Concordia
UNIVERSITY

COURSE	NUMBER	SECTION
GENERAL CHEMISTRY II	CHEM 206	/2 51
EXAMINATION	**DATE**	**TIME**
Final Examination	December 19, 2006	1900-2200
INSTRUCTOR	Dr. Cerrie ROGERS	

MATERIALS ALLOWED:	[X]	NO	[ ]	YES (PLEASE SPECIFY)
CALCULATORS ALLOWED:	[ ]	NO	[X]	YES programmable calculators must be reset

Chem 206 --- GENERAL CHEMISTRY II

LAST NAME: _____ FIRST NAME: _____

STUDENT NUMBER: _____ SIGNATURE: _____

Instructions: PLEASE READ THIS PAGE WHILE WAITING TO START!

- ***Make sure your exam has 12 pages, including this cover page & a periodic table.***
- ***Write your student ID number on all pages.***
- ***Write all answers <u>legibly</u> in the space provided (use the backs of pages for rough work).***
- ***Non-programmable calculators are allowed; cell phones & electronic dictionaries are not.***
- ***You may detach the periodic table and potentially useful information pages.***
- ***Read ALL questions quickly BEFORE starting the exam; do the "easy" questions first.***

<u>Mark breakdown</u>: ***spend ≤ 15 min per page ⇨ 30 minutes extra to check your work.***

Page 2.	/ 12
Page 3.	/ 5
Page 4.	/ 12
Page 5.	/ 17
Page 6.	/ 7
Page 7.	/ 15
Page 8.	/ 11
Page 9.	/ 14
Page 10.	/ 12
TOTAL:	**/ 100 (MAXIMUM MARK = 105)**

 # 1. (__/ 12 marks) TRUE OR FALSE? Circle T or F to describe each of these statements.
(You do not need to show your work.)

T / F London dispersion forces are weak attractive forces that arise between molecules because of mutual polarization of electron clouds that gives rise to transient dipoles.

T / F The concentration of dissolved O_2 will be lower in a solution in contact with a gas mixture containing 0.20 atm of $O_{2(g)}$ than in a solution in contact with pure $O_{2(g)}$ at a pressure of 0.20 atm.

T / F To minimize indicator error during the titration of an acid, it is best to choose an indicator that undergoes a dramatic colour change at a pH very close to the pK_a of the acid being titrated.

T / F If a reaction is performed in a bomb calorimeter, the measured heat flow is not necessarily equal to only the enthalpy change for the reaction, because the system is not permitted to lose extra energy by performing work.

T / F Carbonate (CO_3^{2-}) is a weaker base than phosphate (PO_4^{3-}) because the average charge on each oxygen atom in carbonate is lower.

T / F Molecules of formaldehyde (H_2CO) interact with each other via hydrogen bonding.

 # 2. (__/ 5 marks) CHOOSE ONE TASK FROM THIS PAGE (if you do both, only the first will be marked.)

The reaction $2\ Mg_{(s)} + O_{2(g)} \rightarrow 2\ MgO_{(s)}$ is highly spontaneous at room temperature and has a negative value for $\Delta S°$. The second law of thermodynamics states that in any spontaneous process, there is always an increase in the entropy of the universe. Is there an inconsistency between the above reaction and the second law? Explain.

A gas is confined to a cylinder under constant atmospheric pressure P_{ext}, as shown in the diagram. When the gas undergoes a particular chemical reaction, it releases 79 kJ of heat and does 18 kJ of PV work on its surroundings. What are the values of ΔH and ΔE for this process? Explain briefly, and show any necessary calculations.

 # 3. (__/ 12 marks) Many home swimming pools are disinfected by adding calcium hypochlorite, $Ca(OCl)_2$. Calcium hypochlorite is fully soluble in water, and the K_a of its conjugate acid HOCl is 3.5×10^{-8}.

a) **(4 marks)** Write balanced chemical equations to illustrate the two equilibria this substance participates in when $Ca(OCl)_{2(s)}$ is added to water. Include the appropriate equilibrium constant expressions.

b) **(8 marks)** Calculate the pH of a pool with 0.050 M $Ca(OCl)_2$. Is the water acidic, basic or neutral?

CHEM 206 Fall 2006 Section 51 ID #:_____

 # 4. (__/ 17 marks) Consider the following two dissolution equilibria:

$$NaCl_{(s)} \rightleftharpoons Na^+_{(aq)} + Cl^-_{(aq)}$$
$$AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$$

Thermodynamic data for 298 K		
Species	**ΔH°_f ($kJ \cdot mol^{-1}$)**	**S°_f ($J \cdot mol^{-1} \cdot K^{-1}$)**
NaCl(s)	-410.9	72.33
AgCl(s)	-127.0	96.11
Na^+(aq)	-240.1	59.0
Ag^+(aq)	105.90	73.93
Cl^-(aq)	-167.2	56.5

a) **(6 marks)** Calculate ΔG° at 298 K for each reaction.

b) **(1 mark)** Is the difference in the ΔG° values due primarily to the entropy term or the enthalpy term?

c) **(4 marks)** Calculate the thermodynamic value of the equilibrium constant, K_{sp}, for NaCl and for AgCl, and comment on the relationship between the K_{sp} values and the relative solubilities of these salts.

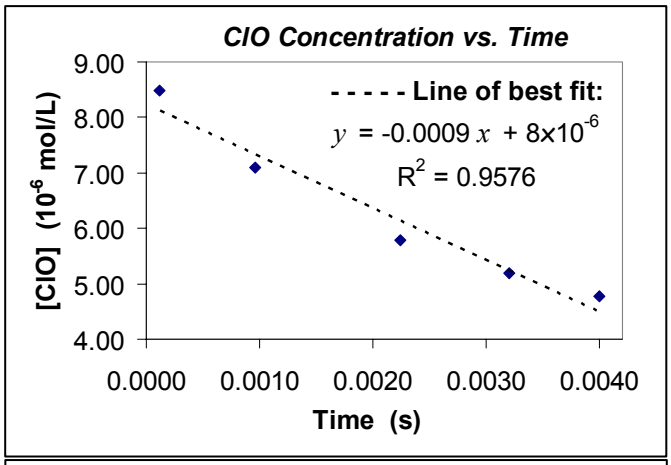
d) **(6 marks)** Now consider a saturated solution of AgCl. Would the solubility of AgCl increase, decrease or stay the same after the following changes in conditions?

Change in conditions	**Solubility:** increase, decrease, no change	**Provide a few words of explanation.**
Increase in temperature		
Addition of some NaCl		
Addition of more AgCl		

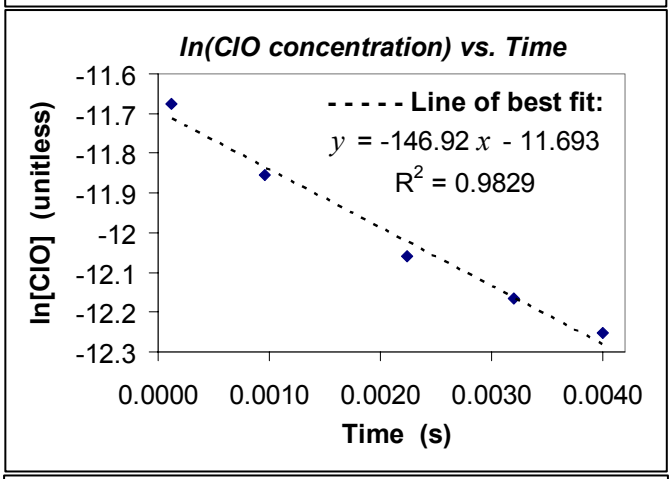
 # 5. (__/ 7 marks) Chlorine oxide (ClO), which plays an important role in the depletion of ozone, decays rapidly at room temperature:

$$2\ ClO_{(g)} \rightarrow Cl_{2(g)} + O_{2(g)}$$

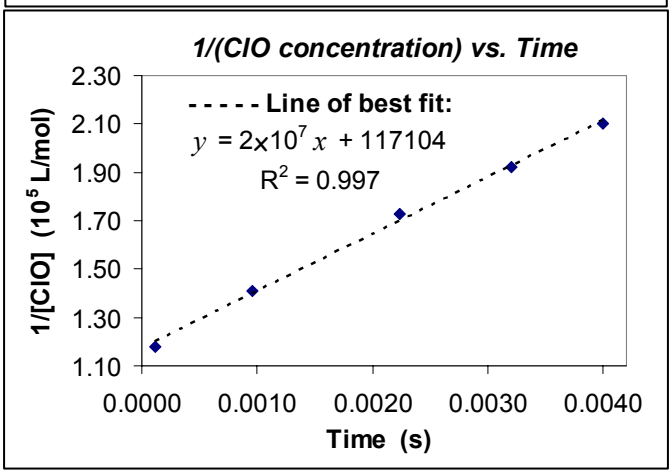
A single kinetics experiment was performed, and the data set was plotted in the three ways shown here.



a) **(2 marks)** What is the rate law for this reaction? How were you able to come to this conclusion?



b) **(1 mark)** What is the value of the rate constant?



c) **(4 marks)** How long would it take for the concentration of ClO to drop from 4.77×10^{-6} M to 1.0×10^{-8} M?

 # 6. (__/ 15 marks) Hydrogen sulfate anion is a weak acid with $K_a = 1.2\times10^{-2}$. Consider a 0.30 M solution of $NaHSO_4$ with a density of 1.005 g/mL.

a) **(8 marks)** Calculate the total solute concentration in this solution, in molarity.

b) **(7 marks)** What is the boiling point of this solution?

 # 7. (__/ 11 marks) The following three-step mechanism has been proposed for the reaction of chlorine and chloroform. The numerical value (*i.e.,* without units) of the rate constant for each step is provided.

STEP 1: $Cl_{2(g)} \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2Cl_{(g)}$ $k_1 = 4.8\text{x}10^3$ and $k_{-1} = 3.6\text{x}10^3$

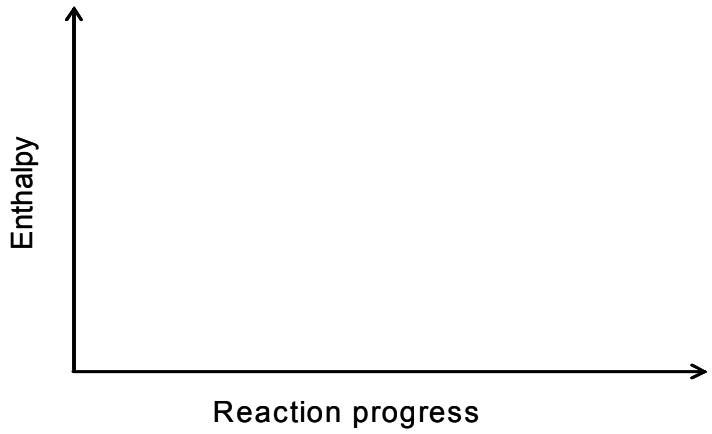
STEP 2: $Cl_{(g)} + CHCl_{3(g)} \xrightarrow{k_2} HCl_{(g)} + CCl_{3(g)}$ $k_2 = 1.3\text{x}10^{-2}$

STEP 3: $CCl_{3(g)} + Cl_{(g)} \xrightarrow{k_3} CCl_{4(g)}$ $k_3 = 2.7\text{x}10^2$

a) **(1 mark)** Write a balanced chemical equation for the overall (net) reaction.

b) **(2 marks)** Which step is rate limiting? How can you tell?

c) **(3 marks)** Draw an approximately-to-scale energy diagram to match this mechanism. Assume that the overall reaction is exothermic. Label the graph with the terms listed below, as appropriate (some may need to be used more than once):



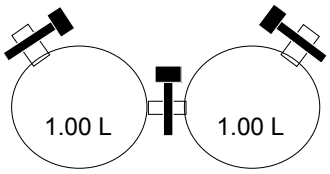
LABELS TO USE:

reactants
products
transition state
ΔH_{rxn}
intermediate
rate-limiting step
activation energy

d) **(5 marks)** Assuming the proposed mechanism is correct, what do you predict the overall rate law of the reaction to be, and why?

 # 8. (__/ 14 marks) At 150°C, the endothermic reaction below has $K_p = 1.5 \times 10^{-4}$: (data modified for exam purposes)

$$2\ IBr_{(g)} \rightleftharpoons I_{2(g)} + Br_{2(g)}$$



a) **(8 marks)** A 1.25 mol quantity of IBr gas is added to the 1.00 L flask on the left. What will be the total pressure in the flask at equilibrium at 150°C? *Assume that all three black valves remain closed, so the volume is 1.00 L.*

b) **(6 marks)** Now consider disturbing this equilibrium mixture. How would the following changes affect the quantity of Br_2 present in the flask when equilibrium is re-established? Very briefly explain why.

Disturbance	***Will the quantity of Br_2 increase, decrease or stay the same? Why?***
Adding a substance that reacts with I_2	
Decreasing the temperature to 400 K	
Opening the valve that connects the two flasks	

 # 9. (__/ 12 marks) Imagine you are preparing to perform an experiment on a pH-sensitive compound, and you need the solution to be kept at pH 8.50 throughout the experiment.

a) **(4 marks)** Evaluate <u>each</u> of the pairs below in terms of their usefulness in a buffer for your experiment.

PAIR	Acid	K_a	Base	Good choice or bad choice? WHY?
1	HF	6.8×10^{-4}	NaF	
2	H_2CrO_4	3.0×10^{-7}	Na_2CrO_4	
3	H_3BO_3	5.8×10^{-10}	NaH_2BO_3	
4	$C_2H_5NH_3Br$	1.6×10^{-11}	$C_2H_5NH_2$	

b) **(3 marks)** For the best choice from part (a), what is the ratio of [acid form] to [base form] necessary to maintain a pH of 8.50?

c) **(5 marks)** If the total initial buffer concentration ($[acid]_o + [base]_o$) must be 1.00 M in your experiment, what mass of each compound should you dissolve in water in order to prepare 1.0 L of buffer?

POTENTIALLY USEFUL INFORMATION

Constants:

$R = 8.314\ J \cdot mol^{-1}K^{-1} = 0.08206\ L \cdot atm \cdot mol^{-1}K^{-1}$

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

Data:

Properties of liquid water:

bp (at 1 atm) = 100.00°C

$C_{H_2O(l)} = 4.184\ J \cdot g^{-1}K^{-1}$

$d_{H_2O(l)} = 1.00\ g \cdot mL^{-1}$

$K_{f\ H_2O} = 1.86\ °C \cdot kg \cdot mol^{-1}$

$K_{b\ H_2O} = 0.52\ °C \cdot kg \cdot mol^{-1}$

$K_w = 10^{-14}$

Properties of solid water:

mp (at 1 atm) = 0.00°C

$C_{H_2O(s)} = 2.06\ J \cdot g^{-1}K^{-1}$

$d_{H_2O(s)} = 0.917\ g \cdot mL^{-1}$

Formulae:

$\Delta G^o = \Delta H^o - T\Delta S^o$

$\Delta G = \Delta G^o + RT \ln Q$

$\Delta G^o = -RT \ln K_{eq}$

$PV = nRT$

$C = k\,P \quad (\text{or, } S = k\,P)$

$P = \chi\, P^o$

$\Delta T = K\, m$

$\pi V = nRT$

$k = A\, e^{(-Ea/RT)}$

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

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

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

$$x = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$$

$pH = -\log[H_3O^+]$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$