Experiment Four – Precipitation Reactions

Objective

Identify the ions present in various aqueous solutions. Systematically combine solutions and identify the reactions that form precipitates and gases. Write a balanced molecular equation, complete ionic equation, and net ionic equation for each metathesis (double replacement) reaction.

Introduction

When on substance dissolves in another substance, a **solution** is formed. A **solution** is a homogenous mixture in which the components are uniformly mixed. A solution consists of **solute** (the species/molecule that is being 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, a 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, due to the presence of ions which allows the transfer of electrons through the solution.

For example, when NaCl dissolves in water it dissociates into two separate ions, Na^+ and Cl^-. This process occurs as polar water molecules orient themselves around the two ions and begin to free them from the solid crystal lattice, shown below in figure 9.1:

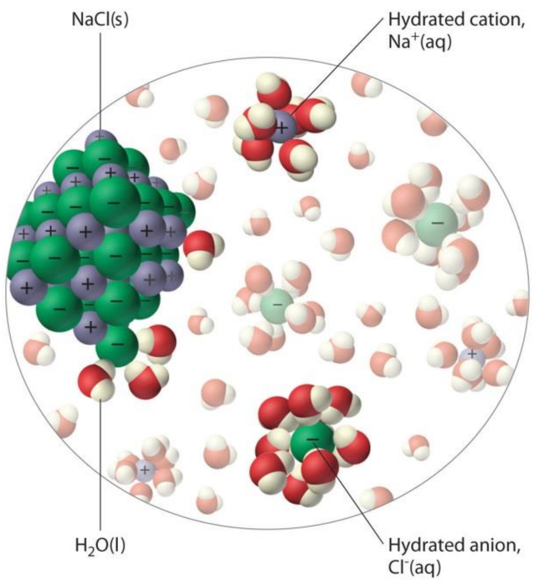

Figure 9.1Sodium chloride dissolved in water, via dissociation of the ions from the crystal lattice.

Now the solution consists of mostly water, with sodium and chloride ions that are being solvated (surrounded) by the solvent (water). For all practical purposes, there are no undissociated NaCl units floating around, they are all separated into the cation, Na^+ and anion, Cl^-.

Precipitation reactions: A chemical reaction that involves the formation of an insoluble product (precipitate = solid product that forms in a solution) is called a precipitation reaction. The reactants are soluble, but the product formed would be insoluble and separates out as a solid.

Understanding what is occurring in solution will be a three stage process, involving three distinct reaction equations: molecular equation, complete ionic equation, and net ionic equation. These three equations will build upon each other and have their own nuances and importance in the grand scheme of what is actually occurring within the solution.

Before we begin discussing how to completely represent a precipitation reaction, it's important we discuss **solubility rules**. One of the factors driving a double-replacement reaction is the formation of a precipitate. A precipitate is an insoluble solid compound formed during a chemical reaction in solution. To predict whether a precipitate will form when you mix together two ionic reactants, you need to know whether any of the possible products are insoluble. Considering the number of ionic compounds, it would be very difficult to memorize solubilities of so many compounds. Fortunately we can group compounds into solubility categories. This is done with a set of eight rules called **solubility rules**. *This is one of the most important things to understand moving forward.*

Solubility Rules

Soluble Ionic Compounds		**Important Exceptions**
Compounds containing	NO_3^-	None
	CH_3COO^-	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}
Insoluble Ionic Compounds		**Important Exceptions**
Compounds containing	S^{2-}	Compounds of NH_4^+, the alkali metal cations, and Ca^{2+}, Sr^{2+}, and Ba^{2+}
	CO_3^{2-}	Compounds of NH_4^+ and the alkali metal cations
	PO_4^{3-}	Compounds of NH_4^+ and the alkali metal cations
	OH^-	Compounds of the alkali metal cations, and NH_4^+, Ca^{2+}, Sr^{2+}, and Ba^{2+}

Figure 9.2 – Solubility rules for a select group of anions.

Below is a complete guide to writing chemical equations, this material will also be covered in detail in lecture, as well as the homework material. Please refer to your book should you have further questions or need more clarification. We will use the example of adding a solution of silver (I) nitrate (AgNO3) with sodium chloride (NaCl).

<u>Step 1</u>: **Molecular equation** represents the neutral compounds/molecules that will have been combined, and gives an overall picture of what the reactant and product will be. Every ion will be accounted for, but not as an ion, only as its representative ionic compound. For example, if the molecular equation were to include NaCl (aq) in actuality it is Na+ and Cl- in solution, but the molecular equation will represent it as a complete ionic compound NaCl. *Molecular equations have only neutral ionic compounds or molecules, there should be NO CHARGES present in molecular equation.*

Write the molecular equation, including phase tag designations, solid (s), liquid (l), gas (g) and dissolved ions as aqueous (aq). We know what phase tags each of the compounds gets by looking at our solubility rules. **Be sure to balance the equation.**

$$\mathbf{AgNO_3}\textit{(aq)} + \mathbf{NaCl}\textit{(aq)} \rightarrow \mathbf{AgCl}\textit{(s)} + \mathbf{NaNO_3}\textit{(aq)}$$

<u>Step 2</u>: Complete ionic equation represents what has happened in solution, all ions will still be present. If anything has dissolved (has an aqueous tag) then we assume it will break into its two ions. Anything that's not aqueous, solid, liquid, gas, will be rewritten as it appears in the molecular equation. **Be sure the equation is still balanced, both in atoms and charges**.

$$Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$$

<u>Step 3</u>: Net ionic equation by eliminating the spectator ions, if any exist. **Spectator ions**, or simply **spectators**, are ions which appear on both sides of an equation and experience no chemical change themselves. *If an ion has the same tag on both reactant and product sides of the equation, it's a spectator*. **Be sure the equation is still balanced, both in atoms and charge, and contains no spectator ions.**

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

<u>Procedure</u>

In Part I work with your instructor to complete the balanced molecular equation reactions, complete ionic equation reactions, and net ionic equation reactions that occur for each reaction.

In Part II you will work independently to carry out each of the reactions in one clean "spot plate" and note the observations. For each of the reactions indicated in your report sheet, add 4-5 drops of each of the two specified reactants and mix well. A precipitation reaction is said to have occurred if the solution turns cloudy. A gas reaction is said to have occurred if the solution bubbles. 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 visible reaction is observed.

Data/Results

Part I. Equations

1	Molecular: $AgNO3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO3(aq)$ Ionic: $Ag^{+}(aq) + NO_3^{-}(aq) + Na^{+}(aq) + Cl^{-}(aq) \rightarrow AgCl(s) + Na^{+}(aq)\ NO_3^{-}(aq)$ Net: $Ag^{+}(aq) + Cl^{-}(aq) \rightarrow AgCl(s)$
2	Molecular: Ionic: Net Ionic: Spectator ions:
3	Molecular: Ionic: Net Ionic: Spectator ions:
4	Molecular: Ionic: Net Ionic: Spectator ions:
5	Molecular: Ionic: Net Ionic: Spectator ions:
6	Molecular: Ionic: Net Ionic: Spectator ions:

7	Molecular: Ionic: Net Ionic: Spectator ions:
8	Molecular: Ionic: Net Ionic: Spectator ions:
9	Molecular: Ionic: Net Ionic: Spectator ions:
10	Molecular: Ionic: Net Ionic: Spectator ions:
11	Molecular: Ionic: Net Ionic: Spectator ions:
12	Molecular: Ionic: Net Ionic: Spectator ions:

Part II. Observations:

Mix 5-10 drops of the following pairs of solutions in a well plate (spot test plate). Mix well with a stirring rod (be sure to clean off the rod before mixing another solution). Record any observed change, in the appropriate box, as:

"**Gas**" – if a gas is evolved

"**Solid**" – if a precipitate is formed

"**Odor**" – if a sharp odor is released

"**NR**" – if No Reaction is occurs.

#1 - Silver nitrate & Sodium chloride	**#2 -** Silver Nitrate & Hydrochloric acid	**#3 -** Barium chloride & Sodium Phosphate	**#4 -** Barium chloride & Sodium carbonate
#5 - Silver Nitrate & Sodium hydroxide	**#6 -** Silver nitrate & Ammonium chloride	**#7 -** Barium chloride & Sodium hydroxide	**#8 -** Silver nitrate & Sodium Phosphate
#9 - Silver nitrate & Sodium sulfate	**#10 -** Silver nitrate & Sodium carbonate	**#11 -** Barium chloride & Sodium sulfate	**#12 -** Barium chloride & Sodium nitrate

Post-Lab Questions

1. Define the following:
   a. Precipitation reaction –

   b. Spectator ions –

   c. Aqueous solution –

2. Write the ions generated upon dissociation of the following chemicals in water.

a) HBr *ex.* H^+, Br^-	b) $AlCl_3$	c) NH_4OH
d) Na_2CO_3	e) $Pb(NO_3)_2$	f) K_2SO_4

3. How might you use a precipitation reaction to prepare a sample of $CuCO_3$? What two solutions would you mix together?

   Write the net ionic equation of that mixture.

4. Complete the following reactions and write the spectators for each if any.
   a. Iron (III) chloride (aq) and cesium phosphate (aq)

Molecular:

Spectators:

   b. Sodium phosphate (aq) and calcium chloride (aq)

Molecular:

Spectators: