Final Exam – CHM 1311 – F **Prof. Sandro Gambarotta**

Date: Dec 20th 2016 **Length: 3 hours**

Last Name: ______________________ **First Name:________________________**

Student #_______________ Seat # ☐

- **Instructions:**

- **Calculator permitted (Faculty approved or non-programmable)**
- **Open book**
- **This exam contains 14 pages**

Read carefully:

By signing below, you acknowledge that you have read and ensured that you are complying with the above statement.

Signature:________________________________

Cellular phones, unauthorized electronic devices or course notes (unless an open-book exam) are not allowed during this exam. Phones and devices must be turned off and put away in your bag. Do not keep them in your possession, such as in your pockets. If caught with such a device or document, the following may occur: you will be asked to leave immediately the exam, academic fraud allegations will be filed which may result in you obtaining a 0 (zero) for the exam.

Please put your INITIALS IN THE BOX when you have verified that there are 14 pages in this exam.

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1. The industrial synthesis of methanol, CH_3OH, is catalyzed by metal oxides. Billions of kg are produced annually for use in polymers and fuel additives.

$CO + 2\ H_2 \rightarrow CH_3OH$

How many kg of hydrogen will be required to produce 1.0×10^5 kg of methanol?

$1.0x10^5/M_{methanol}$ x 2 x 2 = $1.3\ x10^4$ Kg

2. A way of generating dry O_2 in the lab is to heat potassium chlorate.

$2KClO_3 \rightarrow 2KCl + 3O_2$

If you determined that 25 grams of O_2 are needed, how much potassium chlorate do you need to start with?

$25/M_{O2}$ x 2/3 x M_{KClO3} = 64 g

3. Balance the following redox reaction:

$$MnO_4^- + Sn^{2+} \rightarrow Sn^{4+} + Mn^{2+} \text{ (acidic solution)}$$

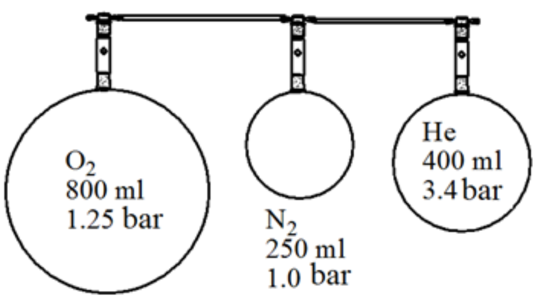
$16H^+ + 2MnO_4^- + 5Sn^{2+} \rightarrow 5Sn^{4+} + 2Mn^{2+} + 8H_2O$

4. Balance the following redox reaction:

$$MnO_4^- + S \rightarrow Mn^{2+} + SO_4^{2-} \text{ (acidic solution)}$$

$8H^+ + 6MnO_4^- + 5S \rightarrow 5SO_4^{2-} + 6Mn^{2+} + 4H_2O$

5. The following set up is arranged in a laboratory. Assuming the volume of the connecting tubing is negligible and there is no temperature change, determine the final total pressure if all three flasks were allowed to mix.



$P_{O2} = X_{O2}P_{tot}$

$P_{O2} = 0.8 \times 1.25/V_{fin}$ $X_{O2} = 0.8x1.25/RT \ / \ (0.8x1.25 + 0.25x1 + 0.4x3.4)/RT$

$P_{tot} = 1.8$ bar

6. If a 0.18 g sample of aluminum metal is dropped into 400 mL of 6 M HCl, hydrogen gas is evolved. The hydrogen evolved is collected over water, so the gas collected is a mixture of water vapour (vapour pressure = 23.8 mm Hg) and hydrogen gas. If the external pressure is 1.02 atm and temperature is 25˚C, what will be the total volume of gas collected in L?

$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$

Al is the limiting reagent 0.18/26.98 x 3/2 = 0.01 mole H_2. P_{H2} = 1.02-23.8/760 = 0.988
V_{H2} = 0.25L

7. When 0.1 mole of methylamine is dissolved in 500 mL of water, the following hydrolysis reaction occurs:

$H_2O(l) + CH_3NH_2(aq) \rightleftarrows CH_3NH_3^+(aq) + OH^-(aq)$

The hydroxide concentration is found to be 8.6×10^{-3} **M** when equilibrium is reached. What is the value of the equilibrium constant for this reaction?

Initial conc amine = 0.2 M equilibrium conc. = 0.2 -8.6E(-3) = 0.1914 K = $[8.6E(-3)]^2$ / 0.1914 = 3.9×10^{-4}

8. The synthesis of nitrogen monoxide proceeds by the reaction of ammonia with oxygen as shown in the following unbalanced reaction:

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$

If O_2 is being consumed at a rate of 32 mole/sec, what is the rate of NO production?

$Rate_{NO}$ = rate of O_2 x 4/5 = 25.6 mole/sec

9. A 1.66×10^{-4} mole sample of ^{239}Pu undergoes 9×10^{7} decays per second obeying first-order kinetics. How many decays per second would be expected from a 5.46×10^{-1} mole sample?

$k_{reac} = 9x10^7 / 1.66x10^{-4}$ $x = k_{reac} \times 5.46x10^{-1} = 3 \times 10^{11}$ decays/second

10. For a 5.0 M solution of $HClO_2$, do the following ($K_a = 1.1 \times 10^{-2}$):

a) Identify all species in the solution;

b) compute the concentration of the major cationic species;

c) compute the concentration of the major anionic species;

d) compute the concentration of the major neutral species (except water);

e) find the pH

a) ClO_2^- H_3O^+ $HClO_2$ H_2O OH^-
b) 0.23M
c) 0.23 M
d) 4.77 M
e) 0.64

11. When ammonium acetate dissolves in water, both of the resulting ions undergo proton transfer reactions with water, but the net reaction can be written without using water:

$$NH_4^+(aq) + CH_3CO_2^-(aq) \rightleftharpoons NH_3(aq) + CH_3CO_2H(aq)$$

The following proton transfer reactions combine to give the reaction above. Express the equilibrium constant for each reaction in terms of K_a (for $CH_3CO_2H = 1.8x10^{-5}$), K_b (for $NH_3 = 1.8x10^{-5}$), and K_w ($1x10^{-14}$). Use just the symbols (e.g. Kw/Ka, etc.) and no numeric values

$CH_3CO_2^- + H_2O \rightleftharpoons CH_3CO_2H + OH^-$ Kw/Ka

$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ Kw/Kb

$H_3O^+ + OH^- \rightleftharpoons 2\ H_2O$ 1/Kw

Overall reaction: Kw/(Ka*Kb)

Calculate the concentration of H_3O^+ due to the reaction of 0.25 M NH_4^+ with water.

1.2E-5 M

Calculate the concentration of OH^- due to the reaction of 0.25 M $CH_3CO_2^-$ with water.

1.2E-5 M

Based on your calculated values in the last two parts, would you expect the pH for this solution to be?

7.0

12. A constant pressure "coffee-cup" calorimeter is used to measure the heat of reaction between 0.10 L of 1.0 *M* NaOH and 0.10 L of 1.0 *M* HCl. Both solutions initially are at 24.0°C; after the solutions are mixed, the final temperature is 30.4°C. If the heat capacity of the resulting solution is assumed to be totally due to water, how much heat was evolved from the reaction *per mole* of limiting reactant? Assume the density of all solutions is 1.0 g/mL.

200g of solution x 4.18(heat capacity per gram) x 6.4 (delta T)= heat per 0.1 mole x 10 = heat per mole = 54 kJ/mol

13. When 0.149 g of lactic acid is combusted in a constant volume calorimeter in an excess of oxygen, only CO_2 and water are products and 2.24 kJ of energy is released. If the heat capacity of the calorimeter is 0.827 kJ/K and the initial temperature was 23.44°C, what is the final temperature in °C?

$2.24 = 0.827(T_f - 23.44)$ $T_f = 26.15°C$

14. A solution is made by the addition of 0.34 mole of Na_2HPO_4 and 0.65 mole of NaH_2PO_4 and sufficient water to give a total volume of 1.2 L. How many grams of NaOH would need to be added to increase the pH by 0.2 pH units? $K_a = 6.2x10^{-8}$

Initial pH = 7.21 + log (0.34)/(0.65) = 6.93
Final pH = 6.92+0.2 = 7.13 = 7.21 + log A_{new}/HA_{new}

$A_{new}/HA_{new} = 0.83 = A_{in} + mol_{NaOH}/HA_{in}-mol_{NaOH}$

$mol_{NaOH} = 0.109 \rightarrow 4.36$ g

15. The pK_a's of the three acid-conjugate base pairs derived from phosphoric acid, H_3PO_4, are 2.12, 7.21 and 12.32. How many g of sodium hydroxide would have be added to 150 mL of 0.1 M H_3PO_4 to prepare a buffer of pH = 7.41?

The value of the three pKa indicates that it is the second dissociation which will give the required buffer. Therefore H3PO4 needs to be convereted first into the monodeprotonated form. That requires 0.015 moles of NaOH. Additional NaOH is required to create the buffer

7.41 = 7.21 + log(ratio)   ratio = 1.58 = x/(0.015-x) x = 0.00918
total NaOH (0.00918+0.015)x40 = 0.97 g

16. The series of emission lines that result from excited hydrogen atoms undergoing transitions from higher levels to the n = 3 level is called the "Paschen series". Calculate the energy (in J) of the first five lines of this series. $E = -2.18 \times 10^{-18}/n^2$ J

first = $2.18 \times 10^{-18}(1/4^2 - 1/3^2)$ = 1.06E-19
second = $2.18 \times 10^{-18}(1/5^2 - 1/3^2)$ = 1.55E-19
third = $2.18 \times 10^{-18}(1/6^2 - 1/3^2)$ = 1.82E-19
fourth = $2.18 \times 10^{-18}(1/7^2 - 1/3^2)$ = 1.98E-19
fifth = $2.18 \times 10^{-18}(1/8^2 - 1/3^2)$ = 2.08E-19

17. Determine the frequencies of light in Hz that hydrogen atoms emit in transitions from n = 6 and n = 5 levels to the n = 3 level. For the H atom, $E_n = -2.18 \times 10^{-18}(1/n^2)$ J.

from n = 6 to n = 3 v = E/h = $2.18 \times 10^{-18}/6.626 \times 10^{-34}(1/36 - 1/9) = 2.74 \times 10^{14}$

from n = 5 to n = 3 $= 2.33 \times 10^{14}$

18. Which element has the electron configuration $[Ar]4s^1 3d^5$ in its ground state ?

Cr

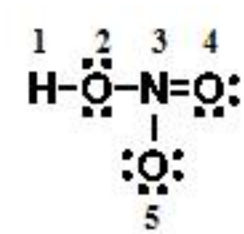
19. How many unpaired electrons are in Mn^{2+}?

5

20. Give the quantum numbers describing the two outermost electrons of the ground state of carbon (n, l, m_l, m_s)

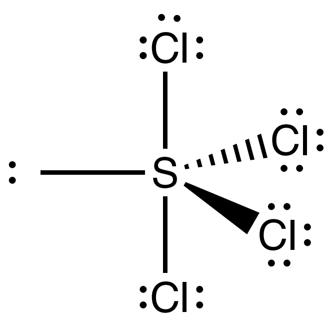
(2,1,1,+1/2) and (2,1,0,+1/2)

21. Draw the Lewis formula of HNO_3 and give the formal charge for every atom



0; 0; 1; 0; –1

22. Write the Lewis structure of SCl_4 and draw its structure.



23. Draw the 3D structure (bold, solid and broken lines) of $CH_2=C=CH_2$