

Chemistry 1215 Experiment #8
Double Displacement and Gas Forming Reactions

Objective

The objective of this experiment is to identify six ionic solutions based on their reactions with each other.

Introduction

An observation of the reaction that occurs when two solutions are mixed can often bring valuable information. Results of this mixing could include formation of a precipitate, a change of color, the evolution of a gas, the evolution or absorption of heat, or no observable change (no reaction). Some reactions are specific for certain ions, thus facilitating the identification of a cation or anion in an unknown solution. For example, halide (group 7 anions) salts are generally soluble. Exceptions to that rule include silver (Ag^+), mercury (Hg^{+2}), and lead (Pb^{+2}) cations. Thus, sodium chloride could be added to a solution suspected of containing Pb^{+2} . Formation of a precipitate would indicate, but not prove, that lead ions are present. To prove that lead ions are present we would have to prove the absence of both silver and mercury ions.

See Table 1 for a table of solubility rules for common ions that can be used to predict the results of many common aqueous reactions. The solubility of a substance at a given temperature refers to the amount of that substance that will dissolve in a known quantity of water. A compound with a solubility of less than 0.01 mole/Liter is usually considered to be insoluble.

Table 1: Solubility rules for common binary ionic compounds in water.

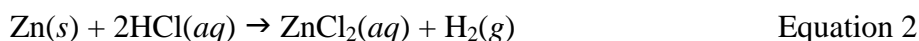
1. Salts of Group 1 metals and ammonium, NH_4^+ , are soluble.
2. Nitrate, NO_3^- , and acetate, $\text{C}_2\text{H}_3\text{O}_2^-$, salts are soluble.
3. Binary ionic compounds of Group 7 anions (omitting F^-) are soluble except those of Ag^+ , Hg_2^{+2} , and Pb^{+2} .
4. Sulfate, SO_4^{-2} , salts are soluble except those of Ag^+ , Hg_2^{+2} , Pb^{+2} , Ca^{+2} , Sr^{+2} and Ba^{+2} .
5. Hydroxide, OH^- , and sulfide, S^{-2} salts are insoluble except those of Group 1 metals and NH_4^+ (Rule 1), and those of Ca^{+2} , Sr^{+2} , and Ba^{+2} .
6. Carbonate, CO_3^{-2} , and phosphate, PO_4^{-3} , salts are insoluble except those of Group 1 and ammonium cations (Rule 1).

Information concerning the water solubility of a given ionic compound can also be obtained by mixing two ionic solutions, one containing a soluble compound of the desired cation and the other containing a soluble compound of the desired anion. For example, suppose you needed to know whether or not aluminum molybdate, $\text{Al}_2(\text{MoO}_4)_3$, is soluble (See Equation 1). Since neither aluminum nor molybdate salts appear on common solubility charts it may be easier to conduct a simple experiment than to do an exhaustive literature search. Solubility tables do tell us that all metal nitrate salts are soluble, thus we can assume that aluminum nitrate is soluble. Similarly, all sodium salts

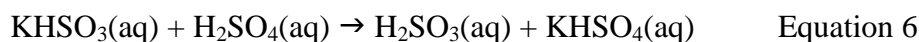
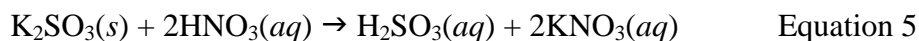
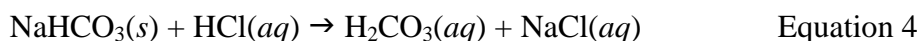
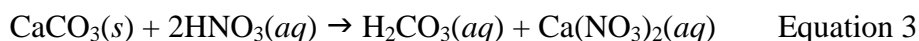
are soluble so we can expect that sodium molybdate is soluble. We can then make solutions of the two salts and combine them. Since we know that sodium nitrate is soluble, any precipitate that forms must be aluminum molybdate. Conversely, if no precipitate forms we know that aluminum molybdate is soluble.



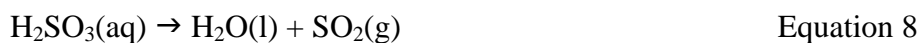
Another indication that a reaction has taken place is the formation of a gas. Gas formation is recognized when bubbles form in the reaction solution. This can happen either through a replacement reaction in which H_2 is formed by the action of an acid on a metal as shown in Equation 2.



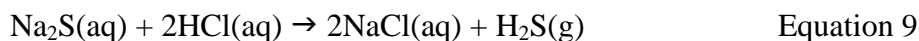
Carbonates, bicarbonates (hydrogen carbonates), sulfites, and bisulfites (hydrogen sulfites) react with acid to produce carbonic and sulfurous acids (Equations 3-6).



The resulting carbonic or sulfurous acids are unstable in aqueous solution and decompose readily to carbon dioxide and water (Equations 7 & 8).



Dihydrogen sulfide, commonly referred to as rotten egg gas can also be synthesized by the action of acid on sulfides or hydrogensulfides (Equation 9)



By paying attention to colors and smells of gases released by a reaction one can often infer the chemical identity of the original compound. Be careful, however, many of the smells are strong and some are toxic. To smell a gas, don't hold a solution under your nose and inhale, rather hold the solution away from you and waft the gases toward your nose with your hand.

The experiment

This experiment consists of two parts. In part 1 you will study the interactions between six aqueous solutions of known chemical compounds. By systematically mixing

them in pairs (a total of 15 different pairs) and observing the resulting reactions you will identify characteristics of each reaction and thus will be able to identify each compound. You should record as much information about each reaction as possible, such as color and texture of any precipitate formed, the color of the solution before and after the reaction, the evolution of a gas and its smell, etc. Any information you record in part 1 of the experiment can be helpful in part 2 of the experiment.

In part 2 of the experiment you will obtain six solutions of unknown identity (they are the same solutions as the known solutions but you won't know which is which at first). You will mix the six unknown solutions in pairs as you did with the known solutions and record the data in a second data table. Then using the data from the reactions of the known solutions you are to identify the six unknown solutions.

As you record your data on the data table you may use abbreviations such as ppt for precipitate or NR for no reaction. Make sure that you understand any abbreviations you use so you can understand them later when you analyze your data. Your identification of the unknowns should be based on your comparison of the reactions of the unknown solutions with those of the known solutions. Refer to Table 2 for an example of a data table for mixing 5 known solutions in pairs and to Table 3 for the corresponding unknown solutions. In this case you can identify unknown solution A as silver nitrate, AgNO_3 , because it produced the largest number of precipitates. Then, since a yellow precipitate was formed when AgNO_3 was mixed with KI and also when unknown solutions A and B were mixed you can identify solution B as KI (since you already identified A as AgNO_3). A similar deduction process leads to identification of unknown solution C as HCl and to identification of unknown solution E as Na_2CO_3 . Mixing of HCl and Na_2CO_3 produced a gas which also can help in identifying unknown solutions C and E. By elimination and comparison of results, unknown solution D is identified as Na_2SO_4 .

Table 2. Known solutions

	Na_2CO_3	Na_2SO_4	HCl	AgNO_3
KI	NR	NR	NR	yellow ppt, small particles
AgNO_3	cream ppt curd-like heavy	white ppt small amount milky soln	white curd like ppt, later turned purple	
HCl	bubbles, colorless, odorless	NR		
Na_2SO_4	NR			

Table 3. Unknown solutions

	A	B	C	D
E	cream ppt curd-like	NR	bubbles, no color or odor	NR
D	white ppt, small amount	NR	NR	
C	white ppt curd- like, turned purple	NR		
B	yellow ppt small particles			

Procedure

The six solutions to be studied in this experiment are AgNO_3 , Na_2CO_3 , HCl , NaOH , Na_3PO_4 , and FeCl_3 .

Safety alert: hydrochloric acid and sodium hydroxide are both corrosive and toxic. Silver nitrate is toxic and an oxidant.

Helpful hints: Some of the reactions occur quickly and others more slowly. Make sure that you observe the reaction from the start and for 1-2 minutes, and then record your observations. Make sure that your observations include types and textures of precipitates formed as well as their colors, e.g. off-white ppt, cottage cheese-like curds, heavy ppt, light ppt, etc. Also describe how quickly gases are given off, whether gas release was vigorous or one bubble at a time, and note any odor produced by the gas. Make sure you understand your own notes and can interpret them later.

Always stir the mixed pair of solutions with a glass rod or a plastic or wooden stirrer (a toothpick for each solution can be helpful). To wash a rod or stirrer, always squirt water onto the rod with a wash bottle or pipet. Don't dip the rod into a beaker of water.

Part 1: known solutions

1. Label six small test tubes to reflect the names of the six known solutions.
2. Obtain about 1 mL of each known solution in the labeled test tubes.
3. Obtain six plastic transfer pipets. Place each pipet into a test tube with a known solution and use that pipet only for that known solution. Do not mix pipets and solutions. As long as you work with one solution at a time and replace the pipet in the tube you will not need to label the pipets.
4. Obtain a spot plate and label five wells with the formula of the first known solution on your data table. You will not be adding the solution that is already in the well to itself. E.g. you don't need to add NaCl to NaCl . You may also place a sheet of paper under the spot plate and label the sheet instead of the plate.

5. Using the designated pipet, transfer about 3 drops of the first known solution into the appropriate wells (see your data sheet) of the spot plate.
6. Next, using the designated pipet, transfer 3 drops of the second solution into the first well of the spot plate (which already contains 3 drops of solution 1). Stir the solution with a toothpick or stirring rod. Record your observations on the data sheet.
7. Add 3 drops of the third solution to well number 2 of the spot plate. Record your observations. Repeat these steps until each solution has been mixed with solution 1. Stir each mixture and record your observations.
8. In the same manner, continue mixing the solutions until you data for all 15 different pairs of solutions. You may need to use two spot plates or, if necessary, clean and dry your one spot plate and reuse it. Dispose of all waste in the designated waste container.

Part 2: unknown solutions

Obtain a new set of six pipets or clean the six pipets you already have. Clean your test tubes and spot plate(s). Obtain 1 mL of each unknown solution in appropriately labeled test tubes (labeled A-F). Repeat the procedure described for the known solutions with the six unknown solutions. Record all observations.

Clean up

Rinse all pipets in the following manner

1. Expel any remaining solution from the pipet into the waste container.
2. Pour distilled water into three test tubes.
3. Draw some water from the first test tube with the pipet to be rinsed, invert the pipet, and then expel the contents of the pipet into the waste container.
4. Draw some water from the second pipet and repeat the rinsing process.
5. Repeat for all pipets. Wash the spot plates and test tubes. Return the washed pipets and spot plates to the equipment cart.

Discussion

Use the table of data from the known solutions to identify the six unknowns. Report the results in your discussion. Explain your reasoning for the identification of each unknown. Write a balanced net ionic equation, including phase labels, for each combination of solutions that produced a solid or a gas.

Chemistry 1215, Experiment #8: Double Displacement and Gas Forming Reactions,

Pre-lab

Name _____

- List at least three solubility rules that you can use to identify the ionic solutions used in today's lab. You may need to consult your lecture textbook.
- Write the complete ionic equation for the reaction of aqueous copper nitrate with aqueous potassium phosphate.
- Write the net ionic equation for the reaction in question 2.
- A student was given the following five labeled solutions: NiCl_2 , $\text{Pb}(\text{NO}_3)_2$, NaOH , $\text{Na}_2\text{C}_2\text{O}_4$, and CuSO_4 .
After systematically mixing the solutions in pairs, the student recorded her observations in **Table 3**. She was also given the same five solutions in containers labeled A -E. In **Table 4**, she recorded the results of mixing those solutions in pairs. Identify the 5 unknown solutions. *Include the deductive thought process by which you arrived at your final conclusions.*

Table 4

Table 5

	CuSO_4	$\text{Na}_2\text{C}_2\text{O}_4$	NaOH	$\text{Pb}(\text{NO}_3)_2$		E	D	C	B
NiCl_2	NR, blue- green solution	NR, green solution	green ppt, green solution	white ppt, green solution	A	blue ppt, blue solution	white ppt, colorless solution	NR, colorless solution	green ppt, green solution
$\text{Pb}(\text{NO}_3)_2$	white ppt, blue solution	white ppt., colorless solution	white ppt, colorless solution		B	NR, blue-green solution	White ppt, green solution	NR, green solution	
NaOH	blue ppt, blue solution	NR, colorless solution			C	white ppt, blue solution	white ppt, colorless solution		
$\text{Na}_2\text{C}_2\text{O}_4$	white ppt, blue solution				D	white ppt, blue solution			

