CHEMISTRY 204
Hour Exam II
Practice Exam Spring 2024
Dr. D. DeCoste

Name ______________________________

Signature ___________________________

T.A. _______________________________

Section _____________________________

This exam contains 23 questions on 14 numbered pages. Check now to make sure you have a complete exam. You have two hours to complete the exam. Determine the **best** answer to the first 20 questions and enter these on the special answer sheet. Also, circle your responses in this exam booklet. **Show all of your work and provide complete answers to questions 21, 22 and 23.**

1-20	(60 pts.)	____________
21	(25 pts.)	____________
22	(20 pts)	____________
23	(15 pts.)	____________
Total	(120 pts)	____________

Useful Information:

- Unless otherwise noted, all solutions referred to on this exam are aqueous solutions at 25°C.
- On this exam, H_3O^+ and H^+ are used interchangeably.

$K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$ at 25°C.

For $ax^2 + bx + c = 0$, $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

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

$$K_a = \frac{[H^+]^2 - K_w}{[HA]_o - \dfrac{[H^+]^2 - K_w}{[H^+]}}$$

1. Consider a 100.0 mL solution of 2.00*M* HCN. How many moles of NaOH(s) must be added to obtain a pH of 9.00? Neglect any volume change from the addition of the solid NaOH.

   a) 1.00×10^{-6} mol b) 1.00×10^{-5} mol c) 0.0765 mol d) 0.163 mol e) 0.2001 mol

2. Consider a 100.0 mL solution of 0.100*M* NaCN. What volume of 0.100*M* HCl must be added to obtain a solution with a pH of 3.00?

   a) 82.5 mL b) 100.0 mL c) 102.0 mL d) 108.0 mL e) 150.0 mL

3. Recall the demonstration in which we added baking soda to separate 30.0 mL solutions of 3.00*M* HCl, 3.00*M* $HC_2H_3O_2$, and a mixture of 3.00*M* $HC_2H_3O_2$/3.00*M* $NaC_2H_3O_2$. Suppose instead of adding baking soda, we added 15.0 mL of 3.00M NaOH to each of the solutions. For which of the cases would the **change in pH** (to three significant figures) be the **lowest**?

   a) Adding 15.0 mL of 3.00M NaOH to 30.0 mL of 3.00*M* HCl.
   b) Adding 15.0 mL of 3.00M NaOH to 30.0 mL of 3.00*M* $HC_2H_3O_2$.
   c) Adding 15.0 mL of 3.00M NaOH to 30.0 mL of 3.00*M* $HC_2H_3O_2$/3.00*M* $NaC_2H_3O_2$.
   d) The change in pH would be equally low for a and b above.
   e) The change in pH would be equally low for a and c above.

4. Consider four beakers, each with 100.0 mL of an aqueous solution of 1.00*M* HCN. You add the following to the beakers:

   - Beaker 1: 100.0 mL of 1.00 *M* $HC_2H_3O_2$
   - Beaker 2: 100.0 mL of 1.00 *M* HF
   - Beaker 3: 100.0 mL of 1.00 *M* NH_3
   - Beaker 4: 100.0 mL of water

   Which beaker, at equilibrium, will contain the lowest concentration of CN^-(*aq*)?

   a) Beaker 1 b) Beaker 2 c) Beaker 3 d) Beaker 4 e) They are all the same.

5. Order the bases F^-, NO_3^-, NH_3, $C_2H_3O_2^-$, and H_2O from strongest to weakest. Which comes third in this ranking?

   a) F^- b) NO_3^- c) NH_3 d) $C_2H_3O_2^-$ e) H_2O

6. How many of the following decrease as an aqueous weak acid is diluted with water?

   I. The pH of the solution.
   II. The percent dissociation of the solution.
   III. The concentration of OH^-(*aq*).
   IV. The K_a value of the acid.

   a) 0 b) 1 c) 2 d) 3 e) 4

7. You titrate a solution of acetic acid ($HC_2H_3O_2$) with the same concentration as a solution of NaOH to the "quarter-equivalence" point (that is, you add a volume of the base that is one-quarter, or ¼, the volume of the acid). Which of the following best estimates the pH of the solution at the quarter-equivalence point?

a) 3.56 b) 4.14 c) 4.27 d) 4.53 e) 4.74

8. Determine the pH of a solution made by dissolving 1.256 mg of NaOH in 100.0 L of aqueous solution.

a) 6.38 b) 6.50 c) 7.50 d) 7.54 e) 7.62

9,10. Recall the demonstration in which we added Universal indicator (which is actually a mixture of indicators such that we see several colors from pH values of 0 to 14) to different salt solutions. As a rough estimate these colors are as follows:

- pH 1-3: red-orange
- pH 4-5: orange-yellow
- pH 6-8: green
- pH 9-11: green-blue
- pH 12-14: purple

Consider 1.00*M* solutions of the two salts listed below. What color would each solution appear when we add some Universal indicator?

9. NH_4F

a) red-orange b) orange-yellow c) green d) green-blue e) purple

10. NH_4CN

a) red-orange b) orange-yellow c) green d) green-blue e) purple

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11. For Chemistry 205 you are asked to make separate aqueous solutions of $NaHCO_3$, $NaHSO_3$, and $NaHC_2O_4$, and $NaHSO_4$. Unfortunately, your lab partner misread the instructions and instead of 3.14*M* solutions, your lab partner made 0.314*M* solutions. Which of the 0.314*M* solutions will have the **greatest difference in pH** as the 3.14*M* solution of that salt?

a) $NaHCO_3$
b) $NaHSO_3$
c) $NaHC_2O_4$
d) $NaHSO_4$
e) Each of the salts with have essentially the same pH at 3.14*M* as 0.314*M*.

12. You have a 1.000-mol sample of the solid weak acid HA, for which $K_a = 1.00 \times 10^{-3}$. How much water must you add to this acid such that at equilibrium the percent dissociation of the acid is 50.0%?

a) 250.0 mL b) 500.0 mL c) 1.000 L d) 250.0 L e) 500.0 L

13. You titrate 1.000 L of a 1.00×10^{-3} *M* NaCN(*aq*) solution with 1.00×10^{-4} *M* HCl(*aq*) to the endpoint. Determine the pH of the solution at the endpoint.

a) 6.53 b) 6.59 c) 6.62 d) 6.72 e) 6.94

14. Consider two separate solutions containing buffer systems. Beaker A has the H_2CO_3/HCO_3^- system, and beaker B has the $H_2PO_4^-/HPO_4^{2-}$ system. The pH of both solutions is 7.00. Which of the following is true concerning the relative amounts of acid and conjugate base in each beaker?

	Beaker A	Beaker B
a)	$[H_2CO_3] > [HCO_3^-]$	$[H_2PO_4^-] > [HPO_4^{2-}]$
b)	$[H_2CO_3] > [HCO_3^-]$	$[HPO_4^{2-}] > [H_2PO_4^-]$
c)	$[HCO_3^-] > [H_2CO_3]$	$[HPO_4^{2-}] > [H_2PO_4^-]$
d)	$[H_2CO_3] = [HCO_3^-]$	$[H_2PO_4^-] = [HPO_4^{2-}]$
e)	$[HCO_3^-] > [H_2CO_3]$	$[H_2PO_4^-] > [HPO_4^{2-}]$

15. Consider the titration of 100.0 mL of a 0.100*M* weak acid solution with 0.100*M* NaOH. After 31.4 mL of 0.100M NaOH is added, the pH is noted to be 7.12. Identify the weak acid.

a) HF b) HOCl c) HCN d) $HC_2H_3O_2$ e) HNO_2

16. You have 2.00*M* solutions of HF, HNO_2, HCl, HCN, and $HC_2H_3O_2$. You make four solutions by mixing equal volumes of two of the acids as follows:

Beaker A: HCl and HF
Beaker B: $HC_2H_3O_2$ and HCN
Beaker C: HNO_2 and HF
Beaker D: HCl and HCN

For how many of the solutions can you determine the pH to two significant figures by considering only one acid in the mixture?

a) 0 b) 1 c) 2 d) 3 e) 4

17-18. Consider the formation of the complex ion $Ag(NH_3)_2^+$ (*aq*) when Ag^+ (*aq*) and NH_3 (*aq*) react:

$$Ag^+ (aq) + NH_3 (aq) \rightleftharpoons Ag(NH_3)^+ (aq) \qquad K_1 = 2.1 \times 10^3$$

$$Ag(NH_3)^+ (aq) + NH_3 (aq) \rightleftharpoons Ag(NH_3)_2^+ (aq) \qquad K_2 = 8.2 \times 10^3$$

50.0 mL of 2.00×10^{-3} *M* $AgNO_3$ is reacted with 50.0 mL of 5.00 *M* NH_3.

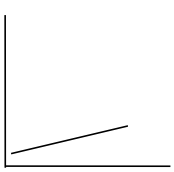
17. Determine the equilibrium concentration of $Ag(NH_3)^+$.

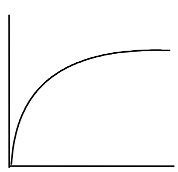
a) 9.31×10^{-12} *M*
b) 4.88×10^{-8} *M*
c) 1.00×10^{-3} *M*
d) 2.00×10^{-3} *M*
e) 5.00 *M*

18. Which of the following is true about the relative equilibrium concentrations of the silver containing ions in solution?

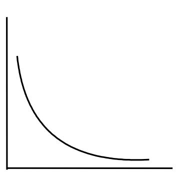
a) $[Ag(NH_3)_2^+] > [Ag(NH_3)^+] > [Ag^+]$
b) $[Ag^+] > [Ag(NH_3)^+] > [Ag(NH_3)_2^+]$
c) $[Ag(NH_3)^+] > [Ag(NH_3)_2^+] > [Ag^+]$
d) $[Ag(NH_3)^+] > [Ag^+] > [Ag(NH_3)_2^+]$
e) $[Ag(NH_3)_2^+] > [Ag^+] > [Ag(NH_3)^+]$

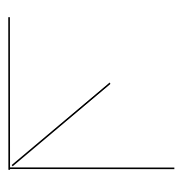
19-20. Indicate which of the graphs below **best** represents each plot described. A graph may be used once, more than once, or not at all.

a)


b)


c)


d)


e)


19. pH (y) vs. pK_a (x) for a series of aqueous 1.00*M* weak acid solutions at constant temperature.

20. pH (y) vs. pOH (x) for pure water at different temperatures.

21. We discussed in lecture (and I said in the videos) that we generally make assumptions in acid-base problems, and that this isn't bad – as long as we know what our assumptions are and how to deal with situations when they don't apply. Let's look into this a bit.

a. Suppose you have a 10.00 mL sample of HCl(*aq*) which has a pH = 3.00, and you dilute it to 1.000 L with water. What is the pH of the resulting solution?

i. The easiest way to do this problem is to assume that water merely increases the volume of the solution. Making this assumption, what is the pH of the resulting solution? **Show all work**. Why is this assumption reasonable to make in this case? **Explain your answer**. **[5 points]**

ii. Water, though, is an amphoteric substance (that is, it can act as an acid or a base) and this means that it might have some effect on the pH of the solution. Suppose we had this fantastic pH meter so that we could read the pH to nine digits after the decimal point. Would you expect the pH to be a bit lower, a bit higher, or exactly the same as what you determined above in part i? **Do not calculate** this (unless you want to do so on scratch paper to check your thinking), but **explain why** this would be true. **[5 points]**

21. b. Suppose you have a 10.00 mL sample of HCl(*aq*) which has a pH = 3.00, and you dilute it to 75.00 L with water. Can you still make the assumption that you did in the first part of question 21a? **Determine the pH in two ways**: once with making the assumption that water simply changes the volume and once with consideration of the acid-base properties of water. **Show all work.** Are these values the same if reported to two digits after the decimal point? **Explain why or why not** (do not simply use the results of the calculations **– explain your answer**). **[9 points]**

21. c. Suppose you have 10.00 mL of a weak acid aqueous solution with pH of 3.00. You decide to add enough water so that the solution has the same pH as you calculated in question 21a. Would you need to dilute the solution to a total volume of less than 1.00 L, greater than 1.00 L, or exactly 1.00 L? **Do not calculate** this (unless you want to do so on scratch paper to check your thinking), but **explain why** this would be true. **[6 points]**.

22. Great! Your friends throw you a surprise party, and knowing your love of chemistry, one of the party games is an acid-base titration. And because they know you are in Accelerated Chemistry at the prestigious University of Illinois at Urbana-Champaign, they have you titrate a solution composed of three acids!

You have 100.0 mL of a solution labeled "0.100*M* HCl, 0.100*M* HF, and 0.100 *M* HCN". You will titrate this solution with 1.00*M* NaOH. Determine the pH of the solutions at various points along the titration. **Show all work**. [**20 points; 5 points each**]

Full credit is reserved for a coherent, systematic method that we can follow.

a. Calculate the initial pH before any NaOH is added to the acid mixture.

22. b. Calculate the pH after 8.00 mL of 1.00*M* NaOH is added to the acid mixture.

22. c. Calculate the pH after 14.00 mL of 1.00*M* NaOH is added to the acid mixture.

22. d. Calculate the pH after 20.00 mL of 1.00*M* NaOH is added to the acid mixture.

23. Recall the demonstration where we added 3*M* HCl to Milk of Magnesia (which is a saturated solution/suspension of magnesium hydroxide). It looked so "milky" because it is not terribly soluble. In fact, you may remember that one of the solubility rules states that "most hydroxide salts are only slightly soluble". Slightly soluble, of course, is a bit vague, so let's quantify this. For each of the following three hydroxide solutions, **determine the concentration of the metal ion at equilibrium** (the hydroxides are added to pure water at 25°C).

Justify any assumptions/simplifications and **show all work**. If for any of these simplifications cannot be made and the problem is too complex to solve, **determine an estimate** for the answer (a **range** is fine), **explain why it is too complex to solve,** and **determine the equation** you would need to solve. [**15 points; 5 points each**]

a. Magnesium hydroxide has a K_{sp} value of 8.90 x 10^{-12}. Determine the concentration of the Mg^{2+} ion in a saturated solution.

23. b. Cobalt(III) hydroxide has a K_{sp} value of 2.50 x 10^{-43}. Determine the concentration of the Co^{3+} ion in a saturated solution.

23. c. Copper(II) hydroxide has a K_{sp} value of 1.60×10^{-20}. Determine the concentration of the Cu^{2+} ion in a saturated solution.