

Memorial University of Newfoundland

St. John's, Newfoundland and Labrador

Chemistry 1051 Intersession 2007

Midterm Exam 2

May 28th, 2007

Time: 50 Minutes

Name: _____

MUN #: _____

Dr. Peter Warburton

READ THE FOLLOWING CAREFULLY!

1. This exam has 7 pages with 2 sections. SECTION A is comprised of longer answer questions and SECTION B is comprised of short answer questions. Ensure that this examination paper is complete, i.e. that all pages are present.
2. Failure to submit this paper in its entirety at the end of the examination may result in disqualification.
3. A Periodic Table and physical constants are provided. These are on the last page of the examination and may be detached for use during the examination.
4. Answer each question in the space provided. Should you require more space, use the **back of the page** and **indicate clearly where this has been done**.
5. When answering questions show **all** relevant formulae, **all** calculations, and justify **all** simplifying assumptions.
6. **Correct units** should be maintained in **all** steps of a calculation.
7. Numerical answers should be reported with the **correct significant digits**.

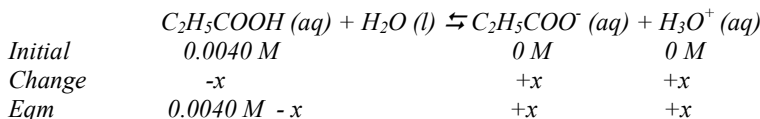
Do not write in the enclosed area below.

Question	Value	Mark
A1	5	
A2	7	
A3	9	
Section B	21	
Total	42	

Section A
Longer Answer Questions
(21 Marks)

The value of each part of a question is given in the square brackets in the left margin beside each question.

- [5] A1. What is the K_a value at 25 °C for propionic acid (C_2H_5COOH) if the percent ionization of a 0.0040 M solution of propionic acid is 5.6%?

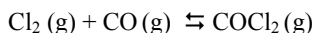


By the definition of percent ionization, we know that

$$\begin{aligned}
 \%_{ion} &= [H_3O^+]_{eqm} / [C_2H_5COOH]_{initial} \\
 \text{Since } [H_3O^+]_{eqm} &= x \text{ this means} \\
 x &= ([C_2H_5COOH]_{initial}) (\%_{ion}) = (0.0040\text{ M})(5.6\%) = 0.000224\text{ M}
 \end{aligned}$$

$$K_a = \frac{[C_2H_5COO^-][H_3O^+]}{[C_2H_5COOH]} = \frac{x^2}{0.0040 - x} = \frac{(0.000224)^2}{0.0040 - 0.000224} = \frac{5.02 \times 10^{-8}}{3.76 \times 10^{-3}} = 1.33 \times 10^{-5}$$

- [7] A2. An **equilibrium** mixture at a particular temperature contains 0.310 M CO (g), 0.140 M Cl_2 (g) and 0.780 M $COCl_2$ (g) in a 2.00 L container. Calculate the number of moles of Cl_2 (g) which must be **added** to the equilibrium mixture in the 2.00 L flask to reduce the concentration of CO (g) to 0.250 M when equilibrium **is re-established** at the same temperature for the chemical system shown below:



For our original system at equilibrium

$$K_c = \frac{[COCl_2]}{[Cl_2][CO]} = \frac{(0.780)}{(0.140)(0.310)} = 18.0$$

(all in mol·L ⁻¹)	$Cl_2(g)$	+	$CO(g)$	\rightleftharpoons	$COCl_2(g)$
Initial []	0.140 + x		0.310		0.780
Change in []	-y		-y		+y
Equilibrium []	0.140 + x - y		0.310 - y = 0.250		0.780 + y

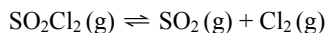
We can see that $y = 0.060\text{ M}$

$$\begin{aligned}
 K_c &= \frac{[COCl_2]}{[Cl_2][CO]} = \frac{(0.780 + y)}{(0.140 + x - y)(0.250)} = \frac{(0.780 + 0.060)}{(0.140 + x - 0.060)(0.250)} = 18.0 \\
 &\text{so } \frac{(0.840)}{(0.080 + x)(0.250)} = 18.0 \\
 &\text{so } 0.080 + x = \frac{(0.840)}{(18.0)(0.250)} = 0.187 \quad \text{so } x = 0.107\text{ M}
 \end{aligned}$$

Which means since we have 2.00 L container we needed to add 0.214 mol of Cl_2 .

Out of interest, this question represents an application of Le Chatalier's principle. If we add Cl_2 to the equilibrium mixture, the system will respond by trying to get rid of the added Cl_2 . The only way it can do this is by reacting some of the new Cl_2 with CO, decreasing the amount of CO and increasing the $COCl_2$ in the new equilibrium mixture.

[9] A3. The reaction



has the equilibrium constant $K_c = 0.011$ at a certain temperature.

A 2.0 L flask starts with 0.30 mol of SO_2 , 0.16 mol of Cl_2 , and 0.50 mol of SO_2Cl_2 . Calculate the equilibrium concentrations of the gases.

If we start with a reaction quotient calculation in terms of concentration, we need the initial **concentrations** of the gases. Since concentration is number of moles divided by volume, the initial concentrations of the gases will be

$$0.15 \text{ mol}\cdot\text{L}^{-1} \text{ of } \text{SO}_2, 0.080 \text{ mol}\cdot\text{L}^{-1} \text{ of } \text{Cl}_2, \text{ and } 0.25 \text{ mol}\cdot\text{L}^{-1} \text{ of } \text{SO}_2\text{Cl}_2$$

$$Q_c = \frac{[\text{SO}_2][\text{Cl}_2]}{[\text{SO}_2\text{Cl}_2]} = \frac{(0.15)(0.080)}{(0.25)} = 0.048 > K_c$$

Since $Q > K$, we expect to lose products and gain reactants, so the ICE table looks like

(all in $\text{mol}\cdot\text{L}^{-1}$)	$\text{SO}_2\text{Cl}_2(\text{g})$	\rightleftharpoons	$\text{SO}_2(\text{g})$	+	$\text{Cl}_2(\text{g})$
Initial	0.25		0.15		0.080
Change	+x		-x		-x
Equilibrium	$0.25 + x$		$0.15 - x$		$0.080 - x$

$$K_c = \frac{[\text{SO}_2][\text{Cl}_2]}{[\text{SO}_2\text{Cl}_2]} = \frac{(0.15 - x)(0.080 - x)}{(0.25 + x)} = 0.011$$

Rearranging, we get

$$\begin{aligned} 0.011(0.25 + x) &= (0.15 - x)(0.080 - x) \\ 0.00275 + 0.011x &= 0.0120 - 0.230x + x^2 \\ x^2 - 0.241x + 0.00925 &= 0 \end{aligned}$$

This is a quadratic equation of the form $ax^2 + bx + c = 0$, which has solutions given by

$$\begin{aligned} x &= \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad \text{so} \quad x = \frac{-(-0.241) \pm \sqrt{(-0.241)^2 - 4(1)(+0.00925)}}{2(1)} \\ x &= \frac{(0.241) + \sqrt{(-0.241)^2 - 4(1)(+0.00925)}}{2} \quad \text{or} \quad x = \frac{(0.241) - \sqrt{(-0.241)^2 - 4(1)(+0.00925)}}{2} \\ x &= \frac{(0.241) + \sqrt{0.05808 - 0.037}}{2} \quad \text{or} \quad x = \frac{(0.241) - \sqrt{0.05808 - 0.037}}{2} \\ x &= \frac{(0.241) + \sqrt{0.02108}}{2} \quad \text{or} \quad x = \frac{(0.241) - \sqrt{0.02108}}{2} \quad \text{so} \quad x = \frac{(0.241) + 0.145}{2} \quad \text{or} \quad x = \frac{(0.241) - 0.145}{2} \\ x &= \frac{0.386}{2} \quad \text{or} \quad x = \frac{0.096}{2} \quad \text{so} \quad x = 0.193 \text{ mol}\cdot\text{L}^{-1} \quad \text{or} \quad x = 0.048 \text{ mol}\cdot\text{L}^{-1} \end{aligned}$$

If we choose $x = 0.174 \text{ mol}\cdot\text{L}^{-1}$ as the answer, then $[\text{SO}_2] = 0.15 \text{ mol}\cdot\text{L}^{-1} - (0.193 \text{ mol}\cdot\text{L}^{-1}) = -0.043 \text{ mol}\cdot\text{L}^{-1}$, which isn't physically possible. Therefore $x = 0.048 \text{ mol}\cdot\text{L}^{-1}$. This means our equilibrium concentrations are

$$\begin{aligned} [\text{SO}_2\text{Cl}_2] &= 0.25 \text{ mol}\cdot\text{L}^{-1} + (0.048 \text{ mol}\cdot\text{L}^{-1}) = 0.298 \text{ mol}\cdot\text{L}^{-1} \\ [\text{SO}_2] &= 0.15 \text{ mol}\cdot\text{L}^{-1} - (0.048 \text{ mol}\cdot\text{L}^{-1}) = 0.102 \text{ mol}\cdot\text{L}^{-1} \\ [\text{Cl}_2] &= 0.080 \text{ mol}\cdot\text{L}^{-1} - (0.048 \text{ mol}\cdot\text{L}^{-1}) = 0.032 \text{ mol}\cdot\text{L}^{-1} \end{aligned}$$

We should check our answer:

$$K_c = \frac{[\text{SO}_2][\text{Cl}_2]}{[\text{SO}_2\text{Cl}_2]} = \frac{(0.102)(0.032)}{(0.298)} = 0.011$$

This is the equilibrium constant we were given, within rounding errors, so we should have the right answer.

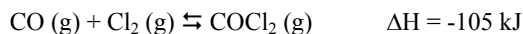
Section B
Short Answer
(21 Marks)

The value of each part of a question is given in the square brackets in the left margin beside each question.

- [1] B1. What is the chemical formula for “slaked lime”?



- [3] B2. Phosgene is formed from carbon monoxide and chlorine:



Briefly explain whether the amount of phosgene increases, decreases or remains the same when an equilibrium system for the above reaction is disturbed by:

- a) decreasing the volume.

*Decreasing the volume increases the total pressure of the system. The system responds by trying to decrease the pressure by shifting towards the side with less moles of gas. For this reaction this is the products, so the amount of phosgene **increases**.*

- b) increasing the temperature.

*Since the reaction is exothermic, increasing the temperature favours the reverse reaction (it's like increasing the concentration of the product “heat”) and so the amount of phosgene **decreases**.*

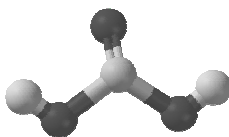
- c) adding sulphur dioxide (SO₂) to the container. Sulphur dioxide reacts with chlorine to form SO₂Cl₂.

*Since sulphur dioxide reacts with chlorine, it decreases the amount of chlorine available to be used in the first reaction. Decreasing the amount of a reactant shifts the reaction from right to left and the amount of phosgene **decreases**.*

- [1] B3. Xenon forms compounds with highly electronegative fluorine and oxygen. In these compounds the xenon often is found in one of four common oxidation states. Give two of these four oxidation states. **Only the first two will be marked**

The common oxidation states of xenon are +2, +4, +6 and +8.

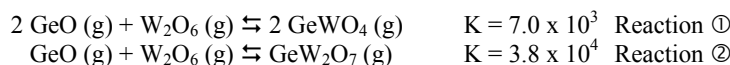
- [1] B4. What is the structure of the **oxoacid** H₂SeO₃ [selenous acid]?



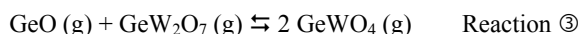
- [2] B5. What are the definitions of a Brønsted-Lowry base and an Arrhenius base. Give an example of a Brønsted-Lowry base that **IS NOT** also an Arrhenius base.

A BL base is a proton acceptor. An Arrhenius base dissociates in water to give OH⁻. NH₃ is an example of BL base while not being an Arrhenius base.

- [2] B6. Suppose in a sealed container that two gas phase equilibria occur at the same time:



What is the equilibrium constant for the following reaction?



When we add reactions ② and ③ we get reaction ①. Adding together equilibria means we multiply equilibrium constants, so

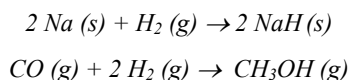
$$\begin{aligned} K_{\textcircled{1}} &= K_{\textcircled{2}} \times K_{\textcircled{3}} \\ \text{so } K_{\textcircled{3}} &= K_{\textcircled{1}} / K_{\textcircled{2}} = 7.0 \times 10^3 / 3.8 \times 10^4 = 0.18 \end{aligned}$$

- [3] B7. What is the pH of a 0.080 mol·L⁻¹ solution of CaO at 25 °C?

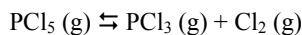
Since CaO is an alkaline earth metal oxide, it is a strong base and will react with water completely such that

$$\begin{aligned} 2 [\text{CaO}]_i &= [\text{OH}^-]_{eq} \\ \text{so } [\text{OH}^-]_{eq} &= 2(0.080 \text{ mol} \cdot \text{L}^{-1}) = 0.16 \text{ mol} \cdot \text{L}^{-1} \\ \text{and } \text{pH} &= 14.00 - \text{pOH} = 14.00 - (-\log [\text{OH}^-]_{eq}) = 14.00 - (-\log 0.16) \\ \text{pH} &= 14.00 - 0.80 = 13.20 \end{aligned}$$

- [2] B8. Hydrogen gas can react with sodium to form sodium hydride. Hydrogen gas can also be used in the formation of methanol by the reduction of carbon monoxide. What are the balanced equations for these two reactions?



- [3] B9. The reaction



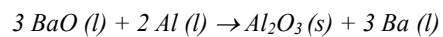
has the equilibrium constant $K_p = 11.5$ at 300 °C. Calculate the equilibrium constant K_c for this reaction at 300 °C.

$$\begin{aligned} K_p &= K_c (RT)^{\Delta n} \text{ where } \Delta n = (\text{moles of product gases} - \text{moles of reactant gasses}) \\ K_c &= K_p / (RT)^{(2-1)} \\ K_c &= K_p / (RT)^1 \\ K_c &= K_p / (RT) \\ K_c &= (11.5) / [(0.08206)(573)] \\ \text{note } T &\text{ is in Kelvin and the specific value of } R \text{ used!} \\ K_c &= 0.244 \end{aligned}$$

- [1] B10. What is the characteristic colour of sodium in a Bunsen burner flame?

Yellow

- [1] B11. What is the balanced equation for the production of liquid barium from the reaction of liquid barium oxide by liquid aluminum?



- [1] B12. Which two noble gases are used in lasers?

Kr and Xe

The End