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.

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. The following properties are typically used to classify compounds as acids and 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 different 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. Acids and bases are substances that alter the concentrations of hydronium and hydroxide ions in solution.

$$H_2O_{(l)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + OH^-_{(aq)}$$

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

1. In the laboratory, acids present a hazard because they are corrosive. What is meant by the term corrosive?
2. Acids and bases have both a strength and a concentration. What is the difference between strength and concentration?
3. Acid rain is recognized as a growing danger to the environment. Briefly describe two problems associated with acid rain.

Materials

0.1 M Acetic Acid solution, $HC_2H_3O_2$	Conductivity tester
0.1 M Ammonia solution, NH_3	Forceps
0.1 M Hydrochloric Acid solution, HCl	Litmus paper
Magnesium ribbon or turnings	pH test strips
0.5% Phenolphthalein solution	Pipets
0.1 M Sodium Hydroxide solution, NaOH	Reaction plate
Universal Indicator	Stirring Rod
Wash bottle and distilled water	Unknown from home

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. Phenolphthalein is an alcohol-based solution and is flammable. Keep away from flames. Wear goggles and apron. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part A. Classifying Acids and Bases

1. Obtain a well plate and place it on a piece of white paper.
2. Label six pipets 1-6 and fill them with solution as shown below

Label	1	2	3	4	5	6
Solution	Hydrochloric Acid	Acetic Acid	Distilled Water	Ammonia	Sodium Hydroxide	Unknown Solution

3. For all tests, you will need to add 10 drops of hydrochloric acid to the first well, 10 drops of acetic acid to the second well, 10 drops of distilled water to the third well, 10 drops of ammonia to the fourth well, 10 drops of sodium hydroxide to the fifth well, and 10 drops of unknown solution to the sixth well.
4. You may reuse the solutions as long as you have not added metal or indicator solution to the well. If you have added metal or indicator solution to the well, clean out the wells and start with fresh solution for the next test.

Conductivity Test

5. Test each solution using a conductivity tester. Describe each solution as a strong conductor, weak conductor, or a non-conductor and record any additional observations in Data Table A. Rinse the conductivity tester with distilled water and wipe clean between each test.
6. You may reuse the solutions after performing this test.

Litmus Paper

7. Dip a stirring rod into the hydrochloric acid solution and spot on red litmus paper. Rinse stirring rod.
8. Repeat with other five solutions, recording the color of the litmus paper in Data Table A.
9. Repeat steps seven and eight on blue litmus paper.
10. You may reuse the solutions after performing this test.

Phenolphthalein Test

11. Add one drop of phenolphthalein to each well. Record the color of each solution in Data Table A.
12. You must clean out the wells and start with fresh solution after this test.

pH Paper

13. Dip a stirring rod into the hydrochloric acid solution and spot on the pH paper. Compare the color to the color chart on the pH paper container to assign a numerical pH value to each solution.
14. Repeat step 13 for the other five solutions. Record in Data Table A.
15. You may reuse the solutions after performing this test.

Universal Indicator

16. Add one drop of universal indicator to each well. Compare the color of the solution with the universal indicator color chart. Record BOTH the color and the pH value in Data Table A.
17. You must clean out the wells and start with fresh solution after this test.

Magnesium Test

18. Add one small piece of magnesium metal to each solution. 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.
19. You must clean out the wells and start with fresh solution after this test. Remove the unreacted magnesium metal with forceps and put in waste receptacle. Rinse the contents of the reaction plate down the drain with plenty of water.

Part B. Neutralization Reactions of Acids and Bases

Hydrochloric Acid and Sodium Hydroxide

1. Carefully add exactly 20 drops of hydrochloric acid followed by one drop of phenolphthalein to a medium size test tube
2. Add sodium hydroxide *one drop at a time* to the solution in the test tube until a stable color change occurs. Shake the test tube in between drops.
3. Record the number of drops of sodium hydroxide necessary to obtain the stable color change in Data Table B.
4. Clean out the test tube thoroughly.
5. To a new test tube, add exactly 20 drops of hydrochloric acid, 10 drops of distilled water, and one drop of phenolphthalein.
6. Add sodium hydroxide *one drop at a time* to the solution in the test tube until a stable color change occurs. Shake the test tube in between drops.
7. Record the number of drops of sodium hydroxide necessary to obtain the stable color change in Data Table B.
8. Clean out the test tube thoroughly.

Acetic Acid and Sodium Hydroxide

1. Carefully add exactly 20 drops of acetic acid followed by one drop of phenolphthalein to a medium size test tube
2. Add sodium hydroxide *one drop at a time* to the solution in the test tube until a stable color change occurs. Shake the test tube in between drops.
3. Record the number of drops of sodium hydroxide necessary to obtain the stable color change in Data Table B.
4. Clean out the test tube thoroughly.
5. To a new test tube, add exactly 20 drops of acetic acid, 10 drops of distilled water, and one drop of phenolphthalein.
6. Add sodium hydroxide *one drop at a time* to the solution in the test tube until a stable color change occurs. Shake the test tube in between drops.
7. Record the number of drops of sodium hydroxide necessary to obtain the stable color change in Data Table B.
8. Clean out the test tube thoroughly.

Name: _____ Lab Partner's Name: _____

Data Table A. Classifying Acid and Bases

	Solution					
Property	1 Hydrochloric Acid	2 Acetic Acid	3 Distilled Water	4 Ammonia	5 Sodium Hydroxide	6
Conductivity						
Litmus Paper (Red)						
Litmus Paper (Blue)						
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 (No Extra Water)		
Number of Drops of Sodium Hydroxide Added (With 10 Drops Distilled Water)		

Post Lab Questions

1. How can litmus paper and phenolphthalein be used to tell whether a solution is an acid or a base? Be specific.

2. Compare the pH data for the solutions. Identify each solution as an acid or a base. Then, give a general pH range for acids and bases.

3. Write chemical equations for the ionization of the strong and weak acids in water. Identify the common ion that is produced in acidic solution.

4. Write chemical equations for the ionization of the strong and weak bases in water. Identify the common ion that is produced in basic solution.

5. Which solutions in Part A reacted with magnesium metal? For those solutions, write a balanced chemical equation for the reaction of the solution with magnesium.

6. Use the results of the conductivity test to identify each solution in Part A as a strong acid, strong base, weak acid, weak base, or neutral solution. Briefly explain how you determined this.

7. Relate the strength of the solution with the speed of the reaction with magnesium. Explain.

8. Explain the color change observed for the indicator in the neutralization reaction of the hydrochloric acid in Part B.

9. What is the pH range of the final solution in Part B once a stable color change has occurred?

10. (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 necessary for complete neutralization of the acids.

(c) Did the strong and weak acid 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.

11. Complete the following table to summarize the properties of acids and bases

Property	Acids	Bases
Conductivity		
Litmus Paper		
Phenolphthalein		
Reaction with metals		
pH		