Properties of Acids and Bases
Identification and Classification

Introduction

Acids and bases are useful reagents in the chemistry laboratory and play an important role in biology and nature. What are acids and bases? What properties can be used to distinguish acids and bases? Let's explore the properties of acids and bases and identify the characteristic features that will allow us to classify substances as acids and bases.

Concepts

- Acids and bases
- Indicators
- Active metals
- Conductivity
- pH Scale
- Neutralization

Background

The word acid is derived from the Latin verb *acere* which means "to (be) sour." The origin of the word acid reveals a characteristic physical property of acids—they taste sour. Lemons, oranges, and grapefruits are called citrus fruits because they contain citric acid, an acidic compound which gives them their sour taste. Although taste is an interesting property of the foods we eat, it is NOT a property that we will use in the chemical laboratory to classify compounds as acids or bases. The following properties are typically used to classify compounds as acids or bases.

Conductivity. Some acids and bases ionize completely into ions when dissolved in water. Solutions that contain large numbers of dissolved ions conduct an electric current and are called electrolytes. Other weaker acids and bases may ionize only partially when dissolved in water and may conduct electricity only weakly—they are called weak electrolytes. Substances that do not produce dissolved ions will not conduct electricity and are called nonelectrolytes.

Effect on Indicators. Indicators are organic dyes that change color in acidic or basic solutions. One of the oldest known acid–base indicators is litmus, a natural dye obtained from lichens. Its use was described as early as the sixteenth century. Litmus paper, prepared by soaking paper in a solution of the dye, is often used as a general test for acids and bases. Phenolphthalein is another indicator that shows a color change as solutions change from acidic to basic. Although these indicators are useful for broadly classifying substances as acids or bases, they are not able to distinguish among different levels of acidity or basicity. By using combinations of different indicators, however, it is possible to obtain a spectrum of color changes over a wide range of acidity levels. Universal indicator and pH paper are two products that use combinations of indicators to rank substances from most acidic to least acidic, or most basic to least basic.

The pH Scale. The pH scale is a numerical scale that is used to describe the relative acidity or basicity of a solution and is related to the concentration of H_3O^+ ions. The abbreviation pH stands for "power of hydrogen"—a difference of one unit on the pH scale corresponds to a power of ten difference in the concentration of H_3O^+ ions. Pure water contains extremely small, but equal, concentrations of H_3O^+ and OH^- ions due to self-ionization *(Equation 1)*. Acids and bases are substances that alter the concentrations of H_3O^+ and OH^- ions in solution.

$$H_2O(l) + H_2O(l) \rightarrow H_3O^+(aq) + OH^-(aq) \qquad \textit{Equation 1}$$

Reaction with Metals. Acids react with so-called *active metals*—reactive metals such as magnesium and zinc—to produce hydrogen gas and solutions of metal ions. The reaction of different metals with acids is a well-known test used to rank metals from most active to least active. Reaction of a single active metal with a variety of different solutions is one of the best methods to identify acids and to compare their relative acidity.

Neutralization reactions. Acids and bases react with each other to give *neutral* products—solutions that are neither acidic nor basic. The products of neutralization of an acid and a base are an ionic compound (generally referred to as a salt) and water. The amount of acid that will react with a specific amount of base is governed by stoichiometry. Neutralization reactions are frequently used in the laboratory to determine how much of an acidic or basic compound is present in a substance.

Experiment Overview

The purpose of this experiment is to explore the properties of aqueous solutions and to classify them as acidic, basic, or neutral. The results will be used to develop working definitions and to analyze the pH scale for identifying acids and bases.

Pre-Lab Questions

Acid wit, acid rain, and an acid test—these familiar expressions suggest some interesting properties and uses of acids.

1. The phrase *acid wit* is defined in the dictionary as humor that is sharp, biting, or sour in nature. In the laboratory, acids present a hazard because they are corrosive. What is meant by the term corrosive? How does this relate to acid wit?
2. *Acid rain* is recognized as a growing danger to the environment. Briefly describe two problems associated with acid rain.
3. *(Optional)* The phrase *acid test* has entered the popular vocabulary to describe a severe but conclusive test of whether something is authentic. What is the origin of the term acid test?

Materials

Acetic acid solution, CH_3COOH, 0.1 M, 6 mL
Ammonia solution, NH_3, 0.1 M, 4 mL
Hydrochloric acid solution, HCl, 0.1 M, 6 mL
Magnesium ribbon or turnings, Mg, 5 pieces
Phenolphthalein solution, 0.5% in alcohol, 2 mL
Sodium hydroxide solution, NaOH, 0.1 M, 8 mL
Universal indicator, 1 mL
Wash bottle and distilled or deionized water
Conductivity tester
Forceps
Litmus paper, neutral, 5 pieces
pH test strips, wide range
Pipets, Beral-type, 5
Reaction plate, 24-well
Stirring rod
White paper (for background)

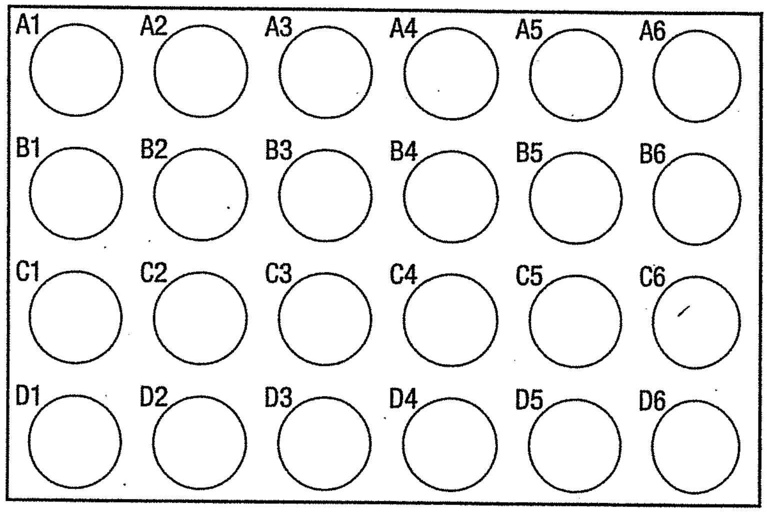
Safety Precautions

All of the acids and bases used in this lab are corrosive to eyes, skin, and other body tissues. They are toxic by ingestion. Avoid contact of all chemicals with eyes and skin. Notify your teacher and clean up all spills immediately with large amounts of water. Magnesium metal is a flammable solid and burns with an intense flame. Keep away from flames. Phenolphthalein is an alcohol-based solution and is flammable. It is moderately toxic by ingestion. Keep away from flames and other ignition sources. Wear chemical splash goggles and chemical-resistant gloves and apron. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part A. Classifying Acids and Bases

1. Obtain a 24-well reaction plate and place it on a piece of white paper as shown below. Note that each well is identified by a unique combination of a letter and number, where the letter refers to the horizontal row and the number to the vertical column.



2. Label five pipets 1–5 and fill them with solution, as shown below.

Label	1	2	3	4	5
Solution	Hydrochloric Acid	Acetic Acid	Distilled Water	Ammonia	Sodium Hydroxide

3. Fill wells A1–A5 in Row A about two-thirds full with the corresponding solutions 1–5. *Note:* The wells in a 24-well reaction plate have a 3-mL capacity. Add about 2 mL (40 drops) of solution to each well.

4. Test each solution in Row A (wells A1–A5) using a conductivity tester. Describe each solution as a strong conductor, weak conductor, or non-conductor and record any additional observations in Data Table A. Rinse the conductivity tester with distilled water and wipe clean between each test.

5. Test each solution in Row A (wells A1–A5) using a piece of neutral litmus paper. Record the color of the paper in Data Table A. *Note:* Dip a stirring rod into the solution, then

touch the stirring rod to the test paper. When used in this way, one test paper may be used for more than one solution. Be sure to wipe the stirring rod clean before testing each new solution.

6. Add 1 drop of phenolphthalein solution to each well A1–A5. Record the color of each solution in Data Table A.
7. Add 20 drops of solutions 1–5 to the corresponding wells B1–B5 in Row B.
8. Test each solution in Row B (wells B1–B5) using a pH test strip. Use the color chart on the pH paper container to assign a numerical pH value to each solution. Record the pH value for each solution in Data Table A.
9. Add 1 drop of universal indicator to each well B1–B5. Record the color of each solution in Data Table A.
10. Add 20 drops of solutions 1–5 to the corresponding wells C1–C5 in Row C.
11. Add one small piece of magnesium metal to each solution in wells C1–C5. Observe any apparent reaction that takes place and compare the speed of reaction, if any, in each well. Record all observations in Data Table A.

Part B. Neutralization Reactions of Acids and Bases

12. Carefully add 20 drops of hydrochloric acid (solution 1), followed by 1 drop of phenolphthalein, to each well D1 and D2.
13. Carefully add sodium hydroxide (solution 5) *one drop at a time* to the solution in well D1 until a stable color change occurs. Stir the solution in between drops. Record the number of drops of sodium hydroxide added (Trial 1) in Data Table B.
14. Add 10 drops of distilled water to the solution in well D2. Repeat step 13 to test the solution in well D2. Record the number of drops of sodium hydroxide added (Trial 2) in Data Table B.
15. Carefully add 20 drops of acetic acid (solution 2), followed by 1 drop of phenolphthalein, to each well D5 and D6.
16. Carefully add sodium hydroxide (solution 5) *one drop at a time* to the solution in well D5 until a color change occurs. Record the number of drops of sodium hydroxide added (Trial 1) in Data Table B.
17. Add 10 drops of distilled water to the solution in well D6. Repeat step 16 to test the solution in well D6. Record the number of drops of sodium hydroxide added (Trial 2) in Data Table B.

Disposal

18. Using forceps, remove any pieces of unreacted metal from wells C1–C5. Dispose of these metal pieces as instructed by your teacher. Rinse the contents of the reaction plate down the drain with plenty of excess water.

Name: ____________________

Class/Lab Period: ____________________

Properties of Acids and Bases

Data Table A. *Classifying Acids and Bases*

Test Property	Solution				
	1	2	3	4	5
	Hydrochloric Acid	Acetic Acid	Distilled Water	Ammonia	Sodium Hydroxide
Conductivity					
Litmus Paper					
Phenolphthalein					
pH Test Paper					
Universal Indicator					
Reaction with Magnesium					

Data Table B. *Neutralization Reactions of Acids and Bases*

	Hydrochloric Acid	Acetic Acid
Number of Drops of Sodium Hydroxide Added (Trial 1)		
Number of Drops of Sodium Hydroxide Added (Trial 2)		

Post-Lab Questions *(Use a separate sheet of paper to answer the following questions.)*

1. Use the results of the conductivity test to identify each solution in Part A as a strong electrolyte, weak electrolyte, or nonelectrolyte.
2. Which solutions in Part A reacted with magnesium metal? Write a balanced chemical equation for the reaction of each acid in Part A with magnesium.
3. *Strong acids* ionize completely in water to form ions and are thus strong electrolytes. In contrast, *weak acids* do not readily ionize in water—in fact, less than 1% of the molecules are probably ionized at any given time. Weak acids are therefore weak electrolytes. Classify each acid as either a strong or weak acid. Which reacted faster with magnesium metal, the strong acid or the weak acid?
4. Write chemical equations for ionization of the strong and weak acids in water. Identify the common ion that is produced in acidic solutions.
5. How can litmus paper and phenolphthalein be used to tell whether a solution is an acid or a base? Be specific.
6. Use the combined results of the conductivity and indicator tests to identify the basic solutions in Part A. Classify each as a *strong* versus *weak* base.
7. Write chemical equations for the ion-forming reactions of the strong and weak bases in water. Identify the common ion that is produced in basic solutions.
8. Compare the pH data for the solutions which you labeled as acids and bases. What pH values can be assigned to acids and bases, respectively?
9. Compare the pH values of strong versus weak acid and strong versus weak base solutions. How does pH vary with the "strength" of an acid or base, respectively?
10. Explain the color change observed for the indicator in the neutralization reaction of hydrochloric acid in Part B. What is the pH range of the final solution?
11. (a) Write separate, balanced equations for the neutralization reactions of hydrochloric acid and acetic acid with sodium hydroxide.
    (b) Use the stoichiometry of the balanced chemical equations to explain the number of drops of sodium hydroxide required for complete neutralization of the acids.
    (c) Did the strong and weak acids require equal number of drops of sodium hydroxide? Explain.
    (d) Did adding water to the acid solutions change the number of drops of sodium hydroxide required for neutralization? Explain.
12. Complete the following table to summarize the properties of acids and bases.

Property	Acids	Bases
Conductivity		
Litmus		
Phenolphthalein		
Reaction with metals		
pH		