CH 223 Spring 2026:
Problem Set #3
Instructions

Step One:

• **Learn the material** for Problem Set #3 by **reading Chapter 14** of the textbook and/or by watching the videos found on the website (https://mhchem.org/223video)

• **Try the problems** for Problem Set #3 found on the next pages on your own first. Write your answers in the space provided or write your answers on separate paper (your choice.) Include your name on your problem set!

Step Two:

Watch the recitation video for Problem Set #3:

http://mhchem.org/3/3

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.)

Step Three:

Turn the Problem Set in at the beginning of recitation to the instructor on **Monday, April 20 (section L1)** *or* **Wednesday, April 22 (section L2.)** The graded problem set will be returned to you the following week during recitation.

Do *not* include this page to avoid a point penalty; your front page should be page II-3-3.

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

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CH 223 Problem Set #3

Name:

Complete the problem set on your own first using these sheets for your work or separate paper (your choice.) **Self correct your work *(all problems!)*** using the recitation video for this problem set, found here: **http://mhchem.org/3/3**

***** *Covering:* **Chapter Fourteen** *and* **Chapter Guide Three**

***** *Important Tables and/or Constants:* **periodic table** found here: http://mhchem.org/pertab, t*he* **Table of Acids and Bases for CH 223** *which follows this problem set and here:* **http://mhchem.org/KaKb***),* **K_w = 1.00 x 10^{-14}** at 25 °C, "**Buffers and Henderson-Hasselbalch Guide**" *(Handout)*

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1. In each of the following acid-base reactions, identify the Brønsted acid and base on the left and their conjugate partners on the right.

   a. $HCO_2H(aq) + H_2O(\ell) \rightleftharpoons HCO_2^{-1}(aq) + H_3O^{+}(aq)$

   b. $NH_3(aq) + H_2S(aq) \rightleftharpoons NH_4^{+}(aq) + HS^{-1}(aq)$

   c. $HSO_4^{-1}(aq) + OH^{-1}(aq) \rightleftharpoons SO_4^{2-}(aq) + H_2O(\ell)$

2. What are the products of each of the following acid-base reactions? Indicate the acid and its conjugate base, and the base and its conjugate acid.

   a. $HClO_4 + H_2O \rightarrow$

   b. $NH_4^{+} + H_2O \rightarrow$

   c. $HPO_4^{2-} + H_2O \rightarrow$ (show HPO_4^{2-} as both a Brønsted acid and a Brønsted base, two equations)

3. Several acids are listed here with their respective equilibrium constants:

$$HF(aq) + H_2O(\ell) \rightleftharpoons H_3O^{+}(aq) + F^{-1}(aq)$$

$$K_a = 7.2 \times 10^{-4}$$

$$HPO_4^{-2}(aq) + H_2O(\ell) \rightleftharpoons H_3O^{+}(aq) + PO_4^{-3}(aq)$$

$$K_a = 3.6 \times 10^{-13}$$

$$CH_3CO_2H(aq) + H_2O(\ell) \rightleftharpoons H_3O^{+}(aq) + CH_3CO_2^{-1}(aq)$$

$$K_a = 1.8 \times 10^{-5}$$

   a. Which is the strongest acid? Which is the weakest acid?

   b. What is the conjugate base of the acid HF?

   c. Which acid has the weakest conjugate base?

   d. Which acid has the strongest conjugate base?

4. pH and pKa:
    a. An organic acid has pK_a = 8.95. What is its K_a value?

    b. A weak base has $K_b = 1.5 \times 10^{-9}$. What is the value of K_a for the conjugate acid?

    c. HCl, a strong acid, has a concentration of 0.30 M. What is the pH of the solution?

    d. NaOH, a strong base, has a concentration of 0.010 M. What is the pH of the solution?

    e. Acetic acid, a weak acid with $K_a = 1.8 \times 10^{-5}$, has a concentration of 0.10 M. What is the pH of the solution?

    f. Methylamine, a weak base with $K_b = 4.2 \times 10^{-4}$, has a concentration of 0.25 M. What is the pH of the solution?

5. The pH of a solution of $Ba(OH)_2$ is 10.66 at 25 °C. Is this solution acidic, basic or neutral? What is the hydroxide ion concentration in the solution? If the solution volume is 125 mL, how many grams of $Ba(OH)_2$ must have been dissolved?

6. 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?

7. 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

8. 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.*

9. 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?

10. 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.*

Table of Acids and Bases for CH 223

Increasing Acid Strength ↑

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 Base Strength ↓

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