CH 223 Sample Exam
Exam I Name: ______________________________ Lab Section: ______

Part I: Multiple Choice Questions (100 Points) There is *only* one best answer for each question.

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1. Write the expression for K for the reaction: $\mathbf{Al_2S_3(s) \rightleftharpoons 2\ Al^{3+}(aq) + 3\ S^{2-}(aq)}$

   a. $K = [Al^{3+}]^2[S^{2-}]^3$
   b. $K = [Al^{3+}][S^{2-}]$
   c. $K = [2\ Al^{3+}][3\ S^{2-}]$
   d. $K = \dfrac{[Al_2S_3]}{[Al^{3+}]^2[S^{2-}]^3}$
   e. $K = \dfrac{[Al^{3+}]^2[S^{2-}]^3}{[Al_2S_3]}$

2. Write the expression for K_p for the reaction: $\mathbf{2\ HBr(g) \rightleftharpoons H_2(g) + Br_2(l)}$

   a. $K_p = \dfrac{P_{HBr}^2}{P_{Br_2}P_{H_2}}$
   b. $K_p = \dfrac{P_{H_2}}{P_{HBr}^2}$
   c. $K_p = P_{HBr}^2$
   d. $K_p = \dfrac{P_{HBr}^2}{P_{H_2}}$
   e. $K_p = \dfrac{P_{H_2}P_{Br_2}}{P_{HBr}^2}$

3. A 4.00 L flask is filled with 0.75 mol SO_3, 2.50 mol SO_2, and 1.30 mol O_2, and allowed to reach equilibrium. Predict the effect on the concentrations of SO_3 as equilibrium is achieved by using Q, the reaction quotient. Assume the temperature of the mixture is chosen so that $K_c = 12$. $\mathbf{2\ SO_3(g) \rightleftharpoons 2\ SO_2(g) + O_2(g)}$

   a. $[SO_3]$ will decrease because Q > K.
   b. $[SO_3]$ will decrease because Q < K.
   c. $[SO_3]$ will increase because Q < K.
   d. $[SO_3]$ will increase because Q > K.
   e. $[SO_3]$ will remain the same because Q = K.

4. This reaction below is studied at a high temperature. $\mathbf{PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)}$ At equilibrium, the partial pressures of the gases are as follows: $PCl_5 = 1.8 \times 10^{-2}$ atm, $PCl_3 = 5.6 \times 10^{-2}$ atm, and $Cl_2 = 3.8 \times 10^{-4}$ atm. What is the value of K_p for the reaction?

   a. 3.8×10^{-7}
   b. 1.2×10^{-3}
   c. 3.1
   d. 8.5×10^{2}
   e. 2.6×10^{6}

5. A sealed tube is prepared with 1.07 atm PCl_5 at 500 K. The PCl_5 decomposes until equilibrium is established; 1.54 atm is the equilibrium pressure of the tube. Calculate K_p using the equation: $\mathbf{PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)}$

   a. 0.052
   b. 0.20
   c. 0.27
   d. 0.37
   e. 2.2

6. Hydrogen monoiodide can decompose into hydrogen and iodine gases: $\mathbf{2\ HI(g) \rightleftharpoons H_2(g) + I_2(g)}$ $\mathbf{K_p = 0.016}$ at -17 °C. If 0.820 atm of HI(g) is sealed in a flask at -17 °C, what is the pressure of each gas when equilibrium is established?

   a. HI = 0.576 atm, H_2 = 0.096 atm, I_2 = 0.096 atm
   b. HI = 0.654 atm, H_2 = 0.083 atm, I_2 = 0.083 atm
   c. HI = 0.728 atm, H_2 = 0.092 atm, I_2 = 0.092 atm
   d. HI = 0.737 atm, H_2 = 0.083 atm, I_2 = 0.083 atm
   e. HI = 0.768 atm, H_2 = 0.111 atm, I_2 = 0.111 atm

7. Using the chemical reactions below, determine the equilibrium constant for the following reaction:
   $\mathbf{Ca^{2+}(aq) + 2\ H_2O(l) \rightleftharpoons Ca(OH)_2(s) + 2\ H^+(aq)}$

   $Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2\ OH^-(aq)$ $\quad K = 6.5 \times 10^{-6}$
   $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$ $\quad K = 1.0 \times 10^{-14}$

   a. 1.5×10^{-23}
   b. 6.5×10^{-20}
   c. 1.3×10^{-19}
   d. 1.5×10^{-9}
   e. 1.5×10^{19}

8. Hydrogen and iodine react to form hydrogen monoiodide according to: $\mathbf{H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)}$ $\mathbf{K_c = 0.504}$ at 25 °C. If initial concentrations of 0.170 M H_2 and 0.170 M I_2 are allowed to equilibrate, what is the equilibrium concentration of HI?

   a. 0.0445 M
   b. 0.0891 M
   c. 0.0684 M
   d. 0.0706 M
   e. 0.0129 M

9. Which of the following is never a Brønsted-Lowry acid in an aqueous solution?

   a. hydrogen monochloride, HCl(g)
   b. dihydrogen monosulfide, $H_2S(g)$
   c. ammonium chloride, $NH_4Cl(s)$
   d. hydrogen monofluoride, HF(g)
   e. sodium perchlorate, $NaClO_4(s)$

10. What is the conjugate base of $[Cr(H_2O)_6]^{3+}(aq)$?

   a. H_3O^+
   b. $[Cr(H_2O)_5OH]^{2+}$
   c. $[Cr(H_2O)_5H_3O]^{4+}$
   d. $[Cr(H_2O)_6]^{2+}$
   e. $[Cr(H_2O)_5]^{3+}$

11. At 25 °C, what is the H_3O^+ concentration in 0.044 M NaOH(aq)?

    a. 4.4×10^{-16} M
    b. 2.3×10^{-13} M
    c. 4.4×10^{-7} M
    d. 1.36 M
    e. 12.6 M

12. Assuming equal initial concentrations of the given species, which of the following weak acids has the strongest conjugate base in an aqueous solution?

    a. acetic acid, $K_a = 1.8 \times 10^{-5}$
    b. formic acid, $K_a = 1.8 \times 10^{-4}$
    c. hydrogen sulfite ion, $K_a = 6.2 \times 10^{-8}$
    d. nitrous acid, $K_a = 4.5 \times 10^{-4}$
    e. phosphoric acid, $K_a = 7.5 \times 10^{-3}$

13. Given the following acid dissociation constants,

    K_a (HF) = 7.2×10^{-4}
    K_a (NH_4^+) = 5.6×10^{-10}

    determine the equilibrium constant for the reaction below at 25 ºC.

    $$\mathbf{HF(aq) + NH_3(aq) \rightleftharpoons NH_4^+(aq) + F^-(aq)}$$

    a. 4.0×10^{-13}
    b. 1.3×10^{-8}
    c. 7.8×10^{-7}
    d. 1.3×10^{6}
    e. 2.5×10^{12}

14. What is the pH of 5.0×10^{-3} M HF? The K_a for hydrofluoric acid is 7.2×10^{-4}. *Hint: Is 100*K < C?*

    a. 2.72
    b. 2.80
    c. 4.60
    d. 5.44
    e. 6.12

15. A solution is made by diluting 0.50 mol NaClO to a volume of 3.0 L with water. What is the pH of the solution? (K_b of ClO^{-1} = 2.9×10^{-7})

    a. 3.66
    b. 7.46
    c. 10.34
    d. 10.58
    e. 13.22

16. What is the effect of adding 10 mL of 0.1 M NaOH(aq) to 100 mL of 0.2 M NH_4^+(aq)?

    1. The pH will decrease.
    2. The concentration of NH_3 will increase.
    3. The concentration of NH_4^+ will decrease.

    a. 1 only
    b. 2 only
    c. 3 only
    d. 2 and 3
    e. 1, 2, and 3

17. What is the pH of a solution that results from adding 25 mL of 0.50 M NaOH to 75 mL of 0.50 M CH_3CO_2H? (Note that the K_a of $CH_3CO_2H = 1.8 \times 10^{-5}$)

    a. 2.67
    b. 3.17
    c. 4.44
    d. 5.04
    e. 5.35

18. What is the pH of an aqueous solution of 0.30 M HF and 0.15 M F^-? (K_a of HF = 7.2×10^{-4})

    a. 1.83
    b. 2.84
    c. 3.14
    d. 3.44
    e. 10.86

19. Which of the following combinations would be best to buffer an aqueous solution at a pH of 2.0?

    a. H_3PO_4 and $H_2PO_4^-$, $K_{a1} = 7.5 \times 10^{-3}$
    b. HNO_2 and NO_2^{-1}, $K_a = 4.5 \times 10^{-4}$
    c. CH_3CO_2H and CH_3COO^{-1}, $K_a = 1.8 \times 10^{-5}$
    d. $H_2PO_4^{-1}$ and HPO_4^{2-}, $K_{a2} = 6.2 \times 10^{-8}$
    e. NH_4^+ and NH_3, $K_a = 5.7 \times 10^{-10}$

20. What is the pH of the buffer that results when 11 g of $NaCH_3CO_2$ is mixed with 85 mL of 1.0 M CH_3CO_2H and diluted with water to 1.0 L? (K_a of $CH_3CO_2H = 1.8 \times 10^{-5}$)

    a. 2.91
    b. 3.86
    c. 4.55
    d. 4.74
    e. 4.94

21. The K_a of hypochlorous acid, HClO, is 3.5×10^{-8}. What $[ClO^-]/[HClO]$ ratio is necessary to make a buffer with a pH of 7.71?

    a. 2.0×10^{-8}
    b. 0.25
    c. 0.56
    d. 1.8
    e. 3.9

22. What volume of 0.50 M NaOH should be added to 2.0 L of 0.25 M HCO_3^{-1} to make a buffer with a pH of 10.02? (Note that the pK_a of HCO_3^{-1} = 10.32)

    a. 0.17 mL
    b. 83 mL
    c. 2.5×10^2 mL
    d. 3.3×10^2 mL
    e. 5.0×10^2 mL

23. A volume of 25.0 mL of 0.100 M HCO_2H(aq) is titrated with 0.100 M NaOH(aq). What is the pH after the addition of 12.5 mL of NaOH? (K_a for $HCO_2H = 1.8 \times 10^{-4}$)

    a. 2.52
    b. 3.74
    c. 4.74
    d. 7.00
    e. 10.26

24. A 50.0 mL sample of 0.0240 M NH_3(aq) is titrated with aqueous hydrochloric acid. What is the pH after the addition of 15.0 mL of 0.0600 M HCl(aq)? (K_b of $NH_3 = 1.8 \times 10^{-5}$)

    a. 8.78
    b. 8.86
    c. 9.25
    d. 9.38
    e. 9.73

25. Which is the best colored indicator to use in the titration of 0.0010 M $CH_3CO_2^{-1}$(aq) with HCl(aq)? Why? (Note that the K_b of $CH_3CO_2^{-1} = 5.6 \times 10^{-10}$)

Indicator	pK_a
Bromocresol green	4.7
Phenol Red	7.8
Phenolphthalein	9.0

    a. Bromocresol green. The pH at the equivalence point is less than 7.0.
    b. Phenol Red. The pK_b of acetate ion and the pK_b of the indicator are similar.
    c. Phenol Red. The equivalence point of an acid-base titration occurs at a pH of 7.0.
    d. Phenolphthalein. The pK_b of acetate ion and the pK_b of the indicator are similar.
    e. Phenolphthalein. The pH at the equivalence point is greater than 7.0.

Part II: Short Answer / Calculation. *Show all work!*

1. Consider a 1.00 L solution which is 0.700 M CH_3CO_2H and 0.600 M $NaCH_3CO_2$. $K_a = 1.8*10^{-5}$

   a. What is the pH of the initial solution?

   b. Calculate the pH upon adding 10.00 mL of 1.00 M HCl to the solution from part a.

   c. Calculate the pH upon adding 15.00 mL of 2.10 M NaOH to the solution from part a.

2. Consider the reaction: $\mathbf{B_2H_6(g) \rightleftharpoons 2\ BH_3(g),\ \Delta H = +112\ kJ}$ Use Le Chatelier's principle to predict the effect of the following changes on this reaction at equilibrium. Write **RIGHT**, **LEFT** or **NO CHANGE** to indicate the effect observed.

	Effect
Addition of B_2H_6:	______________
Addition of a catalyst:	______________
Increasing the pressure:	______________
Removal of BH_3:	______________
Increasing temperature:	______________

3. A solution contains 50.0 mL of 0.100 M acetic acid (CH_3CO_2H). K_a= 1.8*10^{-5}

a. What is the pH of the initial acetic acid solution?

b. What is the pH after 10.0 mL of 0.100 M NaOH has been added to the mixture?

c. What is the pH after 40.0 mL of 0.100 M NaOH has been added to the mixture?

d. How many mL of 0.100 M NaOH are required to reach the equivalence point?

e. How many mL of 0.100 M NaOH are required to reach the half-equivalence point? What is the pH of the solution at the half-equivalence point?

f. What is the pH at the equivalence point?

g. What is the pH after 60.0 mL of 0.100 M NaOH has been added to the mixture?