

Name\_\_\_\_\_

Date\_\_\_\_\_Period\_\_\_\_\_

## The Ion Exchange

### Introduction

**"It is a capital mistake to theorize before one has data"**

The master detective Sherlock Holmes made the above statement. You may have found yourself adopting this philosophy. You should realize that your goal in the chemistry lab should **not** be "to get the right answer"! Often, there is no right answer! This is what experimentation is all about. Asking questions leads to new experiments. New experiments lead to new questions and the process repeats itself. Your goal in the lab should be to record accumulated data in a neat and organized fashion. From this information, ask questions, look for pattern, arrive at conclusions; theorize. Put your whole self into the process of experimentation. It's FUN to do chemistry. It's boring and frustrating to just go through the motions.

By now you should understand what a double replacement reaction is. Do you think *all* double replacement reactions produce precipitates? Well we are going to find out! No test tubes will be used in this experiment! You will record data in such a way that comparisons of the chemical behavior can be made easily. Then what? There are a great many questions one can ask upon analyzing the data from this experiment. Along the way we will try and figure out the title of this experiment.

### Materials

#### Equipment

- 1 acetate sheet (overhead transparency)
- 1 data table to slip under the acetate sheet

#### Chemicals

Beral pipets and/or dropper bottles containing solutions of the following:

Barium nitrate	Ba(NO <sub>3</sub> ) <sub>2</sub>	Sodium carbonate	Na <sub>2</sub> CO <sub>3</sub>
Calcium nitrate	Ca(NO <sub>3</sub> ) <sub>2</sub>	Sodium hydroxide	NaOH
Copper (II) nitrate	Cu(NO <sub>3</sub> ) <sub>2</sub>	Sodium iodide	NaI
Iron (III) nitrate	Fe(NO <sub>3</sub> ) <sub>3</sub>	Sodium oxalate	Na <sub>2</sub> C <sub>2</sub> O <sub>4</sub>
Lead (II) nitrate	Pb(NO <sub>3</sub> ) <sub>2</sub>	Sodium phosphate	Na <sub>3</sub> PO <sub>4</sub>
Potassium nitrate	KNO <sub>3</sub>	Sodium sulfate	Na <sub>2</sub> SO <sub>4</sub>
Silver nitrate	AgNO <sub>3</sub>	Sodium Thiosulfite	Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub>
Sodium chloride	NaCl		

### *Procedure*

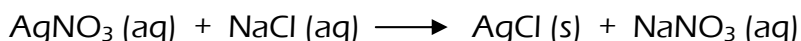
1. Place your data table under the acetate sheet.
2. Mix two drops of each chemical in the appropriate space. For contrast, place each drop so that it overlaps both a white and black background. Stir each mixture by blowing air from a dry plastic pipet at the drops. Do not let the pipet touch the solutions, however!
3. Record your observations in an identical matrix drawn in your laboratory notebook. Develop and use an efficient code: For example, "WP" might mean white precipitate. You may wish to add a less important adjective like "cloudy" or "milky" to the same box.
4. Use a piece of paper towel to wipe up the solutions. Throw the towel into the trash.

5. When answering the questions that follow, feel free to repeat some of the combinations in order to verify your data.

### **Discussion**

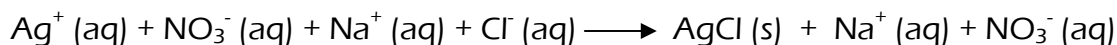
Did you notice all the precipitates that formed? Were they all the same color? Were some cloudy? Were some particulate in nature? What is the name of the precipitate? How could you find out? Would this involve a deductive process? Hmm...this sounds like it could be a chemistry logic problem.

You learned in previous experiments that precipitates can form during double replacement reactions from the rearrangement of ions that are present in ionic solutions. Since the solutions used were ionic compounds, you may assume that each precipitate formed was due to a new combination of these ions. For example,



As shown by the equation, AgCl is a precipitate. For some reason, AgCl is *insoluble*, (i.e., it does not dissolve in water). NaNO<sub>3</sub>, on the other hand, is *soluble*, (i.e., it does dissolve in water). To really show what is happening during the reaction, two different equations can be written.

An **Ionic Equation** would be:



The above equation shows how the compounds exist in solution. The precipitate is written as a formula because it represents a solid substance. The Na<sup>+</sup> and NO<sub>3</sub><sup>-</sup> are separated because those ions (for some reason) do not get together to make a solid.

A **Net Ionic Equation** would be:

$\text{Ag}^+ (\text{aq}) + \text{Cl}^- (\text{aq}) \longrightarrow \text{AgCl} (\text{s})$  This equation shows only those ions that participate in the formation of the precipitate. The ions not included are called *spectator ions*.

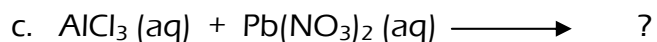
### **Questions** (Data Analysis)

1. Using your data table, find all combinations of chemicals that produced a precipitate.
2. Write a balanced equation for these reactions using your knowledge of double replacement reactions. Clearly mark each species as being aqueous (aq), solid (s), liquid (l) or gas (g).
3. For each precipitation reaction write a second, full ionic, balanced equation. Identify spectator ions, then write a third, balanced, net ionic equation for the reaction, excluding spectator ions.
4. Which cation(s) formed precipitates with all or almost all its anions horizontally across in Columns 1 through 8?
5. What anion is found in all solution combinations in this activity? What cation is common to all the solution mixtures?
6. Analyze your data regarding the solubility behavior of carbonate CO<sub>3</sub><sup>2-</sup>; sulfate, SO<sub>4</sub><sup>2-</sup>; and iodine, I<sup>-</sup>. State your conclusion to match the following sample conclusions: *All chlorides are soluble except silver chloride and lead chloride.*

7. Repeat your analysis of the data to create a generalized rule for the solubility behavior of each of these metallic cations: lead(II),  $\text{Pb}^{2+}$ ; calcium,  $\text{Ca}^{2+}$ ; copper (II),  $\text{Cu}^{2+}$ ; and zinc,  $\text{Zn}^{2+}$ .

**Implications and Applications:**

1. Predict whether or not the following reactions will form a precipitate. For those that do, complete the reaction using the symbols (aq) and (s) where appropriate.



2. In Columns 1 through 8, only sodium salts were used. Could potassium salts be substituted for the sodium salts? Why or why not?

3. Assume we mix solutions of barium nitrate and sodium sulfate. Using your data table, complete a word equation for the reaction that is expected. Indicate which product is the precipitate. Complete a generalized equation for this reaction if A and C represent cations and B and D represent anions.



	1 Na <sub>2</sub> CO <sub>3</sub>	2 NaCl	3 NaOH	4 Na <sub>2</sub> SO <sub>4</sub>	5 Na <sub>3</sub> PO <sub>4</sub>	6 Na <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	7 NaI	8 Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub>
A AgNO <sub>3</sub>								
B Ba(NO <sub>3</sub> ) <sub>2</sub>								
C Ca(NO <sub>3</sub> ) <sub>2</sub>								
D Cu(NO <sub>3</sub> ) <sub>2</sub>								
E Zn(NO <sub>3</sub> ) <sub>2</sub>								
F Pb(NO <sub>3</sub> ) <sub>2</sub>								
G KNO <sub>3</sub>								
H Fe(NO <sub>3</sub> ) <sub>3</sub>								