

**CHEMISTRY 1B – Fall, 2015**  
**EXAM 1 – VERSION A**  
**KEY**

Use Scantron Form SC982-E and select the letter corresponding to the correct answer. Make sure to put **your full name, lab section number, and exam version** (under test no.) on the Scantron Form.

Equations and constants that you could need:  $0^{\circ}\text{C} = 273 \text{ K}$ ;  $K_w = 1.0 \times 10^{-14}$

The quadratic equation for  $ax^2 + bx + c = 0$  is  $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

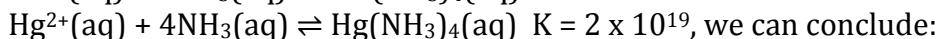
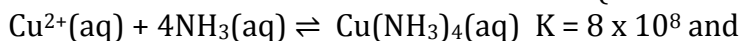
A periodic table is provided on the last page along with a blank page to be used as scratch paper.

**Part I. Multiple Choice Section.** All Questions have only one correct answer. Each Question is worth 4 points.

1. The reaction  $2\text{NO}_2(\text{g}) \leftrightarrow \text{N}_2\text{O}_4(\text{g})$  is at equilibrium. This means that:

- a) No molecules of reactant or product are being converted any longer
- b) For every 2 molecules of  $\text{NO}_2$  that react to form  $\text{N}_2\text{O}_4$ , one of  $\text{NO}_2$  reacts backwards.
- c) The rate constants for the forward reaction and backwards reaction are equal
- d) The forward and backwards rates have decreased to zero

2. Given the K values for the two reactions (with the right side called a “complex”):



- a)  $\text{Cu}^{2+}$  complexes weakly with  $\text{NH}_3$
- b)  $\text{Hg}^{2+}$  complexes more strongly with  $\text{NH}_3$  than  $\text{Cu}^{2+}$
- c)  $\text{NH}_3$  is a poor Lewis base
- d)  $\text{Cu}^{2+}$  and  $\text{Hg}^{2+}$  would remain mostly uncomplexed even with  $\text{NH}_3$  present

3. Which of the following concentration based equilibrium equations correctly corresponds to the following chemical equation:  $2\text{CO}(\text{g}) + 4\text{H}_2(\text{g}) \rightleftharpoons \text{C}_2\text{H}_5\text{OH}(\text{g}) + \text{H}_2\text{O}(\text{g})$ ?

a)  $K_c = \frac{[\text{CO}][\text{H}_2]}{[\text{C}_2\text{H}_5\text{OH}][\text{H}_2\text{O}]}$

b)  $K_c = \frac{[\text{CO}]^2[\text{H}_2]^4}{[\text{C}_2\text{H}_5\text{OH}][\text{H}_2\text{O}]}$

c)  $K_c = \frac{[\text{C}_2\text{H}_5\text{OH}][\text{H}_2\text{O}]}{[\text{CO}][\text{H}_2]}$

d)  $K_c = \frac{[\text{C}_2\text{H}_5\text{OH}][\text{H}_2\text{O}]}{[\text{CO}]^2[\text{H}_2]^4}$

4. In the reaction:  $\text{CO}_3^{2-}(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons 2\text{HCO}_3^-(\text{aq})$ , all of the species except \_\_\_\_\_ will be included in the equilibrium equation.

- a)  $\text{CO}_3^{2-}(\text{aq})$
- b)  $\text{CO}_2(\text{g})$
- c)  $\text{H}_2\text{O}(\text{l})$
- d)  $\text{HCO}_3^-(\text{aq})$

5. For the reaction  $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ , If the initial partial pressure of  $N_2$ ,  $H_2$ , and  $NH_3$  are 10.0, 10.0 and 0 atm and the equilibrium partial pressure of  $NH_3$  is 6.0 atm,  $K_P =$

ICE Table

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Init.	10.0	10.0	0
Change	-x	-3x	+2x
Equil.	10 - x = 7.0	10 - 3(3) = 1.0	2x = 6.0

$$(x = 3) K = (6.0)^2 / [(7.0)(1.0)^3] = 5.1$$

- a)  $3.6 \times 10^{-3}$       b) 0.06      c) 0.14      **d) 5.1**

6. Sulfur gases leaving a power plant exhaust stack have  $P_{SO_2}$  and  $P_{SO_3}$  equal to  $1.0 \times 10^{-2}$  atm and  $5.0 \times 10^{-4}$  atm, respectively and enter the air. If  $K_P$  for the reaction  $2SO_2(g) + O_2(g) \leftrightarrow 2SO_3(g)$  is 320, in which direction with the reaction proceed if  $P_{O_2} = 0.20$  atm?

$$Q = P_{SO_3}^2 / [P_{SO_2}^2 P_{O_2}] = (5.0 \times 10^{-4})^2 / [(1.0 \times 10^{-2})^2 (0.20)] = 0.013 < K$$

- a) to the products**      b) to the reactants  
c) it is at equilibrium      d) depends on  $\Delta H$

7. If  $K_C$  for the reaction  $2Na_2O_2(s) + 2CO_2(g) \rightleftharpoons 2Na_2CO_3(s) + O_2(g)$  is  $6.3 \times 10^4$ , what is the equilibrium concentration of  $CO_2$  in M if the equilibrium concentration of  $O_2$  is 0.0100 M?

$$K_C = 6.3 \times 10^4 = [O_2] / [CO_2]^2 = 0.0100 \text{ M} / [CO_2]^2 \text{ or } [CO_2]^2 = 0.0100 / 6.3 \times 10^4$$

$$[CO_2]^2 = 1.59 \times 10^{-7} \text{ or } [CO_2] = (1.59 \times 10^{-7})^{0.5} = 4.0 \times 10^{-4} \text{ M}$$

- a)  $1.6 \times 10^{-7}$       **b)  $4.0 \times 10^{-4}$**       c)  $2.0 \times 10^{-4}$       d) 0.020 M

8. The reaction  $2N_2(g) + O_2(g) \rightleftharpoons 2N_2O(g)$  starts with  $P_{N_2} = 0.79$  atm,  $P_{O_2} = 0.20$  atm (and no  $N_2O$ ) and proceeds to an equilibrium. The ICE table **equilibrium** partial pressures of  $N_2$ ,  $O_2$  and  $N_2O$  (bottom row of table) will be:

ICE Table

$$2N_2(g) + O_2(g) \rightleftharpoons 2N_2O(g)$$

Init.	0.79	0.20	0
Change	-2x	-x	+2x
Equil.	0.79 - 2x	0.20 - x	2x

- a) 0.79 - x and 0.20 - x, and +x, respectively      **b) 0.79 - 2x and 0.20 - x, and +2x, respectively**  
c) 0.79 + x and 0.20 + x, and -x, respectively      d)  $0.79^2$ , 0.2, and  $2x^2$ , respectively

9. If at  $1000^\circ\text{C}$ ,  $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$  has  $K = 2.0 \times 10^{-9}$  and  $N_2(g) + 2O_2(g) \rightleftharpoons 2NO_2(g)$  has  $K = 38$ , then  $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$  has  $K =$

if first rxn is 1 and 2<sup>nd</sup> is 2, we can see that 3<sup>rd</sup> rxn is  $2 + -1$  (-1 means in reverse direction).

$$\text{Thus } K = K_2 / K_1 = 38 / 2.0 \times 10^{-9} =$$

- a)  $5.3 \times 10^{-11}$       b)  $7.6 \times 10^{-8}$       c) 38      **d)  $1.9 \times 10^{10}$**

10. The reaction  $N_2O_4(g) \rightleftharpoons 2NO_2(g)$  reaches an equilibrium in a sealed 1.0 L flask. This reaction is endothermic. Which of the following changes will result in a shift toward the products?

- a) decreasing the flask temperature      **b) increasing the flask volume**  
c) adding a catalyst      d) removing through  $N_2O_4$  condensation

11. In the reaction:  $\text{Al}(\text{H}_2\text{O})_6^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{Al}(\text{H}_2\text{O})_5\text{OH}^{2+}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$ , the Bronsted-Lowry acid (in the direction shown) is:

- a)  $\text{Al}(\text{H}_2\text{O})_6^{3+}(\text{aq})$       b)  $\text{H}_2\text{O}(\text{l})$       c)  $\text{Al}(\text{H}_2\text{O})_5\text{OH}^{2+}(\text{aq})$       d)  $\text{H}_3\text{O}^+(\text{aq})$

12. A Lewis acid is defined as a:

- a) a compound that produces  $\text{H}^+$  in water      b) a proton donor  
 c) an electron pair acceptor      d) a positively charged acid

13. Which of the following salt solutions is neutral?

- a) KOH      b)  $\text{NH}_4\text{Cl}$       c)  $\text{Na}_2\text{CO}_3$       d)  $\text{KNO}_3$

$\text{OH}^-$  and  $\text{CO}_3^{2-}$  are basic and  $\text{NH}_4^+$  is acidic (other ions are all neutral)

14. Which of the following acids has the strongest conjugate base (conjugate base with the greatest  $K_b$ )?

- a)  $\text{HSO}_4^-$  ( $\text{p}K_a = 2.00$ )      b) HF ( $\text{p}K_a = 3.17$ )  
 c)  $\text{N}_2\text{H}_5^+$  ( $\text{p}K_a = 7.98$ )      d) HCN ( $\text{p}K_a = 9.24$ )

$K_w = K_a K_b$  or  $14 = \text{p}K_a + \text{p}K_b$  or  $\text{p}K_b = 14 - \text{p}K_a$  (smallest  $\text{p}K_b$  is strongest)

15. What is the pH of a 0.0050 M  $\text{Ba}(\text{OH})_2$  solution? (Note:  $K_w$  given on p. 1)

- a) 0.01      b) 2.00      c) 11.70      d) 12.00

$[\text{OH}^-] = 2[\text{Ba}(\text{OH})_2]_o = 0.010 \text{ M}$  and  $\text{pH} = 14 - \text{pOH} = 14 + \log[\text{OH}^-] = 12.00$

16. A solution has a pH of 4.89.  $[\text{H}^+]$  is:

- a)  $7.8 \times 10^{-10}$       b)  $1.3 \times 10^{-5}$       c)  $7.5 \times 10^{-3}$       d) 0.69

$[\text{H}^+] = 10^{-4.89}$

17. What is the pH of a 0.20 M  $\text{HC}_2\text{H}_3\text{O}_2$  acid ( $K_a = 1.8 \times 10^{-5}$ )?

- a) 0.70      b) 2.72      c) 4.74      d) 7.00

ICE Table       $\text{HC}_2\text{H}_3\text{O}_2(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{C}_2\text{H}_3\text{O}_2^-(\text{aq})$

Init.	0.20	0	0
Change	-x	+x	+x
Equil.	$0.20 - x \sim 0.20$	x	x

$K_a = 1.8 \times 10^{-5} = x^2/(0.20)$  or  $x = (3.6 \times 10^{-6})^{0.5} = 1.9 \times 10^{-3} \text{ M}$   $\text{pH} = -\log(1.9 \times 10^{-3})$

18. An unknown weak acid is prepared to an initial concentration of 0.010 M. The pH is measured to be 3.16. The percent ionization of that weak acid is:

- a) 0.16%      b) 3.3%      c) 6.9%      d) 135%

ICE Table       $\text{HA}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{A}^-(\text{aq})$

Init.	0.010	0	0
Change	-x	+x	+x
Equil.	$0.010 - x$	x	x

$\text{pH} = 3.16$  so  $[\text{H}^+] = 10^{-3.16} = 6.92 \times 10^{-4} = x = [\text{A}^-]$

percent ionization =  $[\text{A}^-] * 100 / [\text{HA}]_o = (6.92 \times 10^{-4})(100) / 0.010 = 6.9\%$

19. A polyprotic acid is defined as an acid which:

- a) releases two or more protons per molecule      b) is a polymer that is acidic  
 c) has both acid and base functional groups      d) all of the above

20. Which of the following combinations makes the best buffer?

- a) HCl + NaCl      b) NH<sub>4</sub>Cl + NH<sub>3</sub>      c) HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> + HCl      d) KOH + H<sub>2</sub>O  
*strong + neutral      weak acid + conj. base      weak + strong      strong + neutral*

21. Fluorine is the most electronegative element and it stabilizes electron rich anions. Based on this, which of the following acids would be expected to be the strongest?

- a) CH<sub>3</sub>CO<sub>2</sub>H      b) CFH<sub>2</sub>CO<sub>2</sub>H      c) CF<sub>2</sub>HCO<sub>2</sub>H      d) CF<sub>3</sub>CO<sub>2</sub>H

22. How many moles of sodium acetate should be added to a 1.0 L solution of 0.040 M acetic acid to make a pH = 5.00 buffer? (acetic acid K<sub>a</sub> = 1.8 x 10<sup>-5</sup>)

- a) 0.023 moles      b) 0.050 moles      c) 0.070 moles      d) 1.00 moles  
 $pH = pK_a + \log[n(C_2H_3O_2^-(aq))/n(HC_2H_3O_2)]$  (applicable to moles due to V dropping out)  
 $n(HC_2H_3O_2) = (1.0 L)(0.040 \text{ mol/L}) = 0.040 \text{ mol}$  and  $pK_a = -\log(1.8 \times 10^{-5}) = 4.74$   
 $5.00 = 4.74 + \log[n(C_2H_3O_2^-(aq))/0.040 \text{ mol}]$  or  $10^{0.24} = n(C_2H_3O_2^-(aq))/0.040 \text{ mol}$   
 or  $n(C_2H_3O_2^-(aq)) = (1.74)(0.040 \text{ mol}) = 0.0695$

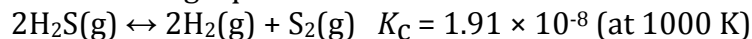
23 - Bonus. Given K<sub>a</sub> values below, which anion will make an acidic solution?

- a) HPO<sub>4</sub><sup>2-</sup>      b) HCO<sub>3</sub><sup>-</sup>      c) HC<sub>8</sub>H<sub>4</sub>O<sub>4</sub><sup>-</sup>      d) C<sub>2</sub>H<sub>3</sub>O<sub>2</sub><sup>-</sup>

Acid	K <sub>a1</sub>	K <sub>a2</sub>	K <sub>a3</sub>
H <sub>3</sub> PO <sub>4</sub>	7.1 x 10 <sup>-3</sup>	6.3 x 10 <sup>-8</sup>	4.2 x 10 <sup>-13</sup>
H <sub>2</sub> CO <sub>3</sub>	4.5 x 10 <sup>-6</sup>	4.7 x 10 <sup>-11</sup>	NA
H <sub>2</sub> C <sub>8</sub> H <sub>4</sub> O <sub>4</sub>	1.1 x 10 <sup>-3</sup>	3.9 x 10 <sup>-6</sup>	NA
HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	1.8 x 10 <sup>-5</sup>	NA	NA

<i>ion</i>	<i>compare</i>	<i>result</i>
HPO <sub>4</sub> <sup>2-</sup>	acid K <sub>a3</sub> with base = K <sub>w</sub> /K <sub>a2</sub>	4.2 x 10 <sup>-13</sup> vs 1.6 x 10 <sup>-7</sup> basic
HCO <sub>3</sub> <sup>-</sup>	acid K <sub>a2</sub> with base = K <sub>w</sub> /K <sub>a1</sub>	4.7 x 10 <sup>-11</sup> vs 2.2 x 10 <sup>-9</sup> basic
HC <sub>8</sub> H <sub>4</sub> O <sub>4</sub> <sup>-</sup>	acid K <sub>a2</sub> with base = K <sub>w</sub> /K <sub>a1</sub>	3.9 x 10 <sup>-6</sup> vs 9.1 x 10 <sup>-12</sup> acidic
C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> <sup>-</sup>	only has base reaction so only basic	

Work out Problem (12 pts) – Answer on the back of the Scantron and show work  
Consider the following equation:



If the initial concentration of  $\text{H}_2\text{S}(\text{g})$  was 0.060 M and the other species were at zero, what is the equilibrium concentration of the product,  $\text{H}_2(\text{g})$ ? You must show your work for full credit. If you make any simplifying assumptions, show and validate them.

The equilibrium equation is:  $K_C = 1.91 \times 10^{-8} = [\text{H}_2]^2[\text{S}_2]/[\text{H}_2\text{S}]^2$

Because we are only given an initial concentration, we need to set up an ICE table

	$2\text{H}_2\text{S}(\text{g})$	$\leftrightarrow$	$2\text{H}_2(\text{g})$	+	$\text{S}_2(\text{g})$
initial	0.060 M		0		0
change	-2x		+2x		+x
equil.	$0.060 - 2x$		2x		x

Putting these into the equation, we get:  $1.91 \times 10^{-8} = (2x)^2x/(0.060 - 2x)^2$  and we see we cannot solve this without a simplifying assumption. Because  $K_C$  is a small number, we can expect that x will be small and can make the assumption that  $0.060 \gg 2x$ , replacing  $0.060 - 2x$  with 0.060.

Now, we get  $1.91 \times 10^{-8} = (2x)^2x/(0.060)^2$

Simplifying that, we get  $1.91 \times 10^{-8} = 4x^3/(0.0036)$  and  $x^3 = 1.91 \times 10^{-8}(0.0036)/4 = 1.719 \times 10^{-11}$

or  $x = (1.719 \times 10^{-11})^{1/3} = 2.58 \times 10^{-4}$

$[\text{H}_2] = 2x = 2(2.58 \times 10^{-4}) = 5.2 \times 10^{-4} \text{ M}$

Our assumption is valid because  $2x \ll 0.060$  (can write as 0.060 vs. 0.0005 so that the equilibrium  $[\text{H}_2\text{S}]$  would barely be affected or  $0.0005/0.060 = 1\%$  change which is less than 5%)