Lab: The pH of Salts

FOR THE TEACHER

Summary
In this lab, students will determine whether an aqueous solution is acidic, basic, or neutral. Students will write net ionic equations for the hydrolysis of a solution.

Grade Level
High School

AP Chemistry Curriculum Framework
This lab supports the following units, topics and learning objectives:

- **Unit 4: Chemical Reactions**
  - **Topic 4.2**: Net Ionic Equations
    - TRA -1.B: Represent changes in matter with a balanced chemical or net ionic equation: a. For physical changes. b. For given information about the identity of the reactants and/or product. c. For ions in a given chemical reaction.
  - **Topic 4.8**: Introduction to Acid-Base Reactions
    - TRA-2.B: Identify species as Brønsted-Lowry acids, bases, and/or conjugate acid-base pairs, based on proton-transfer involving those species.

- **Unit 7: Equilibrium**
  - **Topic 7.13**: pH and Solubility
    - SPQ-5.C: Identify the qualitative effect of changes in pH on the solubility of a salt.

- **Unit 8: Acids and Bases**
  - **Topic 8.2**: pH and pOH of Strong Acids and Bases
    - SAP-9.B: Calculate pH and pOH based on concentrations of all species in a solution of a strong acid or a strong base.
  - **Topic 8.5**: Acid-Base Titrations
    - SAP-9.E: Explain results from the titration of a mono- or polyprotic acid or base solution, in relation to the properties of the solution and its components.
  - **Topic 8.7**: pH and pKa
    - SAP-10.A: Explain the relationship between the predominant form of a weak acid or base in solution at a given pH and the pKa of the conjugate acid or the pKb of the conjugate base.

Objectives
By the end of this lab, students should be able to

- Predict the pH of a solution based on the formula of the salt
- Test the pH of a solution
- Write equations for the hydrolysis of a salt

Chemistry Topics
This lab supports students’ understanding of

- Acids & Bases
- Ionic compounds
- pH
- Salts
- Hydrolysis
Time
Teacher Preparation: 15 minutes
Lesson: 45 minutes

Materials (per lab group)
- six different ionic compounds (see examples in Teacher Notes)
- distilled water
- six test tubes
- test tube rack
- masking tape
- stir rod
- litmus paper (red and blue)
- universal indicator solution in a dropper bottle
- pH meter or pH probe

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.
- When working with acids, if any solution gets on students’ skin, they should immediately alert you and thoroughly flush their skin with water.
- When working with acids and bases, if any solution gets on your skin immediately rinse the area with water.
- When diluting acids, always add acid to water.

Teacher Notes
- This lab was designed for AP Chemistry classes.
- Choose different salts that will give students a variety of pH readings—some basic, some acidic, some neutral. For example: copper (II) chloride, sodium acetate, iron (III) nitrate, sodium chloride, potassium bromide, and calcium phosphate. List the names or formulas for the salts you will use on the board before the activity.
- This lab should follow a lesson on hydrolysis of salts as part of an AP Chemistry unit covering acids and bases.
- One way to differentiate this lab is to have students look up the $K_a$ or $K_b$ of the conjugate acids and bases of the salts and determine the pH of a 0.10M solution of the salt. This is included as optional questions in the post lab section.
- Answers to student questions:

PRE LAB
1. The strong acids are HCl, HBr, HI, HNO₃, H₂SO₄, and HClO₄.
2. Ni(OH)₂ would not be considered a strong base because it will not dissociate fully in water. It is not an oxide or hydroxide of an alkali or alkaline earth metal.
3. Lithium acetate will form a basic solution. It contains an alkali metal and the anion of a weak acid. The net ionic equation is as follows:
   $$C_2H_3O_2^- + H_2O \rightarrow HC_2H_3O_2 + OH^-$$
   *Note that the strong ion (alkali metal) is the spectator ion.
4. Predictions will vary depending on the salts used.

ANALYSIS: will vary due to the salts used in the lab.

POST LAB QUESTIONS
1. Alkali and alkaline earth metals form strong bases because they dissociate nearly 100% in water. Salts containing these metals will typically be basic (unless they
are bonded to an anion of a strong acid). For this reason, basic salts can be described as alkaline.

2. $K_3PO_4$ will be basic because potassium is a strong basic cation and $PO_4^{3-}$ is a weak acid anion. $KNO_3$ will be neutral because $NO_3^-$ is a strong acid anion, so both will be spectators in solution and hydrolysis will not occur.

3. Bleach will be basic because of the presence of sodium. Hypochlorite is not a strong acid anion.

4. (Optional) Using the equation from pre lab question 3, an example equilibrium expression and solution is given.

$$K_b = \frac{[HC_2H_3O_2^-][OH^-]}{[C_2H_3O_2^-]}$$

5. (Optional) $K_a$ of $HC_2H_3O_2^-$ = $1.8 \times 10^{-5}$

6. (Optional) $K_b = (1.0 \times 10^{-14} / 1.8 \times 10^{-5}) = \frac{[HC_2H_3O_2^-][OH^-]}{0.10} = x^2/0.10$

$$x = [OH^-] = 7.45 \times 10^{-6}$$

$$-\log[OH^-] = pOH = 5.13,$$ therefore $14 - 5.13 = pH = 8.87$

**FOR THE STUDENT**

Lesson

The pH of Salts

Background

Ionic compounds, commonly called salts, may cause a pH change when added to water. The way that salts change the pH of a solution can be predicted. In this activity, you will predict whether the pH of a solution will be acidic, basic, or neutral based on the formula of the salt being added.

How can the pH of the salt be predicted? Ionic compounds are composed of an anion and a cation. If the cation is an alkali or alkaline earth metal (with the exception of magnesium and beryllium) it will form a basic solution in water. How? These are the cations of strong bases. The hydroxides of these metals dissociate nearly completely when added to water, which produces the hydroxide ion and causes the pH to increase. Acidic solutions can also be predicted, as these salts will contain anions that form strong acids. Strong acids, like strong bases, will dissociate completely in water. When strong acids dissociate they produce the $H^+$ ions, which drops the pH of the solution. The strong acids are HCl, HBr, HI, HNO$_3$, H$_2$SO$_4$, and HClO$_4$; therefore, salts containing Cl$^-$, Br$^-$, I$^-$, NO$_3^-$, SO$_4^{2-}$, or ClO$_4^-$ ions will produce acidic solutions. If the salt contains both a strong base cation and a strong acid anion, the solution will be neutral.

When a salt is added to water, hydrolysis occurs. Hydrolysis is the decomposition of water. The strong ion acts as a spectator in the solution, where the weak ion bonds to form an acid or base. A net ionic equation can be written for this reaction. For example, calcium bicarbonate is a mineral commonly found in hard water. The calcium ion is a strong base cation and when calcium bicarbonate reacts with water, hydrolysis occurs and a basic solution is produced. The calcium ion acts as a spectator ion because it completely dissociates. The bicarbonate ion reacts with water to form carbonic acid, a weak acid that barely dissociates. The net ionic equation for the hydrolysis reaction that occurs is as follows:
\[ \text{HCO}_3^- + \text{H}_2\text{O} \rightarrow \text{OH}^- + \text{H}_2\text{CO}_3 \]

The presence of the hydroxide ion raises the pH of the solution significantly. The basic pH will turn red litmus paper blue and produce cool colors (green, blue, violet) in the presence of universal indicator solution.

**Pre-Lab Questions**

1. List the six strong acids:

2. Would nickel (II) hydroxide be considered a strong base? Why or why not?

3. Will lithium acetate produce an acidic or basic solution? Prove your answer by providing an equation for the reaction.

4. Predict the pH (acidic, basic, or neutral) of each salt by examining the formula for the compound.

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<th>pH</th>
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**Objective**
The purpose of this activity is to observe the change in pH of an aqueous solution when a salt is added and to explain this change.

**Materials**
- Six different ionic compounds
- Distilled water
- Six test tubes
- Test tube rack
- Masking tape
- Stirring rod
- Scoopula
- Litmus paper (red and blue)
- Universal indicator solution in a dropper bottle
- pH meter or pH probe

**Safety**
- Always wear safety goggles when handling chemicals in the lab.
• Wash your hands thoroughly before leaving the lab.
• When you complete the lab, clean up all materials according to your teacher’s instructions.
• When working with acids, if any solution gets on your skin, you should immediately alert the teacher and thoroughly flush your skin with water.
• When working with acids and bases, if any solution gets on your skin immediately rinse the area with water.

Procedure
1. Six different salts are listed on the board. Use this information to fill in the first two columns on your data table.
2. Use the masking tape to label the test tubes with the formulas of the six salts being tested.
3. Fill each test tube ¾ full of distilled water.
4. Add 3 drops of universal indicator solution to each test tube.
5. Place a very small scoop of salt in each test tube according to their label.
6. Carefully mix the solution in the test tubes to dissolve the salts.
7. Write down color change observations in your data table.
8. Test each solution with red and blue litmus paper. In your data table, indicate if the solution tests acidic or basic.
9. Test each solution with the pH meter or probe. Indicate the measured pH of each solution in the data table. Make sure to rinse the probe with distilled water between each solution.
10. Clean your area according to your teacher’s instructions.

Data Table

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<tr>
<th>Salt Name</th>
<th>Salt Formula</th>
<th>Color Change</th>
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Analysis
Briefly explain the pH change observed when each salt was dissolved in water. Determine the spectator ion for each salt. Write an equation for each hydrolysis reaction.

| Salt Formula | Explanation | Equation |
Post Lab Questions

1. Basic substances are commonly referred to as “alkaline”. Provide a brief explanation.

2. Why would potassium phosphate produce a basic solution while potassium nitrate produces a neutral solution? Explain.

3. Bleach, the household cleaner, contains the active ingredient sodium hypochlorite. Predict if bleach is acidic, basic, or neutral, and explain your answer.

4. (Optional) Write an equilibrium expression for each hydrolysis reaction.

5. (Optional) Look up the $K_a$ or $K_b$ for the acids or bases formed during each hydrolysis in the lab.

6. (Optional) Using the answers to questions 4 and 5, determine the pH of a 0.10M solution of each salt in which an acid or base formed.
Conclusion
Explain how the pH of a solution containing a salt can be predicted.