Name_____

Chemistry 1A, Fall 2007

KEY

Midterm Exam #2
October 16, 2007
(90 min, closed book)

Name:_____

SID:_____

GSI Name:_____

- The test consists of 6 short answer questions and a page of 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.

Question	Page	Points	Score
Question 1	2	10	
Question 2	3	6	
Question 3	3	8	
Question 4abc	4	12	
Question 4def	5	10	
Question 5	5	8	
Question 6	7	14	
Multiple Choice	8	12	
Total		80	

Useful Equations and Constants:

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

$pX = - \log X$

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

Strong acids and bases:

HCl	LiOH
HNO_3	NaOH
H_2SO_4	KOH
$HClO_4$	
HBr	
HI	

Name_____

Acid-base chemistry (10 points)

1. A group of students measures and records the pH of each of the 0.10 M aqueous acid solutions shown below:

pH = 1.1 pH = 2.4 pH = 2.9 pH = 5.1

a) List the four acids in order of increasing dissociation.

D < C < B < A

b) Based on this information, Marco states that "The solution of pH 1.1 will require the most base to titrate it to the equivalence point since it is the strongest acid and its pH is the farthest away from 7."

Jovan disagrees: "I think that all four solutions will require the same amount of base to reach the equivalence point because they all contain the same concentration of acid."

Katrina does not agree with either of these statements: "Since we don't know the identity of the acids, we can't determine which one will require the most base to titrate it to the equivalence point."

Which student do you agree with?

_____I agree with Marco.

_____I agree with Jovan.

_____I agree with Katrina.

_____I don't agree with any of them.

c) Explain your reasoning.

Several logical explanations are acceptable.

- *I agree with Jovan- assume same volume, given same concentration, each flask contains the same number of moles of acid so will require the same number of moles of base to titrate*
- I agree with *Katrina- we are not told whether or not all the acids are monoprotic so they might take different amounts of base to titrate to equivalence, a diprotic acid will take twice as much base to titrate it fully*
- *I don't agree with any of them.- we can't assume the solutions of acid all have the same volume so although the concentrations are equal, we don't know the moles of acid in each flask*

Name_____

Two-phase equilibria (6 points)

2. Suppose that you establish an equilibrium between NH_3 (g) and NH_3 (aq) in a closed 2.0 L container at 25°C.

$$NH_3\ (g) \rightleftharpoons NH_3\ (aq)$$

For each of the following, circle the correct answer:

a) If the pressure of NH_3 (g) is increased, the molar concentration of NH_3 (aq) will:

[increase] stay the same decrease

b) If the temperature is increased from 25°C to 80°C, the molar concentration of NH_3 (aq) will:

increase stay the same [decrease]

c) If the total pressure is increased by adding air, the molar concentration of NH_3 (aq) will:

increase [stay the same] decrease

Solubility equilibria (8 points)

3. Consider the solubility of $Cu(OH)_2$.

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

a) The pH of a solution of 1 mole $Cu(OH)_2$ (s) dissolved in 1.0 L of water is 7.66. Does all the $Cu(OH)_2$ dissolve?

yes [no] not enough information

b) Determine the solubility of $Cu(OH)_2$ in 1.0 M NaOH (aq). The K_{sp} is 4.8×10^{-20}.

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

equilibrium ***S*** ***1M***

$$\boldsymbol{Ksp = 4.8\times10^{-20} = [Cu^{2+}]\,[OH^-]^2 = [Cu^{2+}]\,[1M]^2}$$

$$\boldsymbol{[Cu^{2+}] = 4.8\times10^{-20}}$$ ***which is the solubility of the salt***

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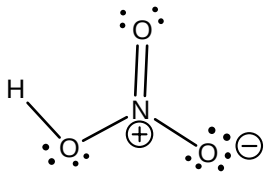
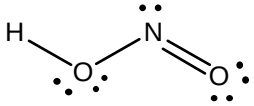
Acid-Base Equilibria (12 points)

4. NO_2 gas can dissolve in water and react to make acids. This pollutant is one of the causes of acid rain

$$2NO_2\,(g) + H_2O\,(l) \rightleftharpoons HNO_3\,(aq) + HNO_2\,(aq)$$

nitric acid nitrous acid





a) Write the chemical reaction for the reaction of nitric acid with water. Circle the conjugate base of HNO_3.

$$HNO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + (NO_3^-(aq))$$

b) Write the chemical reaction for the reaction of nitrous acid with water. Circle the conjugate base of HNO_2.

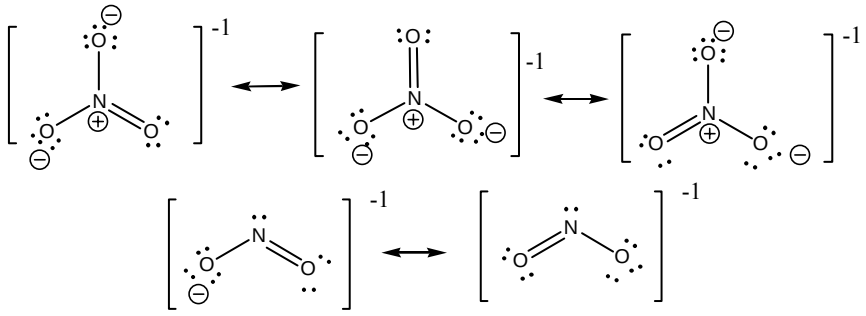
$$HNO_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + (NO_2^-(aq))$$

c) Based on the relative stabilities of the conjugate bases produced, which acid is stronger? Circle one and explain your reasoning.

(nitric acid) nitrous acid

NO_3^- is more stable than NO_2^- because it has more oxygens. Oxygen is electronegative and will stabilize the extra e^- in the ion.

Also, NO_3^- has 3 resonance structures while NO_2^- has only two. Resonance allows the electron density to be spread over the entire molecule further lowering the energy of the ion.



#4) Continued (10 points)

d) A buffer solution is made by mixing HNO_2 and $NaNO_2$. What is the pH of a 1.00 L buffer solution that is 0.100 M HNO_2 and 0.150 M $NaNO_2$?

($K_a = 4.3 \times 10^{-4}$) ***pKa = -log K_a*** ***pKa = 3.37***

$$pH = pKa + \log \frac{[A^-]}{[HA]}$$ ***pH = 3.37 + log (0.150NO_2^-/0.100HNO_2) = 3.55***

e) Consider adding a strong base to a buffer. Write the chemical reaction that occurs when the strong base NaOH reacts with the buffer solution from part 4d.

HNO_2 (aq) + NaOH (aq) → $NaNO_2$ (aq) + H_2O (l)

f) If you add 20.00 mL of 1.00 M NaOH to the solution, estimate the resulting pH. (circle one)

1 2 3 4 5 6 7 8 9

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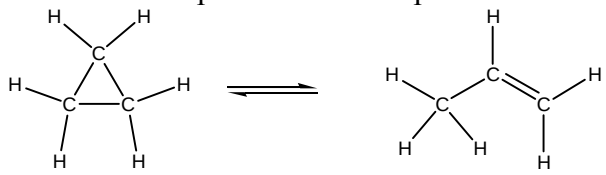
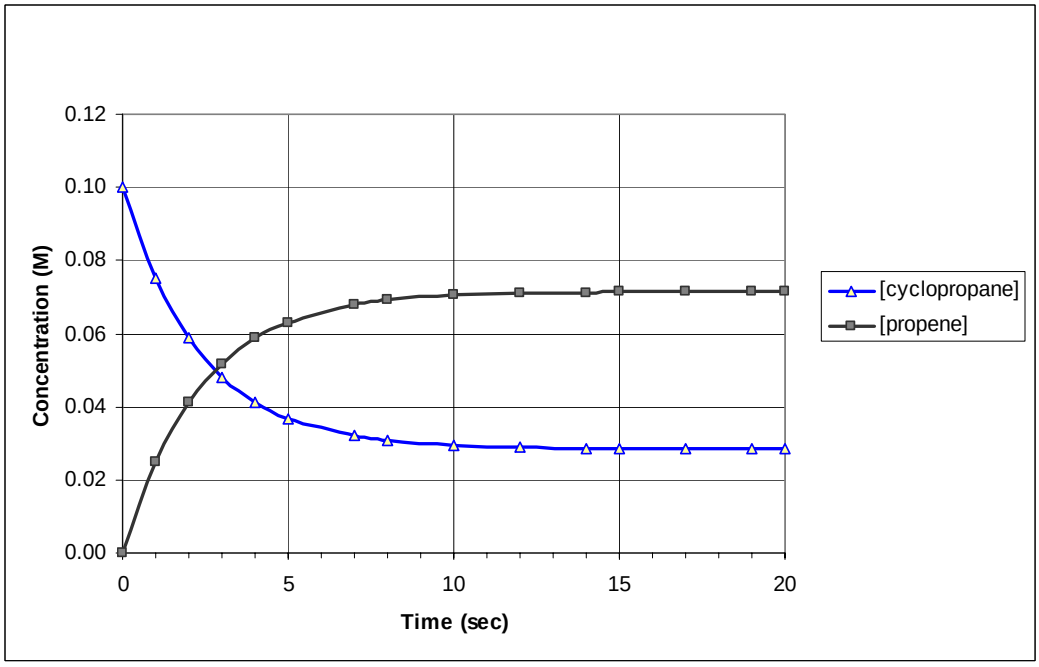
Equilibrium (8 points)

5. Cyclopropane can convert to propene. Given the reaction and data below, answer the following questions. Assume that pressure and temperature are constant.





a) Which is true for the reaction at 2 seconds? (circle one)

$\boxed{Q < K}$ $\quad Q = K \quad Q > K$

b) Which is true for the reaction at 17 seconds? (circle one)

$Q < K \quad \boxed{Q = K} \quad Q > K$

c) What is the value of the equilibrium constant for the reaction?

$$K = \frac{[propene]}{[cyclopropene]} = \frac{0.07M}{0.03M} = 2.3 \text{ (or just 2 with 1 sig fig)}$$

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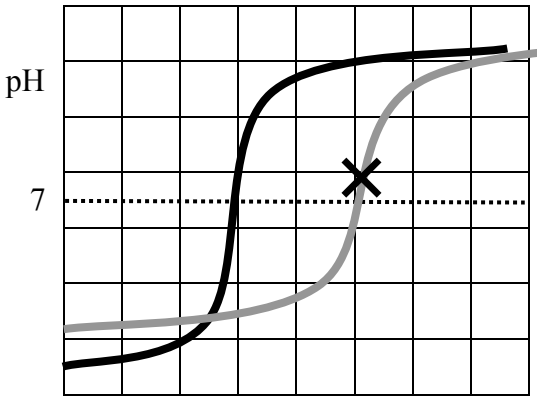
Titration Curves (14 points)

6. The titration curve of 30 mL 0.10 M HCl with 0.10 M NaOH is shown for your reference in the graph below. The dotted line indicates pH of 7.



a) Roughly sketch a second titration curve on the graph above for 60 mL of 0.10 M formic acid, HCOOH, ($K_a = 1.8 \times 10^{-4}$) that is titrated with 0.10 M NaOH.

b) Explain your choice for initial pH. Rigorous calculations are not needed.

Since formic acid is a weak acid, it will not completely dissociate in water so the pH will be higher than 1. It is an acid so the pH will be less than 7.

c) Mark the equivalence point on the curve you drew with an "x".

d) Explain your choice for the pH at equivalence.

At equivalence all the initial moles of HCOOH has been reacted. The major species in solution is the conjugate base, $HCOO^-$. This ion can take a proton from water making the solution basic. The pH should therefore be slightly basic.

e) Explain your choice for the equivalence volume.

Since the formic acid has the same concentration as the HCl but twice the volume, the moles of acid are doubled with respect to the reference solution. The amount of base needed to titrate the HCOOH will be twice that for the HCl.

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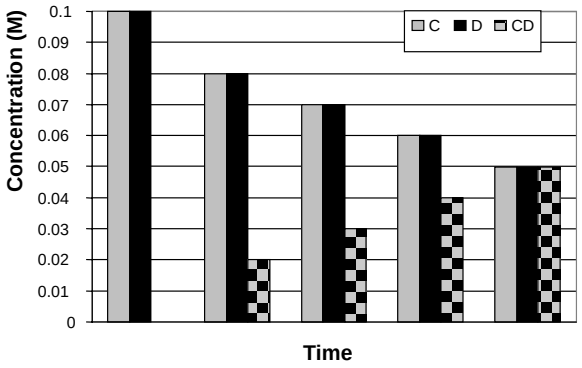
Multiple Choice, Fill in the Blank (12 points)

7. Which acid is the strongest? A. BrOH B. CH_3OH C. KOH

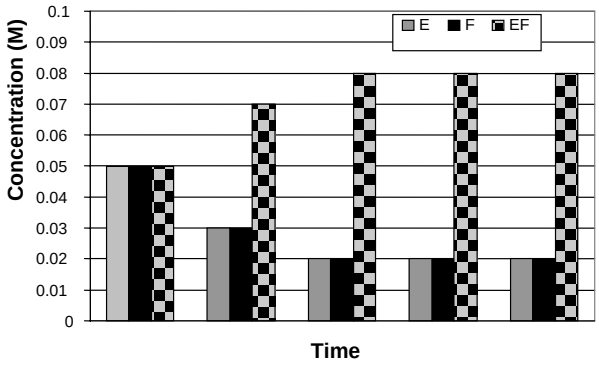
8. Which mixture is most resistant to changes in pH:
   A. HCl and NaCl B. NH_4Cl and NH_3 C. HBr and NaBr

9. The two sets of graphs below show how the concentrations of the species in two different chemical reactions change over time. Circle the reaction that is at equilibrium.

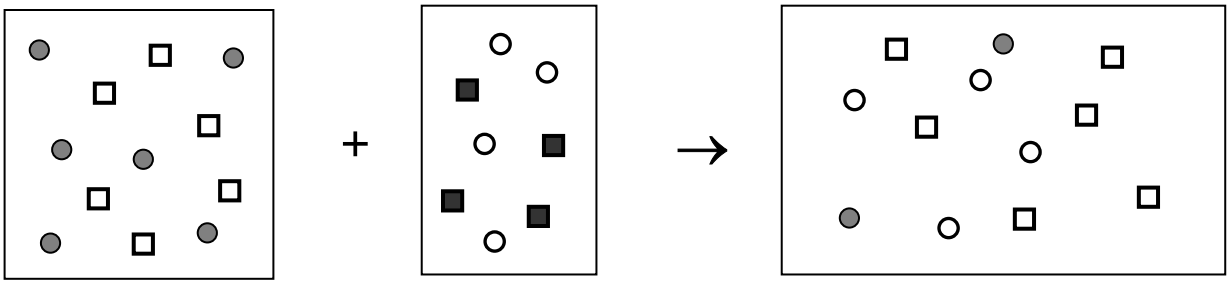
$C + D \rightleftharpoons CD$



$E + F \rightleftharpoons EF$



10. Sketch the product of the reaction in the box provided.



● H_3O^+ □ Cl^- ○ Na^+ ■ OH^- white background = water

11. Predict the products of the reaction below. Be sure to balance the equation.

$Ca^{2+}(aq) + 2\,NO_3^-(aq) + 2\,K^+(aq) + 2\,F^-(aq) \rightarrow$

$CaF_2(s) + 2\,NO_3^-(aq) + 2\,K^+(aq)$ _____

$K_{sp}\,[Ca(NO_3)_2] = 1.6 \times 10^3$
$K_{sp}\,[CaF_2] = 3.5 \times 10^{-11}$
$K_{sp}\,[KNO_3] = 1.3 \times 10^6$
$K_{sp}\,[KF] = 8.7 \times 10^5$