CH 223 Spring 2024:

Problem Set #3

Instructions

Step One (all sections):

- **Learn the material** for Problem Set #3 by **reading Chapter 14** of the textbook and/or by watching the videos found on our website (https://mhchem.org/223)
- **Try the problems** for Problem Set #3 found on the next pages on your own first. Use separate paper and write out your answers, showing all of your work. If you write the answers on the problem set itself, you will receive fewer points. Include your name on your problem set!

Step Two:

Section 01 and H1: We will go over Problem Set #3 during recitation. ***Self correct all problems*** of your problem set before turning it in at the end of recitation.

- *Section 01:* due **Monday, April 22 at 1:10 PM**
- *Section H1:* due **Wednesday, April 24 at 1:10 PM**

Section W1: **Watch the recitation video** for Problem Set #3:

http://mhchem.org/v/p.htm

- **Self correct *all* of the problems** while viewing the video. Mark correct problems with a star (or other similar mark), and correct all incorrect problems (show the correct answer and the steps required to achieve it.)
- **Submit Problem Set #3 via email (mike.russell@mhcc.edu) as a single PDF file** (use CamScanner (https://camscanner.com), CombinePDF (https://combinepdf.com), etc.) **by 11:59 PM Wednesday, April 24.**

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!

CH 223 Problem Set #3

** Complete problem set on separate pieces of paper showing all work, circling final answers, etc.*
** Self correct your work before turning it in to the instructor.*

Covering: **Chapter Fourteen Part II** *and* **Chapter Guide Three**
Important Tables and/or Constants: "**Titration Guide**" *(Handout),* "**Buffers and Henderson-Hasselbalch Guide**" *(Handout)* and the **Table of Acids and Bases for CH 223** *(after this problem set),* $\mathbf{K_w = 1.00 \times 10^{-14}}$ at 25 °C

---

1. Calculate the hydronium ion concentration and the pH when 50.0 mL of 0.40 M NH_3 is mixed with 50.0 mL of 0.40 M HCl. *Use a table to look up relevant K values. Hint: Determine the region this problem would use from the WB + SA Titration Calculations lab.*
2. What is the pH of the solution that results from adding 25.0 mL of 0.12 M HCl to 25.0 mL of 0.43 M NH_3? *Use a table to look up relevant K values.*
3. For each of the following, decide whether the pH is less than, equal to, or greater than 7.
    a. 150 mL of 0.20 M HNO_3 is mixed with 75 mL of 0.40 M LiOH
    b. equal volumes of 0.10 M acetic acid, CH_3CO_2H, and 0.10 M KOH are mixed
    c. 25 mL of 0.015 M NH_3 is mixed with 12 mL of 0.015 M HCl
    d. 25 mL of 0.45 M H_2SO_4 is mixed with 25 mL of 0.90 M NaOH
4. Does the pH of the solution increase, decrease or stay the same when you:
    a. Add solid sodium oxalate, $Na_2C_2O_4$, to 50.0 mL of 0.015 M oxalic acid, $H_2C_2O_4$?
    b. Add solid ammonium chloride to 75 mL of 0.016 M HCl?
    c. Add 20.0 g of NaCl to 1.0 L of 0.10 M sodium acetate, $NaCH_3CO_2$?
    d. Add 10.3 g of $FeCl_3$ to 1.0 L of pure water?
5. Which of the following combinations would be the best choice to buffer the pH of a solution at approximately 7? *Use a table to look up relevant K values.*
    a. H_3PO_4 and NaH_2PO_4
    b. NaH_2PO_4 and Na_2HPO_4
    c. Na_2HPO_4 and Na_3PO_4
6. What is the pH of 100. mL of 0.15 M acetic acid to which 1.56 g of sodium acetate, $NaCH_3CO_2$, has been added? *Use a table to look up relevant K values.*
7. Lactic acid, $CH_3CHOHCO_2H$, is found in sour milk, in sauerkraut, and in muscles after activity. K_a for lactic acid = 1.4×10^{-4}.
    a. If 2.75 g of $NaCH_3CHOHCO_2$, sodium lactate, is added to 5.00×10^2 mL of 0.100 M lactic acid, what is the pH of the resulting buffer solution?
    b. Will the pH be lower or higher than the pH of the pure lactic acid solution?
8. Calculate the pH of a solution that has an ammonium chloride concentration of 0.050 M and an ammonia concentration of 0.045 M. *Use a table to look up relevant K values.*
9. What mass of ammonium chloride, NH_4Cl, must be added to exactly 5.00×10^2 mL of 0.10 M NH_3 to give a solution with a pH of 9.00? *Use a table to look up relevant K values.*
10. A buffer solution is composed of 1.360 g of KH_2PO_4 and 5.677 g of Na_2HPO_4. *Use a table to look up relevant K values.*
    a. What is the pH of the buffer solution?
    b. What mass of KH_2PO_4 must be added to decrease the buffer solution pH by 0.5 units?

Problem Set #3 continues on the next page

11. You dissolve 0.425 g of NaOH in 2.00 L of a buffer solution that has $[H_2PO_4^-] = [HPO_4^{2-}] = 0.132$ M. What is the pH of the solution before adding the NaOH? After adding the NaOH? *Use a table to look up relevant K values.*
12. What will be the pH change when 20.0 mL of 0.100 M NaOH is added to 80.0 mL of a buffer solution consisting of 0.169 M NH_3 and 0.183 M NH_4Cl? *Use a table to look up relevant K values.*
13. Assume you dissolve 0.235 g of the weak acid benzoic acid, $C_6H_5CO_2H$, in enough water to make 1.00 x 10^2 mL of solution and then titrate the solution with 0.108 M NaOH. *Use a table to look up relevant K values.*

$$C_6H_5CO_2H(aq) + OH^{-1}(aq) \rightleftharpoons C_6H_5CO_2^{-1}(aq) + H_2O(\ell)$$

    a. What is the pH of the original benzoic acid solution?
    b. What are the concentrations of the following ions at the equivalence point? Na^+, H_3O^+, OH^-, and $C_6H_5CO_2^-$? What is the pH at the equivalence point?

14. A solution of the weak base aniline, $C_6H_5NH_2$, $K_b = 4.0 \times 10^{-10}$, in 25.0 mL of water requires 25.67 mL of 0.175 M HCl to reach the equivalence point.

$$C_6H_5NH_2(aq) + H_3O^+(aq) \rightleftharpoons C_6H_5NH_3^+(aq) + H_2O(\ell)$$

    a. What was the concentration of the aniline in the original solution?
    b. What are the concentrations of H_3O^+, OH^- and $C_6H_5NH_3^+$ at the equivalence point? What is the pH of the solution at the equivalence point?

Table of Acids and Bases for CH 223

Acid Name	Acid	K_a	Base	K_b	Base Name
Perchloric acid	$HClO_4$	large	ClO_4^-	very small	perchlorate ion
Sulfuric acid	H_2SO_4	large	HSO_4^-	very small	hydrogen sulfate ion
Hydrochloric acid	HCl	large	Cl^-	very small	chloride ion
Nitric acid	HNO_3	large	NO_3^-	very small	nitrate ion
Hydronium ion	H_3O^+	1.0	H_2O	1.0×10^{-14}	water
Sulfurous acid	H_2SO_3	1.2×10^{-2}	HSO_3^-	8.3×10^{-13}	hydrogen sulfite ion
Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}	SO_4^{2-}	8.3×10^{-13}	sulfate ion
Phosphoric acid	H_3PO_4	7.5×10^{-3}	$H_2PO_4^-$	1.3×10^{-12}	dihydrogen phosphate ion
Hexaaquairon(III) ion	$[Fe(H_2O)_6]^{3+}$	6.3×10^{-3}	$[Fe(H_2O)_5OH]^{2+}$	1.6×10^{-12}	pentaaquahydroxoiron(III) ion
Hydrofluoric acid	HF	7.2×10^{-4}	F^-	1.4×10^{-11}	fluoride ion
Nitrous acid	HNO_2	4.5×10^{-4}	NO_2^-	2.2×10^{-11}	nitrite ion
Formic acid	HCO_2H	1.8×10^{-4}	HCO_2^-	5.6×10^{-11}	formate ion
Benzoic acid	$C_6H_5CO_2H$	6.3×10^{-5}	$C_6H_5CO_2^-$	1.6×10^{-10}	benzoate ion
Acetic acid	CH_3CO_2H	1.8×10^{-5}	$CH_3CO_2^-$	5.6×10^{-10}	acetate ion
Propanoic acid	$CH_3CH_2CO_2H$	1.3×10^{-5}	$CH_3CH_2CO_2^-$	7.7×10^{-10}	propanoate ion
Hexaaquaaluminum ion	$[Al(H_2O)_6]^{3+}$	7.9×10^{-6}	$[Al(H_2O)_5OH]^{2+}$	1.3×10^{-9}	pentaaquahydroxoaluminum ion
Carbonic acid	H_2CO_3	4.2×10^{-7}	HCO_3^-	2.4×10^{-8}	hydrogen carbonate ion
Hexaaquacopper(II) ion	$[Cu(H_2O)_6]^{2+}$	1.6×10^{-7}	$[Cu(H_2O)_5OH]^+$	6.3×10^{-8}	pentaaquahydroxocopper(II) ion
Hydrogen sulfide	H_2S	1×10^{-7}	HS^-	1×10^{-7}	hydrogen sulfide ion
Dihydrogen phosphate ion	$H_2PO_4^-$	6.2×10^{-8}	HPO_4^{2-}	1.6×10^{-7}	hydrogen phosphate ion
Hydrogen sulfite ion	HSO_3^-	6.2×10^{-8}	SO_3^{2-}	1.6×10^{-7}	sulfite ion
Hypochlorous acid	$HClO$	3.5×10^{-8}	ClO^-	2.9×10^{-7}	hypochlorite ion
Hexaaqualead(II) ion	$[Pb(H_2O)_6]^{2+}$	1.5×10^{-8}	$[Pb(H_2O)_5OH]^+$	6.7×10^{-7}	pentaaquahydroxolead(II) ion
Hexaaquacobalt(II) ion	$[Co(H_2O)_6]^{2+}$	1.3×10^{-9}	$[Co(H_2O)_5OH]^+$	7.7×10^{-6}	pentaaquahydroxocobalt(II) ion
Boric acid	$B(OH)_3(H_2O)$	7.3×10^{-10}	$B(OH)_4^-$	1.4×10^{-5}	tetrahydroxoborate ion
Ammonium ion	NH_4^+	5.6×10^{-10}	NH_3	1.8×10^{-5}	ammonia
Hydrocyanic acid	HCN	4.0×10^{-10}	CN^-	2.5×10^{-5}	cyanide ion
Hexaaquairon(II) ion	$[Fe(H_2O)_6]^{2+}$	3.2×10^{-10}	$[Fe(H_2O)_5OH]^+$	3.1×10^{-5}	pentaaquahydroxoiron(II) ion
Hydrogen carbonate ion	HCO_3^-	4.8×10^{-11}	CO_3^{2-}	2.1×10^{-4}	carbonate ion
Hexaaquanickel(II) ion	$[Ni(H_2O)_6]^{2+}$	2.5×10^{-11}	$[Ni(H_2O)_5OH]^+$	4.0×10^{-4}	pentaaquahydroxonickel(II) ion
Hydrogen phosphate ion	HPO_4^{2-}	3.6×10^{-13}	PO_4^{3-}	2.8×10^{-2}	phosphate ion
Water	H_2O	1.0×10^{-14}	OH^-	1.0	hydroxide ion
Hydrogen sulfide ion*	HS^-	1×10^{-19}	S^{2-}	1×10^{5}	sulfide ion
Ethanol	C_2H_5OH	very small	$C_2H_5O^-$	large	ethoxide ion
Ammonia	NH_3	very small	NH_2^-	large	amide ion
Hydrogen	H_2	very small	H^-	large	hydride ion

Increasing Acid Strength

Increasing Base Strength

* The values of K_a for HS^- and K_b for S^{2-} are estimates.