Name_____GSI_____

Chemistry 1A, Fall 2008

KEY

Midterm Exam #2
October 14, 2008
(90 min, closed book)

Name:_____ _____
SID:_____
GSI Name:_____

- The test consists of 4 short answer questions and 11 multiple choice questions.
- Put your written answers in the boxes provided. Answers outside the boxes may not be considered in grading.
- Show your work to receive the maximum credit possible.
- Write your name on every page of the exam.

	Page	Points	Score
Question A	2	15	
Question B(i-vii)	3	17	
Question B (viii-ix) Question C (bonus)	4	6	
Question D	5	27	
Question E	6	13	
Question F and G (multiple choice)	7-8	24	
Total		100	

Useful Equations and Constants:

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

$pX = - \log X$

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

$N_0 = 6.02\times10^{23}$ 1/mol

Strong acids and bases:

HCl	LiOH
HNO_3	NaOH
H_2SO_4	KOH
$HClO_4$	
HBr	
HI	

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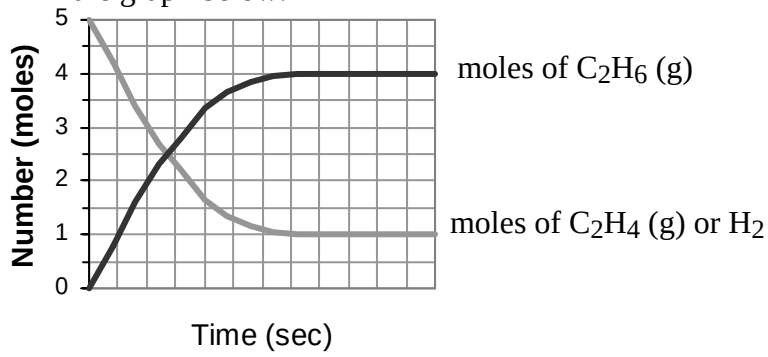
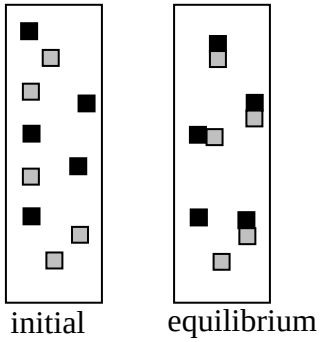
A) Gas Phase Equilibria

Consider the reaction between ethylene, C_2H_4, and hydrogen, H_2 to form ethane, C_2H_6.

$$C_2H_4\,(g) + H_2\,(g) \leftrightarrows C_2H_6\,(g)$$

The progress of a reaction between 5.0 moles of C_2H_4 (g) and 5.0 moles of H_2 (g) is shown in the graph below.





i. What is the equilibrium constant for the reaction? Assume the reaction container is 1.0 liter. Show your work.

$$K_{eq} = \frac{[C_2H_6]}{[C_2H_4][H_2]} = \frac{(4.0\,M)}{(1.0\,M)(1.0\,M)} = 4.0$$

Imagine that the same reaction starts with the ethylene, C_2H_4 (g), and hydrogen, H_2 (g) reactants only. This reaction mixture results in the moles listed below <u>at equilibrium</u>.

moles ethylene, C_2H_4 (g) at equilibrium = 1.0 moles
moles hydrogen, H_2 (g) at equilibrium = 0.50 moles
moles ethane, C_2H_6 (g) at equilibrium = 2.0 moles

ii. How many moles of ethylene, C_2H_4 (g), and hydrogen, H_2 (g) were present at the start of the reaction?

	C_2H_4 (*g*)	+	H_2 (*g*)	⇆	C_2H_6 (*g*)
Initial	X		Y		0
Change	-2.0		-2.0		+2.0
Equilibrium	1.0		0.50		2.0

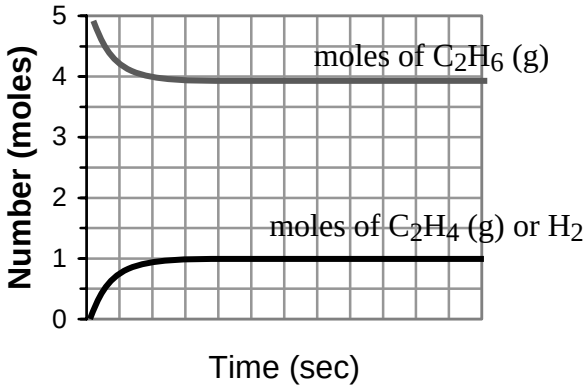
X – 2.0 = 1.0, X = moles of C_2H_4 (*g*) = 3.0 moles
Y – 2.0 = 0.50, Y = moles of H_2 (*g*) = 2.5 moles

Imagine that the same reaction begins with 5.0 moles of ethane, C_2H_6 (g) and no reactants.

iii. moles C_2H_6 + moles C_2H_4 = ____5.0 moles_____

iv. moles C_2H_6 + moles H_2 = _____5.0 moles____

v. Draw a graph showing the progress of the reaction. Label the curves showing all 3 molecules.



may have reasoned it out or done ICE table, if ICE then $4x^2 - x - 5 = 0$ and x = 1 = moles C_2H_4 and H_2

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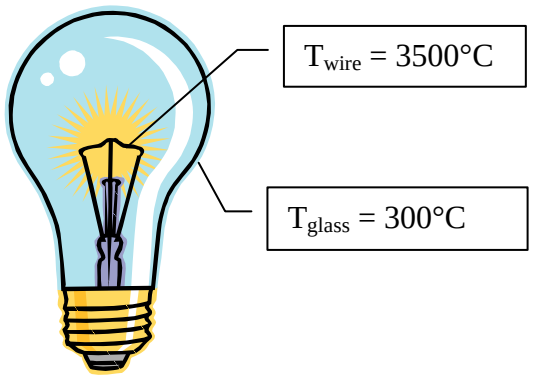
B) Heterogeneous Equilibria

The common light bulb has a thin wire made of tungsten, W, in a glass bulb with all the air removed. The tungsten wire glows when it is heated with an electric current. If the tungsten wire breaks, the light bulb no longer lights.



i. Write the chemical equation for the sublimation of tungsten.

$$W(s) \leftrightarrows W(g)$$

ii. Write the equilibrium expression for the sublimation of tungsten.

$$K_P = P_{W(g)} \quad \text{or} \quad K_{eq} = [W(g)]$$

iii. For the sublimation reaction, K (300°C) < K (3500°C). Explain why.

Heat is required to convert tungsten solid to gas (endothermic). Increasing the heat will favor more products (tungsten in gas form). Since the K expression is only dependent on the products formed, increasing the pressure or concentration of the products increases the value of K.

After the light bulb is in use for a long time, you can observe a black substance coating the glass. Eventually, the light bulb no longer lights.

iv. What is the black substance?____W (*s*)____

v. Why does it deposit on the inside of the glass bulb?

The glass bulb is cooler than the tungsten filament. As the tungsten gas comes in contact with the cooler surface, some of the tungsten gas deposits as solid. Another way to explain this could be, since K decreases with lower temperatures, less product is favored so some of the tungsten gas deposits on the glass.

Light bulbs with a small amount of iodine gas, I_2, are called tungsten-halogen light bulbs. Iodine reacts with tungsten according to the chemical equation given on the left below.

$$W(s) + 3\,I_2(g) \leftrightarrows WI_6(g)$$

For this reaction, K (300°C) > K (3500°C)

vi. What happens when you raise the temperature?

favors reactants more favors products more no preference

vii. Explain why the addition of iodine makes the light bulbs last longer.

The sublimation of tungsten is favored at higher temperatures and the solid tungsten gets "used up" as it is converted to a gas. Since the reaction with Iodine favors the reactants, I_2 (g) and W (s), more at higher temperatures, more W(s) will deposit back onto the filament rather than on the cooler outside of the glass.

B) Heterogeneous Equilibria (continued)

All of the air has been removed from inside the glass bulb, but there is always a small amount of water. The water reacts with the tungsten according to the chemical equation given below.

$$W\,(s) + 4\,H_2O\,(g) \leftrightarrows WO_2(OH)_2\,(g) + 3\,H_2\,(g)$$

viii. Balance the reaction.

ix. How would you classify this reaction? single exchange or single displacement or redox

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C) Bonus Point

What is the chemical analogy to this cartoon?

Equilibrium reactions vs. product-favored reactions

Customers (exiting) ⇆ Customers (entering) **VS.** *Customers (exiting) → Customers (entering)*

The left "reaction" is at equilibrium with K≈1 and the right "reaction" favors products (customers entering) with a K>>1.

D) Lakes and Ksp

A lake is surrounded by rocks containing gypsum, a mineral with the chemical formula $CaSO_4(s)$ ($K_{sp}=1.9\times10^{-4}$) and magnesite, a mineral with the chemical formula $MgCO_3(s)$ ($K_{sp}=6.8\times10^{-6}$).

i. List at least three ions you would expect to find in the lake as a result of the dissolution of the minerals near the lake. *Be sure to include the correct charge on each ion.*

i. Mg^{2+} ii. Ca^{2+} iii. SO_4^{2-} CO_3^{2-} maybe even HCO_3^- , HSO_4^-

ii. If gypsum, $CaSO_4$ (s), is dissolved in pure water, what would the equilibrium concentration of calcium ions be? Show your work.

	$CaSO_4$ (*s*)	⇆	Ca^{2+} (*aq*)	+	SO_4^{2-} (*aq*)
I	-----		0		0
C	-----		+ s		+ s
E	-----		s		s

$K = [Ca^{2+}(aq)][SO_4^{2-}(aq)] = 1.9 \times 10^{-4}$

$K = (s)(s) = s^2 = 1.9 \times 10^{-4}$

$s = 0.014\ M = [Ca^{2+}]$

concentration of calcium ions = $[Ca^{2+}]= 0.014\ M$

The water in this lake is found to have a Ni^{2+} concentration of 1.0×10^{-5} M. A river that feeds the lake brings the OH^- concentration to 1.0×10^{-6} M where the lake and river water meet. The $K_{sp} = 6.5\times10^{-18}$ for $Ni(OH)_2$.

iii. Write the chemical equation.

$$Ni(OH)_2\ (s) \leftrightarrows Ni^{2+}\ (aq) + 2\ OH^-\ (aq)$$

iv. Write the equilibrium expression.

$$K_{sp} = [Ni^{2+}][OH^-]^2$$

v. What is the value of Q when the river meets the lake?

$$Q = [Ni^{2+}][OH^-]^2$$

$$Q = (1.0x10^{-5})(1.0x10^{-6})^2 = 1.0x10^{-17}$$

vi. Will $Ni(OH)_2$ (s) precipitate? *yes (Q > K, so reaction favors reactants)*

vii. Suppose that a lake is saturated with dissolved $MgCO_3$ (s). If more $MgCO_3$ (s) is added to the water, the concentration of aqueous magnesium ions will (circle the correct answer):

increase **stay the same** decrease

viii. Explain your reasoning.

If the lake is saturated, then the maximum concentration of Mg^{2+} ions are already dissolved. Adding additional $MgCO_3$ (s) will just sink to the bottom. The rate of the dissolution of Mg^{2+} may increase, but the rate of precipitation will increase the same amount and the concentration of Mg^{2+} ions remains constant.

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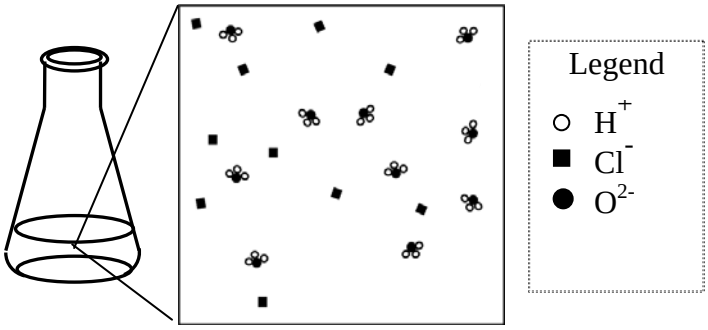
E) Lab and Lecture Linked

In the laboratory experiment, *Determination of the Molarity of a Strong Acid*, you determined the concentration of a concentrated stock solution of HCl.

i. From the molecular picture shown below, calculate the concentration of the HCl solution. The volume of the solution shown is 1.52×10^{-23}L. Show your work.

10 molecules of H_3O^+ present



$$10\,mcls\,H_3O^+ \cdot \frac{1\,mol\,H_3O^+}{6.02x10^{23}\,mcls\,H_3O^+}$$

$$= 1.66x10^{-23}\,mol\,H_3O^+$$

$$\frac{1.66x10^{-23}\,mol\,H_3O^+}{1.52x10^{-23}\,L} = 1.09\,M\,H_3O^+$$

$1.09\,M\,H_3O^+$ M HCl

To make a solution that is easier to use for a titration, it is necessary to dilute the solution. You pipet 10.00 mL of the concentrated solution above into a 50.00 mL volumetric flask and dilute to the mark with distilled water.

ii. After mixing thoroughly, what is the concentration of this solution?

$$M_1V_1 = M_2V_2$$
$$(1.09\ M)(0.01000\ L) = M_2(0.05000\ L)$$
$$M_2 = 0.219\ M$$

0.219 M M HCl

iii. For the same volume of solution shown in the picture above, how many H_3O^+ molecules would be in a picture of the diluted solution?

2 H_3O^+ molecules

iv. Explain your answer in words or equations.

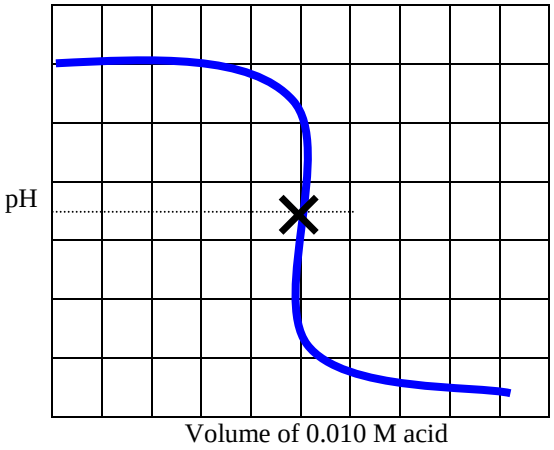
$$\frac{0.219\,moles\,H_3O^+}{1.0\,L} \cdot 1.52x10^{-23}\,L \cdot \frac{6.02x10^{23}\,mcls\,H_3O^+}{1\,mol\,H_3O^+} = 2\,mcls\,H_3O^+$$

or

M_1:M_2 = 1.09/0.219 = 5:1
If there are 10 molecules in the concentrated flask, then there should be 2 molecules in the diluted flask to maintain the 5:1 ratio.

F) Titration Curves

The titration of 20 mL of 0.010 M NaOH with 0.010 MHCl is shown for your reference in the graph below. The dotted line indicates pH of 7.



For the following questions mark all that apply. Mark your exam and your scantron form. The scantron machine can read multiple marks.

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1) If the concentration of HCl was doubled, which of the following would be true?

A) the initial pH would be lower
B) the initial pH would be higher
C) the pH at the equivalence point would be lower
D) the volume at the equivalence point would be smaller

---

2) If the concentration of NaOH was doubled, which of the following would be true?

A) the initial pH would be lower
B) the initial pH would be higher
C) the pH at the equivalence point would be lower
D) the volume at the equivalence point would be smaller

---

3) If the NaOH was replaced with 0.020 M NH_3, which of the following would be true?

($K_b = 1.8\times10^{-5}$)

A) the initial pH would be lower
B) the pH at the equivalence point would be lower
C) the volume at equivalence would be smaller
D) the pH at ½ equivalence would be lower

---

4) Examine the data past the equivalence point in the reference graph. The pH is low and keeps getting lower. This is because ...

A) the hydronium ion (H_3O^+) concentration is decreasing
B) there is excess strong acid in solution
C) the solution is getting more dilute as the titration proceeds
D) the conjugate base makes the pH drop

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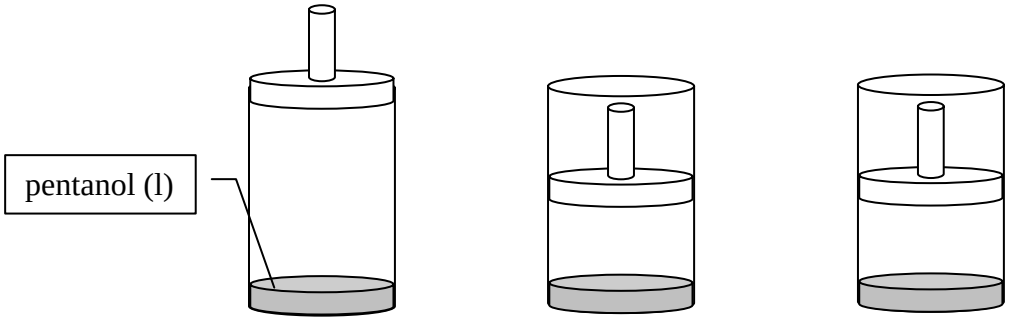
G) Vapor Pressure

Shown below is a sample of liquid pentanol placed in a cylinder by a moveable piston and allowed to reach equilibirum. The piston is then pushed down so the volume of the cylinder is half of what it was originally. Assume the temperature is constant at 25°C for the process.



time = 0 sec time = 0.0001 sec time = 1000 sec

$CH_3CH_2CH_2CH_2CH_2OH$ (l) ⇆ $CH_3CH_2CH_2CH_2CH_2OH$ (g) K (25°C) = $P_{pentanol} = 2.1\times10^{-3}$

5) At time = 0 sec, what is the pressure inside the cylinder?	A) 0 atm	B) 2.1×10^{-3} atm	C) 4.2×10^{-3}atm	
6) At time = 0 sec, which is true?	A) Q < K	B) Q > K	C) Q = K	D) K = 1
7) In the instant that the piston is lowered (t = 0.0001 sec) which is true?	A) Q < K	B) Q > K	C) Q = K	D) K = 1
8) Compare the system at 0 sec and 1000 sec, Which is true for the process?	A) $P_{pentanol}$ increases	B) $P_{pentanol}$ decreases	C) $P_{pentanol}$ stays the same	
9) Compare the system at 0 sec and 1000 sec, Which is true for the process?	A) moles vapor increases	B) moles of vapor decreases	C) moles of vapor stay the same	
10) If the liquid in the container was hexane (C_6H_{14}) instead of pentanol ($C_5H_{12}O$) which is true?	A) $K<2.1\times10^{-3}$	B) $K>2.1\times10^{-3}$	C) $K=2.1\times10^{-3}$	

11) The best explanation for my previous answer is...?

A) the molar mass of the compounds is about the same

B) both have van der Waals attractions (London forces) of about the same magnitude

C) pentanol can form hydrogen bonds

D) OH bonds are stronger than CH bonds

E) K should be the same at the same temperature