Weak Acids, Weak Bases, and Salts

Introduction:

Weak acids and weak bases only dissociate to a small degree (typically less than 5%). Weak acids vary in their tendency to ionize in water. A weak acid that ionizes to a greater extent will form more H_3O^+ ions and thus will have a larger K_a (acid ionization constant) value than a weak acid that ionizes to a smaller extent. By comparing the K_a values for different weak acids, the relative strength of weak acids can be determined.

Weak bases vary in their relative ability to accept protons. Thus, a weak base with a larger K_b (base ionization constant) value is stronger than a weak base with a smaller K_b.

A salt is the ionic compound formed during an acid-base neutralization reaction. Almost all salts are strong electrolytes (soluble in water) and thus exist as ions in aqueous solutions. Salt solutions can be neutral, acidic, or basic depending on the behavior of the component ions.

Cations from the strong bases (group IA and group IIA) and anions from the monoprotic strong acids (Cl^-, Br^-, I^-, NO_3^- and ClO_4^-) will not react with water and are neutral ions. Salt solutions that contain only these ions will be neutral. For example, NaCl and $SrBr_2$ are neutral salts.

Cations that are derived from weak bases can react with water (hydrolyze) to form acidic solutions. For example, NH_4^+ is the conjugate acid of the weak base NH_3, so NH_4^+ acts as a weak acid and donates a proton to water to produce H_3O^+ ions:

$$NH_4^+\,(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + NH_3(aq)$$

On the other hand, anions that are derived from weak acids tend to form basic solutions. For example, CN^- is the conjugate base of the weak acid HCN. Thus, CN^- acts as a weak base and accepts a proton from water to produce OH^- ions:

$$CN^-\,(aq) + H_2O(l) \rightleftharpoons HCN(aq) + OH^-(aq)$$

The pH values for various acidic, basic, and salt solutions will be measured in this experiment. For each acidic solution, you will use the pH to calculate the equilibrium concentration of the hydronium ions, $[H_3O^+]_{eq}$. The initial concentration of the weak acid, $[HA]_i$, and the $[H_3O^+]_{eq}$ will then be used in an ICE table to calculate a K_a value for each acidic solution. For each basic solution, $[OH^-]_{eq}$ will need to be calculated and used in an ICE table to determine a K_b value. Percent dissociation values will also be calculated for all six solutions. Acid ionization constants will be used to compare the relative strength of the acidic solutions; base ionization constants will be used to compare the relative strength of the basic solutions.
Refer to Sections 14.1-14.4 of Openstax Chemistry for information on defining Bronsted-Lowry Acids and Bases, calculating $[H_3O^+]$ from pH, relative strengths of acids and bases, and hydrolysis of salt solutions.

Equations to use for calculations:

Acid Dissociation: $HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$

$$K_a = \frac{[H_3O^+]_{eq}[A^-]_{eq}}{[HA]_{eq}}$$

$pH = -\log\,[H_3O^+]_{eq}$ $\quad$ $[H_3O^+] = 10^{-pH}$

$$\%\ \text{dissociation} = \frac{[H_3O^+]_{eq}}{[HA]_i} \times 100$$

Base Dissociation: $B(aq) + H_2O(l) \rightleftharpoons BH^+(aq) + OH^-(aq)$ $K_b = \frac{[BH^+]_{eq}[OH^-]_{eq}}{[B]_{eq}}$

$pOH = -\log [OH^-]_{eq}$ $[OH^-] = 10^{-pOH}$ $\% \text{ dissociation} = \frac{[OH^-]_{eq}}{[B]_i} \times 100$

$pH + pOH = 14.00$

Materials:

6 – 30 mL beakers
1 – 250 mL beaker
Chromebook
GoLink
pH probe
DI water
KimWipes

$CH_3COOH(aq)$
$NH_4Cl(aq)$
$HC_2H_3O_3(aq)$
$NaCH_3COO(aq)$
$NH_3(aq)$
$Na_2CO_3(aq)$

Note: Handle the pH probe carefully to avoid breakage fees!

Procedure:

1. Obtain about 15 mL of each of the following solutions in labelled 30 mL beakers: acetic acid, ammonium chloride, glycolic acid, sodium acetate, ammonia, and sodium carbonate. Refer to the "Transferring liquids" technique.
2. Assemble the Chromebook, pH probe, and GoLink system as directed in the "Using and calibrating a pH probe" technique. In the Vernier Graphical Analysis window, click the 3-square icon in the upper right corner to select "Meter".
3. Use the 250 mL beaker to collect the pH probe rinsings, and rinse the pH probe with deionized water every time it is transferred from one solution to another. Measure the pH of all six solutions being careful not to contaminate solutions.
4. Using pH paper, test the pH of each of the six solutions. Record your results.
5. Have your instructor double-check your pH readings before you put away the computer equipment. When you are done with the pH sensor, rinse it with deionized water and place in the sensor storage container. Clean and return your glassware.

Note: The solutions we test will generally be more acidic than we would predict them to be. A major reason for this increased acidity is the presence of dissolved CO_2 in aqueous solutions. CO_2 reacts with water to generate H^+:

$$CO_2(g) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

The solubility of CO_2 is greatest in basic solutions and least in acidic ones so basic solutions will be affected more than acidic solutions.

Waste Disposal: Discard your solutions in the waste container in the fume hood.

Clean-Up: Rinse all glassware with lots of tap water and then a final rinse with DI water. Wipe your entire bench with a damp paper towel. Put all equipment back where you found it.

Weak Acids, Weak Bases, and Salts Pre-Lab Questions and Calculations

You will complete this quiz in Canvas 1 hour before your lab period. This page will not be turned in or graded. You may use this page to set up your calculations before you take the Canvas quiz.

1. Which of the solutions used in lab this week are predicted to be acidic?

2. Which of the solutions used in lab this week are predicted to be basic?

3. Acidic ions tend to have a pH value that is __________

4. If the pH of a 0.45 M weak acid is measured to be 4.32, what is its K_a (acid ionization constant) value?

5. Which one of the following salts is predicted to be basic?
   a. KCl
   b. $CaBr_2$
   c. $LiNO_2$
   d. NH_4I

6. Why is KF a basic salt?

7. A student accidentally takes too much solution for this week's lab. What should the student do with the excess solution?

8. Why is it important to rinse the pH probe with DI water after taking a pH measurement?

Name: ______________________________ Partners: _________________________

Weak Acids, Weak Bases, and Salts Lab Report
Turn in Pages 4-6 as your Graded Lab Report.

Data and Calculations

Table 1: Concentrations and pH values of solutions

Original Solutions	Concentration	pH probe value	pH paper color/value

Instructor Initials: _________

Calculations:

Acidic solution:

Show a sample calculation for: a) all equilibrium concentrations ($[HA]_{eq}$, $[H_3O^+]_{eq}$, and $[A^-]_{eq}$) ; b) K_a ; and c) percent dissociation for **one** acidic solution. Include a sample ICE table showing how you calculated your equilibrium concentrations. Report your calculated values for the three acidic solutions in Results: Table 2.

Basic solution:

Show a sample calculation for: a) all equilibrium concentrations ($[B]_{eq}$, $[OH^-]_{eq}$, and $[BH^+]_{eq}$); b) K_b ; and c) percent dissociation for **one** basic solution. Include a sample ICE table showing how you calculated your equilibrium concentrations. Report your calculated values for the three basic solutions in Results: Table 3.

Results

Table 2: Results of acidic solution calculations

Acid	**pH**	**[HA]**$_i$, M	**[H$_3$O$^+$]$_{eq}$**, M	**[A$^-$]$_{eq}$**, M	**[HA]$_{eq}$**, M	**K$_a$**	**% dissociation**
CH_3COOH							
NH_4Cl							
$HC_2H_3O_3$							

Table 3: Results of basic solution calculations

Base	**pH**	**[B]**$_i$, M	**[OH$^-$]$_{eq}$** , M	**[BH$^+$]$_{eq}$**, M	**[B]$_{eq}$**, M	**K$_b$**	**% dissociation**
$NaCH_3COO$							
NH_3							
Na_2CO_3							

Conclusion: Summarize the trends for the pH readings, K values, and % ionization values relative to the strength of the acidic solutions. Do the same for the basic solutions. What was the strongest and weakest acidic solution and how did you determine this? What was the strongest and weakest basic solution and how did you determine this?

Post-Lab Questions – These questions will not be graded as part of your lab report grade. You will be responsible for the information in these questions and able to answer these or similar questions on the post-lab quiz at the start of next week's lab.

1. List your solutions (use chemical formulas) in order of **increasing** pH.

Lowest pH ____ Highest pH

2. Rank your acidic solutions (use chemical formulas) by **increasing** pH, K_a, and % dissociation:

pH ____

K_a ____

% dissociation ____

3. Rank your basic solutions (use chemical formulas) by **increasing** pH, K_b, and % dissociation:

pH ____

K_b ____

% dissociation ____

4. Identify what type of cation and anion (acidic, basic, or neutral) typically make up each type of salt below. Circle your answer for each.

Acidic salt:	cation: acidic basic neutral		anion: acidic basic neutral
Neutral salt:	cation: acidic basic neutral		anion: acidic basic neutral
Basic salt:	cation: acidic basic neutral		anion: acidic basic neutral

5. For each of the 3 **salt solutions** used in lab: 1) write the dissociation equation; 2) label the cation as acidic, basic, or neutral; 3) label the anion as acidic, basic or neutral. NaF has been done as an example.

e. g. Salt = __NaF__, dissociation equation: $NaF(aq) \rightarrow Na^+(aq) + F^-(aq)$

formula for cation: _Na^+_ (circle one) acidic basic (neutral)

formula for anion: _ F^-_ (circle one) acidic (basic) neutral

Salt 1 = _______ 1) dissociation equation: ______________________________________

2) formula for cation: _________ (circle one) acidic basic neutral

3) formula for anion: _________ (circle one) acidic basic neutral

Salt 2 = _______ 1) dissociation equation: ______________________________________

2) formula for cation: _________ (circle one) acidic basic neutral

3) formula for anion: _________ (circle one) acidic basic neutral

Salt 3 = _______ 1) dissociation equation: ____

2) formula for cation: _________ (circle one) acidic basic neutral

3) formula for anion: _________ (circle one) acidic basic neutral

6. From what acid and what base were the salts below made?

$Ca(NO_3)_2$: ______________________________

NH_4Br: ________________________________

$BaCl_2$: _________________________________

7. Calculate the K_a value for a 0.010 M solution of acetic acid that is measured to have a pH of 3.38. Show all your work below!

Calculation:

a) How does this calculated value above compare to the K_a value of 1.8×10^{-5} reported in the textbook?

b) State the K_a value you calculated for the 0.50 M CH_3COOH solution in this experiment and compare it to the calculated value above.

c) Should these K_a values be about the same or different? **Explain why**.

8. Discuss at least 2 sources of error in this experiment. How did they affect your results and how would you correct them if you were to repeat the experiment?

9. Complete the table below. Classify each of the following solutions as a weak acid, weak base, acidic salt, basic salt or neutral salt.

substance	**type of compound**	**substance**	**type of compound**
K_2CO_3*(aq)*		H_3PO_4*(aq)*	
NH_4ClO_3*(aq)*		$CaCl_2$*(aq)*	
CsF*(aq)*		KNO_3*(aq)*	
$NH(CH_3)_2$*(aq)* (an amine)		$Sr(ClO_2)_2$*(aq)*	
CH_3COOH*(aq)*			

10. Complete the table below for each solution used in this lab. NaF has been done as an example.

0.50 M Solution	**Species Expected to Hydrolyze**	**Spectator Ion (if none, write N/A)**	**Net-Ionic Equation for Hydrolysis**	**Equilibrium Expression (specify K_a, K_b)**
Example: **Sodium Fluoride (NaF)**	F^-	Na^+	$F^-(aq) + H_2O(l) \leftrightarrows HF(aq) + OH^-(aq)$	$K_b = [HF][OH^-] / [F^-]$
Acetic Acid (CH_3COOH)				
Ammonium chloride (NH_4Cl)				
Glycolic Acid ($HC_2H_3O_3$)				
Sodium acetate ($NaCH_3COO$)				
Ammonia (NH_3)				
Sodium Carbonate (Na_2CO_3)				