Activity 18 - Predicting the Products of Precipitation Reactions: Solubility Rules[1]

Goals

- Observe and record precipitation reactions.
- Derive general solubility rules from the experimental data.
- Describe precipitation reactions by writing net ionic equations.
- Understand the relationship between solubility and precipitation reactions.

Pre-Lab Lecture Questions. *Answer these questions on a separate sheet using complete sentences.*

1. What is a precipitate? To the best of your ability, describe what a precipitate looks like.
2. What is a precipitation reaction? What type of chemical reaction is this? What type of compound is usually involved in precipitation reactions?
3. How does the Law of Conservation of Mass relate to writing chemical equations?
4. What is the difference between chemical equations and net ionic equations? How are they similar? How are they different?
5. Name the chemical compound represented by $Pb(NO_3)_2$.

Concepts to Review

Types of Chemical Reactions
Writing Chemical Equations
Nomenclature
Definition of a Salt, Cation, Anion
Solutions
Small-scale laboratory techniques

Introduction

Water-soluble ionic compounds in solution consist of free ions surrounded by water. In the case of zinc chloride being dissolved in water to form an aqueous solution, the dissolution of the ionic compound can be depicted as follows:

$$ZnCl_{2(s)} \longrightarrow Zn^{2+}_{(aq)} + 2\,Cl^{-}_{(aq)}$$

These free aqueous ions can react with other ions. Mixing of dissolved ionic compounds can lead to a precipitation reaction, an example of a double displacement reaction. The **precipitate** is a **solid product**, a new ionic compound that is different from the reactants in both composition and solubility. Solubility is defined as the amount of substance (solute) that dissolves in a given amount of solvent. Solubility is a physical property that can be useful in predicting whether the mixing of aqueous ionic compounds will lead to a precipitation reaction. The mixing of a variety of combinations of ions and observing the resulting formation of precipitates leads to the formulation of general rules of solubility. Some examples of these rules include “All sodium salts are soluble in water” or “The mixing of two ionic compounds that contain a common ion will not lead to a precipitate”.

Let’s look at an example to see how these solubility rules can help us. As part of the lab, silver nitrate and sodium carbonate are mixed. A foggy white precipitate is formed. To write the chemical equation:

1. *Identify the reactants and write their correct formulas*:

[1] Adapted from: Waterman, E. L. *Chemistry: Small-Scale Chemistry Laboratory Manual;* Addison-Wesley/Prentice-Hall, Inc.: Upper Saddle River, New Jersey, 2002; pp 165-172.

$$AgNO_{3(aq)} \quad + \quad Na_2CO_{3(aq)}$$

silver nitrate sodium carbonate

2. *"Swap" and replace the cations of the reactant to form the products, two new ionic compounds:* the products will be **sodium nitrate** and **silver carbonate**.

$$AgNO_{3(aq)} \quad + \quad Na_2CO_{3(aq)} \longrightarrow \qquad + \qquad$$

silver nitrate sodium carbonate silver carbonate sodium nitrate

3. *Write the correct formulas for the products after the arrow.* (Use the names of the product to get the formula correct.)

$$AgNO_{3(aq)} \quad + \quad Na_2CO_{3(aq)} \longrightarrow Ag_2CO_3 \quad + \quad NaNO_3$$

silver nitrate sodium carbonate silver carbonate sodium nitrate

4. *Use solubility rules to determine which product is the precipitate*:

   "All sodium salts are soluble"; therefore silver carbonate must be the foggy, white precipitate.

$$AgNO_{3(aq)} + Na_2CO_{3(aq)} \longrightarrow Ag_2CO_{3(s)} + NaNO_{3(aq)}$$

5. *LAST but not least, balance the equation using whole number coefficients*:

$$2\ AgNO_{3(aq)} + Na_2CO_{3(aq)} \longrightarrow Ag_2CO_{3(s)} + 2\ NaNO_{3(aq)}$$

How do you convert a chemical equation into a correct net-ionic equation?

1. *Rewrite the correct chemical equations,* ***but*** *this time write any aqueous (not solid) ionic compounds as free cations and anions. This form is referred to as the total ionic equation.* Use the coefficients to correctly multiply the ions and keep the equation balanced. Subscripts may or may not multiply the number of ions formed. Look below, which subscripts changed coefficients when the aqueous compounds were written as free ions?

$$2\ Ag^+_{(aq)} + 2\ NO_3^-{}_{(aq)} + 2\ Na^+_{(aq)} + CO_3^{2-}{}_{(aq)} \longrightarrow Ag_2CO_{3(s)} + 2\ Na^+_{(aq)} + 2\ NO_3^-{}_{(aq)}$$

2. Once you are sure you have the correct total ionic equation, look at the equation again. It should be balanced and you will be able to see what ions actually changed. Any species that is exactly the same on both sides is considered to be a spectator ion. *To write the net ionic equation, eliminate the spectators and only write the species that changed*:

$$2\ Ag^+_{(aq)} + CO_3^{2-}{}_{(aq)} \longrightarrow Ag_2CO_{3(s)}$$

Why so many types of equations? Each equation type is useful for different reasons. The net ionic equation is preferred in double displacement reactions because it focuses solely on the product. Now that we know silver ion precipitates with carbonate ion, it will be the goal of this lab to determine whether this is normal behavior for these ions (the general rule) or unusual (an exception).

In this lab you will mix a variety of solutions. By using (soluble) sodium salts for at least one of the reactants you will be able to identify which product is the precipitate. To assist you in identifying the solid product, you will write chemical equations for all observable reactions. These chemical reactions will be translated into net ionic equations. After examining the chemical formulas of the precipitates, you will "conclude" by summarizing your results as a set of solubility rules.

6. Safety

Act in accordance with the laboratory safety rules of Cabrillo College.
Wear safety glasses at all times.
Avoid contact* with all chemical reagents and dispose of reactions using appropriate waste container.

*Contact with silver nitrate ($AgNO_3$) will stain the skin.

Use microburets to dispense reagents in such a way that they do not make contact with other drops or the reaction surface.
Return any contaminated microburets to your instructor.

Materials:

Reagent Central chemicals include aqueous solutions of the compounds listed on your experimental page.

Equipment: Clean, dry transfer pipet for mixing. Lab-top reaction surface

Experimental Procedure

1. Insert your experimental page under your reaction surface. Place one drop of each solution in the squares on your experimental page. Record what happened after mixing (by blowing air past the drop using a clean, dry pipet). ("NVR" can indicate no visible reaction). Please include adjectives that describe both color and texture being as specific as possible (not all white precipitates look the same).
2. After all the reactions are completed and all observations recorded, take one last look at your surface. Have any of the squares changed over time? Record any noticeable changes (there won't be many). Clean your surface by absorbing the contents onto a paper towel. Rinse the reaction surface with a damp paper towel and dry it. Dispose of paper towels in the waste bin. Clean your area. Wash your hands thoroughly with soap and water.
3. Answer the questions, writing both chemical and net ionic equations correctly.
4. Draw general conclusions about the cations and anions in your experiment by formulating your own solubility rules.
5. Apply your rules to unknown combinations.

7. **Reaction Template:** Insert this page into the labtop. Mix one drop of each, using a long stem pipet to blow air past the droplet to complete the mixing.

Sol'ns	Na_2CO_3	NaCl	NaOH	$NaNO_3$	Na_3PO_4	Na_2SO_4
$AlCl_3$	✖	✖	✖	✖	✖	✖
NH_4Cl	✖	✖	✖	✖	✖	✖
$CaCl_2$	✖	✖	✖	✖	✖	✖
$CuSO_4$	✖	✖	✖	✖	✖	✖
$FeCl_3$	✖	✖	✖	✖	✖	✖
$Pb(NO_3)_2$	✖	✖	✖	✖	✖	✖
KI	✖	✖	✖	✖	✖	✖
$AgNO_3$	✖	✖	✖	✖	✖	✖

Activity 18 – Precipitation Reactions

Name______________________________

Section_____________ Date_______

Experimental Data:

1. Complete the following table by recording any observed precipitates (ppt.). Write "NR" for no reaction.

Sol'ns	Na_2CO_3	$NaCl$	$NaOH$	$NaNO_3$	Na_3PO_4	Na_2SO_4
$AlCl_3$						
NH_4Cl						
$CaCl_2$						
$CuSO_4$						
$FeCl_3$						
$Pb(NO_3)_2$						
KI						
$AgNO_3$						

2. Write out the chemical equation, the total ionic equation, and the net ionic equation for each reaction that formed a precipitate *on separate sheets of paper* and attach them.

3. Look at your data table and the net ionic equations in Question 2. What cations regularly formed precipitates (at least half of the combinations in a row)? Give both the correct name(s) and formula(s) for the cation(s).

4. What cations never formed precipitates (blank rows)? Give both the correct name(s) and formula(s) for the cation(s).

5. What anions regularly formed precipitates (at least half of the combinations in a column)? Give both the correct name(s) and formula(s) for the anion(s).

6. What anions never formed precipitates (blank columns)? Give both the correct name(s) and formula(s) for the anion(s).

7. Review your Questions 3 through 6 answers thus far. Complete the following set of solubility rules:

   Salts containing the following ions tend to be soluble:

   Salts containing the following ions tend to be insoluble:

8. According to your solubility rules from your data, predict whether the following combinations with produce a precipitate. Write "ppt." in the squares where a reaction will occur.

Solutions	Potassium phosphate	Ammonium hydroxide
Magnesium chloride		
Sodium chloride		

Summary

9. Return to your solubility rules. Notice the phrase "tend to be soluble" or "tend to be insoluble". What is the significance of the word "tend"?

10. Each type of equation, chemical, total ionic and net ionic is practical or useful in a way that the others are not. Describe what is useful about each type.