

CHEMISTRY 104-4

Spring , 2006, FINAL EXAM **A**

NAME Key

Section \_\_\_\_\_ T.A. \_\_\_\_\_

1. This exam has 11 pages, counting the cover sheet and 3 supplementary pages. If a page is missing, take the exam to a proctor immediately.
2. PRINT your name now at the top of this page, and your name or initials at the top of pages 2-8.
3. It will help us if you detach the supplementary sheets.
4. Show work for all mathematical problems. If you give a correct answer without showing work points will be deducted. In addition, it will be impossible to assess whether partial credit is deserved if work isn't shown.
5. Give proper units, when appropriate. Correct use of significant figures is always important.
6. There are 125 points on this exam. The score of this exam will be entered into the grade sheet at Learn@UW. In the final grade calculation, this score will be doubled.
7. The exam must be completed in 120 minutes. Budget your time for each question. Check your work after completing the exam

**PLAN FOR 15 OR LESS MINUTES PER PAGE (7 X 15 MIN -- 1 hour 45 min).**

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Page 3		/14
Page 4		/18
Page 5		/12
Page 6		/33
Page 7		/15
Page 8		/15
Total		/125

## Part I (Organic) 32 pts (16 questions, 2 points each)

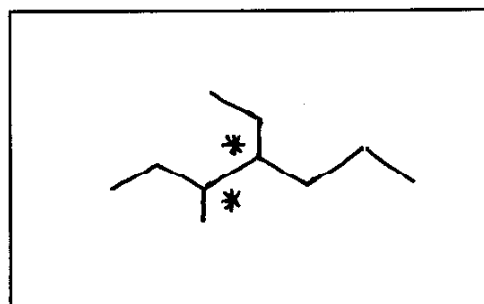
1. What hybridization is assigned to the carbonyl carbon of a ketone?

sp<sup>2</sup>

2. What is the carbon-carbon bond order in benzene?

1.5

3. Draw the structure of 3-methyl-4-ethylheptane. Indicate any carbon atom(s) that is/are chiral with an asterisk.

4. Write a balanced chemical equation for the reaction involving addition of H<sub>2</sub>O to ethene.

5. Does 2-methyl-2-butene exist as cis- and trans- isomers?

NO6. A breathalyzer is a device that changes color from yellow (from Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>) to grey green (Cr<sup>3+</sup>) if ethanol is present. What chemical reaction of ethanol is occurring to cause this color change (word answer)?oxidation of ethanol

7. Give the formulas for the products of hydrolysis of ethyl propanoate.



8. What is the general formula for an aldehyde?

RCHO

9. The fact that chlorination of methane is initiated by light and gives a mixture of chlorinated products is evidence for what kind of mechanism?

free radical

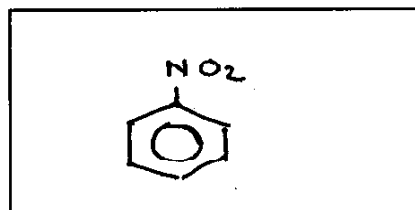
10. Write a balanced chemical equation for the polymerization of ethylene.



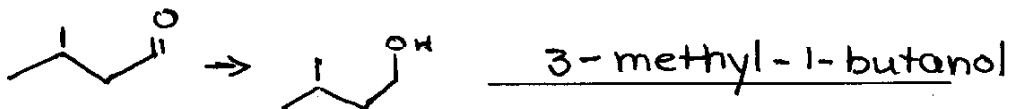
11. What property of a polymer is a direct consequence of cross-linking of polymer chains?

rigidity

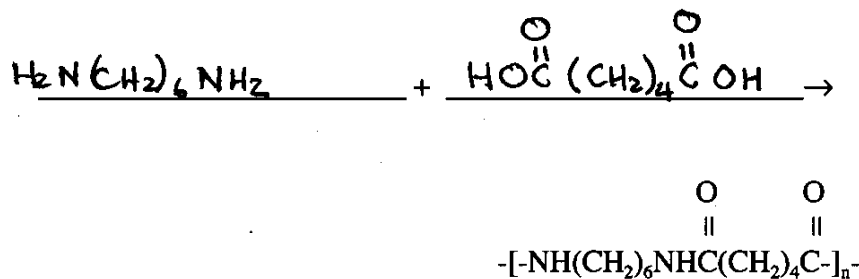
12. Draw the structure of the product of a reaction of benzene with a mixture of nitric and sulfuric acids.



13. Name the product that is formed by reduction (using  $\text{LiAlH}_4$ ) of 3-methylbutanal.



14. Give the formulas for the reactants in this polymerization.



15. What does the term "primary structure" of a protein describe?

sequence (order) of amino acids

16. You discover an old sample of aspirin that smells like acetic acid. What reaction of aspirin has occurred to form acetic acid?

hydrolysis of aspirin

## Part II. Kinetics and Equilibrium (5 Questions, each worth 6 points)

1. Data for the reaction  $2 \text{NO}(\text{g}) + 2 \text{H}_2(\text{g}) \rightarrow \text{N}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{g})$  are given below:

	[NO]	[H <sub>2</sub> ]	N <sub>2</sub> formation, Initial Rate (mol/L·s)
1.	0.42 M	0.24 M	0.284
2.	0.14 M	0.24 M	0.0315
3.	0.42 M	0.36 M	0.426

*Handwritten notes: (1/3) change by (1/3)<sup>2</sup>*

a) What is the rate law for this reaction?

$$\text{rate} = k [\text{NO}]^2 [\text{H}_2]$$

b) What is the rate constant for the reaction?

$$k = \frac{0.284}{[0.42]^2 [0.24]} =$$

$$6.7 \frac{\text{L}^2}{\text{mol}^2 \cdot \text{s}}$$

c) If the rate of formation of N<sub>2</sub> is 0.284 mol/L·s, (in Exp. 1) what is the rate of formation of H<sub>2</sub>O?

$$0.568 \frac{\text{mol}}{\text{L} \cdot \text{s}}$$

2. The decomposition of CH<sub>3</sub>N=NCH<sub>3</sub> to form C<sub>2</sub>H<sub>6</sub> and N<sub>2</sub> is a first order reaction, with a rate constant of 0.289 h<sup>-1</sup>. What fraction of this compound will remain after 8 hrs?

$$\ln \frac{[A]}{[A_0]} = -0.289 \text{ h}^{-1} \times 8 \text{ h}$$

$$= -2.312$$

(or 9.9%)

$$\frac{[A]}{[A_0]} = 0.099$$

Fraction 0.099

3. Which of the statements below about reaction rates and mechanisms are correct? Identify the correct statements by entering T (true) or F (false) in the line.

- F a) In the presence of a catalyst, there are more collisions between reactant molecules.
- T b) At higher temperature a larger fraction of molecules have enough energy to get over the activation energy barrier.
- T c) The average kinetic energy of gaseous reactant molecules depends only on temperature.
- T d) It is possible to predict a rate law for a single step reaction.
- T e) A graph of  $\ln k$  vs.  $1/T$  will give a straight line.
- T f) It is possible to predict a rate law of a multiple step reaction if the mechanism is known.

4. Ammonia decomposes on heating at 450 °C until equilibrium is reached:  $2 \text{NH}_3(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 3 \text{H}_2(\text{g})$ . A 0.36 mole sample of  $\text{NH}_3$  was placed in a 1.0 L flask. At equilibrium, one-third of the  $\text{NH}_3$  had decomposed. Calculate equilibrium concentrations of all species; then calculate the equilibrium constant K

	$[\text{NH}_3]$ , mol/L	$\text{N}_2$ [mol/L]	$[\text{H}_2]$ mol/L
I	0.36	0	0
C	-0.12	+0.06	+0.18
E	0.24	0.06	0.18

$$K = \frac{(0.06)(0.18)^3}{(0.24)^2} = 6.1 \times 10^{-3}$$

$$K = \underline{6.1 \times 10^{-3}}$$

5. Assume the following system is at equilibrium:  $2 \text{NH}_3(\text{g}) \xrightleftharpoons{\text{heat} +} \text{N}_2(\text{g}) + 3 \text{H}_2(\text{g})$ . A series of stresses are applied; How do  $[\text{NH}_3]$  and  $K_c$  change as the system returns to equilibrium? Write I (increase), D (decrease) or N (no change). The heat of formation of  $\text{NH}_3$  from the elements,  $\Delta H_f^\circ$ , is -45.9 kJ/mol

Stress	Effect on $[\text{NH}_3]$	Effect on $K_c$
a) The volume of the container is increased	D	N
b) The temperature is lowered	I	D
c) More $\text{H}_2$ is added	I	N

## Part III. Acids, bases, aqueous equilibrium. 33 pts (11 questions, each worth 3 pts.)

1. List the following bases in order of increasing base strength:  $\text{H}_2\text{O}$   $\text{CO}_3^{2-}$   $\text{OH}^-$   $\text{F}^-$  least  $\text{H}_2\text{O}$   $\text{F}^-$   $\text{CO}_3^{2-}$   $\text{OH}^-$  highest

2. Is the reaction  $\text{HF} + \text{Ac}^- \rightleftharpoons \text{HAc} + \text{F}^-$  product- or reactant-favored?

product favored

3. What is the conjugate base of  $\text{HCO}_3^-$ ?

$\text{CO}_3^{2-}$

4. Is the pH at the equivalence point of a titration of  $\text{NH}_3$  with  $\text{HCl}$  7 >7 <7?

< 7

5. What is the pH at the half neutralization point in the titration of  $\text{HAc}$  with  $\text{NaOH}$ ?

4.74

6. Calculate the pH of a buffer solution composed of 0.50 M  $\text{NaHCO}_3$  and 0.25 M  $\text{Na}_2\text{CO}_3$ .

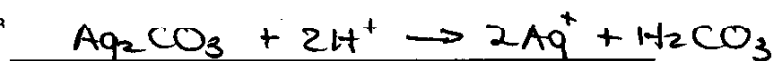
$$\text{pH} = \text{p}K_a + \log \frac{0.25}{0.50}$$

$$= 10.32 - 0.30 = 10.02$$

pH = 10.02

7. Write the net ionic equation for the reaction of silver carbonate and  $\text{HNO}_3$ .

(or  $\text{H}_2\text{O} + \text{CO}_2$ )



8. Identify the least soluble salt among the following:  $\text{AgBr}$   $\text{FeCO}_3$   $\text{BaSO}_4$   $\text{CuBr}$

$\text{AgBr}$

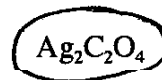
9. Which of the following silver salts is expected to be soluble in  $\text{HNO}_3$ ? Circle all correct answers.



$\text{AgCl}$



$\text{AgI}$



10. The solubility of  $\text{Co}(\text{OH})_2$  is  $6.9 \times 10^{-6}$  mol/L. Calculate its  $K_{sp}$ .

$$K_{sp} = (6.9 \times 10^{-6})(13.8 \times 10^{-6})^2$$

$$= 1.3 \times 10^{-15}$$

$K_{sp} = \underline{1.3 \times 10^{-15}}$

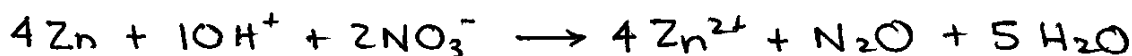
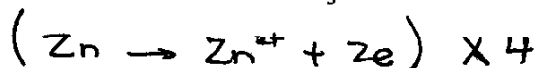
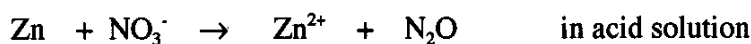
11. What equilibrium constants are needed to calculate the equilibrium constant for the reaction  $\text{AgCN} + \text{CN}^- \rightleftharpoons \text{Ag}(\text{CN})_2^-$ ?

$K_{sp}$  for  $\text{AgCN}$

$K_f$  for  $\text{Ag}(\text{CN})_2^-$

## Part IV. Electrochemistry (6 questions, each worth 5 points)

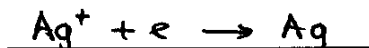
1. Write a balanced equation for the following redox reaction:

2. In a voltaic cell made up of Zn/Zn<sup>2+</sup> and Ag/Ag<sup>+</sup> half cells. Identify:

which metal is the anode

Zn

the reaction occurring at the cathode



the direction of electron flow

in the external circuit

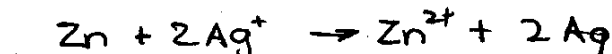
from Zn half-cell to Ag half cell

the direction of negative ion flow

in the salt bridge

from Ag half-cell to Zn half cell

the cell reaction (net equation)



3. a) (2) Calculate the standard potential of the cell in Q2.

$$E_{\text{cell}}^{\circ} = E_{\text{cath}}^{\circ} - E_{\text{anode}}^{\circ}$$

$$= 0.80 - (-0.76)$$

$$E^{\circ} = \underline{1.56 \text{ V}}$$

b) (3) Calculate the cell voltage, if [Zn<sup>2+</sup>] = 0.50 M and [Ag<sup>+</sup>] = 1.0 × 10<sup>-3</sup> M.

$$E = E^{\circ} - \frac{0.0257}{2} \ln \frac{[0.50]}{[1 \times 10^{-3}]^2}$$

$$E = 1.56 - 0.17$$

$$E = \underline{1.37 \text{ V}}$$

4. Predict the following (use the table of SRP), Circle all correct answers, more than one answer is possible for some questions.

Which metals will react with  $H^+$  : (Mg) Cu Ag (Al)

Which is the strongest oxidizing agent  $H^+$  (Ag<sup>+</sup>) Zn<sup>2+</sup> Sn<sup>4+</sup>

Species that will reduce Cu<sup>2+</sup> to Cu (Fe) I<sup>-</sup> (H<sub>2</sub>) Cl<sub>2</sub>

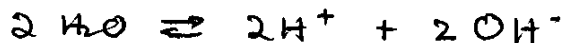
Easiest halide ion to oxidize F<sup>-</sup> Cl<sup>-</sup> Br<sup>-</sup> (I<sup>-</sup>)

$Cl_2 + 2 Br^- \rightleftharpoons 2 Cl^- + Br_2$  product-favored or reactant-favored

5. a) (2) What is the overall cell reaction using the following two half-reactions.

cathode:  $2 H_2O + 2 e^- \rightleftharpoons H_2 + 2 OH^-$   $E = -0.828 V$

anode:  $H_2 \rightleftharpoons 2 H^+ + 2 e^-$   $E = 0.0 V$



b) (3) What is the equilibrium constant for a reaction?

$$E^\circ = \frac{0.0257}{n} \ln K$$

$$-0.828 = \frac{0.0257}{2} \ln K$$

$$K = 1.04 \times 10^{-28}$$

$$K = \underline{1.04 \times 10^{-28}}$$

6. In the electrolysis of CuBr<sub>2</sub>(aq) to electroplate copper:

a) (2) What is the anode reaction?



b) (2) What is the minimum voltage required for electrolysis to occur?

$$E^\circ_{(cell)} = 0.337 - (+1.08)$$

$$\underline{(-) 0.74 V}$$

c) (1) If 1.00 Faradays (96,500 amp sec) of current is consumed how much copper metal will be formed?

$$1 \text{ mol } e^- \left( \frac{1 \text{ mol Cu}}{2 \text{ mol } e^-} \right) \frac{63.5 \text{ g Cu}}{1 \text{ mol Cu}}$$

$$\underline{31.8 \text{ g}}$$