eScience Labs INC.

Lab Manual
Introductory Chemistry: *A Green Approach*
Version 2.1

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Concepts to explore:

- Understand qualitative tests for ions that are based on solubility
- Learn that Na^+, K^+, NH_4^+, NO_3^-, and CH_3COO^- are water soluble
- Recognize balanced chemical equations
- Qualitatively test for fluoride ions in mouth rinses

Introduction

Have you ever wondered how toothpaste helps prevent cavities?

Remember your last visit to the dentist to have your teeth cleaned and a check-up? You most likely waited anxiously as the dentist finished checking your teeth and breathed a big sigh of relief if he pronounced, "No cavities!" But what causes cavities anyway, and how does brushing your teeth help to prevent them?

Figure 1: Brushing with a fluoride toothpaste can help prevent tooth decay. Fluoride mouth rinses are also popular dental hygiene products that contain fluoride. Other products include fluoride gels and foams that are applied to teeth for a period of time.

Your teeth, like many other bones in the body, are mostly made of a substance called hydroxyapatite. The empirical formula of hydroxyapatite is $Ca_{10}(PO_4)_6(OH)_2$. Plaque organisms that live in your mouth produce acids that dissolve minerals, such as the calcium and phosphorous found in hydroxyapatite. The active ingredient in toothpaste, fluoride, help replace those lost minerals. It has been found that the hydroxyapatite in your teeth can easily replace lost minerals with fluoride. Because of this, a tooth's crystal structure that has incorporated fluoride is more resistant to decay than the original structure, which is why we need to brush our teeth with toothpaste that contains fluoride every day!

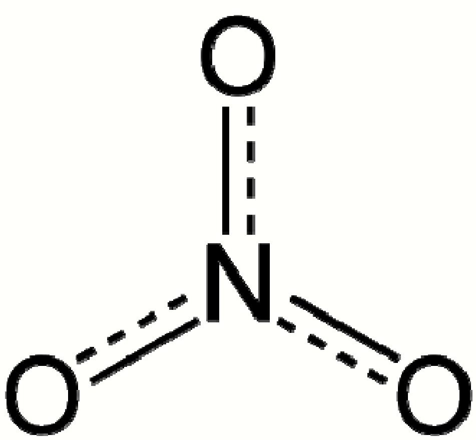

Figure 2: Diagram showing the molecular structure of a nitrate ion (NO_3^-)

Ions have very different chemical and physical properties than atoms. For instance, fluoride (F^-) as an ion is safe enough to add to drinking water and toothpaste to help prevent cavities; while fluorine (F_2) is a very poisonous gas. Throughout history, scientists have developed many ways to test for the presence of different types of ions. These are called **qualitative** tests. In many of these tests, one ion replaces another to produce a solid precipitate. There are also some useful generalizations that can help a chemist know whether or not a particular chemical is soluble in water. One of the useful solubility rules for ionic compounds states that compounds containing Li^+, Na^+, K^+, or NH_4^+ are soluble in water. The water solubility of many other compounds can also be found in handbooks.

You can see that nitrates (NO_3^-), acetates (CH_3COO^- or $C_2H_3O_2^-$), and ammonium ions (NH_4^+) all have a charge like the fluoride ion, but they are made up of more than one atom. These are called **polyatomic ions**, which are molecules with a net charge.

Calcium acetate can be used to qualitatively test for the existence of fluoride in a solution. This relates to another important solubility rule, which states that nitrates and acetates are water soluble—therefore calcium acetate, $Ca(C_2H_3O_2)_2$, is soluble in water. A solution of calcium acetate will react with fluoride to make calcium fluoride, which is not very soluble in water and will form a solid precipitate that is easily observed.

Chemists have a short way to write out what is happening in a reaction. It is called a **chemical equation**. The chemicals that are reacting are called the reactants and placed on the left side of an arrow. The chemicals that result from the reaction are called products and are placed on the right side of the arrow. The reaction that you will be observing in this lab can be written as the following chemical equation:

$$2\ NaF_{(aq)} + Ca(C_2H_3O_2)_{2(aq)} \rightarrow CaF_{2(s)} + 2\ Na\,(C_2H_3O_2)_{(aq)}$$

The abbrevation "aq" by the chemical formula stands for "aqueous," meaning that reactant or product is dissolved in water, while the "s" indicates that the substance is a solid.

This chemical equation has also been *balanced*. This means there is the same number of each of the different atoms on either side of the equation. This may not be very clear when you first look at it. Notice that there is a 2 in front of the NaF and no number in front of the $Ca(C_2H_3O_2)_2$. A number in front of a molecule, such as the 2 in front of the NaF, is called a **coefficient**. A coefficient of 1 is usually not written, but can be assumed. As you can see, one molecule of a substance does not always react with just one molecule of another substance. The coefficients tell us the ratio of how the molecules react. In this reaction 2 NaF react with 1 $Ca(C_2H_3O_2)_2$.

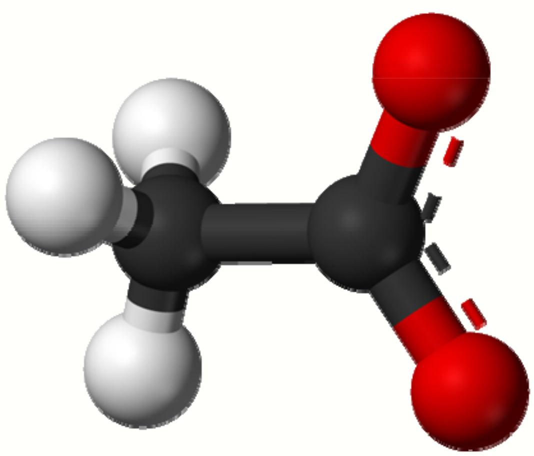

Figure 3: A three-dimensional model of an acetate (CH_3COO^-) anion—can you identify the structures pictured above?

A subscript after an element's symbol in a chemical formula indicates the quantity of atoms of that element in the compound. For example, the CaF_2 molecule has one calcium (Ca) and two fluorine molecules (F). This is also true for polyatomic ions. In $Ca(C_2H_3O_2)_2$, the ion $(C_2H_3O_2)^-$ is in parentheses and has a subscript 2. This means there are two $(C_2H_3O_2)^-$ ions in calcium acetate. You can think of it as a shorter way of writing $Ca(C_2H_3O_2)(C_2H_3O_2)$. In total, $Ca(C_2H_3O_2)_2$ has one Ca atom, four C atoms, six H atoms, and four O atoms. If a molecule with a polyatomic ion in it does not have it in parenthesis it means that there is only one of them for each molecule. The $NaC_2H_3O_2$ has only one $(C_2H_3O_2)^-$.

Now that you know how a chemical equation is written, you can count the number of each elements on the reactants side and on the products side for the reaction above. Did you get 2 Na, 2 F, 1 Ca, 4 C, 6 H, and 4 O on each side? If so, you are correct! Since there is the same number of each atom on both sides of the arrow, the chemical equation is balanced.

Pre-lab Questions

1. Name the chemical that makes up teeth.

2. How does plaque harm teeth?

3. How does fluoride promote dental health?

4. Write two solubility rules that are used in this lab.

Lab 3: Chemical Reactions I

Experiment: Battle of the Mouth Rinses

Some mouth rinses also contain fluoride, usually in the form of sodium fluoride which is soluble in water. In this lab, you will determine which one of two mouth rinses would be better at preventing cavities by replacing lost minerals with fluoride. You will do this by determining which mouth rinse contains fluoride.

Materials

Safety Equipment: Safety goggles, gloves

Mouth rinse A (10 mL)

Mouth rinse B (10 mL)

1 M Calcium acetate $Ca(C_2H_3O_2)_2$

Test tube rack

2 Test tubes

10 mL Graduated cylinder

Stirring rod

Permanent marker

Procedure

1. Label the two test tubes with a Sharpie: **A**, and **B**. **HINT:** Make sure to write down which rinse is A and which is B.
2. Pour 10 mL of Rinse A into the test tube marked **A. HINT**: If using the same graduated cylinder, rinse WELL to prevent cross contamination.
3. Pour 10 mL of Rinse B into the test tube marked **B**.
4. Pour 3 mL of 1 M $Ca(C_2H_3O_2)_2$ solution into each of the test tubes. Gently stir each test tube with a stirring rod to mix. Be sure to clean your stirring rod each time before placing it in a solution. **CAUTION: Mixing should be done gently to prevent glass breakage and injury.**
5. Observe the reactions for at least 10 minutes to insure it is finished. **HINT:** A positive test is indicated by a cloudy appearance of the solution. The precipitate formed can be more easily seen if the test tube is held up to the light. The precipitate will eventually settle to the bottom of the test tube.
6. Record all observations in the Data section.
7. To clean up, you can rinse the small amount of precipitate down the drain.

Data

- Observations of NaF and $Ca(C_2H_3O_2)_2$ (See sequence of pictures below):

Addition of $Ca(C_2H_3O_2)_2$ to NaF; 57 seconds after the addition of $Ca(C_2H_3O_2)_2$; 20 minutes after the addition of $Ca(C_2H_3O_2)_2$; 35 minutes after the addition of $Ca(C_2H_3O_2)_2$; and 1 hour after the addition of $Ca(C_2H_3O_2)_2$.

- Observations of Rinse A and $Ca(C_2H_3O_2)_2$:

- Observations of Rinse B and $Ca(C_2H_3O_2)_2$: