Lab 5. The Nine-Solution Problem

Prelab Assignment

Before coming to lab:

- Use the handout "Lab Notebook Policy" as a guide to complete the following sections of your report for this lab exercise *before* attending lab: Title and Date of Lab, Introduction, Materials/Methods and Data Tables (see page 3 for sample data tables). An outline or flow chart of the procedure is appropriate for the Materials/Methods section. Ensure that the table of contents of your lab notebook is current.
- Read the introduction, below, and sections 4.1-4.3 in the textbook (*Silberberg 5th ed.)* and then complete the Prelab questions on the last page and hand in at the start of lab or when instructed by your instructor.
- *Start this prelab assignment early….If your background knowledge is displacement reactions is weak, itt may take you an hour or more to complete!!*

Purpose

In this laboratory you will be provided with a set of nine solutions. Unfortunately, the labels have fallen off the bottles! It will be your task to identify the contents of each bottle. Part of your grade will be based on the correct identification of each. Moreover, you will write molecular and net ionic equations for each pair of solutions that result in a chemical reaction.

Introduction

An important class of chemical reactions is double replacement, or metathesis, reactions. These occur when aqueous ionic compounds combine by trading or replacing ions. For example, in the following double replacement reaction (shown as a ***molecular equation***):

$$3\ AgNO_3\ (aq) + Na_3PO_4\ (aq) \rightarrow Ag_3PO_4\ (s) + 3\ NaNO_3\ (aq)$$

You can see that the ions have "traded place." The cation from the first compound forms a compound with the anion from the second compound and *visa versa*. In a double replacement reaction one of the products is frequently insoluble and appears as a ***precipitate***. In the case of the reaction above a precipitate of solid silver phosphate forms.

Because the reaction takes place in solution it is often appropriate to write the reaction in ionic or net ionic form. When ionic compounds are in solution, ***those compounds that are soluble will dissociate into ions***; compounds that are insoluble do not dissociate. You will need to consult your text **(Table 4.1 on page 148 of the textbook)** or a reference book to determine which compounds are soluble and which are insoluble. In this case, both of the reactants are soluble, while one of the products is insoluble and the other is soluble. Thus, the ***total ionic equation*** for this reaction is best written as:

$$\mathbf{3\ Ag^+\ (aq) + 3\ NO_3^-\ (aq) + 3\ Na^+\ (aq) + PO_4^{-3}\ (aq) \rightarrow Ag_3PO_4\ (s) + 3\ Na^+\ (aq) + 3\ NO_3^-\ (aq)}$$

In this example, the compounds that are soluble in water ($AgNO_3$, Na_3PO_4 and $NaNO_3$) have been shown ***dissociated into ions***. An ***ionic equation*** indicates how ionic compounds actually exist in solution.

The ***net ionic equation*** is similar, but removes clutter in the reaction by "canceling out" those ions that appear on both sides of the equation. These are called ***spectator ions***; they have not undergone any chemical change. Thus, the net ionic equation for this reaction would be:

$$\mathbf{3\ Ag^+\ (aq) + PO_4^{-3}\ (aq) \rightarrow Ag_3PO_4\ (s)}$$

This equation shows only those substances that are undergoing chemical change. The ***spectator ions*** (Na^+ and NO_3^-) have been removed.

In this lab you will work with the following nine aqueous solutions: **$AgNO_3$**, **Na_2CO_3**, **NaBr**, **NH_4Cl**, **$Ca(NO_3)_2$**, **H_2SO_4**, **NaOH**, **$BaCl_2$**, and **H_2O**.

By combining the solutions, observing the results and making careful, systematic notes, you will generate a record of which combinations produced a chemical reaction to form new substances. You will be able to determine if a chemical reaction has occurred if you observe one of the following:

- ***The formation of a precipitate***. Indications of precipitate formation include the solution becoming cloudy/opaque or a solid settling to the bottom. You can use the solubility rules **(Table 4.1 on page 148)** to predict which solutions will form a ***precipitate*** when mixed.
- ***A gas is formed***. The primary method for detecting these gases is by the appearance of bubbles or by the characteristic odor of ammonia gas, both of which can be difficult to observe due to the small reacting quantities use. Refer to your text **(p. 156)** for help in predicting which reactions will produce these gases.
- ***The generation of heat***. Most acid-base neutralization reactions do not give any visible sign of a reaction. But since acid-base neutralization reactions are exothermic, a slight amount of warming of the solutions may be noticed.
- ***A color change***. A color change may indicate that something new has been produced, a sign that a chemical reaction took place.

Procedure (Work in teams of two)

1. Obtain a well plate and nine plastic droppers from the lab cart. Be certain that all of your equipment is clean. Rinse well with D.I. water as any contamination will affect your results.
2. Use tape to label each of the plastic droppers with numbers 1-9. Fill each dropper with the appropriate solution and then place them on a paper towel on your desk.
3. Combine within separate wells of the plate all of the solutions in pairs of two, *i.e.*, 1 & 2, 1 & 3, *etc.* – obviously you do not have to combine a solution with itself! Swirl the plate gently to ensure mixing of the solutions. Observe carefully for signs of a chemical reaction and record your observations (e.g. color and texture of a precipitate, bubbles, odors, heat, color change, etc.) in a ruled chart/grid (e.g. table 2 on page 3) in your lab notebook. If no reaction occurs, record ***NR*** in the data table.
4. Clean the well plate and droppers thoroughly and return to the lab cart. Make your final rinse with D.I. water.
5. Use the information from your text and the results from your experiments to identify the nine solutions and to write molecular and net ionic equations for all combinations that resulted in a chemical reaction.

Analysis and Report

Be sure to include the following in your laboratory report:

1. Complete table 1 (see the next page) in your lab notebook. Do this by using the introduction of this lab and sections 4.1 - 4.3 in your textbook to predict the outcome of the reaction between each of the solutions in table 1. Four of the cells in table 1 have been completed for you as examples.
2. Your data, showing the results when every possible combination of solutions is mixed. Use tables 2 on the following page as a guide.
3. Your identification of the nine solutions—you must explain how you identified the solutions. Your identification of the nine solutions must follow from your experimental data. You will lose points if you give results that are not supported by your data.
4. Write molecular and net ionic equations for every reaction that produced an observable result. *Do not write equations for those combinations of solutions that did not result in a chemical reaction.*

Table 1. Predicted results. NR = No Reaction; ppt = precipitate

Solution	$AgNO_3$	Na_2CO_3	NaBr	NH_4Cl	$Ca(NO_3)_2$	H_2SO_4	NaOH	$BaCl_2$
$AgNO_3$								
Na_2CO_3	Ag_2CO_3 ppt							
NaBr	AgBr ppt	NR						
NH_4Cl	AgCl ppt							
$Ca(NO_3)_2$								
H_2SO_4								
NaOH								
$BaCl_2$								
H_2O								

Table 2. Experimental results. NR = No Reaction; ppt = precipitate

Solution #	1	2	3	4	5	6	7	8
1								
2								
3								
4								
5								
6								
7								
8								
9								

Lab Report Guidelines

As indicated previously, be sure to write your report according to the guidelines in the "*Lab Notebook Policy*" handout. Below is a checklist of what should appear in each of the 5 sections of your lab report.

Lab 5 Report Checklist

1. Introduction
- Goal/purpose of the lab is stated clearly?
- Includes summary of background information?
- Equations for molecular and net ionic equations?

2. Materials and Methods
- Procedure is brief, but detailed enough that a competent student could use it to replicate the experiment?
- Uses own words—doesn't plagiarize the procedure from the handout?

3. Results
- Is the table for the predicted results complete
- Is the table for the experimental results complete?
- Table includes observations (e.g. color of each ppt)?

4. Analysis of Results
- Correctly identifies the 9 solutions?
- Uses experimental results to justify/support the identification of the 9 solutions?
- Includes for each reaction that occurs…
  - Balanced molecular Equations?
  - Balanced net ionic equations?
  - Net ionic equations have correct ionic charges?
  - All equations include the states of all substances: (aq), (s), (l), etc.

5. Conclusion
- Uses "*bullets"* to state concisely the major conclusions?
- Includes ID of each of the nine solutions?
- Summarizes sources of error or uncertainty?

Overall quality: the report is neat, easy to follow, uses proper format, completed at a depth appropriate for a college chemistry class?

Lab 5 Prelab Questions **Name** _____
The Nine-Solution Problem **Date** _____ **Section** ____ **Group No.** _____

Instructions: Complete all parts of the following four questions in the spaces provided and hand in at the start of your lab period or when instructed by your instructor. Carefully read the background information on page 1 and **sections 4.1-4.3** in the textbook before attempting these questions.

1. For each of the following pairs of aqueous solutions, state whether a precipitation reaction occurs when they are mixed. Write the names and formulas of any precipitates that form. See **Table 4.1 (page 148)** in the textbook for the solubility rules for ionic compounds.

Reactants	Will a precipitate form?	Name & Formula of Precipitate
a) Ammonium iodide + Silver Nitrate		
b) Sodium nitrate + Copper (II) sulfate		
c) Potassium carbonate + Barium Hydroxide		

2. Complete the following precipitation reactions with balanced molecular, total ionic, and net ionic equations.

   a. **Molecular equation**

   $CaCl_2$ *(aq)* + Na_3PO_4 *(aq)* →

   Total Ionic Equation

   Net ionic equation

   b. **Molecular equation**

   NH_4OH *(aq)* + $FeSO_4$ *(aq)* →

   Total Ionic Equation

   Net ionic equation:

3. **Acid-Base Reactions.** According to the *Arrhenius* definition, an acid is any substance, which when dissolved in water, tends to increase the concentration of ***hydrogen ions, H^+***. For example, hydrogen chloride gas dissolves in water to produce hydrochloric acid, an aqueous solution containing hydrogen ions and chloride ions.

$$HCl_{(g)} \xrightarrow{water} H^+_{(aq)} + Cl^-_{(aq)}$$

On the other hand, an *Arrhenius* base is any substance, which when dissolved in water, tends to increase the concentration of ***hydroxide ions, OH^-***. E.g. Sodium hydroxide dissolves in water to produce a solution containing sodium and hydroxide ions.

$$NaOH_{(s)} \xrightarrow{water} Na^+_{(aq)} + OH^-_{(aq)}$$

When an acid is mixed with a base a ***neutralization reaction*** occurs as the hydrogen ions react with the hydroxide to produce water. Write the balanced molecular, total ionic, and net ionic equations for the acid-base reaction between potassium hydroxide and phosphoric acid. (Assume their is an enough base to neutralize all hydrogen ions.)

Molecular equation

$KOH\ (aq) + H_3PO_4\ (aq) \rightarrow$

Total Ionic Equation

Net ionic equation

4. Another kind of neutralization reaction involves the neutralization of hydrogen ions, H^+, by carbonate ions, CO_3^{2-}, to form carbonic acid, H_2CO_3, an unstable acid that quickly decomposes to form water and CO_2 gas:

$$\mathbf{2\ H^+\ (aq) + CO_3^{2-}\ (aq) \rightarrow [\ H_2CO_3\ (aq)\ ] \rightarrow H_2O + CO_2\ (g)}$$

or

$$\mathbf{2\ H^+\ (aq) + CO_3^{2-}\ (aq) \rightarrow H_2O + CO_2\ (g)}$$

Write the balanced molecular and net ionic equations for the following neutralization reaction.

Molecular equation

$HCl\ (aq) + K_2CO_3\ (aq) \rightarrow$

Total Ionic Equation

Net ionic equation