CHM 111: The Case of the Unlabeled Bottles

Goals

1. To deduce the identity of five unknown solutions by comparison to reactions with known solutions.
2. To observe and predict reactions based on solubility rules.
3. To practice writing balanced complete ionic and net ionic equations for chemical reactions.

Introduction

While Mrs. Phan was putting away the materials from an experiment, she observed that five bottles of aqueous solutions had lost their labels. By checking the inventory of chemicals used in the experiment, Mrs. Phan determined the names of the five chemicals. When Mrs. Phan saw the list, she was able to set up a simple series of experiments that would identify each of the unlabeled bottles using only the contents of the bottles.

Mrs. Phan now challenges you to identify as many of the five solutions as you can. You will take two identical sets of solutions. One with their proper labels in place (knowns) and the other set unlabeled (unknowns). In Part A, you will mix each of the known solutions together (2 at a time) and observe what happens. Since you know the contents of each bottle, you should be able to predict the results. Possible reactions include precipitation reactions, formation of a gas and production of heat. The results of these reactions will be tabulated and used to identify the contents of the unknowns.

After performing the same experiments using unknown solutions in Part B, you should be able to determine the identity of each of the unlabeled bottles by using the information you collected from Part A. (You will get the same results, just in a different order.) You will compare the results from mixing the known solutions with the results from mixing the unknown solutions to determine the proper labels for the unlabeled bottles.

The three indicators of a reaction that you will be observing are

a) the formation of an insoluble ionic solid (precipitate)
b) the formation of a gas (H_2CO_3 decomposes to make H_2O as a liquid and CO_2 as a gas)
c) the change in the amount of heat (solution becomes hot or cold). When an acid reacts with a base, heat is produced**.**

Laboratory Activity

Equipment: 10 test tubes test tube rack disposable plastic pipettes.

Chemicals: The five "known" bottles with their names and concentrations (0.50 M $CaCl_2(aq)$, 0.50 M $Na_2CO_3(aq)$, 0.50 M NaCl(aq), 0.50 M NaOH(aq), and 0.50 M $H_2SO_4(aq)$)
Five "unknown" bottles (labeled as 1-5).

A. Reactions of Known Solutions

1. Obtain and clean at least 10 test tubes (dry is not necessary). You do not need to label the test tubes!
2. Place the test tubes in the rack in a pattern corresponding to the unshaded boxes in Table 1. **Note that half of the reactions are repeats and it is unnecessary to mix a solution with itself.** Therefore, fill in only the parts of Table 1 that are unshaded.
3. Mix about 1 mL each of the known solutions together following Table 1. Use the pipette provided or get a clean pipette for each different solution. **Make sure that you do not use a pipette in more than one solution.**
4. Write down the result of the reaction that occurs (or NR for no reaction) in Table 1. Write ppt if a precipitate forms and describe the precipitate. Write gas if a gas is produced (bubbles), heat if the solution becomes hotter, ignore cold. Describing the appearance of the products formed can help with the identification.
5. **Pour the waste down the sink. Clean and rinse the test tubes with deionized water.**

B. Reactions of Unknown Solutions

1. Clean the test tubes from Part I.
2. Place the clean test tubes in a pattern following the unshaded boxes of Table 2.
3. Mix the appropriate unknown solutions together and write the results in Table 2.
4. **Dispose of the waste in the sink, rinse the test tubes and return them to the box.**
5. Compare the reactions of the known solutions with the reactions of the unknowns. Use the comparison to identify the unlabeled bottles.

Solubility Rules (adapted from OpenStax)	
Compounds that are generally soluble	**Exceptions (when paired with)**
Group 1 metal cations, NH_4^+	none
NO_3^-, $C_2H_3O_2^-$, HCO_3^-, ClO_3^-	none
Cl^-, Br^-, I^-	Ag^+, Hg_2^{2+}, Pb^{2+}
F^-	Group 2 metal cations, Pb^{2+}, Fe^{3+}
SO_4^{2-}	Ag^+, Ba^{2+}, Ca^{2+}, Pb^{2+}, Sr^{2+}
Compounds that are generally insoluble	**Exceptions (when paired with)**
CO_3^{2-}, CrO_4^{2-}, PO_4^{3-}	Group 1 metal cations, NH_4^+
OH^-	Group 1 metal cations, NH_4^+, Ba^{2+}

CHM111 Lab – The Case of the Unlabeled Bottles – Grading Rubric

Criteria	Points
Lab work performed correctly. Proper safety procedures followed and waste disposed of correctly. Work space and glassware cleaned up. Participated actively in performing the experiment.	2
All observations recorded clearly	2
Q1. Unknowns identified	1
Q2 4 sets of molecular, complete ionic, and net ionic equations are legibly written, all are balanced with correct charges and phases written	12
Q3 molecular, complete ionic, and net ionic equations are legibly written, all are balanced with correct charges and phases written	3
Total	20

Subject to other additional penalties as per the instructor

Unlabeled Bottles Name _____ Team Name: _____

Part A: Known Solutions (Fill in the table with the results from your experimental observations: ppt, gas, heat etc.)

	$CaCl_2$	Na_2CO_3	NaCl	NaOH	H_2SO_4
$CaCl_2$					
Na_2CO_3					
NaCl					
NaOH					
H_2SO_4					

Part B: Unknowns: (Fill in the table with the results from your experimental observations: ppt, gas, heat etc.)

	1	2	3	4	5
1					
2					
3					
4					
5					

Q1. Unknown **1** is _____

Unknown **2** is _____

Unknown **3** is _____

Unknown **4** is _____

Unknown **5** is _____

Q2. For the three precipitate reactions and the acid-base reaction (even if not observed) Write the a) **Molecular** equation b) the **Complete ionic** equation and c) the **Net ionic** equation.

Ask yourself the following

- Are the product ionic formulas the simplest ratio where charges equal to zero? If you are not thinking about charges when you write the product formulas you are not doing it right.
- Are all lines of each equation balanced?
- Does every separated ion have the correct charge written?
- Does every species have a phase written?

Q3. A student combines a solution of aqueous rubidium sulfate with a solution of aqueous strontium chloride. Write the balanced molecular equation, the complete ionic equation and the net ionic equation.