CAPE BRETON UNIVERSITY

Chem 1105-Summer Final Exam **Instructor: Calvin Howley**
Date: August 12, 2015 **Time Period: 3 hours**

Student:____________________________

Student #:__________________________

Instructions:

Please turn off all cell phones. Only scientific calculators are allowed in the exam room. Students found to be using any electronic organizer or other electronic device during the exam will be given a grade of zero and asked to leave the testing area.

All answers are to be done on test paper. If more room is needed use the back side of the paper and indicate.

Read all questions carefully.

Answer all questions for full point value. Partial marks may be awarded for incomplete questions.

Make sure you have all data sheets and test pages.

Complete as many questions as soon as possible and then go back to incomplete questions.

Test papers not turned in to the instructor at the end of the test period will not be accepted.

Part I: Short Answer

Instructions: Circle the correct answer(s) or fill your answer in the space provided.

1. Coal, which is primarily carbon, can be converted to natural gas, primarily CH_4:

$$C(s) + 2H_2(g) \leftrightharpoons CH_4(g) \qquad \Delta H = -75 \text{ kJ}$$

Circle the **change(s)** below that will favour the formation of CH_4 at equilibrium.

a) adding more C(s) to the equilibrium.
b) adding more H_2 to the equilibrium.

c) raising the temperature.
d) lowering the temperature of the reaction mixture.

e) decreasing the volume of the system.
f) lowering the pressure of the system.

2. Determine the position of the equilibrium and state in the boxes below if the equilibrium favours the formation of "products" or "reactants" or lies "in the middle" for the following chemical equations:

a) $4NH_3(g) + 5O_2(g) \leftrightharpoons 4NO(g) + 6H_2O(g)$ $\qquad K_p = 7.985$ $\boxed{}$

b) $2NH_3(g) + 3CuO(s) \leftrightharpoons 3H_2O(g) + N_2(g) + 3Cu(s)$ $K_p = 1.2\times10^5$ $\boxed{}$

c) $N_2(g) + O_2(g) \leftrightharpoons 2NO(g)$ $\qquad K_p = 0.0021$ $\boxed{}$

3. An aqueous solution is 0.10 M in the weak base methylamine, CH_3NH_2. Which **one** of the following is true for this solution?

a) $[H^+(aq)] = 0.10$ M
b) $[OH^-(aq)] = 0.10$ M
c) pH < 7
d) pH > 7

4. A solution has a pH of 5.00. In this solution, $[OH^-(aq)]$¸ must be

a) 1.0×10^{-9} M
b) 1.0×10^{-7} M
c) greater than 1.0×10^{-5} M
d) 1.0×10^{-5} M

5. Consider the following redox reaction and identify:

$$Zr(s) \quad + \quad 2H_2O \rightarrow \quad ZrO_2 \quad + \quad 2H_2$$

a) The species oxidized is ______________________________.

b) The species reduced is ______________________________.

c) The oxidizing agent is ______________________________.

d) The reducing agent is ______________________________.

6. Consider the following redox reaction:

$$2Cr(s) + 3Fe^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 3Fe(s) \qquad E_{cell}° = +0.335 \text{ V}$$

Circle the **statement(s)** below that are **true.**

a) The nonspontaneous reaction can be made to occur in an electrolysis cell.

b) The spontaneous reaction can be used to produce electricity in a voltaic cell.

c) The reaction occurs whenever Cr(s) and Fe^{2+} are mixed in an aqueous solution.

d) Fe^{2+} is reduced to Fe(s) at the cathode.

e) Fe^{2+} is reduced to Fe(s) at the anode.

Part II: Long Answer
Instructions: Fill your answer in the space provided. Show all work for full point value.
A. Equilibrium

1. Write the equilibrium constant expressions(K_c) for the following:

a) $2BrNO(g) \rightleftharpoons 2NO(g) + Br_2(g)$

b) $CO_2(g) + C(s) \rightleftharpoons 2CO(g)$

2. Explain why a system at equilibrium

$$\text{Reactants} \rightleftharpoons \text{Products}$$

is referred to as a “dynamic process” when the concentration of Reactants and Products is constant.

3. An industrial chemist puts 1.00 mole each of $H_2(g)$ and $CO_2(g)$ in a 1.00 L container at constant temperature of 800°C. This equilibrium occurs:

$$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$$

When equilibrium is reached 0.49 mole of CO(g) is in the container. Find the value of K_c and K_p for the equilibrium.

4. Consider the following equilibrium

$$H_2(g) + Br_2(g) \leftrightharpoons 2HBr(g) \qquad K_p = 1.50\times10^5 \text{ at } 1024\text{ K}$$

Find the equilibrium pressures of all the gases if 10.0 atm of HBr is introduced into a sealed container at 1024 K.

B: Weak Acids/Bases

5.a) State the difference between the “Bronsted-Lowry” definition of an acid and base and the “Lewis” definition of an acid and a base.

b) What is the difference between a “strong” and “weak” Bronsted-Lowry acid and base.

6.a) Give the reaction equation for the dissociation of the weak acid HOI in an aqueous solution.

b) Determine the pH of a 2.00 M hypoiodous acid, HOI, solution. $K_a(HOI) = 2.30\times10^{-11}$.

7. Give the reaction equation for the dissociation of the weak base $C_6H_5NH_2$ in an aqueous solution.

b) Determine the pH of a 0.200 M aniline, $C_6H_5NH_2$, solution. $K_b(C_6H_5NH_2) = 4.0\times10^{-10}$.

C: Buffers and Solubility

8.a) What components must be present in order to have a buffered system? For what purpose are buffers used?

b) Explain why the strong acid hydrochloric acid, HCl, and its conjugate base Cl^- would not make a suitable buffer system.

c) What is meant by "exceeding the Buffer capacity" of a buffer system?

9. A 500.0 mL formic acid/formate buffer solution is prepared consisting of 0.400 M $HCHO_2$ and 0.300 M CHO_2^-. $K_a = 1.8\times10^{-4}$.

a) Calculate the pH of the original buffer solution.
b) Calculate the pH of the resulting solution if 10.0 mL of 5.00 M HCl is added to 500.0 mL of the buffer solution.
c) Calculate the pH of the resulting solution if 10.0 mL of 5.00 M NaOH is added to 500.0 mL of the buffer solution.
d) Calculate the pH of the resulting solution if 50.0 mL of 5.00 M HCl is added to 500.0 mL of the buffer solution.

10. For this question do either section a) and b) **or** b), c), and d) for full point value.
Calculate the solubility in moles/liter for the following:
a) $Al(OH)_3$, $K_{sp} = 2\times10^{-32}$
b) $PbCl_2$, $K_{sp} = 1.6\times10^{-5}$
c) $PbCl_2$ in 2.0 M NaCl , $K_{sp} = 1.6\times10^{-5}$
d) Compare your answer for b) and c) and explain the difference.

11. A solution is prepared by mixing 100.0 mL of 0.020 M $Pb(NO_3)_2$ and 100.0 mL of 0.020 M NaCl. $K_{sp}(PbCl_2) = 1.6\times10^{-5}$

Determine if the solution is unsaturated, saturated, or supersaturated.

D: Electrochemistry

12. Balance the following redox reactions:

a) $H_2O_2(aq) + MnO_4^-(aq) \rightarrow Mn^{2+}(aq) + O_2(g)$(acidic)

b) $S_8(s) \rightarrow S_2O_3^{2-}(aq) + S^{2-}(aq)$(basic)

13. What is the value of E_{cell} for the following electrochemical cells and state if they are voltaic or electrolytic?

a) ClO_3^-(0.65 M) + Mn^{2+}(0.25 M) + H_2O(l) $\rightarrow$ Cl^-(1.50 M) + MnO_2(s) + H^+(1.25 M) **(not balanced!!!)**

b) Pt, H_2(1 atm) | H^+(0.010 M) | | Ce^{4+}(0.45 M), Ce^{3+}(0.50 M) | Pt

14. Given the electrochemical cell diagrammed below.

$$\mathrm{Pt}\,|\,\mathrm{Fe^{2+}}(0.250\ \mathrm{M}),\ \mathrm{Fe^{3+}}(0.168\ \mathrm{M})\,||\,\mathrm{Pd^{2+}}(?\ \mathrm{M})\,|\,\mathrm{Pd(s)} \qquad E_{cell} = -0.015\ \mathrm{V}$$

Calculate the concentration of Pd^{2+} in the cell.

Grade Sheet

The points awarded for this exam are outlined below. Please review. If there are any questions or possible corrections please consult the instructor.

Question	Points Awarded
Part I	
1-6	
Part II	
A	
1-4	
B	
5-7	
C	
8-11	
D	
12-14	
Total	

Comments:

Some Useful Data or Not!

Constants:

1 kg = 1000 g
1000 mg = 1 g
1 μg = 1×10^{-6} g
1 mole = 6.022×10^{23} elementary particles
$N_a = 6.0223\times10^{23}$
1 kcal = 4.184 kJ
1 kJ =1000 J
1 L = 1000 mL
1 nm = 1×10^{-9}m
1 pm = 1×10^{-12}m
STP: T = 0°C, P = 1.00 atm

R = 8.314 kg·m^2/s^2·K·mole
R = 0.0821 L·atm/K·mole
R = 8.314 J/K·mole
1 atm = 760 mm Hg = 760 torr
1 atm = 101.325 kPa
$K_W = 1.0\times10^{-14}$
1 F = 96,500 C
1 F = 1 mole of electrons
1 A = 1 C/s
1 J = 1 C·V

Equations:

T°C = (5°C/9°F)×(T°F - 32°F)

T(K) = T(°C) + 273.15°C

$\mathbf{M_1V_1 = M_2V_2}$

$\mathbf{K_p = K_c(RT)^{\Delta n}}$

$\mathbf{[H^+] = 10^{-pH}}$

$\mathbf{[OH^-] = 10^{-pOH}}$

$\mathbf{pH = -log[H^+(aq)]}$

$\mathbf{pH = -log[H_3O^+]}$

$\mathbf{pOH = -log[OH^-]}$

pOH + pH = 14

$\mathbf{K_a \cdot K_b = K_w}$

$\mathbf{pK_A = -logK_A}$

$\mathbf{pK_{Hin} = -LogK_{Hin}}$

$\mathbf{K_w = [H^+(aq)][OH^-(aq)]}$

$$\mathrm{pH} = \mathrm{pK_a} + \mathrm{Log}\frac{[\text{base}]}{[\text{acid}]}$$

$$\mathrm{pH} = \mathrm{pK_a} + \mathrm{Log}\frac{\text{moles of base}}{\text{moles of acid}}$$

$$\mathbf{pH} = \mathbf{pK_{HIn}} + \mathbf{Log}\frac{[\mathbf{In}^-]}{[\mathbf{HIn}]}$$

For $\mathbf{0 = ax^2 + bx + c}$

$$X = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$\mathbf{\Delta G° = -nFE°_{cell}}$

$\mathbf{w = nF\mathit{E}_{cell}}$

$\mathbf{\Delta G° = -RTInK}$

$\mathbf{\Delta G = \Delta G° + RTInQ}$

$$\mathrm{E} = \mathrm{E}^\circ - \frac{0.0592\mathrm{V}}{\mathrm{n}}\mathrm{LogQ}$$

<u>SCRAP PAPER(</u>Do not pass in!!)

Answer Set For Chem 1105-Summer Final Exam:

Part I:
1.b), d), e)

2.a) products, b) products, c) reactants

3.d)

4.a)

5.a) Zr(s); b) H_2O; c) H_2O; d) Zr(s)

6.b), c), d)

Part II:
1.a)

$$K_c = \frac{[NO(g)]^2[Br_2(g)]}{[BrNO(g)]^2}$$

b)

$$K_c = \frac{[CO(g)]^2}{[CO_2(g)]}$$

2. An equilibrium is called a “dynamic process” because reactants are continually being converted into products and likewise products are continually being converted back into reactants. The concentration of reactants and products appears to remains constant because the rate of the forward reaction in which reactants are converted into products equals the rate of the reverse reaction in which products are converted back into reactants.

3. $K_c = K_p = 0.92$

4. $P(H_2) = P(Br_2) = 0.026$ atm, $P(HBr) = 10.0$ atm

5.a) Bronsted-Lowry define acids and bases in regards to the donation and acceptance of protons(H^+) while Lewis defines acids and bases in regards to the donation and acceptance of a pair of electrons.

b) A strong Bronsted-Lowry acid and base donate and accept protons completely(100%) while a weak Bronsted-Lowry acid and base only partially donate and accept protons.

6.a) $HOI(aq) \rightleftharpoons H^+(aq) + OI^-(aq)$
b) 5.17

7.a) $C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + OH^-$
b) 8.95

8.a) A buffer consists of a weak acid and its conjugate base. A buffer is used to minimize large shifts in pH.

b) HCl and its conjugate base is not a suitable buffer system because HCl is a strong acid and its conjugate base Cl^- is too weak to be an affective buffer system.

c) The capacity of a buffer system is exceeded when an added acid or base is added that it completely neutralizes the base or acid component of the buffer system.

9.a) 3.62; b) 3.34; c) 3.87; d) 0.74

10.a) 5×10^{-9} M; b) 0.016 M; c) 4.0×10^{-6} M; d) The solubility decreases for $PbCl_2$ in the presence of 2.0 M NaCl. A solution of 2.0 M Cl^- disturbs the equilibrium and forces it towards the formation of more $PbCl_2$ and thus decreases the solubility.

11.a) $Q = 1.0\times10^{-6} < K_{sp}$. Unsaturated.

12.a) $5H_2O_2(aq) + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5O_2(g) + 8H_2O(l)$

b) $S_8(s) + 12OH^-(aq) \rightarrow 2S_2O_3^{2-}(aq) + 4S^{2-}(aq) + 6H_2O(l)$

13.a) 0.215 V, voltaic; b) 1.73 V, voltaic

14. 0.00122 M