Concordia UNIVERSITY

COURSE	NUMBER	SECTION
GENERAL CHEMISTRY II	CHEM 206	/4 01 & 52
EXAMINATION	**DATE**	**TIME**
Final Examination	April 27, 2007	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 13 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 <u>not</u>.***
- ***You may detach the periodic table and "potentially useful information" pages.***
- ***Read ALL questions quickly BEFORE starting the exam; do the "easy" questions first.***
- ***Suggestion: spend ~ 1.5 min/mark to have ~30 minutes left to check your work.***

<u>Mark breakdown</u>*:*

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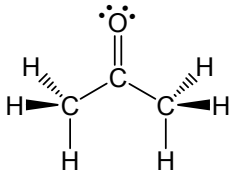
TOTAL:	**/ 100 (MAXIMUM MARK = 103)**

 # 1. (__/ 21 marks) TRUE OR FALSE? Circle T or F to describe each of these statements. (No explanations required.)

T / F Acetone (shown) is a common laboratory solvent that is usually significantly contaminated with water. *True or false:* Dipole-dipole interactions are the dominant forces acting between molecules of acetone and water.



T / F Entropically favoured reactions are always more product-favoured at higher temperatures.

T / F Chemical equilibrium is described as a dynamic state, because the concentrations of all species involved in the reaction change at equal rates at equilibrium.

T / F At the equivalence point of a titration of NH_3 with HNO_3, the solution will have a pH < 7.

T / F To maintain your solution's pH at 9.5, it would be better to use a buffer containing NH_4Cl and NH_3 than a buffer containing $NaCH_3CO_2$ and CH_3CO_2H.

Species	K_a
CH_3CO_2H	1.8×10^{-5}
NH_4^+	5.6×10^{-10}

T / F A solution containing 1.0 M CH_3COOH would exert a lower osmotic pressure than a solution containing 1.0 M HCl.

T / F Based on the K_a values shown in the table, the reaction shown below is expected to be (even slightly) product-favoured:

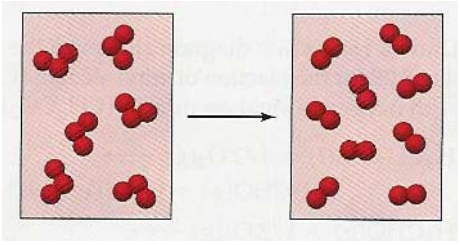
$$HCO_3^-(aq) + HPO_4^{2-}(aq) \rightleftharpoons CO_3^{2-}(aq) + H_2PO_4^-(aq)$$

Species	K_a
HCO_3^-	4.8×10^{-11}
$H_2PO_4^-$	6.2×10^{-8}

 # 2. (__/ 5 marks) CHOOSE <u>ONE</u> OF THESE TASKS (if you do both, only the first one will be marked).

Explain why cold, damp air and hot, humid air feel much more uncomfortable than dry air at the same temperatures. The specific heat capacities of water vapour and air are approximately 1.9 J/g°C and 1.0 J/g°C respectively.

Determine the signs of ΔH, ΔS and ΔG for the spontaneous reaction depicted in the diagrams. Explain your answer.



 # 3. (__/ 8 marks) Ethylene (C_2H_4) can be formed by the following reaction:

$$2\ CH_4(g) \rightarrow C_2H_4(g) + 2\ H_2(g)$$

a) **(5 marks)** Use the following information to calculate ΔH^o for the above reaction:

$$2\ C_2H_6(g) + 7\ O_2(g) \rightarrow 4\ CO_2(g) + 6\ H_2O(\ell) \quad \Delta H^o = -3119.4\ kJ$$
$$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(\ell) \quad \Delta H^o = -890.3\ kJ$$
$$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g) \quad \Delta H^o = -137.0\ kJ$$
$$H_2(g) + \tfrac{1}{2}\ O_2(g) \rightarrow H_2O(\ell) \quad \Delta H^o = -285.8\ kJ$$

b) **(3 marks)** How much heat is released or absorbed when 100.0 g of ethylene is produced in this way?
[If you could not do part (a), assume ΔH^o is -75 kJ…which is not correct….]

 # 4. (__/ 11 marks) Imagine you are trying to characterize an unknown weak acid, HX, but you do not have a pH meter. You prepare a 1.0 M solution of HX, and divide it into four portions. To each portion, you add a few drops of a different pH indicator, with the results show in the table below:

Indicator "In"	**Colour of H-In**	**Colour of In^-**	**pK_a of H-In**	**Colour when added to HX solution**
Bromphenol blue	yellow	blue	4.0	blue
Bromcresol purple	yellow	purple	6.0	yellow
Bromcresol green	yellow	blue	4.8	green
Alizarin	yellow	red	6.5	yellow

a) **(4 marks)** What is the approximate pH of your HX solution? Explain your choice.

b) **(7 marks)** Calculate the approximate value of the K_a for HX. *[If you could not do part (a), assume the pH is 2.5.]*

 # 5. (__/ 12 marks) For the equilibrium:

$$PH_3BCl_3(s) \rightleftharpoons PH_3(g) + BCl_3(g) \qquad K_p = 0.052 \text{ (at } 60^\circ C)$$

a) **(8 marks)** Some solid PH_3BCl_3 is added to a closed 0.500 L vessel at 60°C, and then 0.0128 mol of $BCl_3(g)$ is added. What is the equilibrium partial pressure of PH_3 (a terrible-smelling gas)?

b) **(4 marks)** Is the equilibrium shown above exothermic or endothermic? Explain briefly, and identify the nature of the bonds/interactions made/broken in the reaction.

 # 6. (__/ 6 marks) Chemists commonly use a rule of thumb that an increase of 10 K in temperature doubles the rate of a reaction. What must the activation energy of the reaction be for this statement to be true for a temperature increase from 25 to 35°C? Show your work.

 # 7. (__/ 11 marks) Automotive antifreeze contains ethylene glycol ($HOCH_2CH_2OH$), a nonvolatile nonelectrolyte, dissolved in water. If your car's antifreeze is 25.0% ethylene glycol by mass, is it sufficiently concentrated to remain liquid at a temperature of –25°C? Show your work, and explain your answer briefly.

 # 8. (__/ 8 marks) Metals are often able to form several cations with different charges. Cerium, for example, forms Ce^{3+} and Ce^{4+} ions, and thallium forms Tl^{+} and Tl^{3+} ions. Cerium and thallium ions react with each other as follows:

Elementary step: $2\ Ce^{4+}(aq) + Tl^{+}(aq) \rightarrow 2\ Ce^{3+}(aq) + Tl^{3+}(aq)$ (very slow)

The reaction rate is enhanced by the addition of $Mn^{2+}(aq)$, which changes the reaction's mechanism to:

STEP 1: $Ce^{4+}(aq) + Mn^{2+}(aq) \rightarrow Ce^{3+}(aq) + Mn^{3+}(aq)$

STEP 2: $Ce^{4+}(aq) + Mn^{3+}(aq) \rightarrow Ce^{3+}(aq) + Mn^{4+}(aq)$

STEP 3: $Mn^{4+}(aq) + Tl^{+}(aq) \rightarrow Mn^{2+}(aq) + Tl^{3+}(aq)$

a) **(2 marks)** Write the rate law for the reaction of Ce^{4+} and Tl^{+} in the absence of $Mn^{2+}(aq)$.

b) **(2 marks)** As noted above, this reaction is very slow. Provide a likely reason for this, and explain briefly.

c) **(2 marks)** In the presence of $Mn^{2+}(aq)$, the reaction is first order in $[Ce^{4+}]$ and first order in $[Mn^{2+}]$. Based on this information, which of the three steps in this mechanism is the rate limiting step? Why?

d) **(2 marks)** What term would be best used to describe the role of $Mn^{2+}(aq)$? Why?

 # 9. (__/ 9 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) **(8 marks)** Calculate ΔG° at 298 K for each reaction.

b) **(1 mark)** The two values from part (a) are very different. Is the difference due primarily to the entropy term or the enthalpy term?

 # 9. (__/ 12 marks on this page) CONTINUED FROM PREVIOUS PAGE…

c) **(6 marks)** Using the information calculated in part (a) of this question, calculate the thermodynamic equilibrium constant, K_{sp}, for NaCl and for AgCl. Comment on the relationship between the K_{sp} values and the relative solubilities of these salts (from your previous knowledge).

d) **(6 marks)** Now, think about 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?**	**Provide a few words of explanation.**
Increase in temperature		
Addition of some NaCl		
Addition of more AgCl		

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:

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

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

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

$PV = nRT$

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

$P = \chi\, P^o$

$\Delta T = K\, m$

$\pi V = nRT$

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

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

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

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

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

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

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