Chemistry 301 - Midterm Exam #2 – Answer Key

1. For the reaction: $CH_2O + O_2 \rightleftharpoons CO_2 + H_2O$, what species is being oxidized and what is its final oxidation state?
a) C; +4
b) O; -2
c) C; 0
d) O; 0
e) H; +1
f) O; +2

2. What is the ratio of Hg^{2+} to Cu^{2+} at equilibrium in an electrochemical cell in otherwise pure water, when in contact with Hg^{o} and Cu^{o}?
a) $10^{-7.65}$
b) **$10^{-15.28}$**
c) $10^{-3.82}$
d) $10^{-2.76}$
e) $10^{-2.67}$
f) $10^{-4.67}$

3. What happens to colloids when you increase the ionic strength of a system?
a) attractive and repulsive forces decrease, causing aggregation
b) van der Waals attraction increases, causing aggregation
c) repulsive forces increase, interfering with aggregation
d) attractive forces decrease, interfering with aggregation
e) repulsive forces decrease, causing aggregation
f) attractive and repulsive forces increase, interfering with aggregation

4. Nitrification is the process of converting ___ into ____.
a) N_2, NO_3^-
b) NO_3^-, N_2
c) NO_3^-, NH_4^+
d) **NH_4^+, NO_3^-**
e) N_2, organic N
f) organic N, NH_4^+

5. Why doesn't CO_2 become depleted when it is used an oxidant for organic matter?
a) it comes from the atmosphere
b) there is a source of CO_2 at the bottom of lakes
c) **CO_2 is created during the oxidation process**
d) there is an infinite supply of CO_2 in sediments

6. A sediment sample is measured to have the following metals associated with it: $[Al^{3+}]$ = 3 mmol/100g, $[Ca^{2+}]$ = 5 mmol/100g, and $[Na^{+}]$ = 15 mmol/100g. The ECS of $[H^{+}]$ is calculated to be 35 mmol/100g (and there are no other associated metals). What is the CEC of this sample?

a) 14 meq/100g
b) 1 meq/100g
c) 69 meq/100g
d) 58 meq/100g
e) 9 meq/100g

7. In the clay $(Na^{+}.nH_2O)(Mg_3)(Si_4\text{-}xAl_x)(OH)_2O_{10}$, where is the charge generated and what is the ratio of tetrahedral to octahedral layers?

a) in the Si layer; 2:1
b) in the Al layer; 2:1
c) in the Mg layer; 2:1
d) in the Mg layer; 1:1
e) in the Si layer; 1:1
f) in the Al layer; 1:1

8. A reaction is most likely to proceed toward reduced products when:

a) $p\varepsilon$ is high and $p\varepsilon^{o}$ is high
b) $p\varepsilon$ is high and $p\varepsilon^{o}$ is low
c) $p\varepsilon$ is high regardless of $p\varepsilon^{o}$
d) **$p\varepsilon$ is low and $p\varepsilon^{o}$ is high**
e) $p\varepsilon$ is low and $p\varepsilon^{o}$ is low

9. Corrosion of iron is common in the environment because:

a) Fe^{o} is only stable in water under highly acidic, reducing conditions
b) Fe^{o} is only stable in water under highly basic, reducing conditions
c) Fe^{o} is only stable in water under highly acidic, oxidizing conditions
d) Fe^{o} is only stable in water under highly basic, oxidizing conditions
e) **Fe^{o} is not stable in water under any conditions**

10. Colloids are <u>least</u> stable in solution when:

a) they have negative surface charges
b) they have positive surface charges
c) they have a thick electric double layer
d) they have the same surface charge as other colloids in solution
e) they are at their Zero Point of Charge

11. For a given total mass of particles, heavy metal sorption on particle surfaces is highest when the particles are:

a) smaller and newly formed
b) larger and newly formed
c) smaller and coated with humic matter
d) larger and coated with humic matter
e) smaller and complexed with alkali metals
f) larger and complexed with alkali metals

12. The acid in acid mine drainage comes mostly from:
   a) oxidation of Fe
   b) reduction of Fe
   c) precipitation of Fe
   d) oxidation of S
   e) reduction of S
   f) precipitation of S

13. Why is 'peat' sometimes used in the treatment of acid mine drainage?
   a) It increases BOD and increases pH
   b) It lowers BOD and increases pH
   c) It increases pH and complexes with metals
   d) It increases BOD and complexes with metals
   e) It lowers BOD and complexes with metals

14. In the passive treatment of acid mine drainage, why might water be passed through a thick layer of organic rich material before a layer of limestone?
   a) The organic matter complex the metals
   b) The organic matter raises the pH
   c) The organic matter support bacterial growth
   d) The organic matter removes oxygen
   e) The organic matter removes alkalinity

15. (3 pts) If $[NO_3^-] = 100[NO_2^-]$ and the pH is 7.15, what is the pε of the environment controlled by this redox couple?

$p\varepsilon = p\varepsilon^\circ + 1/n \log(1/Q)$

$p\varepsilon = 14.14 + 1/1\log([NO_3^-]^{1/2}*[H^+]/[NO_2^-]^{1/2})$
$p\varepsilon = 14.15 + \log[H^+] + \log(\{100[NO_2^-]\}^{1/2/[}NO_2^-]^{1/2}$

$p\varepsilon = 14.15 - pH + \log 100^{1/2}$
$p\varepsilon = 14.15 - 7.15 + 1$
$p\varepsilon = 8$

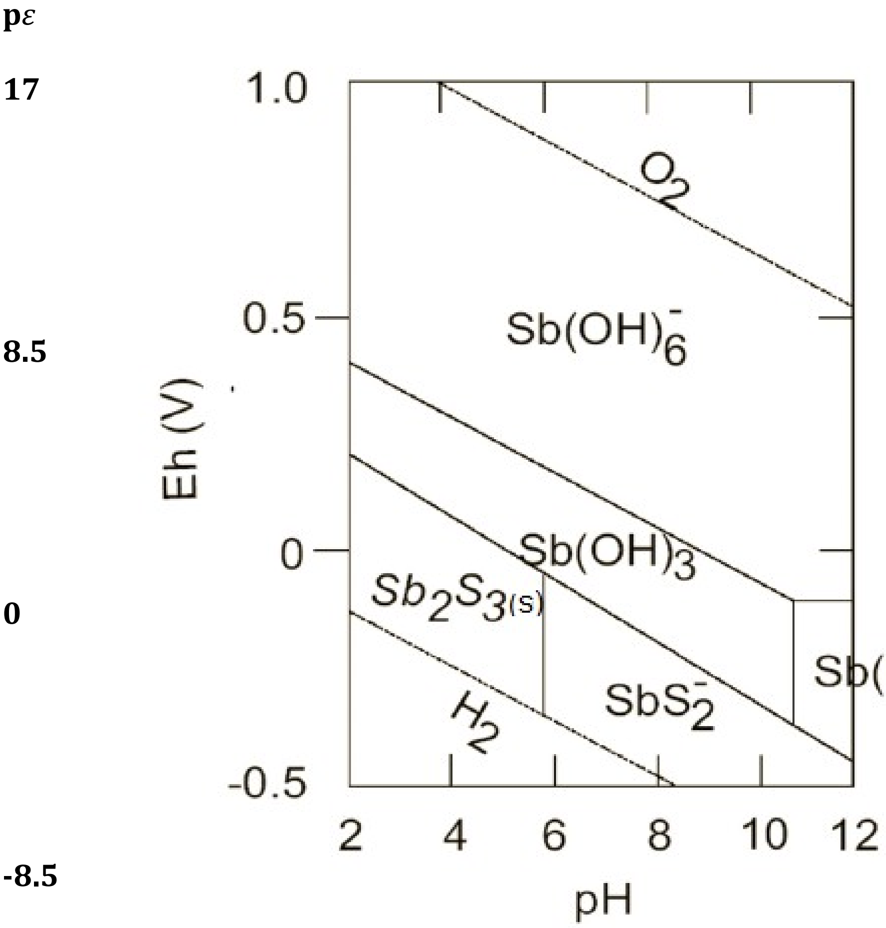
16. (5 pts) List the three major oxidants used after the depletion of oxygen in water - in the order they are used. Why are they used in this order? What other oxidants could be important in other environments? Why aren't they important in water?

$NO_3^- > SO_4^{2-} > CO_2$

They are used in this order based on the free energy produced by the oxidation reaction.

FeOOH and MnO_2 can be used as well, but they form precipitates/are solids in their oxidizing form, so they are not available to react in water systems. They are more relevant in sediments.

17. Using the diagram below for antimony, answer the questions on the following page. *Note that "Eh (V)" = E, and pε = E (2.303RT/F) = E (0.0591) at 25°C (see pε scale added on side)*



17. Using the diagram on the previous page, answer the following questions.

a) **(1 pt) For the conversion between between $Sb(OH)_6^-$ and $Sb(OH)_3$, do you expect a change in oxidation state? Explain how you determine this.**

Yes, you expect a change in oxidation state. The transformation crosses a non-vertical and thus is based on pε, indicating an oxidation state change.

b) **(2 pts) Assign oxidation states to $Sb(OH)_6^-$, $Sb(OH)_3$ and $Sb(OH)_4^-$.**

(OH^-) = -1
$Sb(OH)_6^-$ = 6 * -1 = -6, charge is -1; Sb = +5
$Sb(OH)_3$ = 3 * -1 = -3, charge is 0, Sb = +3
$Sb(OH)_4^-$ is separated from $Sb(OH)_3$ by a vertical line, so it is +3 as well.

c) **(1 pts) For the conversion between $Sb(OH)_3$ and Sb_2S_3, why is there a diagonal line in between them? (What does the diagonal line tell you about the conversion?)**

The diagonal line between the two species indicates both an proton and electron exchange.

d) (1 pts) Why do we only see sulfur-containing species near the bottom of the diagram?

Because S^{2-}, the form of sulfur that complexes readily, only forms near the bottom of the diagram in anoxic conditions. SO_4^{2-} does not form complexes readily and is favored in oxic conditions.

e) (2 pts) What form of Sb do you expect when treating acid mine drainage in an anoxic environment? How would its solubility compare to an oxic acid mine drainage?

In an acid mine drainage, you expect low pH and low pε; therefore, you expect the form to be Sb_2S_3. In an oxic environment, you expect to see $Sb(OH)_6^-$ at all pH. Sb_2S_3 is less soluble than $Sb(OH)_6^-$.

Alternate answer: Because we treated the acid mine drainage with lime/limestone, the pH went above 6 and we created SbS_2^-. The solubility of this species should be comparable to the oxic form since both are ions in solution.