Chemistry 101 **Experiment 14**

SIX BOTTLES: AN EXPERIMENT IN CHEMICAL IDENTIFICATION

INTRODUCTION

A chemist uses several observations to detect the occurrence of a chemical reaction when two or more solutions are mixed together. Most common among these are the formation of a precipitate, a color change, the evolution of heat, and the evolution of a gas. Such a change indicates that a new chemical compound has been formed, and the change in properties can be used to identify unknown solutions. For example, suppose that one adds a solution of Na_2SO_4 to another solution which is known to contain **either** NaCl, $MgCl_2$, or $BaCl_2$. The formation of a precipitate indicates that the unknown was $BaCl_2$, since Ba^{2+} is the only cation of the three possibilities that will form a precipitate ($BaSO_4$). Similarly, if NaOH is added to an unknown solution and an ammonia gas smell is produced, it can be deduced that the unknown contains ammonium ion, NH_4^+, since it produces $NH_3(g)$ and $H_2O(l)$ in the presence of OH^-.

If the reactions of a compound are not known, it can be **tested** with other compounds to see if reactions occur. Consider the following four aqueous solutions: H_2SO_4, $BaCl_2$, KI and $AgNO_3$. The table below indicates what occurs when each of the possible different combinations of two solutions are mixed (a total of six different combinations):

H_2SO_4				
$BaCl_2$	White ppt.			
KI	NR	NR		
$AgNO_3$	v. slight ppt.; NR	white ppt.	yellow ppt.	
	H_2SO_4	**$BaCl_2$**	**KI**	**$AgNO_3$**

ppt. = precipitate; v. = very; NR = no reaction

Notice with $AgNO_3$ and H_2SO_4, there may be a slight reaction or no reaction; Ag_2SO_4 is slightly soluble, so the observer **may** see a reaction if the concentrations are high enough. With dilute solutions, he may see **no reaction**.

These observations can then be used as a guide for the identification of unknown solutions. Suppose that a student is given three of the original four solutions as an unknown. The first step in identifying them will be to form each of the three possible mixtures and to record the observations as before:

1			
2	yellow ppt.		
3	white ppt.	NR	
	1	**2**	**3**

Referring to our original table (previous page), we see that the formation of a yellow precipitate on mixing 1 and 2 indicates that these are $AgNO_3$ and KI. However, to decide which is which, we must examine a further mixture. 1 and 3 yields a white precipitate. Since KI does not form a white precipitate with any of the other reagents, 1 must be $AgNO_3$, and therefore 2 is KI. This leaves 3 still unknown. 3 is either H_2SO_4 or $BaCl_2$, probably the latter; but it is possible to get some white precipitate with either one plus $AgNO_3$, and both give no reaction with KI. To find out for certain, simply add a known reagent. For example, add H_2SO_4 to unknown 3. A white precipitate means 3 is $BaCl_2$. No reaction means 3 is H_2SO_4.

Any unknown compound can be tested with all of the known reagents. This will identify it, but if there are many unknowns, using all the tests is very time-consuming. In this experiment, you will be given 12 **known** solutions to test (66 different mixtures) and then you will identify a group of 6 unknowns taken from the original set of 12.

Many reactions can be predicted in advance, especially those that form precipitates. In your textbook there is a list of **solubility rules** for ionic compounds. If an insoluble compound forms as the result of a chemical reaction, the observer will see a precipitate; therefore she can **predict** many reactions simply by noticing the possible new combinations of ions. Also, a knowledge of common weak electrolytes allows you to predict reactions that make new molecular products, like H_2O, or unstable compounds like $H_2CO_3(aq)$.

Write your predictions into your lab notebook before beginning the experiment. They are to be written as **net ionic equations**. In the **Pre-Laboratory Assignment** are ten predictions for you to make; add as many more predictions as you can.

NET IONIC EQUATIONS

A **net ionic equation** is one in which only those ions that **react** (those that combine as a result of the reaction) are written. For example, if a solution of $BaCl_2$ is mixed with a solution of Na_2SO_4, the Ba^{2+} and SO_4^{2-} ions are now present in the same mixture. They combine and precipitate:

$$Ba^{2+}(aq) + 2Cl^{-}(aq) + 2Na^{+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s) + 2Na^{+}(aq) + 2Cl^{-}(aq)$$

It is seen that the sodium and chloride ions remain unchanged during the reaction. (All possible combinations in this solution of sodium and chloride with other ions give **soluble** compounds.) Such ions are called **spectator ions**. If the spectator ions are eliminated from the ionic equation, what remains is the **net ionic equation**:

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

Any time two solutions are mixed, one containing barium ions and the other containing sulfate ions, a precipitate of barium sulfate will be produced. For example, the reaction of barium nitrate and sulfuric acid has the same net ionic equation.

PROCEDURE

Wear your **safety glasses** while doing this experiment.

Prepare your lab notebook for the experiment, including the net ionic equations you have written as predictions. Check out a spot plate and eight Pasteur pipets from the stockroom. You will use the pipets to deliver solution dropwise to the spot plate. Some students find it helpful to mix solutions on a glass slide or in a test tube instead of the spot plate; in any case, use 2 or 3 drops of each solution for a test. Clean the pipets thoroughly between solutions by rinsing with tap water, then deionized water.

It is best to work with no more than six solutions at a time (15 combinations). Use test tubes for the "knowns"; clean the test tubes between solutions. Carefully observe what happens as the two are mixed. To detect the evolution of a gas, very carefully smell each mixture. If you suspect that heat will be released (especially common in the reaction of an acid with a base) add about 1 mL of each of the two knowns to a test tube and place the tube in the palm of your hand to observe the temperature change.

You will need to complete a chart in your notebook like the one on the report sheet, with observations: color change, precipitate, gas, no reaction. Most people need more space! Try spreading the chart over two pages in the notebook. If you prefer more space, write complete observations in sentence or equation form, and then write a brief summary on the chart.

Example: #1 + #2 → white, grainy precipitate; turns gray-violet with time.

On the chart you record:

white ppt.; → gray

Also**,** note whether your predictions "came true". Did you observe the precipitates, gases etc. that you expected?

After completing the observations on the reactions of the knowns, obtain six plastic bottles from the stockroom and take them to the instructor. The instructor will fill them with your six unknown solutions. Make all possible combinations as before, making careful observations and completing a table for the unknowns. Identify as many of the unknowns as possible from these tests. Use known reagents as necessary to identify all six unknowns.

When your identifications are complete, write net ionic equations for **at least three** of your reactions.

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Section_____ Name_____

Report Sheet

Fill in the table for the mixtures of the knowns. If a reaction occurred, indicate the evidence of reaction, such as "heat", "ppt." (include color and appearance), "gas" etc. Write NR if no reaction occurred. Write any additional observations as notes on the next page. (For example, the space marked * will show your observations when Na_2S and H_2SO_4 are mixed together.)

1 $AgNO_3$											
2 HCl											
3 H_2SO_4											
4 NaOH											
5 $NaNO_2$											
6 KI											
7 $BaCl_2$											
8 NH_4Cl											
9 Na_2SO_3											
10 NaCl/NaClO											
11 Na_2S			*								
12 KIO_3											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**

Notes:

Fill in the table below for mixtures of the unknowns. Use a procedure similar to the table for the knowns. Write the identity of each unknown and **at least three** net ionic equations for your reactions.

1						
2						
3						
4						
5						
6						
	1	**2**	**3**	**4**	**5**	**6**

Notes:

Identity of unknowns:

1_____ 2_____ 3_____ 4_____ 5_____ 6_____

Net ionic equations:

Chemistry 101 **SIX BOTTLES**

Section_____ Name_____

Pre-Laboratory Assignment

1. Predict the solubility in water of the following compounds ("I" for insoluble, "S" for soluble):

$Ca(NO_3)_2$ $NiCl_2$ $(NH_4)_2SO_4$ $Fe_3(PO_4)_2$ $Cu(OH)_2$

2. Use the solubility rules and any other necessary information in the textbook to fill in the following table. You are to predict whether a reaction will occur when each pair of solutions is mixed. Use the procedures given for filling in the tables for the known and unknown as a guide. After completing the table, write the net ionic equations for all the reactions that yield precipitates. Write the molecular equations for those reactions that do not yield precipitates.

1 **H_2SO_4**					
2 **Na_2SO_3**					
3 **$BaCl_2$**					
4 **$AgNO_3$**					
5 **NaOH**					
	1	**2**	**3**	**4**	**5**

Net ionic equations:

Molecular equations: