Surname (last name): _____

Given name (First name): _____

Student Number: _____

CHM 1311 C
Final Exam
Fall 2009

Professor: Dr. Fox

DO NOT WRITE THIS EXAM IF DR. FOX WAS NOT YOUR PROFESSOR!

Please keep your work covered at all times and keep your eyes on your own paper! Cheating or any appearance of cheating will result in an F in the course and possible expulsion from the university.

There are 15 pages in this test. A periodic table, data tables, and a formula sheet are provided at the end. You may rip these pages off of the exam and use them to cover your work. Any scratch work should be done on the back of these pages.

Please show all work to receive partial credit.

You have 180 minutes to complete the exam.

Question	Points Possible	Points Earned	TA Initial
1	20		
2	10		
3	10		
4	10		
5	10		
6	10		
7	10		
8	10		
9	10		
TOTAL	100		

#1. (20 points) Short Answer Questions – stars show marks.

a) *The *spdf* electron configuration of gallium is: _____

b) *Which of the following ions is the strongest base? F^- HO_2^- N_3^- NO_2^-

c) **Name the following compounds:

i. CrO_3 _____

ii. $CaSO_4 \cdot 4H_2O$ _____

d) *For a second order reaction, the plot of _____ versus _____ will yield a straight line, where the slope is equal to _____.

e) *A buffer solution is prepared from 0.450 M HCN and 0.450 M NaCN. The pH of this solution is _____.

f) *In the following reaction, circle the oxidizing agent:

$$Fe_2O_3 + 3\,C \leftrightarrows 3\,CO + 2\,Fe$$

g) *As the activation energy of a reaction increases, the reaction rate

INCREASES DECREASES STAYS CONSTANT

h) *The following compounds are each dissolved in water. Which of the three resulting aqueous solutions would show the greatest conduction of an electric current?

CH_3OH NH_3 KBr

i) *The concentration of lead (II) ions in a saturated solution of lead (II) chloride is _____.

j) *Choose one of the laws of thermodynamics, and describe it in a simple statement.

1^{st} 2^{nd} 3^{rd}

_____

_____

k) *An orbital is a spherical region of space in which there is a high probability of finding an electron. TRUE FALSE

l) *Adding a catalyst to a reaction increases the yield of product. TRUE FALSE

m) *The standard heat of formation of solid $Fe(OH)_3$ is -824 kJ/mol. Write the chemical equation for the reaction to which this value applies.

n) *Which of the following processes corresponds to the largest value of ΔS^o?

i. $CH_3OH(l, 25^oC) \rightarrow CH_3OH (l, 65^oC)$ **ii. $NaCl (s, 801^oC) \rightarrow NaCl (l, 801^oC)$**

iii. $H_2O(l, 100^oC) \rightarrow H_2O (g, 100^oC)$ **iv. $CO_2 (s, 101 kPa) \rightarrow CO_2 (g, 1 kPa)$**

o) *The van't Hoff plot for a reaction has a slope of +550 K and a y-intercept of + 3.75 mol. This reaction will be:

Spontaneous at all T **Spontaneous at high T**

Spontaneous at low T **Non-spontaneous at all T**

p) *A one litre balloon is filled with neon gas. A hole is made in the balloon and the gas effuses at a rate of 0.0106 mol/hr. If the same balloon is refilled with argon at the same pressure and temperature, its rate of effusion would be _____.

q) *The solubility of magnesium carbonate is highest in a buffer solution with a pH of

3.5 8.5 6.5 10.5

r) *As the percent abundance of heavy isotopes of an element increases, the average atomic mass of the element _____.

s) *If the equilibrium constant for the reaction $HA + H_2O \rightleftharpoons H_3O^+ + A^-$ is K_a, then the equilibrium constant for the reaction $A^- + H_2O \rightleftharpoons HA + OH^-$ would be

K_a K_w/K_a $1/K_a$ K_b

BONUS:

t) *For an electrochemical cell, the graph of E_{cell} versus logQ has a y-intercept equal to _____.

u) *The maximum number of electrons with quantum numbers n = 2 and ℓ = 1 is: _____.

#2. (10 points)
(a) Draw a diagram of Bohr's model of the hydrogen atom showing the transition of an electron from the ground state to the $n = 4$ level.

(b) What is the change in energy (in J) of this transition?

Answer : _____

(c) What is the significance of the sign in your answer for part (b)?

(d) Calculate the wavelength (in nm) that corresponds to this energy.

Answer : _____

#3. (10 points). You are given 200.0 mL of an aqueous solution that contains 0.250 M each of Ag^+, Pb^{2+}, and Ba^{2+}. You wish to precipitate these cations sequentially by adding chromate to the solution.

(a) In what order will the solids precipitate as chromate is added to the above solution?

First = _____ Second = _____ Third = _____

(b) What concentration of chromate will cause the first precipitation?

Answer: _____

(c) At the point <u>just before</u> $BaCrO_4$ begins to precipitate, what will be the concentration of all of the ions in solution?

$[Ag^+]$ = _____ $[Pb^{2+}]$ = _____ $[Ba^{2+}]$ = _____

#4. (10 points) Electrolysis is carried out in the following electrochemical cell:

$$\mathbf{Pt \mid H_2O\ (l) \mid O_2\ (g) \parallel Ag^+\ (aq) \mid Ag\ (s)}$$

(a) Determine the overall reaction occurring in the electrolytic cell and its standard cell potential, given the following *unbalanced* half-reactions:

$$\mathbf{O_2\ (g) + e^- \rightarrow H_2O(l)} \qquad \mathbf{E^o = 1.229\ V}$$

$$\mathbf{Ag^+(aq) + e^- \rightarrow Ag\ (s)} \qquad \mathbf{E^o = 0.800\ V}$$

Overall Reaction: _____

$\mathbf{E^o_{cell}}$ **=** _____

(b) The electrolysis is carried out for 2.00 hr. If the mass of the silver cathode increased from 25.0782 g to 25.8639 g in that time, what was the magnitude of the current used?

Answer: _____

(c) Oxygen is collected at the platinum anode. What is the volume of O_2 collected at 23.0°C and 755 mmHg?

Answer: _____

#5. (10 points)

(a) Predict the products and write balanced ionic and net ionic equations for the following reaction:

$$Na_2S(aq) + ZnCl_2(aq) \rightarrow ?$$

Ionic equation:

Net ionic equation:

(b) A 0.250M solution of sodium sulfide is added to 1 L of a saturated solution of zinc chloride. If the reaction has a reported percent yield of 83.5%, how many millilitres of the sodium sulfide solution must be added to form 1.50 g of the solid product?

Answer: _____

#6. (10 points) For the following generic reaction,

$$\mathbf{A\ (g) \leftrightarrows B\ (g) + 2C\ (g)}$$

calculate ΔH^o, ΔS^o, and ΔG^o at 298 K given the following information:

$$\mathbf{K_{eq} = 8.99 \times 10^{11} \text{ at } 298 \text{ K}}$$

$$\mathbf{K_{eq} = 1.73 \times 10^{13} \text{ at } 443 \text{ K}}$$

ΔH^o = _____

ΔG^o = _____

ΔS^o = _____

#7. (10 points) In the titration of 40.00 mL of 0.200 M HOCl by 0.500 M NaOH:
(a) Calculate the initial pH.

Answer: _____

(b) What is the volume of NaOH needed to attain the equivalence point? Calculate the pH at the equivalence point.

Volume of NaOH: _____ pH: _____

#8. (10 points). Steel is an alloy of iron and carbon, with iron being the major component. A steel ball bearing has a radius of 5.85 mm and a density of 7.75 g/cm^3. If the ball bearing contains 0.25% carbon (by mass) and that the percent natural abundance of ^{13}C is 1.108%, how many ^{13}C atoms are present in the ball bearing?
Recall: volume of a sphere = $(4\pi r^3)/3$

Answer: _____

#9. (10 points) A 0.3268 g sample of caffeine ($C_8H_{10}O_2N_4$, heat of combustion = -4.243×10^3 kJ/mol) undergoes complete combustion in a bomb calorimeter. The bomb calorimeter assembly has a heat capacity of 5.136 kJ/°C.

(a) What mass of oxygen is required for the complete combustion of the sample?

___ $C_8H_{10}O_2N_4$ + ___ O_2 → ___ CO_2 + ___ H_2O + ___ NO_2

Answer: _____

(b) What will be the final temperature of the assembly if the initial temperature is 22.43°C?

Answer: _____

(c) What is the change in internal energy for the reaction?

Answer: _____

Gas Laws

$PV = nRT$

$P_T = P_1 + P_2 + P_3 + \ldots$

$d = m/V = P(MW) / RT$

$KE = (1/2)mv_{av}^2$

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{RateA}{RateB} = \sqrt{\frac{M_b}{M_a}}$$

$$\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$$

Equilibrium

$K_P = K_C(RT)^{\Delta n}$

Acid/Base

$pOH = -\log[OH^-]$

$pH = -\log[H^+]$

$pH + pOH = 14$

$K_a \times K_b = K_W$

$pH = pK_a + \log [A^-]/[HA]$

$$pH = \frac{pK_{a1} + pK_{a2}}{2}$$

Kinetics

$[A]_t = [A]_o - kt$

$\ln[A]_t = \ln[A]_o - kt$

$1/[A]_t = 1/[A]_o + kt$

$k = Ae^{(-Ea/RT)}$

$\ln(k_2/k_1) = (-Ea/R)(1/T_2 - 1/T_1)$

Thermodynamics

$\Delta U = Q + W$

$W_{system} = -P\Delta V = -\Delta nRT$

$\Delta H = \Delta U + P\Delta V$

$Q_P = \Delta U + P\Delta V$

$C_P = C_V + R$

$Q = mc\Delta T$

$\Delta H_{rxn}° = \sum n\Delta H_f°(pdts) - \sum n\Delta H_f°(rxts)$

$q_{rev} = -w_{max} = nRT \ln(V_2/V_1)$

$\Delta S = q_{rev}/T$

$\Delta S\ (T_1\text{-}T_2) = nC_P \ln(T_2/T_1)$

$\Delta S\ (T_1\text{-}T_2) = nC_V \ln(T_2/T_1)$

$$\Delta S^0_{ext} = \frac{q_{ext}}{T} = \frac{-\Delta H_{sys}}{T}$$

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta G = \Delta G° + RT \ln(Q)$

$\Delta G° = -RT \ln(K)$

$\ln(K_2/K_1) = (-\Delta H°/R)(1/T_2 - 1/T_1)$

The atom

$E = h\nu$

$c = \nu\lambda$

$E = -R_H/n^2$

Data For Water

Density ρ = 1.00 g/mL (25°C)
C = 2.13 J g^{-1} K^{-1} (solid)
C = 4.18 J g^{-1} K^{-1} (liquid) $\Delta H°_{fus}$ = 6.02 kJ mol^{-1}
C_p = 2.01 J g^{-1} K^{-1} (gas) $\Delta H°_{vap}$ = 40.7 kJ mol^{-1}

Constants and Conversion Factors

1mm Hg = 1 torr 760mm Hg = 1 atm 1atm = 101.325 kPa

Avogadro's Number	*N*	6.022×10^{23} mol^{-1}	
Boltzmann's constant	*k*	1.30866×10^{-23} $J \cdot K^{-1}$	
Faraday's constant	*F*	96,485 $C \cdot mol^{-1}$	
Gas constant	*R*	8.31451 $J \cdot K^{-1} \cdot mol^{-1}$	
	R	0.08206 $atm \cdot L \cdot K^{-1} \cdot mol^{-1}$	
	R	8.31451 $m^3 Pa \cdot K^{-1} \cdot mol^{-1}$	
Planck's constant	*h*	6.62608×10^{-34}	J·s
Speed of Light	*c*	2.99792458×10^{8}	$m \cdot s^{-1}$
Rydberg constant	R_H	2.179×10^{-18} J	

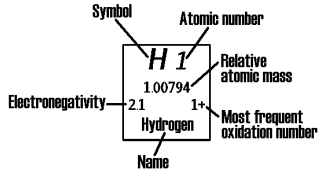
Table of Ionization Constants

Acid		K_a =
Iodic acid	$HIO_3 + H_2O \rightleftharpoons H_3O^+ + IO_3^-$	1.6×10^{-1}
Chlorous acid	$HClO_2 + H_2O \rightleftharpoons H_3O^+ + ClO_2^-$	1.1×10^{-2}
Chloroacetic acid	$HC_2H_2ClO_2 + H_2O \rightleftharpoons H_3O^+ + C_2H_2ClO_2^-$	1.4×10^{-3}
Nitrous acid	$HNO_2 + H_2O \rightleftharpoons H_3O^+ + NO_2^-$	7.2×10^{-4}
Hydrofluoric acid	$HF + H_2O \rightleftharpoons H_3O^+ + F^-$	6.6×10^{-4}
Formic acid	$HCHO_2 + H_2O \rightleftharpoons H_3O^+ + CHO_2^-$	1.8×10^{-4}
Benzoic acid	$HC_7H_5O_2 + H_2O \rightleftharpoons H_3O^+ + C_7H_5O_2^-$	6.3×10^{-5}
Hydrazoic acid	$HN_3 + H_2O \rightleftharpoons H_3O^+ + N_3^-$	1.9×10^{-5}
Acetic acid	$HC_2H_3O_2 + H_2O \rightleftharpoons H_3O^+ + C_2H_3O_2^-$	1.8×10^{-5}
Hypochlorous acid	$HOCl + H_2O \rightleftharpoons H_3O^+ + OCl^-$	2.9×10^{-8}
Hydrocyanic acid	$HCN + H_2O \rightleftharpoons H_3O^+ + CN^-$	6.2×10^{-10}
Phenol	$HOC_6H_5 + H_2O \rightleftharpoons H_3O^+ + C_6H_5O^-$	1.0×10^{-10}
Hydrogen peroxide	$H_2O_2 + H_2O \rightleftharpoons H_3O^+ + HO_2^-$	1.8×10^{-12}

Table of Solubility Product Constants

Compound	K_{sp}	Compound	K_{sp}
$Mg(OH)_2$	1.2×10^{-11}	Ag_2CrO_4	1.9×10^{-12}
AgCl	1.8×10^{-10}	$PbCrO_4$	1.8×10^{-14}
$CaSO_4$	9.1×10^{-6}	$BaCrO_4$	2.1×10^{-10}
AgI	1.5×10^{-16}	Hg_2Cl_2	1.3×10^{-18}
PbI_2	8.7×10^{-9}	Ag_2CO_3	8.5×10^{-12}
$PbCl_2$	1.9×10^{-5}		

Mokeur's Periodic table of the elements



	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	***H 1*** 1.00794 2.1 1+ Hydrogen																	***He 2*** 4.002602 - - Helium
2	**Li 3** 6.941 1.0 1+ Lithium	**Be 4** 9.012182 1.5 2+ Beryllium											**B 5** 10.811 2.0 3+ Boron	**C 6** 12.011 2.5 4+,4- Carbon	*N 7* 14.00674 3.0 3+,3- Nitrogen	*O 8* 15.9994 3.5 2- Oxygen	*F 9* 18.9984032 4.0 1- Fluorine	*Ne 10* 20.1797 - - Neon
3	**Na 11** 22.989768 0.9 1+ Sodium	**Mg 12** 24.3050 1.2 2+ Magnesium											**Al 13** 26.981539 1.5 3+ Aluminum	**Si 14** 28.0855 1.8 4+ Silicon	**P 15** 30.973762 2.1 5+ Phosphorus	**S 16** 32.066 1.8 4+ Sulfur	*Cl 17* 35.4527 3.0 1- Chlorine	*Ar 18* 39.948 - - Argon
4	**K 19** 39.0983 0.8 1+ Potassium	**Ca 20** 40.078 1.0 2+ Calcium	**Sc 21** 44.955910 1.3 3+ Scandium	**Ti 22** 47.88 1.5 4+ Titanium	**V 23** 50.9415 1.6 5+ Vanadium	**Cr 24** 51.9961 1.6 3+ Chromium	**Mn 25** 54.93805 1.5 2+ Manganese	**Fe 26** 55.847 1.8 3+ Iron	**Co 27** 58.9332 1.8 2+ Cobalt	**Ni 28** 58.6934 1.8 2+ Nickel	**Cu 29** 63.546 1.9 2+ Copper	**Zn 30** 65.39 1.6 2+ Zinc	***Ga 31*** 69.723 1.6 3+ Gallium	**Ge 32** 72.61 1.6 4+ Germanium	**As 33** 74.92159 2.0 3+,3- Arsenic	**Se 34** 78.96 2.4 4+ Selenium	***Br 35*** 79.904 2.8 1- Bromine	*Kr 36* 83.80 - - Krypton
5	**Rb 37** 85.4678 0.8 1+ Rubidium	**Sr 38** 87.62 1.0 2+ Strontium	**Y 39** 88.90585 1.3 3+ Yttrium	**Zr 40** 91.224 1.4 4+ Zirconium	**Nb 41** 92.90638 1.6 5+ Niobium	**Mo 42** 95.94 1.8 6+ Molybdenum	Tc 43 98.9063 1.9 7+ Technetium	**Ru 44** 101.57 2.2 3+,4+ Ruthenium	**Rh 45** 102.9055 2.2 3+ Rhodium	**Pd 46** 106.42 2.2 2+ Palladium	**Ag 47** 107.8682 1.9 1+ Silver	**Cd 48** 112.411 1.7 2+ Cadmium	**In 49** 114.82 1.7 3+ Indium	**Sn 50** 118.71 1.8 4+ Tin	**Sb 51** 121.757 1.9 3+,3- Antimony	**Te 52** 127.60 2.1 4+ Tellurium	**I 53** 126.90447 2.5 1- Iodine	*Xe 54* 131.29 - - Xenon
6	***Cs 55*** 132.90543 0.7 1+ Cesium	**Ba 56** 137.327 0.9 2+ Barium	**La 57** 138.9055 1.1 3+ Lanthanum	**Hf 72** 178.49 1.3 4+ Hafnium	**Ta 73** 180.9479 1.5 5+ Tantalum	**W 74** 183.85 1.7 6+ Tungsten	**Re 75** 186.207 1.9 7+ Rhenium	**Os 76** 190.2 2.2 4+ Osmium	**Ir 77** 192.22 2.2 4+ Iridium	**Pt 78** 195.08 2.2 4+ Platinum	**Au 79** 196.96654 2.4 3+ Gold	***Hg 80*** 200.59 1.9 2+ Mercury	**Tl 81** 204.3833 1.8 1+ Thallium	**Pb 82** 207.2 1.8 2+ Lead	**Bi 83** 208.98037 1.9 3+ Bismuth	**Po 84** 208.9824 2.0 2+ Polonium	**At 85** 209.9871 2.2 1- Astatine	*Rn 86* 222.0176 - - Radon
7	***Fr 87*** 223.0197 0.7 1+ Francium	**Ra 88** 226.0254 0.9 2+ Radium	**Ac 89** 227.0278 1.1 3+ Actinium	Rf 104 261.11 - - Rutherfordium	Db 105 262.11 - - Dubnium	Sg 106 263.12 - - Seaborgium	Bh 107 262.12 - - Bohrium	Hs 108 264 - - Hassium	Mt 109 266.1378 - - Meitnerium	Uun 110 269 - - Ununnilium	Uuu 111 272 - - Unununium	Uu 112 277 - - Ununbium		Uuq 114 289 - - Ununquadium		Uuh 116 289 - - Ununhexium		Uuo 118 293 - - Ununoctium

6	**Ce 58** 140.115 1.1 3+ Cerium	**Pr 59** 140.90765 1.1 3+ Praseodymium	**Nd 60** 144.24 1.1 3+ Neodymium	Pm 61 144.9127 1.1 3+ Promethium	**Sm 62** 150.36 1.2 3+ Samarium	**Eu 63** 151.965 1.2 3+ Europium	**Gd 64** 157.25 1.2 3+ Gadolinium	**Tb 65** 168.92534 1.2 3+ Terbium	**Dy 66** 162.50 1.2 3+ Dysposium	**Ho 67** 164.93032 1.2 3+ Holmium	**Er 68** 167.26 1.2 3+ Erbium	**Tm 69** 168.93421 1.2 3+ Thulium	**Yb 70** 173.04 1.1 3+ Ytterbium	**Lu 71** 174.967 1.2 3+ Lutetium
7	**Th 90** 232.0381 1.3 4+ Thorium	**Pa 91** 231.03588 1.5 5+ Protactinium	**U 92** 238.0289 1.4 6+ Uranium	Np 93 237.082 1.3 5+ Neptunium	Pu 94 244.0642 1.3 4+ Plutonium	Am 95 243.0614 1.3 3+ Americium	Cm 96 247 1.3 3+ Curium	Bk 97 247.0703 1.3 3+ Berkelium	Cf 98 251.0796 1.3 3+ Californium	Es 99 252.03 1.3 - Einsteinium	Fm 100 257.0951 1.3 - Fermium	Md 101 258.01 1.3 - Mendelevium	No 102 259.1009 1.3 - Nobelium	Lr 103 260.1053 - - Lawrencium

Under normal conditions, bold symbols correspond to solid state, bold italic correspond to liquid state, italic correspond to gaseous state and normal correspond to synthetic elements.