1. Ionic Reactions in Aqueous Solutions

Introduction

Reactions in aqueous solutions (Ebbing/Gammon, Chapter 4) have far-reaching importance. These reactions occur in our homes as well as in rivers, lakes, and oceans, in biological systems such as our bodies, and in many industrial applications. Most of these reactions involve ions.

Purpose

You will examine precipitation reactions and reactions of acids and bases.

Concept of the experiment

You will have an opportunity to examine certain precipitation reactions and test the solubility rules (Ebbing/Gammon, Section 4.1) shown in Table 1.1. If you did Lab: Identification of an Unknown Compound, you will already have some familiarity with the formation of precipitates.

Table 1.1 Empirical Rules for the Solubilities of Common Ionic Compounds

Soluble Compounds	**Exceptions**
Sodium, potassium, and ammonium compounds	None
Acetates and nitrates	None
Chlorides	Lead and silver chlorides are insoluble.
Sulfates	Calcium, barium, and lead(II) sulfates are insoluble.
Insoluble Compounds	**Exceptions**
Carbonates and phosphates	Sodium, potassium, and ammonium compounds are soluble.
Hydroxides	Sodium, potassium, and calcium compounds are soluble.
Sulfides	Sodium, potassium, calcium, and ammonium compounds are soluble.

You will also examine a reaction in which a gas is formed and some reactions of acids and bases (Ebbing/Gammon, Section 4.4). You will find that H^+ ions from acids cause blue litmus paper to turn red or pink. Similarly, you will see that OH^- ions from bases cause pink litmus paper to turn blue. Moreover, you will find that the liberation of heat, a signal of a chemical reaction, accompanies the reaction of an acid with a base.

A word about molarity

In this experiment, you will encounter the symbol *M*. It stands for molarity and has units of moles per liter (mol/L) (Ebbing/Gammon, Section 4.7). Molarity is a measure of the concentration of a solution.

Procedure

Getting started

1. Obtain several pieces of red and blue litmus paper and 4 small test tubes.
2. Use a 5-mL or a 10-mL graduated cylinder to place 1 mL of distilled water in each of these test tubes. Mark the height of the water with a marking pencil or a small piece of tape. Add an additional 1 mL to each of these test tubes and mark the new height of the water. Pour the water out of each test tube.
3. Obtain instructions for using the centrifuges in the laboratory.

   CAUTION: When you use a centrifuge, do not attempt to stop the centrifuge rotor with your finger or anything else.

4. Obtain directions for discarding the solutions that you use during this experiment.
5. Remember to be careful in your handling of the solutions in this experiment.

   CAUTION: Sodium hydroxide, hydrochloric acid, acetic acid, and ammonia can cause chemical burns in addition to ruining your clothes. If you spill any of these solutions on you, wash the contaminated area thoroughly with water, and report the incident to your instructor. You may require further treatment.

Testing the solubility rules

1. Using the lower marks on the 4 test tubes as guides, add 1 mL of 0.1 *M* NH_4NO_3 to each.
2. Using the upper marks as guides, add 1 mL of 0.1 *M* NaBr to the first tube, 1 mL of 0.1 *M* Na_2SO_4 to the second, 1 mL of 2 *M* NaOH to the third, and 1 mL of 0.1 *M* Na_2CO_3 to the fourth. Shake each test tube gently. Record your observations, noting the colors of all precipitates.
3. Wash the test tubes carefully, and rinse them with distilled water.
4. Repeat Steps 1 through 3 with, in turn, 0.1 *M* $Ba(NO_3)_2$, 0.1 *M* $AgNO_3$, 0.1 *M* $Pb(NO_3)_2$, and 0.1 *M* $Ni(NO_3)_2$ instead of NH_4NO_3 (see Step 5).

   CAUTION: Wash your hands thoroughly after using the solution containing barium because it is poisonous.

5. Centrifuge the contents of the test tube that originally contained 0.1 *M* $Ni(NO_3)_2$ and 2 *M* NaOH. About 1 min will be required. Decant (pour off) and discard the solution. Save the precipitate for subsequent use.

Looking at acids and bases

1. Wash the three remaining test tubes, and rinse them with distilled water.
2. Obtain a pea-sized portion of $CaCO_3$ in one of the test tubes. Add 20 drops of 2 *M* HCl. Record your observations.
3. Add 8 drops of 2 *M* HCl to the precipitate that you saved from the reaction between $Ni(NO_3)_2$ and NaOH. Record the results.
4. Wash these test tubes, and rinse them with distilled water.
5. Using the lower marks as guides, add 1 mL of 2 *M* HCl to one test tube, 1 mL of 2 *M* $HC_2H_3O_2$ (acetic acid) to the second, 1 mL of 2 *M* NH_3 to the third, and 1 mL of 2 *M* NaOH to the fourth.
6. Take a drop of each solution on a clean stirring rod and touch it to a piece of red litmus paper. Record your observations.
7. Repeat Step 6 using blue litmus paper.
8. Add the contents of the test tube containing HCl to the test tube containing NH_3. Is heat evolved? Add the contents of the test tube containing $HC_2H_3O_2$ to the test tube containing NaOH. Is heat evolved? Record the results.

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Date: ..... Student name: .....

Course: ..... Team members: .....

Section: .....

Instructor: .....

Prelaboratory assignment

1. Provide definitions for the following terms:

   a. Exchange (metathesis) reaction

   b. Acid

   c. Base

   d. Neutralization

2. Predict the solubilities of the following substances in water, using Table 1.1. These substances are relevant to this experiment.

a.	$NaNO_3$	e.	$BaBr_2$
b.	NH_4Br	f.	$BaSO_4$
c.	$(NH_4)_2SO_4$	g.	$Ba(OH)_2$
d.	$(NH_4)_2CO_3$	h.	$BaCO_3$

3. Give names and formulas for the acids and bases that you will encounter in this experiment.

4. What safety precautions must be observed during this experiment?

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Results

1. *Testing the solubility rules*

	$NaBr$	**Na_2SO_4**	**$NaOH$**	**Na_2CO_3**
NH_4NO_3				
$Ba(NO_3)_2$				
$AgNO_3$				
$Pb(NO_3)_2$				
$Ni(NO_3)_2$				

2. *Looking at acids and bases*

$HCl + CaCO_3$		**HCl + precipitate from $Ni(NO_3)_2$ + NaOH**	

	Red Litmus Paper	**Blue Litmus Paper**
HCl		
$HC_2H_3O_2$		
NH_3		
NaOH		

	Heat Evolved?
$HCl + NH_3$	
$HC_2H_3O_2 + NaOH$	

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Questions

1. a. Write balanced molecular and ionic equations for each successful precipitation reaction that you observed.

b. Were the solubility rules completely adequate? Explain.

2. a. Describe how red litmus paper is affected by acids and bases.

b. Describe how blue litmus paper is affected by acids and bases.

c. Which litmus paper would you use to test for an acid? Why?

d. Which litmus paper would you use to test for a base? Why?

3. a. Write balanced molecular and ionic equations for each reaction of a solid with HCl.

b. Write balanced molecular and ionic equations for each neutralization reaction in which heat was evolved.