Experiment 10 – Seven Unknown Solutions

In the first part of this experiment, you will be given dilute solutions of seven different ionic compounds: $AgNO_3$, $Pb(NO_3)_2$, KSCN, $FeCl_3$, $Ba(NO_3)_2$, NaCl, and Na_2SO_4. You will mix each solution with each of the others, and you will check for evidence of chemical reactions. After you have recorded all of your data, you will be given a set of seven unknown solutions. These seven solutions will be the same as the solutions listed above. By reacting each solution with each of the others and comparing your data with the data from the first part, you will determine the identity of each of the unknown solutions.

All of the reactions in this experiment will be double-displacement reactions. For background information on these types of reactions, refer to the discussion of Experiment 8 (Double Displacement Reactions). The possible sub-categories of double displacement reactions include precipitation reactions, acid-base reactions, gas-forming reactions, and reactions in which a complex ion forms. A complex ion contains a metal ion attached to one or more *ligands*. The complex ion as a whole is charged and is therefore soluble in water. Precipitation reactions, acid-base reactions, and gas-forming reactions were discussed in Experiment 8. An example of a complex ion formation reaction is the following:

$$Cu^{2+}_{(aq)} + 4\ Cl^-_{(aq)} \rightarrow CuCl_4^{2-}{}_{(aq)}$$

Copper ion is the metal, and chloride ions are the ligands. Reactions in which a complex ion forms do not involve precipitation, so there will be no cloudiness at all in the solution. The visible evidence of reaction is a color change of the solution. In the above case, an aqueous solution of Cu^{2+} is blue, and an aqueous solution of chloride ions is colorless. When they are mixed, the solution turns green, which is the color of the $CuCl_4^{2-}$ complex ion. Here is another example of complex ion formation:

$$Cu^{2+}_{(aq)} + 4\ NH_{3\,(aq)} \rightarrow Cu(NH_3)_4^{2+}{}_{(aq)}$$

In this case, a blue solution of copper ions is mixed with a colorless solution of ammonia (the ligand) to give a very deep blue complex of $Cu(NH_3)_4^{2+}$. In this experiment, the formula of the complex ion that forms is $FeSCN^{2+}_{(aq)}$. In this case, only one ligand (SCN^-) attaches to the metal to form the complex ion. (This is actually a simplification, but you will learn more about complex ions in Chemistry 1B.)

Solubility Rules for Ionic Compounds at 25°C

1. A compound will be soluble if it contains at least one of the following ions: Li^+, Na^+, K^+, NH_4^+, NO_3^-, or $C_2H_3O_2^-$.
2. A compound containing Cl^-, Br^-, or I^- is soluble **unless** the cation is Ag^+, Pb^{2+}, or Hg_2^{2+}.
3. Compounds that contain SO_4^{2-} are soluble **except** those sulfates that also contain Ba^{2+}, Ag^+, Pb^{2+}, or Ca^{2+}.
4. Most other ionic compounds are insoluble (in other words, the amount of solute that dissolves is extremely small and will be regarded as negligible). Compounds containing S^{2-}, CO_3^{2-}, PO_4^{3-}, and OH^- are insoluble unless the cation is one of those listed in #1 above.

Safety Precautions:

- Wear safety goggles.
- Silver nitrate solutions will stain skin and clothing. If you notice any silver nitrate splashing your skin or clothing, rinse it off immediately. Silver nitrate is a colorless solution that is light-sensitive. The stains don't show up immediately, but you will see them by the next day! Stains on your skin will eventually wear off as your skin wears off; stains on your clothing will be permanent. It is therefore best to wear old clothing for this lab.
- Lead solutions are toxic. Wash your hands after working with them.

Waste Disposal:

- While you are doing the experiment, pour your waste into a beaker. When you are finished with the experiment, pour the contents of the waste beaker into the **inorganic waste** container (with a blue label) in the fume hood.

Procedure

Part 1 – Known Solutions

See the suggested data tables at the end of this section. Record your observations at the time of mixing. If there is a precipitate, write "ppt" and state the color. Where there is no visible evidence of reaction, feel each tube, or check with a thermometer, to determine if heat is evolved. When there is no evidence of reaction, write "NR" (no reaction) in the appropriate space of the data table. It is important to use the same volume of each solution.

1. Rinse six test tubes with deionized water and shake them dry. Put 10-15 drops of 0.1 M silver nitrate ($AgNO_3$) into each of the tubes. (Choose some number of drops between 10 and 15, and then use the same number of drops of each solution for every reaction.)
2. To the first tube, add 10-15 drops of 0.1 M $Pb(NO_3)_2$. To the second tube, add 10-15 drops of 0.1 M KSCN. To the third tube, add 10-15 drops of 0.1 M $FeCl_3$. Continue in this manner until each solution has been mixed with the silver nitrate. Shake each test tube, and record observations of each one. Then dump the contents of each tube into your waste beaker, clean the tubes, and rinse them with deionized water.
3. Place 10-15 drops of 0.1 M $Pb(NO_3)_2$ in each of 5 test tubes. In the first tube, place 10-15 drops of 0.1 M KSCN. In the second tube, place10-15 drops of 0.1 M $FeCl_3$. Continue in this way until each solution except $AgNO_3$ has been mixed with lead (II) nitrate. (You already mixed $AgNO_3$ with $Pb(NO_3)_2$ in step 2, so you do not need to do it again.) Shake the tubes, record your observations, dump the waste into the waste beaker, and clean the tubes.
4. Place 10-15 drops of 0.1 M KSCN into each of 4 test tubes. In each tube, place 10-15 drops of one of the other solutions, except silver nitrate and lead nitrate, which have already been reacted with KSCN. Record your observations.
5. Continue mixing solutions until you have mixed every combination together. After you have recorded all of your observations and cleaned your tubes, move on to part 2.

Part 2 – Unknown Solutions

Obtain a set of unknown solutions. Record the code of the set you used. This is very important! With no unknown code, your work cannot be graded.

1. Place 10-15 drops of solution 1 into each of six test tubes. In the first tube, add 10-15 drops of solution 2. Into the second tube, add 10-15 drops of solution 3. Continue with each of the remaining solutions. Record your results, and clean your tubes.
2. Place 10-15 drops of solution 2 into each of five test tubes. React each of the remaining solutions with solution 2. Record your observations.
3. Continue in this manner until you have mixed each solution with each of the other solutions. Record your results, and clean your tubes.
4. Determine the identity of each of the unknown solutions. **Clearly explain each step of your reasoning.**

Suggested Data Tables
Note –do not fill in the gray sections of the tables.

Part 1 – Known Solutions

	$Pb(NO_3)_2$	KSCN	$FeCl_3$	$Ba(NO_3)_2$	NaCl	Na_2SO_4
AgCl						
$Pb(NO_3)_2$						
KSCN						
$FeCl_3$						
$Ba(NO_3)_2$						
NaCl						

Part 2 – Unknown Solutions

Solution Number	2	3	4	5	6	7
1						
2						
3						
4						
5						
6						

Question

1. Write the net ionic equation for each of the reactions in this experiment.