There are two broad categories of problems in analytical chemistry. Quantitative analysis deals with the determination of the amounts of certain species present in a sample. The other area of analysis, qualitative analysis, involves establishing whether given species are or are not present in detectable amounts in a sample. One way to perform qualitative analysis in the laboratory is to test for the presence of a possible component by adding a reagent that will cause the component to react in a characteristic way.

On the day of the scheduled lab, you will be furnished ten numbered bottles, each of which will contain a single substance. Prior to the experiment, you will be provided with a list giving the formula and molarity of each of the ten solutes that will be used. Your problem in the laboratory will be to find out which solution is in which test tube, that is, to assign a test tube number to each of the solution compositions. You are to do this by intermixing small volumes of the solutions. NO EXTERNAL REAGENTS OR ACID-BASE INDICATORS SUCH AS LITMUS PAPER ARE ALLOWED. You are permitted, however, to use the odor and color of the different solute species and to make use of heat effects in reactions in your system of identification. Each student will be assigned a separate set of reagents as outlined below.

Of the ten solutions, four are common laboratory reagents. They are 6 M HCl, 3 M H₂SO₄, 6 M NH₃ (i.e. NH₄OH), and 6 M NaOH. The other six solutions are split up into two sets (one to be assigned by your instructor) that contain 0.1 M solutions of:

- **Set A**: Al(NO₃)₃, AgNO₃, Ca(NO₃)₂, Cu(NO₃)₂, Ni(NO₃)₂, and SnCl₄
- **Set B**: Bi(NO₃)₃, Cr(NO₃)₃, Fe(NO₃)₃, Mg(NO₃)₂, Pb(NO₃)₂, and SnCl₂ (in HCl)

To determine which solution is in each bottle, you will need to know what happens when the various solutions are mixed, one with another. In some cases, nothing happens that you can observe. This will often be the case when a solution containing one of the cations is mixed with a solution of another. When one of the reagents is mixed with a cation solution, you may get a precipitate, white or colored, and that precipitate may dissolve in excess reagent by complex-ion formation (a topic for Chemistry 1B). In a few cases, a gas may be evolved. When one laboratory reagent is mixed with another, you may find that the resulting solution gets very hot and/or that a visible vapor is produced.

There is no way that you will be able to solve your particular ten bottle mystery without doing some preliminary work. You will need to know what to expect when any two of your ten solutions are mixed. In some cases, nothing happens that you can observe. This will often be the case when a solution containing one of the cations is mixed with a solution of another. When one of the reagents is mixed with a cation solution, you may get a precipitate, white or colored, and that precipitate may dissolve in excess reagent by complex-ion formation (a topic for Chemistry 1B). In a few cases, a gas may be evolved. When one laboratory reagent is mixed with another, you may find that the resulting solution gets very hot and/or that a visible vapor is produced.

A convenient way to tabulate the information you obtain is to set up a matrix with ten columns and ten rows, one for each solution. The key information about a mixture of two solutions is put in the space where the row for one solution and the column for another
intersect. For example, if a precipitate forms, you might write “P” along with the color. If heat is evolved, you might write an “H”. If gas or smoke is formed, you might write “G” and “S”, respectively. Since mixing solution A with B is the same as mixing B with A, not all 100 spaces in the 10-by-10 matrix need to be filled. Actually, there are only 45 possible different pairs since A with A is NOT very informative either.

Because you are allowed to use the odor or color of a solution to identify it, the problem is somewhat simpler than it might first appear. In each set of ten solutions, you will probably be able to identify at least two solutions by odor and color tests. Knowing those solutions, you can make mixtures with the other solutions in which one of the components is known. From the results obtained with those mixtures and the information in the matrix, you can identify other solutions. These can be used to identify still others, until finally the entire set of ten is identified unequivocally.

**Pre-lab Questions** – To be completed BEFORE entering the lab:

1. Once you have obtained the listing of your assigned ten solutions from the instructor, construct a 10-by-10 reaction matrix. How do the various solutions react? Fill-in the corresponding matrix.

2. Which solutions should you be able to identify by simple observations?

3. Outline the procedure you will follow in identifying the solutions that will require mixing tests. Be as specific as you can about what you will look for and what conclusions you will be able to draw from your observations.
Name: ______________________

QUALITATIVE ANALYSIS Report Sheet

Final Identifications: Unknown Set ______

No. 1 ______________________  No. 6 ______________________
No. 2 ______________________  No. 7 ______________________
No. 3 ______________________  No. 8 ______________________
No. 4 ______________________  No. 9 ______________________
No. 5 ______________________  No. 10 ______________________

Use the next few pages to write balanced MOLECULAR, IONIC, and NET-IONIC equations for TEN of the reactions that occurred during this laboratory experiment. Make sure to include the physical states of all the products. These equations must be turned in along with this report sheet to receive full credit upon conclusion of the lab.

1. Molecular:

   Ionic:

   Net-ionic:

2. Molecular:

   Ionic:

   Net-ionic:
3. Molecular:
   Ionic:
   Net-ionic:

4. Molecular:
   Ionic:
   Net-ionic:

5. Molecular:
   Ionic:
   Net-ionic:

6. Molecular:
   Ionic:
   Net-ionic:

7. Molecular:
   Ionic:
   Net-ionic:
8. Molecular:

   Ionic:

   Net-ionic:

9. Molecular:

   Ionic:

   Net-ionic:

10. Molecular:

   Ionic:

   Net-ionic: