Writing and Understanding Chemical Equations and Reactions

Cautions

Acids and bases are corrosive and caustic.

Metal salts may be an irritant, toxic, and/or an oxidizer.

Purpose

To identify unknown solutions and write the chemical equations as a precipitate is formed.

Introduction

In chemistry substances may undergo either physical or chemical changes. When a substance undergoes a physical change, its identity is retained. The most common physical changes observed are phase changes, e.g. ice melting from a solid to a liquid. When a substance undergoes a chemical change, new substances are formed. Chemical changes are more commonly known as reactions. For example, when gasoline is burned in an engine, the gasoline molecules are converted into mostly carbon dioxide and water.

Reactions may be further classified by the change observed. The example of gasoline burning is more commonly known as a ***combustion reaction***. Combustion is generally defined as a reaction with oxygen; when hydrocarbons (like gasoline) are combusted, carbon dioxide and water are the two main products. Many other types of reactions are defined:

1. Precipitation Reactions: an insoluble salt is formed by the reaction of two soluble compounds.

$$FeCl_3\,(aq) + 3\,NaOH\,(aq) \rightarrow Fe(OH)_3\,(s) + 3\,NaCl\,(aq)$$

2. Acid-Base Reactions (Neutralization Reactions): transfer of a hydrogen ion from an acid to the base produces a salt and water.

$$HCl\,(aq) + NaOH\,(aq) \rightarrow NaCl\,(aq) + H_2O\,(l)$$

3. Oxidation-Reduction Reactions: substances have a change in oxidation state, one being reduced another other oxidized.

$$2Na\,(s) + Cl_2\,(g) \rightarrow 2NaCl\,(s)$$

In many cases, an observable change occurs upon reaction. These changes may include the formation of a precipitate (solid), the evolution of gas as bubbles, the dissolving of a solid, color changes, or temperature changes of the system.

Today's experiment studies precipitation reactions. The easiest way to determine if a reaction has occurred is to compare the species present in the individual solutions before mixing to the species that may exist in solution after mixing. The indicated states for each substance, ***(s)*** for solid, ***(l)*** for liquid, ***(g)*** for gas, and ***(aq)*** for aqueous solutions, help define the species. Consider the reaction between silver nitrate and sodium chromate:

$$2\,AgNO_3\,(aq) + Na_2CrO_4\,(aq) \rightarrow Ag_2CrO_4\,(s) + 2NaNO_3\,(aq)$$

The equation above is known as the ***molecular equation*** and is useful in identifying the substances involved in the reaction. A ***total ionic equation*** (T. I. E.) describes the details of the reaction by showing the states of all species present in solution before and after a reaction has occurred. For the previous reaction, the T.I.E. is:

$$2Ag^+\,(aq) + NO_3\,(aq) + 2Na^+\,(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4\,(s) + 2Na^+\,(aq) + NO_3^-\,(aq)$$

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Notice that ions of the same type (identity and state) are present on both sides of the reaction arrow. Since they do not undergo a change upon mixing, they are not participating in the reaction and are called spectator ions. The spectator ions may be cancelled and the equation re-written (similar to a math problem) to give the net reaction occurring, which is called the ***net ionic equation:***

$$2Ag^{+}(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s)$$

This reaction only shows the species undergoing a change as the reaction occurs.

A general set of steps may be followed to determine the total ionic and net ionic equations for a chemical reaction:

1. **Write the molecular equation for the reaction.**
2. **Balance the molecular equation for the reaction.**
3. **Rewrite the equation showing all substances in their ionic form while in solution. This is the total ionic equation.**
4. **Identify and cancel all the spectator ions on both sides of the equation. This will yield the net-ionic equation.**

In some cases, the products of the reaction must be determined based on the reactants provided. The general solubility rules are used to predict the solubility of solid, and may indicate whether a chemical reaction will produce a precipitate. The general solubility rules can be found in your textbook and below:

Soluble Compounds	**Exceptions**
All Alkali metal (Group I) compounds	
All ammonium (NH_4^+) salts	
Alll nitrate (NO_3^-), chlorate (ClO_3^-) and bicarbonate (HCO_3^-) salts	
Halides	Halides of Ag^+, Hg_2^{2+}, Pb^{2+}
Sulfates	Sulfates of Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}
Iodates (IO_3^-)	Iodates of Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}
Insoluble Compounds	**Exceptions**
Carbonates (CO_3^{2-}), phosphates (PO_4^{2-}), chromates (CrO_4^{2-})and sulfides (S^{2-})	
Hydroxides	Compounds containing alkali metals, ammonium ion, or Ba^{2+}
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In today's experiment a series of known reactions that form ionic precipitates will be investigated and reaction matrix filled in. The solubility of precipitates that form will be tested using acetic acid. The prepared matrix will then be used to determine the identity of a series of unknown solutions. Total and net ionic equations will be written for selected reactions.

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Procedure

1. Obtain seven small clean test tubes and place them in a test-tube rack. Label one for each of the 6 known solutions and 1 for acetic acid.
2. Obtain 7 small pipettes. Use these to put approximately 3 mL of each of the known solutions into the corresponding test tube.
3. Obtain a well plate and 6 toothpicks.
4. Align your well plate so there are at least 6 wells across and 6 wells down. This corresponds to the table of page 5. Use the corresponding droppers to place 5 drops of the appropriate solution listed along the top of the table in the appropriate well.
5. Add 5 drops of the solutions listed on the side of the table in the appropriate well.
6. Mix the solutions well using a clean toothpick.
7. Make your observations and record your data on the data sheet.
    a. Did a reaction occur? (Reaction box)
    b. Did a precipitate form? (Precipitate box) If yes, describe the precipitate. (Color box)
8. To each of the wells in which a precipitate was formed, add 5 drops of acetic acid and mix well with a clean toothpick. To determine if the precipitate is soluble in acetic acid ($HC_2H_3O_2$):
    a. If the precipitate disappears, then it is ***soluble***
    b. If the precipitate remains, then it is insoluble or it may be slightly soluble.
9. To determine if the precipitate is slightly soluble, mix the solution at 2 minute intervals for a total of 6 minutes.
    a. If the precipitate appears to partially dissolve, then it is ***slightly soluble***
    b. If the precipitate remains, then it is ***insoluble***.
10. Repeat the same process as steps 4 through 7 using the Unknown Solutions.
11. Record your data on the data sheet labeled **"Studying the Reactions and Identification of the Unknown Solutions."** (page 6).

Waste Disposal Collect all of your solutions in a beaker and then place in the waste container after you are done with the experiment.

Clean-Up Wash all glassware with soap then rinse 3 times with tap water, and once with deionized water. Thoroughly rinse plastic pipettes and return to the front of the lab.

Data and Conclusions

Using the data from the known solutions identify the unknowns. Explain the process you used for determining the unknowns.

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Writing and Understanding Chemical Equations and Reactions

Data Sheet

Name: _____ **Lab Partner:** _____

Studying the Reactions of Labeled Solutions

Solution	$Al_2(SO_4)_3$	$BaCl_2$	NaCl	$NaIO_3$	NaOH	$Zn(NO_3)_2$
$Al_2(SO_4)_3$		Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid
$BaCl_2$	Reaction: Precipitate: Color: Soluble with Acetic Acid:		Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid
NaCl	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid:		Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid
$NaIO_3$	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid		Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid
NaOH	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid		Reaction: Precipitate: Color: Soluble with Acetic Acid
$Zn(NO_3)_2$	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	

Writing and Understanding Chemical Equations and Reactions

Name: _____ **Lab Partner:** _____

Studying the Reactions and Identification of the Unknown Solutions

Unknown	1	2	3	4	5	6
1		Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid
2	Reaction: Precipitate: Color: Soluble with Acetic Acid:		Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid
3	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid:		Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid
4	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid		Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid
5	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid		Reaction: Precipitate: Color: Soluble with Acetic Acid
6	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid:	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	Reaction: Precipitate: Color: Soluble with Acetic Acid	

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Name: _____

Unknown	Identity	Experimental Observations and Reasoning
1		
2		
3		
4		
5		
6		

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Post-lab Assignment

Name: _____

1. Write the balanced molecular, total ionic, and net ionic equations for each reaction that yielded a precipitate involving barium chloride.

2. Write the balanced molecular equations for any of the precipitates in Question #1 that were dissolved by acetic acid.

3. Are any of your observations inconsistent with what is expected based upon the solubility rules? Use examples to explain your answer.

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Pre-lab Assignment

Name: _____

1. Predict the products of the following reactions and balance the equation. If names are given write the correct formula for the reactants.

   a. $NaI(aq) + Pb(NO_3)_2(aq) \rightarrow$

   b. $AgNO_3(aq) + KBr\ (aq) \rightarrow$

   c. aqueous hydrochloric acid + aqueous barium hydroxide →

   d. iron(III) chloride (aq) + cesium phosphate (aq) →

2. Write the total ionic and net ionic for the reactions in #1.