THE UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
CHEMISTRY 209
Winter 2013
Final Exam

Date: April 19th, 2013 **Time Allotted: 3 hours**

Please make sure you fill in your NAME, student ID and Lecture Section and encode all information on the optical score sheet.
Failure to do so will result in the loss of at least 2 marks.

Only Casio FX260 or similar non-programmable scientific calculators are permitted.
A Chemical Data and Formula Sheet is attached, which can be detached.

FIRST NAME: ________________________ **LAST NAME:** ___________________________________

ID:__________________________________

Lecture Section: Please check one

☐	L01	TR	12:30 pm	Dr. Masood Parvez
☐	L02	TR	8:00 am	Dr. Scott Hinman

This exam consists of 14 pages, 21 multiple choice questions worth two marks each (total 42 marks), and 4 written answer questions (total 30 marks) for a total of 72 marks. Make sure to count the number of pages (should be 14 pages excluding data sheet) and LET THE INVIGILATOR KNOW IMMEDIATELY IF YOU ARE MISSING A PAGE.

All questions must be answered to earn full marks. The answers to the multiple choice questions must be entered on the optical score sheet using pencil. Answers to the written answer questions should be written in the exam booklet in ink.

AT THE END OF THE EXAMINATION, HAND IN THE WHOLE EXAM BOOKLET AND THE OPTICAL SCORE SHEET

Do not write in spaces in the table below

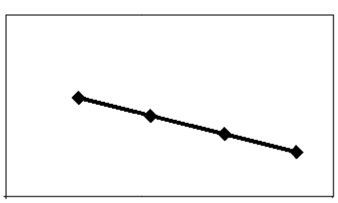
Q 22	Q 23	Q24	Q25

SECTION I - Machine graded section (Total value 42 marks)
Select the best answer and encode it on the Optical Score Sheet

1. What is the mass percent of each element in sulfuric acid, H_2SO_4?

a. 2.055% H, 32.70% S, 65.25% O
b. 1.028% H, 32.69% S, 66.28% O
c. 28.57% H, 14.29% S, 57.17% O
d. 1.028% H, 33.72% S, 65.25% O
e. 2.016% H, 32.07% S, 65.91% O

2. A student analyzed a first-order reaction and obtained the graph below. Unfortunately, the student forgot to label the axes. What are the correct labels for the *x* and *y* axes?



a. *x* axis = time, *y* axis = ln[A]
b. *x* axis = time, *y* axis = [A]
c. *x* axis = ln[time], *y* axis = [A]
d. *x* axis = time, *y* axis = 1/[A]
e. *x* axis = 1/time, *y* axis = 1/[A]

3. According to the collision theory, which one of the following does NOT affect the rate of a reaction:

a. temperature
b. the speed of colliding particles
c. ΔH of the overall reaction
d. the orientation of colliding particles
e. the frequency with which particles collide

4. Nitrogen dioxide reacts with carbon monoxide to produce nitrogen monoxide and carbon dioxide.

$$NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$$

A proposed mechanism for this reaction is:

$2\ NO_2(g) \rightleftharpoons NO_3(g) + NO(g)$ (fast, equilibrium)

$NO_3(g) + CO(g) \rightarrow NO_2(g) + CO_2(g)$ (slow)

What is a rate law that is consistent with the proposed mechanism?

a. rate = $k\,[NO_2]^2\,[CO]\,[NO]^{-1}$
b. rate = $k\,[NO_2]^2\,[CO]$
c. rate = $k\,[NO_2]\,[CO]$
d. rate = $k\,[NO_3]\,[CO]^2$
e. rate = $k\,[NO_2]^2$

5. At 25 °C, the equilibrium constant for the autoionization of water is $K_W = 1.0 \times 10^{-14}$. At 50 °C, $K_W = 5.5 \times 10^{-14}$. Determine ΔH for the autoionization of water.

a. -55 kJ mol^{-1}
b. 710 J mol^{-1}
c. 55 kJ mol^{-1}
d. 750 J mol^{-1}
e. -14 kJ mol^{-1}

6. At 500 °C, K_c for the reaction: $N_2 + 3H_2 \rightleftharpoons 2NH_3$ is $K_c = 6.0 \times 10^{-2}$. The numerical value of K_p at this temperature is:

a. 1.5×10^{-5}

b. 2.5×10^{-5}

c. 1.1×10^{-9}

d. 2.0×10^{-5}

e. 1.5×10^{-9}

7. An evacuated 2.0 L flask was filled with 0.10 moles $SO_3(g)$ and 0.20 moles of NO (g). The following reaction was allowed to come to equilibrium: $SO_3(g) + NO(g) \rightleftharpoons SO_2(g) + NO_2(g)$

If K_c for this reaction is 0.50, the equilibrium concentration of $SO_2(g)$ is:

a. 0.056 M

b. 0.021 M

c. 0.047 M

d. 0.035 M

e. 0.028 M

8. Colgate PreviDent™ toothpaste contains 1.0 mass percent NaF. Given that HF is a weak acid with $K_a = 6.8 \times 10^{-4}$, what mass of PreviDent™ toothpaste would have to be dissolved in pure water to give a total volume of 1.00 L of a solution with pH = 7.9?

a. 210 g

b. 2.0 g

c. 4.9 g

d. 82 g

e. 180 g

9. In which of the following solutions would you expect LiF to be the most soluble given that K_{sp} for LiF is 1.7×10^{-3}?

a. 100.0 mL of pure water

b. 100.0 mL of 1.0 M HCl

c. 100.0 mL of 1.0 M CH_3CO_2H

d. 100.0 mL 0f 1.0 M NH_3

e. 100.0 mL of 1.0 M NaOH

10. What is the resulting pH when 50.00 mL of 0.10 M HCl is added to a buffer prepared by combining 0.100 moles of acetic acid and 0.110 moles of sodium acetate with 500 mL of pure water? K_a for acetic acid is 1.8×10^{-5}.

a. 4.74

b. 4.83

c. 4.60

d. 5.12

e. 4.42

Topics in this question were not covered this year.

12. $CaSO_4$ has $K_{sp} = 2.4 \times 10^{-5}$ while $BaSO_4$ has $K_{sp} = 1.1 \times 10^{-10}$. Determine the equilibrium constant, K_c, for the reaction: $CaSO_4(s) + Ba^{2+}(aq) \rightleftharpoons Ca^{2+}(aq) + BaSO_4(s)$

a. 2.2×10^{5}

b. 2.4×10^{-5}

c. 1.1×10^{-10}

d. 4.4×10^{-6}

e. 2.64×10^{-15}

Standard potentials at 25 °C which may be used in Questions 13 to 15 and 24

$IO_4^- + 2H^+ + 2e^- \rightleftharpoons IO_3^- + H_2O$	E° = 1.589 V
$MnO_4^- + 8H^+ + 4e^- \rightleftharpoons Mn^{2+} + 4H_2O$	E° = 1.507 V
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	E° = 1.360 V
$Fe^{3+} + 1e^- \rightleftharpoons Fe^{2+}$	E° = 0.771 V
$2H^+ + 2e^- \rightleftharpoons H_2(g)$	E° = 0.000 V
$HCO_2H + 2H^+ + 2e^- \rightleftharpoons H_2CO + H_2O$	E° = -0.029 V
$Pb^{2+} + 2e^- \rightleftharpoons Pb(s)$	E° = -0.126 V

13. Which species is the strongest oxidizing agent under standard conditions?

a. Pb(s)

b. IO_4^-

c. Pb^{2+}

d. IO_3^-

e. H_2O

14. Determine the equilibrium constant for the reaction between IO_4^- and Fe^{2+}.

a. 4.32×10^{27}

b. 1.00×10^{12}

c. 0.57×10^{13}

d. 1.00×10^{6}

e. 5.76×10^{19}

15. What is the potential of the following cell?

$$Pb \mid Pb^{2+}(0.200\ M) \parallel Cl^-(0.200M) \mid Cl_2(g,\ 0.400\ atm.) \mid Pt$$

a. 1.26 V

b. 1.52 V

c. 1.49 V

d. 1.54 V

e. 1.23 V

[redacted]

[redacted]

[redacted]

19. An element with the outermost electron configuration

$$\underset{ns}{\uparrow\downarrow} \qquad \underset{np}{\uparrow\downarrow \;\; \uparrow \;\; \uparrow}$$

could be_______.

a. $_{82}Pb$

b. $_{40}Zr$

c. $_{42}Mo$

d. $_{34}Se$

e. $_{19}K$

[redacted]

[redacted]

**********************END OF MULTIPLE CHOICE QUESTIONS SECTION*******************

SECTION II: Fill-in-the-blanks and long answer questions. (Total value 30 marks)

Write your answers *in ink* in the space provided.

22. Fill-in-the-blanks. **10 marks**

a. Nitroglycerine decomposes violently according to the chemical equation below. What mass of carbon dioxide gas is produced from the decomposition of 5.00 g $C_3H_5(NO_3)_3$?

$$4\ C_3H_5(NO_3)_3(\ell) \rightarrow 12\ CO_2(g) + 6\ N_2(g) + 10\ H_2O(g) + O_2(g)$$

b. If 5.15 g $Fe(NO_3)_3$ is dissolved in enough water to make exactly 150.0 mL of solution, what is the molar concentration of nitrate ion?

c. The rate constant at 366 K for a first-order reaction is $7.7 \times 10^{-3}\ s^{-1}$ and the activation energy is 15.9 kJ/mol. What is the value of the frequency factor, A, in the Arrhenius equation?

[redacted]

e. Assign formal charges to all atoms of the thiocyanate ion, SCN^-. Identify the most favored structure.

$$S-C\equiv N \qquad S=C=N \qquad S\equiv C-N$$

23. Long answer question (For full marks, you must show all work). **8 marks**

Meta-nitrobenzoic acid is a weak monoprotic acid with $K_a = 6.5 \times 10^{-3}$. Exactly fifty mL of 0.05 M meta-nitrobenzoic acid is titrated with 0.10 M NaOH. Calculate the pH:

a. Before any titrant is added.

b. After the addition of 10 mL of titrant

c. At the equivalence point

d. After the addition of 40 mL of titrant

24. Long answer question (For full marks, you must show all work). **6 marks**

The standard electrode potential for the Pb(*s*)/Pb^{2+} redox couple is -0.126 V. Sketch the cell in which this potential was measured.

Identify:

a. All concentrations/pressures

b. The cathode and the anode

c. The direction in which cations move in the salt bridge

d. The direction in which electrons would move if a light bulb were connected across the cell.

25. For the species given below, draw Lewis (2D) and VSEPR (3D) structures and identify electron pair geometries, molecular geometries, bond angles around the central atom and molecular polarity. Enter your answers in the appropriate boxes: **6 Marks**

Species	**NCl_3**	**$XeOF_4$**	**SF_4**
Lewis structure (**2D**) (Show all valence electrons)			
VSEPR structure (**3D**)			
Electro pair geometry			
Molecular Geometry			
Bond angles			
Polar or Non-polar			

*********************** END OF WRITTEN ANSWER SECTION ********************

Data Sheet – CHEM 209

Periodic Table

1 1A	2 2A	3	4	5	6	7	8	9	10	11	12	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.008																	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57* **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.0	89** **Ac** (227)	104 **Rf** (261)	105 **Ha** (262)	106 **Sg** (263)	107 **Ns** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Uun** (269)	111 **Uuu** (272)							

Lanthanides *	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
Actinides **	90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237.0	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Strong Acids: HCl, HBr, HI, HNO_3, H_2SO_4, $HClO_4$
Strong Bases: Hydroxides of Group 1A (Li to Cs) and Group 2A (Ca, Sr, Ba)

Constants:

Gas constant, R = 0.08205 L atm mol^{-1} K^{-1}
= 8.314 J mol^{-1} K^{-1}
Avogadro's number: $N_A = 6.022 \times 10^{23}$ mol^{-1}
Faraday: F = 96,485 C / mol electrons
Planck's constant $h = 6.626 \times 10^{-34}$ Js
Speed of light , c = 2.998×10^{8} m/s
Rydberg constant, R = 1.09678×10^{-7} m^{-1}
Factoring constant, $R_H = Rhc = 2.18^{-18}$ J

Conversion factors:

1 J = 1 kg m^2 s^{-2} — 1 Pa = 1 kg m s^{-2}
T K = T °C + 273.15
1 L atm = 101.3 J
1atm = 760.0 torr = 101.3 kPa = 760.0 mm Hg = 1.013 bar
1 L = 10^{-3} m^3
1 C = 1 J / V — 1 A = 1 C s^{-1}
STP conditions: 0 °C, 1 atm
Electrochemical standard state: 1 atm, 1M, 25 °C

$$[A]_t = -kt + [A]_0 \qquad \ln[A]_t = -kt + \ln[A]_0 \qquad \frac{1}{[A]_t} = kt + \frac{1}{[A]_0} \qquad \ln\left(\frac{[A]_0}{[A]_t}\right) = kt$$

$$t_{1/2} = \frac{[A]_0}{2k} \qquad t_{1/2} = \frac{0.693}{k} \qquad t_{1/2} = \frac{1}{k[A]_0} \qquad k = Ae^{\frac{-E_a}{RT}} \qquad \ln\left(\frac{K_2}{K_1}\right) = \frac{\Delta H}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad PV = nRT \qquad K_p = K_c(RT)^{\Delta n} \qquad ax^2 + bx + c = 0$$

$$\mathrm{pH} = -\log[\mathrm{H}^+] \qquad K_w = K_a K_b \qquad K_{sp} = 1 / K_d \qquad K_f = 1 / K_d \qquad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\mathrm{pH} = \mathrm{p}K_a + \log\left(\frac{[\text{cong. base}]}{[\text{cong. acid}]}\right) \quad \text{or} \quad \mathrm{pOH} = \mathrm{p}K_b + \log\left(\frac{[\text{cong. acid}]}{[\text{cong. base}]}\right)$$

$$E^\circ = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} \qquad E = E^\circ - \frac{0.0592}{n_e}\log Q \qquad E^\circ = \frac{0.0592}{n_e}\log K \quad \text{or} \quad nFE^\circ = RT\ln K$$

$$q = It \qquad q = n_e F \qquad c = \lambda v \qquad E = hv \qquad E = mc^2 \qquad \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \qquad \Delta E = -R_H\left(\frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2}\right)$$

$$E = -R_H\left(\frac{Z}{n}\right)^2 \quad \text{or} \quad E_n = -\frac{Rhc}{n^2} \quad \text{for single electron species}$$