EXPERIMENT 3: REACTIONS IN AQUEOUS SOLUTIONS *(Read through this prior to beginning part 1)*
This experiment corresponds to chapter 3 in your text)

Introduction

One of the most important characteristics of water is its ability to dissolve many compounds. Solutions in which water is the solvent are called aqueous solutions. Many important reactions take place in aqueous solutions. In fact, many of the reactions that take place throughout your body (from your organs down to individual cells) are aqueous reactions. Understanding the most common aqueous reactions and how to correctly write them is one of the most important skills you should master in Chemistry 1A. This skill will be used extensively throughout the remainder of the semester and in Chemistry 1B.

Before you begin, one must ask the question: What observations indicate that a chemical reaction has occurred? Some indications include: the formation of an insoluble solid *(precipitate)*, color change, the evolution of a gas, or a temperature change. In this experiment, you will predict what will happen when two *aqueous solutions* are mixed, and then test your predictions in the laboratory. During the previous discussion period, your lab instructor lectured on the topic of reactions in aqueous solution with examples of the correct way to write a molecular equation, an ionic equation, and the overall net ionic equation for several types of aqueous reactions.

In *metathesis* or *double displacement* reactions, cations and anions exchange partners as in the following generic reaction:

$$AX + BY \rightarrow AY + BX$$

There are three types of metathesis reactions—precipitation reactions, gas-forming reactions, and neutralization reactions. An example of each type is given below:

Reaction Type	**Example**
Precipitation—results in the formation of an insoluble solid called a *precipitate*	$Pb(NO_3)_{2\ (aq)} + 2\ KI_{\ (aq)} \rightarrow 2\ KNO_{3\ (aq)} + PbI_{2\ (s)}$ **precipitate**
Gas-forming—results in the formation of a gas that escapes from the solution	$2\ HCl_{\ (aq)} + Na_2S_{\ (aq)} \rightarrow H_2S_{\ (g)} + 2\ NaCl_{\ (aq)}$
Neutralization-reaction of an acid and a base which results in the formation of a salt and water	$HNO_{3\ (aq)} + KOH_{\ (aq)} \rightarrow KNO_{3\ (aq)} + H_2O_{\ (1)}$ **acid** **base** **salt**

A metathesis reaction will occur if (1) a precipitate forms from soluble reactants or (2) a stable molecule forms, such as water or an insoluble gas. Refer to the example on the next page and the sections on ionic equations and metathesis reactions in your textbook for information on writing chemical equations for metathesis reactions. Familiarity with the solubility rules tabulated on the next page is required to write these equations.

Objectives: Upon completion of this exercise and laboratory experiment, you should be able to:

1. Using the solubility rules, determine the species present in aqueous solutions of compounds.
2. Predict the type of reaction that will occur when two aqueous solutions are mixed.
3. Write the chemical equation, the ionic equation, and the net ionic equation for reactions taking place between aqueous solutions.
4. Experimentally identify the type of reaction occurring when two aqueous solutions are mixed through simple visual and temperature measurements.

Adapted from "Reactions in Aqueous Solutions" by David Reichgott and Mary O'Brien, Edmonds Community College, Lynnwood, Washington and "Reactions in Aqueous Solutions" Illinois State University, Normal, Illinois.

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Solubility Rules: You should be familiar with these rules and be able to use them efficiently. You will be provided these rules on quizzes and exams.

Soluble Compounds	**Exceptions**
Compounds containing NO_3^- and $C_2H_3O_2^-$	None
Compounds containing Cl^-, Br^-, and I^-	Compounds containing Pb^{2+} {ss}, Ag^+, Hg_2^{2+}
Compounds containing SO_4^{2-}	Compounds containing Ca^{2+} {ss}, Hg_2^{2+}{ss}, Ag^+{ss}, Sr^{2+}, Ba^{2+}, and Pb^{2+}
Compounds containing NH_4^+	None
Insoluble Compounds	**Exceptions**
Compounds containing CO_3^{2-}	Compounds containing NH_4^+ and alkali metal cations
Compounds containing OH^-	Compounds containing NH_4^+, Ca^{2+}{ss}, Sr^{2+}{ss}, Ba^{2+}{ss}, and alkali metal cations
Compounds containing S^{2-}	Compounds containing NH_4^+ and alkali metal cations

Writing the molecular, ionic, and net ionic equations for a chemical reaction in aqueous solution:

The steps for writing a net ionic equation for the metathesis reaction of aqueous K_2SO_4 and $Pb(C_2H_3O_2)_2$ are outlined below.

1. Write the balanced *molecular equation* which gives the complete chemical formula and the phase of the reactants and products. Switch the reactant cation/anion pair to form the products and use the solubility rules to determine the phase of the products.

   $$K_2SO_{4\ (aq)} + Pb(C_2H_3O_2)_{2\ (aq)} \rightarrow PbSO_{4\ (s)} + 2\ KC_2H_3O_{2\ (aq)}$$

2. Write the balanced *complete ionic equation* which shows all strong electrolytes as ions.

   $$2\ K^+_{(aq)} + SO_4^{2-}{}_{(aq)} + Pb^{2+}_{(aq)} + 2\ C_2H_3O_2^-{}_{(aq)} \rightarrow PbSO_{4\ (s)} + 2\ K^+_{(aq)} + 2\ C_2H_3O_2^-{}_{(aq)}$$

3. Cancel out the *spectator ions,* the ions that appear as both reactants and products in the complete ionic equation. What remains is the *net ionic equation.*

   $$\cancel{2\ K^+}_{(aq)} + SO_4^{2-}{}_{(aq)} + Pb^{2+}_{(aq)} + \cancel{2\ C_2H_3O_2^-}{}_{(aq)} \rightarrow PbSO_{4\ (s)} + \cancel{2\ K^+}_{(aq)} + \cancel{2\ C_2H_3O_2^-}{}_{(aq)}$$

   $$Pb^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow PbSO_{4\ (s)}$$

Experiment 3: Reactions in Aqueous Solutions – Part 1: **Name: _____**
(You may begin this at home, part 1 must be completed prior to leaving lab on day 1) **Section: _____**

1. Precipitation Reactions *(You may begin this at home, it must be completed and turned into your instructor prior to leaving lab on day 1 of the exp.)*

a. On the reverse side of this page or on a separate piece of paper, **neatly** write the balanced molecular equation, an ionic equation with spectator ions crossed out, and the balanced net ionic equation for the reaction of each pair of aqueous solutions. *(Be sure to include all states, aq, l, s or g. Use the solubility rules as a guide.) Attach any extra pages with your work.*

Example: lead nitrate and potassium iodide

Molecular equation: $Pb(NO_3)_{2\,(aq)} + 2\,KI_{\,(aq)} \rightarrow PbI_{2\,(s)} + 2\,KNO_{3\,(aq)}$
Ionic equation: $Pb^{2+}_{(aq)} + 2\,NO_3^-{}_{(aq)} + 2\,K^+_{(aq)} + 2\,I^-_{\,(aq)} \rightarrow PbI_{2(s)} + 2\,K^+_{(aq)} + 2\,NO_3^-{}_{(aq)}$
Net ionic equation: $Pb^{2+}_{\,(aq)} + 2\,I^-_{(aq)} \rightarrow PbI_{2\,(s)}$

a) Sodium chloride and ammonium nitrate
b) Sodium chloride and silver nitrate
c) Sodium chloride and barium nitrate
d) Sodium sulfate and ammonium nitrate
e) Sodium sulfate and silver nitrate
f) Sodium sulfate and barium nitrate
g) Sodium hydroxide and ammonium nitrate
h) Sodium hydroxide and silver nitrate
i) Sodium hydroxide and barium nitrate
j) Sodium carbonate and ammonium nitrate
k) Sodium carbonate and silver nitrate
l) Sodium carbonate and barium nitrate

b. Tabulate your expected results in the chart below based on the solubility rules covered in you text and lecture.
Place a "P" in the box if you expect a precipitate to form and "NR" if you do not think a reaction will occur. Note "SS" as well if any of the reactions generate a slightly soluble product.

Predicted Results

	NH_4NO_3	$AgNO_3$	$Ba(NO_3)_2$
NaCl			
Na_2SO_4			
NaOH			
Na_2CO_3			

Instructor Date and Sign: _____

Adapted from "Reactions in Aqueous Solutions" by David Reichgott and Mary O'Brien, Edmonds Community College, Lynnwood, Washington and "Reactions in Aqueous Solutions" Illinois State University, Normal, Illinois.

Experiment 3: Reactions in Aqueous Solutions Part 2 (Day 2):
Experimental Procedure:

In this part of the experiment, you will compare you predictions of reactions in aqueous solutions against your observed results obtained when aqueous solutions are mixed in the laboratory.

1. Unless noted, the test tubes that you use do not need to be completely dry. However, rinse them with deionized water before use.

2. Select three small test tubes. Using a graduated cylinder, measure 1.0 mL of deionized water and transfer it to a test tube. Use a grease pencil to mark the water level in the test tube and then use the test tube as a guide to make a 1.0 mL mark on the other two test tubes. Repeat this step to make 2.0 mL marks on each test tube. Each of the three test tubes should have a 1.0 mL and a 2.0 mL mark when you are finished.

Precipitation Reactions:

3. Add 1 mL of 0.1 M NaCl to each of the three test tubes. Then, in order, add 1 mL of each of the solutions listed in the first row of the table in question 1 of your lab report. For example, the first test tube should contain NaCl and NH_4NO_3, the second should contain NaCl and $AgNO_3$, and the third should contain NaCl and $Ba(NO_3)_2$. Record your observations. Dispose of the silver and barium solutions in the appropriate waste container.

4. Repeat step 3 for all solution combinations in the table. Again, dispose of all solutions containing silver and barium in the appropriate waste container.

Gas-Forming Reactions:

5. To a <u>dry</u> test tube, add a sample of $CaCO_3$ that is about the size of a pencil eraser. Then add 1 mL of deionized water followed by 1 mL of 2 M HCl. Record your observations.

6. Repeat step 5 using Na_2SO_4 in place of $CaCO_3$.

Neutralization Reactions:

7. Weigh about 0.5 g of $Mg(OH)_2$ on the top loading balance. Transfer the sample to a 150 ml beaker. Use a graduated cylinder to measure 25.0 mL of deionized water. Pour the water into the beaker containing $Mg(OH)_2$. Swirl the mixture.

8. Use a graduated cylinder to measure 25.0 mL of 1.0 M HCl. Add the HCl to the beaker containing the $Mg(OH)_2$ mixture and thoroughly stir the solution. Observe what happens, upon mixing.

EXP 3: REACTIONS IN AQUEOUS SOLUTIONS Name: _____

Part 2: EXPERIMENTAL RESULTS Section: _____

1. Precipitation Reactions: Tabulate your observations in the chart below. Compare your results to your predictions. Use an asterisk (*) to mark any observations that do not agree with your predictions.

Results

	NH_4NO_3	**$AgNO_3$**	**$Ba(NO_3)_2$**
NaCl			
Na_2SO_4			
NaOH			
Na_2CO_3			

2. Gas-Forming Reactions:

a. Describe what happened when you mixed HCl with $CaCO_3$.

b. Describe what happened when you mixed HCl with Na_2SO_4.

3. Neutralization Reactions:

What happened when you mixed the $Mg(OH)_2$ and HCl? Explain your observations.

Instructor Date and Sign: _____

EXP 3: REACTIONS IN AQUEOUS SOLUTIONS Name: _____

Part 2 Predictions Section: _____

1. ***Precipitation Reactions*****: Completed in part 1 of this assignment.**

2. ***Gas-Forming Reactions*** *(refer to you text and notes)*

Which of the following pairs of reactants will give off a gas when mixed?

	Will a gas evolve? (Y/N)	Formula of Gas
HCl and $CaCO_3$	_____	_____
HCl and Na_2SO_4	_____	_____

3. ***Neutralization Reactions***

Write the balanced molecular equation, an ionic equation with spectator ions crossed out, and the balanced net ionic equation for the reactions below. *(Be sure to include all states, aq, l, s or g)*

(a) Solutions of sodium hydroxide and hydrochloric acid.

(b) Solutions of hydrofluoric acid and calcium hydroxide.

(c) Solutions of nitric acid and aqueous ammonia.

(d) Solid magnesium hydroxide and aqueous perchloric acid.

EXP 3: REACTIONS IN AQUEOUS SOLUTIONS Name: _____

(Post-lab questions… what you might see on an exam…) Section: _____

1. Describe how you could experimentally differentiate between the following pairs of solutions using a common aqueous test solution :

Example: A student is presented with two clear and colorless solutions, sodium nitrate and sodium carbonate. The student adds a few drops of a nitric acid solution to each and observes bubbles in one. That solution must be the sodium carbonate solution since the other cannot form a gas via reaction with nitric acid.

a. $Pb(NO_3)_2$ or KNO_3

b. HCl or H_2SO_4

2. Write a balanced net ionic equation for each of the following aqueous metathesis reactions. *(Be sure to include all states, aq, s, l or g)* Refer to the example in the introduction of this experiment and the section on ionic equations in your textbook for assistance. Classify each reaction as a neutralization, precipitation, or gas-forming reaction. *(Refer to ch. 3 section 10 in your text)*

a. Hydrobromic acid and cesium hydroxide

Classification: _____

b. Sulfuric acid and sodium carbonate

Classification: _____

c. Cadmium chloride and sodium sulfide

Classification: _____