

Chem 1721/1821  
Exam 2

March 27, 2014

ID#: 2013172 \_\_\_\_\_

Dr. Susan E. Bates

Name \_\_\_\_\_ Key \_\_\_\_\_

**Please do not remove this page. The periodic table, constants, and equations you may need are on the last page of this exam. Feel free to remove *it*, and use it as scrap paper. All pages must be turned in.**

Be sure to fill out *and bubble in* the proper letters and numbers on the ScanTron sheet for the following information:

your name

Test Form *A*

the 9-digit ID number given above (rightmost digit blank)

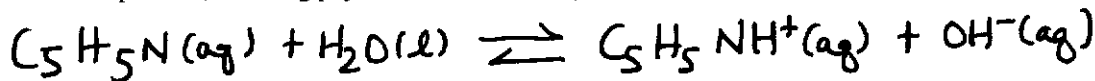
You should answer questions for Part II (1 - 15) on the Scantron sheet.

You will not have the Scantron returned to you, so if you would like to know what you answered after the exam is returned, circle your answers on this form as well.

## Part I (40 points): Short Answer.

1. Write the balanced chemical equation (including physical states and charges on ions) for the base ionization of pyridine,  $C_5H_5N$ .

2



2. Consider an aqueous solution at 25°C with  $pOH = 9.75$ .

a. Determine  $[H_3O^+]$  in this solution.

$$[H_3O^+] = \underline{5.6 \times 10^{-5}} \text{ M}$$

$$pH = 14 - pOH = 4.25; [H^+] = 10^{-4.25}$$

3

b. Is this solution *acidic, basic, or neutral*?

$$pH < 7; [H^+] > [OH^-]$$

acidic

3. Consider the following equilibrium at 350°C:  $2 A(g) + B(g) \rightleftharpoons C(g)$ ;  $K_c = 5.6 \times 10^{-2}$ .

a. Determine the value of  $K_p$  for this reaction at 350°C.

$$K_p = (.056)(.08206 \cdot 623)^{-2}$$

$$K_p = \underline{2.1 \times 10^{-5}}$$

4

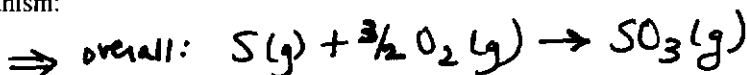
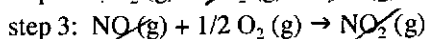
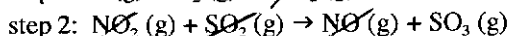
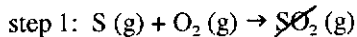
- b. If this reaction is started in a 2.00 L flask with 0.10 mol A, 0.12 mol B, and 0.05 mol C, in which direction will the reaction proceed? Circle the *one* best answer below.  $Q = .025 / (.05)^2 (.06) = 167; Q > K$

forward toward products

reverse toward reactants

there will be no change

4. Consider the following proposed 3-step reaction mechanism:



- a. Which species in this mechanism is/are reaction intermediates? Circle the *one* best answer below.

SO<sub>2</sub> & NO

NO & NO<sub>2</sub>

NO only

6

- b. Which species in this mechanism is/are catalysts? Circle the *one* best answer below.

SO<sub>2</sub> & NO<sub>2</sub>

NO & NO<sub>2</sub>

NO<sub>2</sub> only

- c. If the experimentally determined rate law for reaction  $S(g) + 3/2 O_2(g) \rightarrow SO_3(g)$  is rate =  $k[S][O_2]$ , which step in this mechanism is the rate determining step? Circle the *one* best answer below.

step 1

step 2

step 3

not enough information to answer

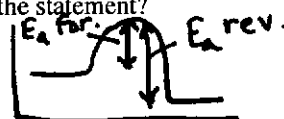
5. For a reversible exothermic reaction, the activation energy for the forward reaction is \_\_\_\_\_ the activation energy of the reverse reaction. Which *one* answer below best fills in this blank to complete the statement?

2

less than

greater than

equal to

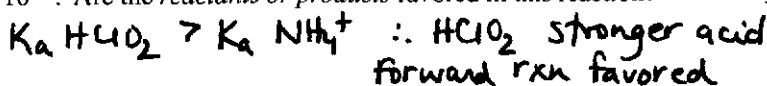


6. Consider the following equilibrium:  $HClO_2(aq) + NH_3(aq) \rightleftharpoons NH_4^+(aq) + ClO_2^-(aq)$ . For  $HClO_2$ ,  $K_a = 1.1 \times 10^{-2}$ , and

2

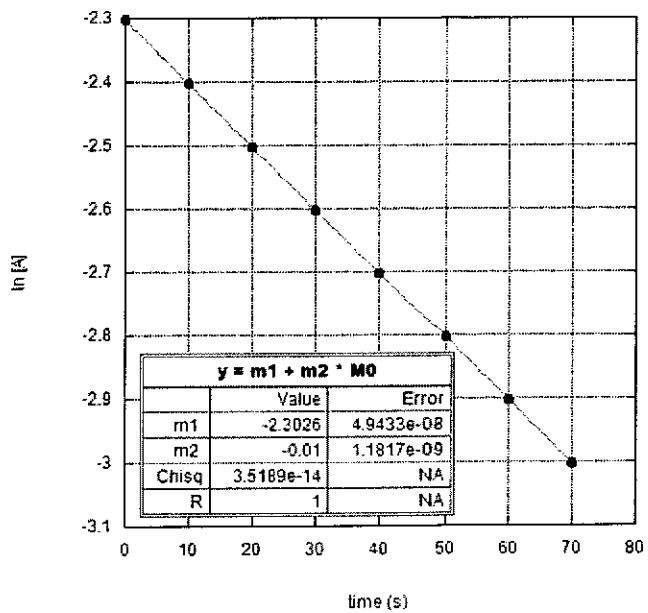
for  $NH_4^+$ ,  $K_a = 5.6 \times 10^{-10}$ . Are the *reactants or products* favored in this reaction?

products





2. For the reaction  $A \rightarrow \text{products}$ , the concentration of A was monitored with time. From the following graph of data collected in studying this reaction, determine the order of the reaction, and its rate constant.



slope = -k

- a. 1<sup>st</sup>; 0.01 s<sup>-1</sup>
- b. 1<sup>st</sup>; -2.30 s<sup>-1</sup>
- c. 2<sup>nd</sup>; 0.01 s<sup>-1</sup>
- d. 2<sup>nd</sup>; 3.52 s<sup>-1</sup>
- e. 2<sup>nd</sup>; -2.30 s<sup>-1</sup>

3. Consider the following data collected to study the reaction  $\text{H}_2\text{O}_2(\text{aq}) + 3\text{I}^-(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow \text{I}_3^-(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$ :

$[\text{H}_2\text{O}_2]_0, \text{M}$	$[\text{I}^-]_0, \text{M}$	$[\text{H}^+]_0, \text{M}$	initial rate, M/s
0.100	$5.00 \times 10^{-4}$	0.010	0.137
0.100	$1.00 \times 10^{-3}$	0.010	0.274
0.200	$1.00 \times 10^{-3}$	0.010	0.548
0.400	$1.00 \times 10^{-3}$	0.020	1.096

→ 1<sup>st</sup> order in I<sup>-</sup>  
 → 1<sup>st</sup> order in H<sub>2</sub>O<sub>2</sub>  
 → 0 order in H<sup>+</sup>; rate change here due to H<sub>2</sub>O<sub>2</sub> ∴ changing H<sup>+</sup> has no affect

Determine the rate law for this reaction.

- a. rate =  $k[\text{H}_2\text{O}_2][\text{I}^-][\text{H}^+]$
- b. rate =  $k[\text{H}_2\text{O}_2]^2[\text{I}^-]^2[\text{H}^+]^2$
- c. rate =  $k[\text{I}^-][\text{H}^+]$
- d. rate =  $k[\text{H}_2\text{O}_2][\text{H}^+]$
- e. rate =  $k[\text{H}_2\text{O}_2][\text{I}^-]$

$k_2 = 3 \cdot k_1$

4. A particular chemical reaction has a rate constant that is three times greater at 40.0°C than at 20.0°C. Determine the activation energy for this reaction.

- a. 3.00 kJ/mol
- b. 366 kJ/mol
- c. 41.9 kJ/mol
- d. 3.20 kJ/mol
- e. none of these

$\ln\left(\frac{3}{1}\right) = \frac{E_a}{.008314 \text{ kJ/K}\cdot\text{mol}} \left(\frac{1}{293\text{K}} - \frac{1}{313\text{K}}\right)$

5. Determine the pH at 25°C of a 0.036 M solution of a weak acid with  $K_a = 3.9 \times 10^{-6}$ .

$3.9 \times 10^{-6} = \frac{x^2}{.036}$ ;  $x = [\text{H}^+] = 3.7 \times 10^{-4} \text{ M}$

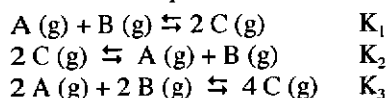
- a. 2.55
- b. 3.43
- c. 5.80
- d. 6.85
- e. 7.15

6. Which of the following are stronger acids than HClO<sub>2</sub>?

- i. HCl
- ii. HBr
- iii. HClO
- iv. HBrO
- v. HBrO<sub>2</sub>

- a. i & ii
- b. i, ii & iii
- c. i, ii & iv
- d. i, ii, iv & v
- e. all of them

7. Consider the following reactions and their associated equilibrium constants:



Which of the following statements is *not true*?

- a.  $K_1 = (K_2)^{1/2}$       b.  $K_1 = K_2 K_3$       c.  $K_1 = (K_2)^{-1}$       **d.  $K_3 = K_1 K_2$**       e. all of these are true

8. Which one of the following is *not* a strong acid or strong base?

- a. CsOH      b. HClO<sub>4</sub>      c. Ba(OH)<sub>2</sub>      d. HI      **e. H<sub>2</sub>SO<sub>3</sub>**

9. Consider 0.78 M aqueous solutions of two monoprotic acids, HX and HZ at 25°C. If [OH<sup>-</sup>] is less in HZ (aq), what must be true?

*HZ Stronger acid*

- a.  $K_a$  of HX =  $K_a$  of HZ      **b.  $K_a$  of HZ >  $K_a$  of HX**      c.  $K_a$  of HZ <  $K_a$  of HX  
d.  $K_a$  of HZ is too large to measure      e. HX is a strong acid

10. Which of the following are conjugate acid/base pairs?

- i. H<sub>2</sub>O and OH<sup>-</sup>      ii. HClO and HCl      iii. HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> and C<sub>2</sub>H<sub>3</sub>O<sub>2</sub><sup>-</sup>      iv. NH<sub>4</sub><sup>+</sup> and NH<sub>2</sub><sup>-</sup>

- a. i & ii      **b. i & iii**      c. ii, iii & iv      d. only i      e. all of these

11. Consider the following equilibrium:  $2 NO(g) + Br_2(g) \rightleftharpoons 2 NOBr(g)$ . 0.0524 mol NO (g) and 0.0262 mol Br<sub>2</sub> (g) are combined in a 1.00 L flask, and the system is allowed to reach equilibrium. It is determined that, at equilibrium, 0.0311 mol NOBr are present. How much NO is present at equilibrium?

*1.00 L flask so mol will = [ ]  
equil [NOBr] = 2x = .0311*

- a. 0.0370 mol      b. 0.0156 mol      c. 0.0107 mol      **d. 0.0213 mol**      e. 0.0262 mol  
*equil [NO] = .0524 - 2x  
= .0524 - .0311  
= .0213 M  
OR .0213 mol*

12. Which one of the following statements is *not true*?

- a. HF is a stronger acid than H<sub>2</sub>O because F is more electronegative than O.  
b. For 1.0 M solutions of any 2 weak bases, the solution of the base with the larger  $K_b$  will have the greater [OH<sup>-</sup>].  
c. A Lewis acid is an electron pair acceptor.  
d. For a polyprotic acid,  $K_{a1}$  is always greater than  $K_{a2}$ .

**e. The pH of a neutral solution is 7.00 at all temperatures.**

*x = [H<sup>+</sup>]; using pH, [H<sup>+</sup>] = .0013  
% ion = (.0013 / .072) × 100*

13. A 0.072 M solution of a weak acid, HA, has pH = 2.90 at 25°C. Determine the percent ionization in this solution of HA.

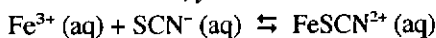
- a. 2.5%      b. 9.1%      **c. 1.7%**      d. 3.5%      e. 0.91%

14. In your *Rate Law of the Iodine Clock Reaction* lab, you measured reaction times for different initial concentrations of reactants. In order to determine the order of reaction with respect to IO<sub>3</sub><sup>-</sup>, what data plot did you prepare?

- a. 1/t vs. 1/[IO<sub>3</sub><sup>-</sup>]      b. t vs. [IO<sub>3</sub><sup>-</sup>]      c. 1/t vs. [IO<sub>3</sub><sup>-</sup>]  
**d. log(1/t) vs. log [IO<sub>3</sub><sup>-</sup>]**      e. log t vs. log [IO<sub>3</sub><sup>-</sup>]

initial  $\text{Fe}^{3+}$  after dilution =  $1.00 \times 10^{-4} \text{ M}$

15. In your *Determination of an Equilibrium Constant* lab, you studied the iron thiocyanate equilibrium:



In one trial 10.0 mL of  $1.00 \times 10^{-3} \text{ M Fe}^{3+}(\text{aq})$  is combined with 50.0 mL of  $0.0200 \text{ M SCN}^{-}(\text{aq})$  and diluted to a total volume of 100.0 mL. The concentration of  $\text{FeSCN}^{2+}(\text{aq})$  at equilibrium is determined via an absorbance measurement to be  $5.75 \times 10^{-5} \text{ M}$ . What is  $[\text{Fe}^{3+}]$  at equilibrium?

- a.  $5.75 \times 10^{-5} \text{ M}$       b.  $1.00 \times 10^{-4} \text{ M}$       **c.  $4.25 \times 10^{-5} \text{ M}$**       d.  $9.42 \times 10^{-4} \text{ M}$       e.  $1.58 \times 10^{-4} \text{ M}$

$$\text{equil } [\text{FeSCN}^{2+}] = x = 5.75 \times 10^{-5} \text{ M}$$

$$\text{equil } [\text{Fe}^{3+}] = (1.00 \times 10^{-4} - x) \text{ M} = 4.25 \times 10^{-5} \text{ M}$$

145

**Part III (15 points): Problems.** Work all of the following problems. Show all work; work with units in all steps; report all answers with appropriate units and significant figures.

1. The reaction of  $\text{NOBr}(\text{g})$  to form  $\text{NO}(\text{g})$  and  $\text{Br}_2(\text{g})$  is 2<sup>nd</sup> order:  $2 \text{NOBr}(\text{g}) \rightarrow 2 \text{NO}(\text{g}) + \text{Br}_2(\text{g})$ .

It takes 88.0 minutes at  $95.0^\circ\text{C}$  for  $[\text{NOBr}]$  to decrease from  $0.1000 \text{ M}$  to  $0.0675 \text{ M}$ .

a. Determine the value of  $k$  at  $95.0^\circ\text{C}$ . Be sure to include units!

$$\frac{1}{.0675 \text{ M}} = k (88.0 \text{ min}) + \frac{1}{.1000 \text{ M}}$$

$$k = \underline{\underline{.0547 \text{ M}^{-1} \cdot \text{min}^{-1}}}$$

$$k = \underline{\underline{.0547 \text{ M}^{-1} \cdot \text{min}^{-1}}}$$

b. How much time (in min) is required for  $[\text{NOBr}]$  to decrease from  $0.1000 \text{ M}$  to  $0.0875 \text{ M}$ ?

$$\frac{1}{.0875 \text{ M}} = (.0547 \text{ M}^{-1} \cdot \text{min}^{-1}) t + \frac{1}{.1000 \text{ M}}$$

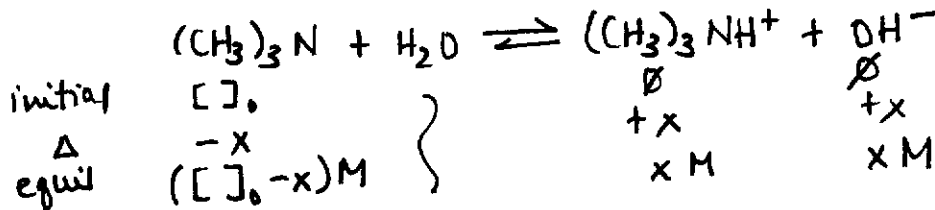
$$t = \underline{\underline{26.1 \text{ min}}}$$

$$\text{time} = \underline{\underline{26.1}} \text{ min}$$

2. At  $25^\circ\text{C}$ ,  $K_b = 7.3 \times 10^{-5}$  for trimethylamine,  $(\text{CH}_3)_3\text{N}$ . If an aqueous solution of this weak base has  $\text{pH} = 11.05$ , determine the *initial* concentration of  $(\text{CH}_3)_3\text{N}$ .

$$\text{pOH} = 2.95$$

$$\text{so } [\text{OH}^-] = .0011 \text{ M}$$



$$K_b = 7.3 \times 10^{-5} = \frac{x^2}{[\ ]_0 - x}$$

$$7.3 \times 10^{-5} = \frac{(.0011)^2}{[\ ]_0 - .0011}$$

$$[(\text{CH}_3)_3\text{N}] = \underline{\underline{.018}} \text{ M}$$

$$[\ ]_0 - .0011 = .017$$

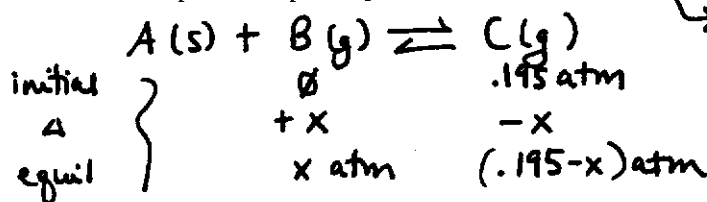
$$\text{so } [\ ]_0 = \underline{\underline{.018 \text{ M}}}$$

3. Consider the equilibrium:  $A(s) + B(g) \rightleftharpoons C(g)$ . In a flask at equilibrium at  $250^\circ\text{C}$ ,  $P_B = 0.240$  atm and  $P_C = 0.195$  atm.
- a. Determine the value of  $K_p$  at  $250^\circ\text{C}$ .

$$K_p = \frac{.195}{.240} = .813$$

$$K_p = \underline{.813}$$

- b. If all of the  $B(g)$  is removed from the system, and the reaction is allowed to return to equilibrium, what will be the new equilibrium partial pressure of  $B$  (in atm)?



$\therefore$  new  $P_B = \emptyset$  initially  
 $P_C = .195$  atm  
 rxn proceeds  $\leftarrow$  to  
 new equilibrium

$$K_p = .813 = \frac{(.195-x)}{x}$$

$$P_B = \underline{.108} \text{ atm}$$

$$.813x = .195 - x$$

$$1.813x = .195$$

$$x = .108$$

Some information that you may find useful:

$$\ln[A] = -kt + \ln[A]_0$$

$$1/[A] = kt + 1/[A]_0$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = .693/k$$

$$t_{1/2} = 1/k[A]_0$$

$$t_{1/2} = [A]_0/2k$$

$$\ln \frac{k_2}{k_1} = \frac{E_a}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$k = Ae^{-E_a/RT}$$

$$K_p = K_c(RT)^{\Delta n}$$

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

$$R = 8.314 \text{ J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1} \text{ OR } 0.08206 \text{ L}\cdot\text{atm}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$$

$$pX = -\log X$$

$$K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

$$pK_w = \text{pH} + \text{pOH}$$

IA	IIA	IIIB	IVB	VB	VIB	VII B	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	Inert gases		
1 H 1.008															2 He 4.003		
3 Li 6.941	4 Be 9.012																
11 Na 22.98	12 Mg 24.31																
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.71	29 Cu 63.55	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.46	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.0	45 Rh 102.9	46 Pd 106.4	47 Ag 107.8	48 Cd 112.4	49 In 114.8	50 Sn 118.6	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.4	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.0	79 Au 196.9	80 Hg 200.5	81 Tl 204.3	82 Pb 207.2	83 Bi 208.9	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0	89 Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (271)	107 Bh (272)	108 Hs (270)	109 Mt (276)	110 Ds (269)	111 Rg (280)	112 Cn (285)	113 Uut (286)	114 Fl (289)	115 Uup (288)	116 Lv (293)	117 Uus (294)	118 Uuo (294)

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (147)	62 Sm 150.4	63 Eu 151.9	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 174.9
90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (254)	103 Lr (262)