2(\text{s}) + \text{H}_2\text{O} + 7/2 \text{O}_2 \rightleftharpoons 2 \text{H}^+ + 2 \text{SO}_4^{2-} + \text{Fe}^{2+}$
- all of 1, 2 and 3
 - 1 and 2 only
 - 1 and 3 only
 - 2 and 3 only
 - none of them
9. The Zero Point of Charge (ZPC) is:
- the point on a particle that has no charge
 - the ionic strength at which a particle has no charge
 - the pH at which a particle has no charge
 - independent of pH and ionic strength
 - the conditions under which the number of positive charges and the number of negative charges on a particle are equal
10. Which of the following is the *best definition* of a colloid?
- a particle that is in the size range of 1 nm to 1 μm
 - a particle that stays in solution due to van der Waals forces
 - a particle which has an electric double layer in solution
 - a particle that aggregates at high ionic strength
 - a large dissolved molecule or cluster of molecules
11. For a clay mineral with the formula: $(\text{K}^+ \cdot n\text{H}_2\text{O})[(\text{Mg}_{3-x}\text{Na}_x)\text{Si}_4(\text{OH})_2\text{O}_{10}]$, a charge is generated by substitution of X for Y, and is neutralized by Z, where X, Y and Z are:
- K, Mg, Na
 - Si, Na, K
 - Mg, Si, Na
 - Na, Mg, K
 - Na, Mg, Si

12. A metal oxide colloid can be a sorption site for:
- anions, cations and neutral molecules
 - anions only
 - cations only
 - neutral molecules only
 - anions and cations only
13. Nitrogen fixation is _____, and occurs in _____:
- the conversion of N_2 gas to nitrate, oxic waters
 - the conversion of nitrate to N_2 gas, suboxic or anoxic waters
 - the conversion of N_2 gas to organic N, oxic waters
 - the conversion of N_2 gas to organic N, suboxic or anoxic waters
 - the conversion of ammonium to N_2 gas, suboxic or anoxic waters
14. The conversion of metals or metalloids to methylated forms:
- is performed by phytoplankton to detoxify the metal(loid)
 - is performed by bacteria to detoxify the metal(loid)
 - is performed by bacteria and increases the toxicity of the metal(loid)
 - is microbially mediated and sometimes increases the toxicity and sometimes decreases the toxicity of the metal(loid)
 - is a purely chemical reaction and has no effect on toxicity
15. Excessive H_2S comes from _____, and is a problem because _____:
- anaerobic decay of sulphur containing organic matter, it is toxic
 - anaerobic decay of sulphur containing organic matter, it smells bad
 - anaerobic reduction of sulphate, it is toxic
 - anaerobic reduction of sulphate, it smells bad
 - all of the above
16. The conversion of thorium to radium:
- occurs by alpha decay, and is a source of anthropogenic water contamination
 - occurs by alpha decay, and is a source of natural water contamination
 - occurs by beta decay, and is a source of anthropogenic water contamination
 - occurs by beta decay, and is a source of natural water contamination
 - is a purely chemical reaction and has no effect on water contamination
17. A septic zone is found in the environment when:
- the amount of organic matter is decreasing and oxygen levels are decreasing
 - the amount of organic matter is decreasing and oxygen levels are increasing
 - the amount of organic matter is increasing and oxygen levels are decreasing
 - the amount of organic matter is increasing and oxygen levels are increasing
 - the amount of organic matter is decreasing and oxygen is absent
18. Dioxins are:
- organochlorine insecticides
 - byproducts of pulp and paper processing
 - formed when water is treated with ozone
 - used as insulants in transformers
 - all of the above

19. Filter alum is _____, and can be used for treating water because it _____ :
- aluminum sulphide, forms colloids which aggregate
 - aluminum sulphate, lowers the pH and alkalinity
 - aluminum sulphate, forms a gel-like precipitate that bridges and sticks together
 - aluminum hydroxide, forms a gel-like precipitate that bridges and sticks together
 - aluminum hydroxide, lowers the pH and alkalinity
20. In the treatment of waste water, the main 3 steps of treatment (primary, secondary, tertiary) are generally categorized by the types of methods used, which are:
- physical, biological, chemical
 - physical, chemical, biological
 - biological, chemical, physical
 - biological, physical, chemical
 - chemical, physical, biological

Section II: Short Answer Questions (33 points).

Answer the short answer questions in the exam booklet.

21. Using the pE-pH diagram below, answer the questions that follow.

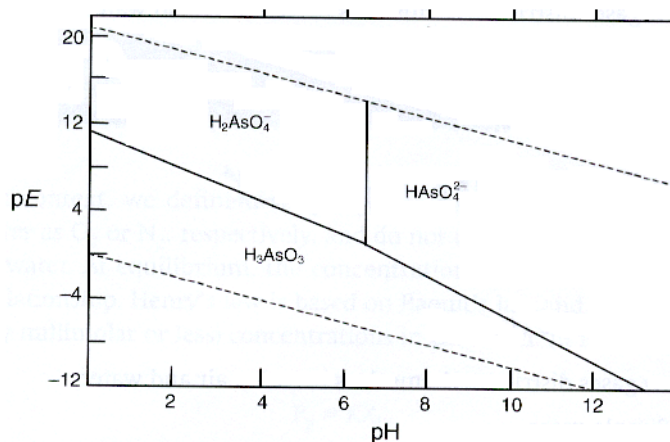


Fig. 10.P.2 The pE / pH diagram for some arsenic species.

- (1 pt) What form of arsenic do you expect to dominate in oxic waters at pH 6.0?
- (1 pt) Estimate the pKa2 (the loss of the *second* proton) for arsenic acid (H_3AsO_4).
- (2 pts) In an anoxic environment controlled by the $\text{SO}_4^{2-} / \text{HS}^-$ redox couple, what is a reasonable estimate for the pE at pH 7? (calculation not required, a range of values is acceptable). Under these condition, what form of arsenic do you predict to dominate?
- (1 pt) Do you expect the conversion between H_2AsO_4^- and H_3AsO_3 to involve a proton transfer? Why?
- (1 pt) Recalling what you learned about arsenic pollution and toxicity, under which conditions (pE and/or pH range) do you expect As to be most toxic? Why?
- (1 pt) Recalling what you learned about arsenic pollution, name one other arsenic species, not included in this diagram, which exists in nature.

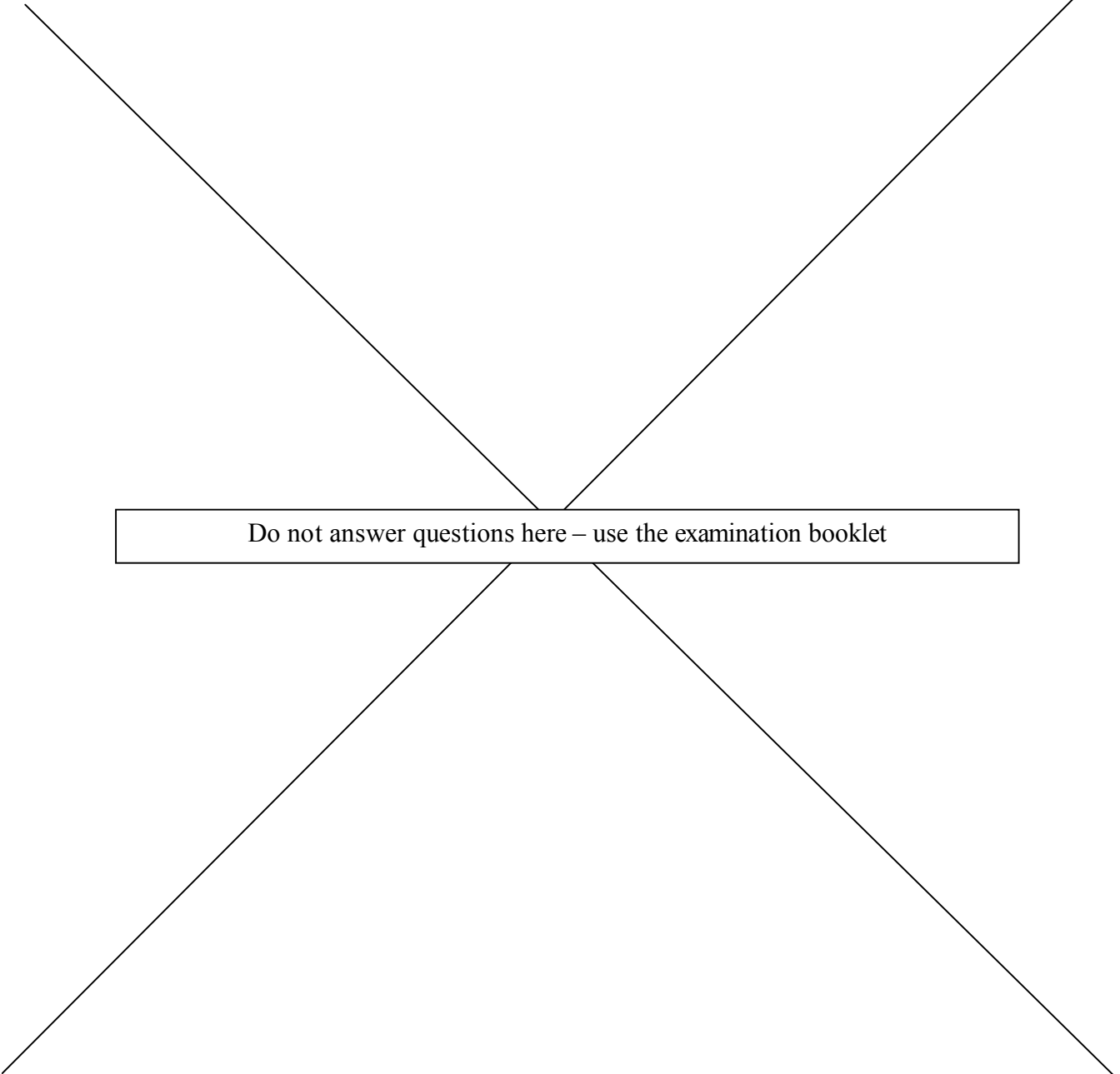
22. (5 pts) In the breakdown of organic matter in sediments, why does denitrification occur before methanogenesis? Define both denitrification and methanogenesis as part of your answer (including identification of the oxidant and the reduced product in each case).
23. (5 pts) Is lead pollution in older houses more likely to be a problem in hot water or in cold water. Why? *Be detailed – where does the Pb come from? What chemical reactions are occurring? Where and why do they occur?*
24. (6 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 measured properties which 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?
25. (5 points) What is the primary purpose for which chlorine is used in water treatment? What is the main disadvantage of using chlorine for this purpose? List 2 alternatives which can be used in place of chlorine. Why might chlorine still be used even when using one of these alternatives?
26. (5 pts) In Brisbane Australia, reverse osmosis is used as one of the steps (“Barrier 4”) in the purification of recycled water.
- What is recycled water?
 - Describe how reverse osmosis works.
 - What is reverse osmosis usually used for?
 - What species are removed by reverse osmosis? (List as many general categories as you can)
 - How is the use of reverse osmosis in Brisbane different than your answer to (c) above?

Section III: Calculation Questions (17 points).

Answer the calculation questions in the exam booklet.

27. (4 pts) Calculate the predicted Pb^{+2} concentration in equilibrium with $\text{PbCO}_3(\text{s})$ at pH 7.5, in a solution with a carbonate alkalinity of 0.5×10^{-3} eq./L.
28. (4 pts) If a solution containing Na_3NTA is equilibrated with $\text{Al}(\text{OH})_3(\text{s})$, and is then measured to have a pH of 6.5, what is the equilibrium ratio of $[\text{Al}(\text{NTA})]/[\text{HNTA}^{-2}]$?
29. (3 pts) A sediment sample with a CEC of 50 meq/100g was found to contain the following exchangeable cations (in mmol/100g): $\text{Ca}^{2+} = 8$; $\text{Na}^+ = 4$; $\text{Mg}^{2+} = 3$; $\text{K}^+ = 1$. The quantity of hydrogen ion displaced was not measured directly. Calculate the ECS of H^+ (in meq/100g). Define CEC and ECS as part of your answer (what do they stand for and what do they mean).

30. (4 pts) Wastewater containing $1.00 \times 10^{-3} \text{ M O}_2$, $1.00 \times 10^{-3} \text{ M NO}_3^-$, and $1.00 \times 10^{-2} \text{ M}$ soluble organic matter, $\{\text{CH}_2\text{O}\}$, is stored isolated from the atmosphere in a container richly seeded with a variety of bacteria. Assume that denitrification is one of the processes which will occur during storage. Consider what will happen after the bacteria have had a chance to do their work.
- (a) Will there be any organic matter $\{\text{CH}_2\text{O}\}$ remaining?
 - (b) Will there be any O_2 remaining?
 - (c) Will there be any NO_3^- remaining?
 - (d) Which process will have consumed the most organic matter, denitrification or aerobic respiration?
31. (2 pts) A sample of water contaminated by the accidental discharge of a radionuclide used for medicinal purposes showed an activity of 12,000 counts per second (cps) at the time of sampling and 9,000 cps exactly 30 days later. What is the half life of the radionuclide?



Do not answer questions here – use the examination booklet