Name ______________________________**Chem 163 Section**: ______ **Team Number:** ______

ALE 14. Buffer Solutions

(Reference: 19.1 Silberberg *5th edition*)

What does a buffer do and how does it do it?

The Model: Change of pH when Strong Acid or Base is added

	Aqueous Solution	pH of Solution	pH after 0.050 mol HCl is added to 1.0L solution	ΔpH Change in pH after adding HCl	pH after 0.050 mol NaOH is added to 1.0L solution	ΔpH Change in pH after adding NaOH
1.	pure H_2O	7.00	1.30	**-5.70**	12.70	**+5.70**
2.	0.20 *M* NH_4Cl	4.98	1.30	**-3.68**	8.77	**+3.79**
3.	0.20 *M* NH_3	11.28	9.73		12.70	
4.	0.12 *M* NH_4^+ and 0.08 *M* NH_3	9.08	8.50		9.52	
5.	0.10 *M* NH_4^+ and 0.10 *M* NH_3	9.25	8.77		9.73	
6.	0.08 *M* NH_4^+ and 0.12 *M* NH_3	9.43	8.99		10.01	
7.	0.20 *M* H_2CO_3	5.69	1.30		7.92	
8.	0.20 *M* $NaHCO_3$	9.83	6.84		12.70	
9.	0.11 *M* H_2CO_3 and 0.09 *M* HCO_3^-	6.29	5.78	**-0.51**	6.75	**+0.46**
10.	0.10 *M* H_2CO_3 and 0.10 *M* HCO_3^-	6.36	5.88	**-0.48**	6.83	**+0.47**
11.	0.09 *M* H_2CO_3 and 0.11 *M* HCO_3^-	6.46	6.01	**-0.45**	6.98	**+0.52**

Key Questions

1. Finish the two columns in the table above for the *change in pH* when either 0.050 mol of H^+ or 0.050 mol of OH^- is added to a solution.

2. a. A buffer is a solution that resists or prevents a large change in pH upon the addition of either a strong acid or a strong base. Compare the ΔpH when the same amount of H^+ or OH^- is added to the same volume of each of the solutions. From this information, which of the solutions in the table above are buffers? (*Circle the number of each solution in the table above that is a buffer.*)

   b. Based on the data in the table above, what are the two components of an aqueous buffer solution? (*Circle your two choices.*)
   i.) Strong Acid
   ii.) Weak acid
   iii.) The conjugate base of the strong acid
   iv.) The conjugate base of the weak acid

3. How effective a buffer solution is in maintaining the solution's pH when *either* an acid *or* a base is added to it is referred to as the solution's **buffering capacity**. Which of the following types of buffer solutions has the best buffering capacity?

   i. one with more moles of weak acid than moles of weak base

   ii. one with equal numbers of moles of weak acid and weak base

   iii. one with more moles of weak base than moles of weak acid

   Explain your answer, drawing upon evidence from the table on page 1. *Hint*: Consider the average $|\Delta pH|$ for each solution.

The Model: The Composition of a Buffer

In a **buffer solution**, there is both a **weak acid** and **the conjugate weak base of that acid**. The equilibrium within a buffer system is easily represented as eqn **1**.

$$\mathbf{HA}(\boldsymbol{aq}) \rightleftharpoons \mathbf{H^+}(\boldsymbol{aq}) + \mathbf{A^-}(\boldsymbol{aq}) \qquad \textbf{(1)}$$

A buffer solution works most efficiently to protect the pH from addition of either a strong acid or the addition of a strong base when it is prepared such that $[HA] \approx [A^-]$.

Key Questions

4. A buffer solution contains a weak acid and the conjugate weak base (represented generically as HA and A^-, respectively) and hydronium ions, which exist in equilibrium according to eqn **1**.

   a. Suppose a modest amount of strong acid is dissolved in the buffer solution. Use Le Châtelier's Principle to explain what happens to [HA], to $[A^-]$, and to $[H^+]$.

   b. Explain why there is not a drastic change in the solution's pH when a modest amount of strong acid is added to a buffer solution.

5 a. Explain why a solution made up of HCl and KCl is not a buffer but a solution made up of HF and KF is.

b. Yes or No: *Could* a solution made up of HF and KCl *possibly* serve as a buffer? Explain your answer.

c. Yes or No: *Could* a solution made up of HCl and KF *possibly* serve as a buffer? Explain your answer.

The Henderson-Hasselbalch equation: $\mathrm{pH} = \mathrm{p}K_a + \log\frac{[\mathrm{A}^-]}{[\mathrm{HA}]}$

Exercises

6. Use the Henderson-Hasselbalch equation to calculate the pH of a buffer solution that is made to have 0.10 *M* NH_4^+(*aq*) and 0.10 *M* NH_3(*aq*). *Hints*: i.) Ignoring the charges of the acid and the base, which species is the weak acid, "HA," and which species is the conjugate base, "A^-"? ii.) Look up in your textbook the K_a of the weak acid or calculate the K_a from the K_b of its conjugate base.

7. a. Suppose a buffer is made to have 0.10 *M* NH_4^+(*aq*) and 0.10 *M* NH_3(*aq*). When 0.050 mol of HCl is added to 1.0 L of that buffer, assuming the present NH_3 completely converts all of the added strong acid to NH_4^+, what do the concentrations of NH_4^+ and NH_3 become? *Hint*: Since the buffer solution has a volume of 1.0 L, the number of moles and the molarity of a solute are equivalent. Consider the reaction that occurs and the stoichiometry between NH_3 and H^+.

b. Use the Henderson-Hasselbalch equation to calculate the pH after 0.050 mol of HCl has been added to 1.0 L of a buffer solution that was originally made to have 0.10 *M* $NH_4^+(aq)$ and 0.10 *M* $NH_3(aq)$.

8. a. If you want to prepare a buffer with a pH of 3.50, explain why you should probably choose HF and NaF to be the solutes rather than CH_3COOH and CH_3COONa. *Hints*: A buffer works most efficiently when $[A^-] \approx [HA]$. Refer to the table of K_a's of weak acids in your textbook. What are the K_a's of HF and CH_3COOH? Which acid has a pK_a closest to the desired pH of the buffer?

   b. What is the desired ratio of $[F^-]/[HF]$ so that the prepared buffer solution will have a pH of 3.50?

9. What are the $[H_3O^+]$ and the pH of a benzoate buffer that consists of 0.33 *M* C_6H_5COOH (benzoic acid) and 0.28 *M* C_6H_5COONa (sodium benzoate)? The K_a of benzoic acid is 6.3×10^{-5}.

10. What is the buffer-component concentration ratio, $[CH_3COO^-]/[CH_3COOH]$, of a buffer that has a pH of 4.39. The K_a of acetic acid is 1.8×10^{-5}.