

Minneapolis Community and Technical College
Introductory Chemistry Laboratory

Experiment: Ionic Precipitation Reactions in Aqueous Solutions

Objectives:

- Identify the ions present in various aqueous solutions.
- Systematically combine solutions and identify the reactions that form precipitates.
- For the reactions that involve a precipitate, use solubility rules to identify the insoluble product.
- Write the correct chemical formulas for precipitates formed.
- Write a balanced chemical equation.
- Write a net ionic equation (for reactions that formed precipitate).

Text references:

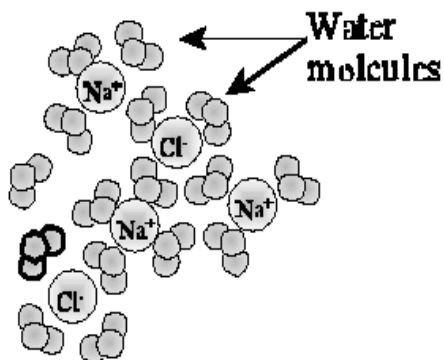
aqueous, dissociation, cation, anion, polyatomic ion, soluble, precipitate, electrolyte, solution, solvent, solute.

Discussion:

Aqueous Solutions:

When one substance dissolves in another substance, a **solution** is formed. A **solution** is a homogeneous mixture in which the components are uniformly mixed. A solution consists of **solute** (the species that is dissolved) and **solvent** (the medium in which the solute has dissolved). The solvent is usually present in larger amount than the solute. When water is the solvent, the solution is called **aqueous solution**.

When an ionic compound dissolves in water, it dissociates into its constituent ions. Such a compound is a strong electrolyte and conducts electricity well in dilute aqueous solutions. For example, when NaCl dissolves in water, it dissociates into separate Na^+ and Cl^- ions.



This process occurs as polar water molecules orient themselves around the sodium and chloride ions and pull them free from the solid crystal. Once removed from the solid crystal, the ions remain separated and surrounded by water molecules. Therefore, the solution now consists of mostly water, and sodium and chloride ions. For all practical purposes, there are no undissociated NaCl units floating around.

Precipitation Reactions: A chemical reaction that involves the formation of an insoluble product (precipitate; solid) is called a Precipitation Reaction. The reactants are soluble, but the product formed would be insoluble and separates out as a solid.

In *today's experiment*, we will be combining different aqueous solutions of ionic compounds in very small amounts and observing them for signs of a **precipitation reaction**. In cases where a reaction occurs, an insoluble solid product (**precipitate**) will be formed. *In precipitation reactions, a color change alone does not indicate a reaction has occurred. A solid must be formed.*

Let us consider the possible reaction of aqueous solution of NaCl with aqueous solution of AgNO₃. We would place a few drops of the NaCl solution in the reaction container followed by a few drops of AgNO₃ solution and observe an immediate cloudiness that indicates a solid precipitate has formed. *Ah hah!* A precipitation chemical reaction has occurred!

To determine the identity of the solid product formed:

In order to determine the possible identity of the solid product that forms, we first identify the ions present in each of the two aqueous solutions we started with: Na⁺ & Cl⁻ (from NaCl) and Ag⁺ & NO₃⁻ (from AgNO₃).

Next we examine the ions for possible new combinations that may lead to a reasonable product formula.

Several guidelines help here. First, the combination of ions (NaCl, AgNO₃) that existed in solution prior to the experiment had been soluble and therefore should remain as such without separating out as solid after the reaction. This allows us to eliminate combinations like NaCl and AgNO₃ from the list of possibilities.

Second, the ions that have the same charge won't combine and in fact will repel one another. Thus, NaAg and ClNO₃ are eliminated.

This leaves us with only two other possibilities, AgCl and NaNO₃. From the knowledge of **Solubility Rules** (listed on the next page), we can determine which of these two products is insoluble. Solubility Rule #1 indicates that nitrate salts are soluble. Therefore, NaNO₃ cannot be the precipitate in this reaction. Solubility Rule #3 states that most chloride salts are soluble. HOWEVER, AgCl is listed as an exception to this rule. In this case, *it is* AgCl which is the precipitate.

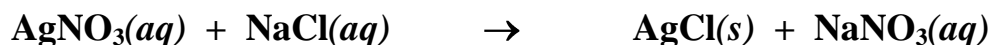
Solubility Rules:

- 1) Most compounds that contain NO_3^- ions are soluble.
- 2) Most compounds that contain Na^+ , K^+ , or NH_4^+ ions are soluble.
- 3) Most compounds that contain Cl^- ions are soluble. Exceptions are AgCl , PbCl_2 and Hg_2Cl_2 (they form precipitate).
- 4) Most compounds that contain SO_4^{2-} ions are soluble. Exceptions are BaSO_4 , PbSO_4 , SrSO_4 , and CaSO_4 (they form precipitate).
- 5) Among compounds that contain OH^- ions, NaOH and KOH are soluble, $\text{Ca}(\text{OH})_2$, $\text{Ba}(\text{OH})_2$ and $\text{Sr}(\text{OH})_2$ are moderately soluble. Other compounds containing OH^- ions are only slightly soluble (they form precipitates).
- 6) Most compounds that contain S^{2-} , CO_3^{2-} , or PO_4^{3-} ions are only slightly soluble (they form precipitate).

Chemical Equations representing the Precipitation Reactions:

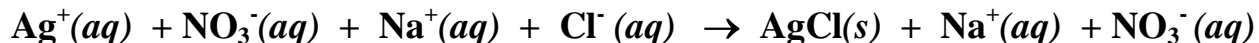
Once the chemical identity of the solid product is determined, we can then determine the **balanced molecular equation**, the **complete ionic equation** as well as the **net ionic equation**, describing the chemistry that has occurred.

a) The **balanced molecular equation** for the reaction of aqueous AgNO_3 with NaCl is written as:



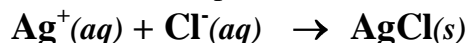
Note that in the above equation, the physical state of the AgCl product is denoted by the letter s , to indicate that it is the precipitate. The number of atoms of each element is same before and after the reaction, indicating that the equation is balanced.

b) The **complete ionic equation**, indicates which reactants and products exist as ions and which ones do not:



The ions that actually undergo change in the chemical reaction and participate in the formation of the insoluble product are called **participating ions**. In the above reaction, Ag^+ and Cl^- are the participating ions. Those that do not undergo change are called **spectator ions**. In the above reaction, Na^+ and NO_3^- are the spectator ions.

c) The **net ionic equation** displays only the participating ions on the reactant side, and the precipitate on the product side. The physical states of the reactants and products are also indicated. The spectator ions are not included.



Safety Warning! Several of the chemicals (salts of heavy metals like barium, strontium and nickel) used in today's experiment can be harmful if spilled on the skin. Should spills occur be sure to notify the lab instructor and immediately begin rinsing the affected area with water. Be sure to wash your hands before leaving the lab.

Aqueous Solutions

The aqueous solutions you will be using today are provided in reagent bottles. Each bottle is labeled with the name and concentration of the reactant (reagent) that it contains. For example,

<p>Sodium Chloride 1.0M</p>

The information **1.0M** in the second line of the label, refers to the concentration of the solution, where **M** stands for Molarity. The sodium chloride solution was prepared prior to this experiment by dissolving an appropriate amount of solid sodium chloride (the solute) in a carefully measured amount of water (the solvent) to get 1.0M concentration

Always watch carefully the concentration of the solution you are using because there can be more than one concentration of a particular aqueous solution available. Using the wrong concentration can have surprising, unexpected and sometimes dangerous consequences.

PROCEDURE:

1. You instructor will demonstrate one of the 14 reactions. For example, for reaction#1, he/she will add 3 drops of barium nitrate and 3 drops of sodium sulfate solutions into a test tube. Your instructor will mix them well by plucking the bottom of the test tube.
2. Observe the contents of the test tube. A precipitation reaction is said to have occurred if the solution turns cloudy (that is, a precipitate forms). In other words, if you do NOT observe the cloudiness or any forms of solid, there is NO precipitation reaction. **Record your observations on the data sheet.** If a reaction occurs, note the color of the solid formed as well as any other observations. Write "no reaction" if no precipitation is observed. Check the solubility rules to make sure your results agree with your solubility rules.
3. Each of the students will then be assigned to perform one of the remaining 13 reactions. Use the clean and dry test tube provided. **Be very careful not to mix up droppers as this would lead to contamination of the dropper bottles. While adding the drops of chemicals to the test tubes, do not touch the dropper tips to the inside of the test tubes.**
4. Record the observation as in step 2. Leave the reaction mixture in the test tube for other students to observe. **Do not dispose of the content into the waste container yet.**

5. Go around to other stations. Record the observations of all the other 12 reactions.
6. After everyone has recorded observations for all 14 reactions, go back to your station and dispose of the waste in the designated waste content. Rinse the tube with water and pour the rinse into the same waste container. Place the tube pointing up in the used-test tube rack.
7. Work on the balanced molecular equations and net ionic equations. For the ones that didn't not react, there will be no net ionic equations.

Ionic Precipitation Reactions in Aqueous Solutions

Name _____ Date _____ Lab Section _____

Solubility Rules

- 1) Most compounds that contain **nitrate (NO_3^-)** ions are soluble.
- 2) Most compounds that contain **sodium (Na^+), potassium (K^+), or ammonium (NH_4^+)** ions are soluble.
- 3) Most compounds that contain **chloride (Cl^-)** ions are soluble. Exceptions are silver chloride (AgCl), lead(II)chloride (PbCl_2) and mercury(I)chloride (Hg_2Cl_2) (they form precipitate).
- 4) Most compounds that contain **sulfate (SO_4^{2-})** ions are soluble. Exceptions are Barium sulfate (BaSO_4), lead(II)sulfate (PbSO_4), Strontium sulfate (SrSO_4), and Calcium sulfate (CaSO_4) (they form precipitate).
- 5) Among compounds that contain **hydroxide (OH^-)** ions, NaOH and KOH are soluble; $\text{Ca}(\text{OH})_2$, $\text{Ba}(\text{OH})_2$ and $\text{Sr}(\text{OH})_2$ are moderately soluble (meaning they form precipitates when present in relatively higher amounts). Other compounds containing OH^- ions are only slightly soluble (they form precipitates).
- 6) Most compounds that contain **sulfide (S^{2-}), carbonate (CO_3^{2-}), or phosphate (PO_4^{3-})** ions are only slightly soluble (they form precipitate).

1.	<p>3 drops of barium nitrate and 3 drops of sodium sulfate solutions to test tube #1; mix well.</p> <p>Observation:</p> <p>Complete the <u>names</u> of the products for the following equation indicating which product is the precipitate (if there is a precipitate):</p> <p>barium nitrate(aq) + sodium sulfate(aq) → _____ + _____</p> <p>Balanced Molecular Equation:</p> <p>_____ + _____ → _____ + _____</p> <p>Net Ionic Equation:</p> <p>_____ + _____ → _____</p>
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2. 3 drops of calcium nitrate and 3 drops of potassium chloride solutions to test tube #2; mix well.

Observation:

Complete the names of the products for the following equation indicating which product is the precipitate (if there is a precipitate).

calcium nitrate(aq) + potassium chloride(aq) → _____ + _____

Balanced Molecular Equation:

_____ + _____ → _____ + _____

Net Ionic Equation:

_____ + _____ → _____

3. 3 drops of barium nitrate and 3 drops of aluminum sulfate solutions to test tube #3; mix well.

Observation:

Complete the names of the products for the following equation indicating which product is the precipitate (if there is a precipitate).

barium nitrate(aq) + aluminum sulfate(aq) → _____ + _____

Balanced Molecular Equation:

_____ + _____ → _____ + _____

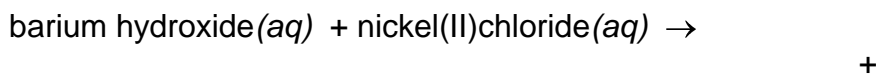
Net Ionic Equation:

_____ + _____ → _____

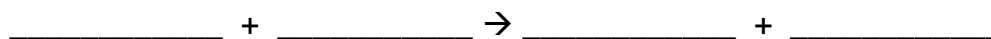
4. **3 drops of barium hydroxide and 3 drops of nickel(II)chloride solutions to test tube #4; mix well.**

Observation:

Complete the names of the products for the following equation indicating which product is the precipitate (if there is a precipitate).



Balanced Molecular Equation:



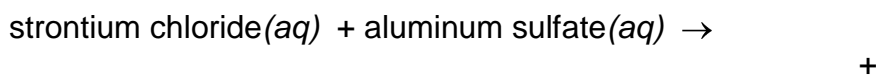
Net Ionic Equation:



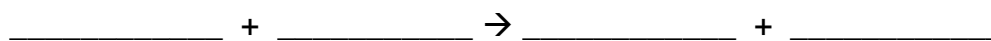
5. **3 drops of strontium chloride and 3 drops of aluminum sulfate solutions to test tube #5; mix well**

Observation:

Complete the names of the products for the following equation indicating which product is the precipitate (if there is a precipitate).



Balanced Molecular Equation:



Net Ionic Equation:



<p>6.</p>	<p>3 drops of iron(III)chloride and 3 drops of potassium hydroxide solutions to test tube #6; mix well.</p> <p>Observation:</p> <p>Complete the <u>names</u> of the products for the following equation indicating which product is the precipitate (if there is a precipitate).</p> <p>iron(III)chloride(aq) + potassium hydroxide(aq) → _____ + _____</p> <p>Balanced Molecular Equation:</p> <p>_____ + _____ → _____ + _____</p> <p>Net Ionic Equation:</p> <p>_____ + _____ → _____</p>
<p>7.</p>	<p>3 drops of cobalt(II)chloride and 3 drops of potassium hydroxide solutions to test tube #7; mix well.</p> <p>Observation:</p> <p>Complete the <u>names</u> of the products for the following equation indicating which product is the precipitate (if there is a precipitate).</p> <p>cobalt(II)chloride(aq) + potassium hydroxide(aq) → _____ + _____</p> <p>Balanced Molecular Equation:</p> <p>_____ + _____ → _____ + _____</p> <p>Net Ionic Equation:</p> <p>_____ + _____ → _____</p>

<p>8.</p>	<p>3 drops of cobalt(II)chloride and 3 drops of sodium nitrate solutions to test tube #8 and mix well.</p> <p>Observation:</p> <p>Complete the <u>names</u> of the products for the following equation indicating which product is the precipitate (if there is a precipitate).</p> <p>cobalt(II)chloride(aq) + sodium nitrate(aq) → _____ + _____</p> <p>Balanced Molecular Equation:</p> <p>_____ + _____ → _____ + _____</p> <p>Net Ionic Equation:</p> <p>_____ + _____ → _____</p>
<p>9.</p>	<p>3 drops of magnesium sulfate and 3 drops of sodium hydroxide solutions to test tube #9; mix well.</p> <p>Observation:</p> <p>Complete the <u>names</u> of the products for the following equation indicating which product is the precipitate (if there is a precipitate).</p> <p>magnesium sulfate(aq) + sodium hydroxide(aq) → _____ + _____</p> <p>Balanced Molecular Equation:</p> <p>_____ + _____ → _____ + _____</p> <p>Net Ionic Equation:</p> <p>_____ + _____ → _____</p>

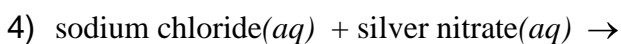
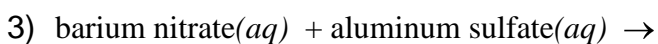
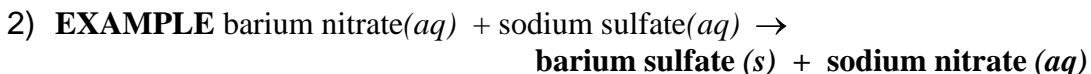
<p>10.</p>	<p>3 drops of sodium chloride and 3 drops of silver nitrate solutions to test-tube #10; mix well</p> <p>Observation:</p> <p>Complete the <u>names</u> of the products for the following equation indicating which product is the precipitate (if there is a precipitate).</p> <p>sodium chloride(aq) + silver nitrate(aq) → _____ + _____</p> <p>Balanced Molecular Equation:</p> <p>_____ + _____ → _____ + _____</p> <p>Net Ionic Equation:</p> <p>_____ + _____ → _____</p>
<p>11.</p>	<p>3 drops of ammonium carbonate and 3 drops of calcium chloride solutions to test tube #11 and mix well.</p> <p>Observation:</p> <p>Complete the <u>names</u> of the products for the following equation indicating which product is the precipitate (if there is a precipitate).</p> <p>ammonium carbonate(aq) + calcium chloride(aq) → _____ + _____</p> <p>Balanced Molecular Equation:</p> <p>_____ + _____ → _____ + _____</p> <p>Net Ionic Equation:</p> <p>_____ + _____ → _____</p>

<p>12.</p>	<p>3 drops of copper(II)sulfate and 3 drops of ammonium hydroxide solutions to test tube#12, mix well. Observation:</p> <p>Complete the <u>names</u> of the products for the following equation indicating which product is the precipitate (if there is a precipitate).</p> <p>copper(II) sulfate(aq) + ammonium hydroxide(aq) → _____ + _____</p> <p>Balanced Molecular Equation: _____ + _____ → _____ + _____</p> <p>Net Ionic Equation: _____ + _____ → _____</p>
<p>13.</p>	<p>3 drops of sodium hydroxide and 3 drops of nickel(II) chloride solutions to test tube#13; Mix well. Observation:</p> <p>Complete the <u>names</u> of the products for the following equation indicating which product is the precipitate (if there is a precipitate).</p> <p>sodium hydroxide(aq) + nickel(II)chloride(aq) → _____ + _____</p> <p>Balanced Molecular Equation: _____ + _____ → _____ + _____</p> <p>Net Ionic Equation: _____ + _____ → _____</p>
<p>14.</p>	<p>3 drops of sodium hydroxide and 3 drops of magnesium chloride solutions to test tube#14; Mix well. Observation:</p> <p>Complete the <u>names</u> of the products for the following equation indicating which product is the precipitate (if there is a precipitate).</p> <p>sodium hydroxide(aq) + magnesium chloride(aq) → _____ + _____</p> <p>Balanced Molecular Equation: _____ + _____ → _____ + _____</p> <p>Net Ionic Equation: _____ + _____ → _____</p>

Ionic Precipitation Reactions in Aqueous Solutions

Pre-lab exercise:

A. Referring to the solubility rules on page 3 of this protocol, predict the products of the following reactions, including their physical states. Use the two examples shown for guidance.



B. Write the formulas for:

Barium nitrate

Aluminum sulfate

C. Describe the proper technique for using droppers to dispense many different chemicals.

D. Describe the proper waste procedures for this week's lab.