Chem 116 POGIL Worksheet - Week 9 - Solutions
Introduction to Acid-Base Concepts

Key Questions

1. In the spaces provided, write the formulas of the conjugate bases of the given Brønsted-Lowry acids.

Acid	HNO_3	NH_4^+	HSO_4^-	H_2SO_4	$HC_2H_3O_2$
Conjugate base	NO_3^-	NH_3	SO_4^{2-}	HSO_4^-	$C_2H_3O_2^-$

2. In the spaces provided, write the formulas of the conjugate acids of the given Brønsted-Lowry bases.

Base	OH^-	NH_3	HS^-	SO_4^{2-}	CH_3NH_2
Conjugate acid	H_2O	NH_4^+	H_2S	HSO_4^-	$CH_3NH_3^+$

3. Using the notation $acid_1/base_1$ and $base_2/acid_2$ (as shown above), identify the Brønsted-Lowry conjugate acid-base pairs in the following reactions.

$$\underset{base_1}{HS^-(aq)} + \underset{acid_2}{HC_2H_3O_2(aq)} \rightleftharpoons \underset{acid_1}{H_2S} + \underset{base_2}{C_2H_3O_2^-}$$

$$\underset{acid_1}{HF(aq)} + \underset{base_2}{PO_4^{3-}(aq)} \rightleftharpoons \underset{base_1}{F^-(aq)} + \underset{acid_2}{HPO_4^{2-}(aq)}$$

$$\underset{acid_1}{HNO_2(aq)} + \underset{base_2}{H_2O(l)} \rightleftharpoons \underset{base_1}{NO_2^-(aq)} + \underset{acid_2}{H_3O^+}$$

$$\underset{base_1}{CH_3NH_2(aq)} + \underset{acid_2}{H_2O(l)} \rightleftharpoons \underset{acid_1}{CH_3NH_3^+(aq)} + \underset{base_2}{OH^-(aq)}$$

4. Given the following concentrations of H_3O^+ or OH^-, calculate the concentration of OH^- or H_3O^+, and indicate whether the solution is acidic or basic.

$[H_3O^+]$	$[OH^-]$	Acidic or basic?
1.0×10^{-9} M	1.0×10^{-5} M	basic
2.5×10^{-6} M	4.0×10^{-9} M	acidic
1.2×10^{-8} M	8.3×10^{-7} M	basic

5. Complete the following table by calculating the missing entries and indicate whether the solution is acidic or basic. Be sure your answers are expressed to the proper number of significant figures.

$[H_3O^+]$	$[OH^-]$	pH	pOH	acidic or basic?
5.8×10^{-5} M	1.7×10^{-10} M	4.24	9.76	acidic
1.6×10^{-9} M	6.2×10^{-6} M	8.79	5.21	basic
5.6×10^{-12} M	1.7×10^{-3} M	11.24	2.76	basic
5.0×10^{-5} M	2.0×10^{-10} M	4.30	9.70	acidic
2.0 M	5.0×10^{-15} M	–0.30	14.30	acidic (very!)

6. Determine the concentrations of H_3O^+ and OH^- in the following solutions of strong acids or bases in water. [Caution: Think about how the acid or base dissociates in water.]

Solution	$[H_3O^+]$	$[OH^-]$
2.5×10^{-3} M HCl	2.5×10^{-3} M	4.0×10^{-12} M
0.0010 M NaOH	1.0×10^{-11} M	1.0×10^{-3} M
7.5×10^{-5} M $Ca(OH)_2$	6.7×10^{-11} M	1.5×10^{-4} M

In the last case, realize that two moles of OH^- are produced for every one mole of $Ca(OH)_2$ by the dissociation reaction, $Ca(OH)_2(aq) \rightarrow Ca^{2+}(aq) + 2\ OH^-(aq)$.

7. A 0.0100 M solution of a weak acid HA has a pH of 2.60. What is the value of K_a for the acid? [Hint: What is the actual concentration of undissociated HA, [HA], in this solution?]

$$\text{pH} = 2.\ 60 \Rightarrow [H_3O^+] = 2.5 \times 10^{-3}\ \text{M}$$

We can assume that the acid is the major source of hydronium ion and that water contributes little to the total $[H_3O^+]$. This concentration of hydronium ion, then, also represents the amount of the initial HA that is lost through hydrolysis. On this basis we have the following equilibrium concentrations:

	HA	+	H_2O	$\rightleftharpoons$	H_3O^+	+	A^-
Initial	0.0100				10^{-7}		0
Equilibrium	0.0100 – 0.0025 = 0.0075				2.5×10^{-3}		2.5×10^{-3}

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = \frac{(2.5\times10^{-3})^2}{7.5\times10^{-3}} = 8.3\times10^{-4}$$

8. What is the pH of 4.0×10^{-2} M benzoic acid ($C_6H_5CO_2H$ = HBz), for which $K_a = 6.46 \times 10^{-5}$? Is it necessary to solve the quadratic equation in this case?

$$HBz + H_2O \rightleftharpoons H_3O^+ + Bz^-$$

The concentration of the acid and the K_a fit our criteria to avoid needing the quadratic equation.

$$[H_3O^+] = \sqrt{(4.0 \times 10^{-2})(6.46 \times 10^{-5})} = \sqrt{2.5_{84} \times 10^{-6}} = 1.6 \times 10^{-3} \text{ M} = [Bz^-]$$

$$\text{pH} = 2.79$$

The percent dissociation of the benzoic acid, based on our calculation, is

$$\%\ \text{dissociation} = \frac{1.6 \times 10^{-3}}{4.0 \times 10^{-2}} \times 100\% = 4.0\%$$

This is acceptable, so the quadratic equation was not necessary.

9. Find the concentrations of all species and pH for a 1.0×10^{-3} M HF solution. $K_a = 6.7 \times 10^{-4}$. You will need to find values for [HF], $[H_3O^+]$, $[F^-]$, and $[OH^-]$.

$$HF + H_2O \rightleftharpoons H_3O^+ + F^-$$

Trying the quick method, we obtain

$$[H_3O^+] = \sqrt{C_{HA}K_a} = \sqrt{(1.0 \times 10^{-3})(6.7 \times 10^{-4})} = 8.2 \times 10^{-4} \text{ M} = [F^-]$$

$$\%\ \text{dissociation} = \frac{8.2 \times 10^{-4}}{1.0 \times 10^{-3}} \times 100\% = 82\%$$

This is not acceptable. Notice that $C_{HA} = 1.0 \text{ x } 10^{-3}$ and $K_a = 6.7 \text{ x } 10^{-4}$ are within two powers of 10 of each other, suggesting that HF is appreciably dissociated. We must solve the quadratic. This means that we will assume $[HF] = C_{HF} - [H_3O^+]$. Substituting into the K_a expression:

$$K_a = 6.7 \times 10^{-4} = \frac{[H_3O^+]^2}{1.0 \times 10^{-3} - [H_3O^+]}$$

$$[H_3O^+]^2 = 6.7 \times 10^{-7} - 6.7 \times 10^{-4}\,[H_3O^+]$$

$$[H_3O^+]^2 + 6.7 \times 10^{-4}\,[H_3O^+] - 6.7 \times 10^{-7} = 0$$

Solving the quadratic equation and ignoring the negative root (-1.22×10^{-3}) gives

$$[H_3O^+] = 5.4_9 \times 10^{-4}\ \text{M} = [F^-] \qquad \Rightarrow \text{pH} = 3.26$$

$$[HF] = C_{HF} - [H_3O^+] = 1.0 \times 10^{-3} - 5.4_9 \times 10^{-4} = 4.5_1 \times 10^{-4}\ \text{M}$$

To find $[OH^-]$, use K_w:

$$[OH^-] = \frac{K_w}{[H_3O^+]} = \frac{1.00 \times 10^{-14}}{5.49 \times 10^{-4}} = 1.8_2 \times 10^{-11}\ \text{M}$$