Solubility of Inorganic Salts

Information:

NaCl is soluble in water
$NaNO_3$ is soluble in water
$AgNO_3$ is soluble in water
AgCl is **in**soluble in water

Task:
Each group has ten minutes to prepare a presentation concerning the following:

> Consider a 0.10 M solution of NaCl and a 0.10 M solution of $AgNO_3$. Describe, as precisely as you can, the composition of these solutions. Then describe, with as much detail as possible, what will happen when 2 drops of the NaCl solution is mixed with 2 drops of the $AgNO_3$ solution.

Each presenter will have two minutes to give the presentation.

Question of the Day: What specific and/or general statements (if any) can be Made concerning the solubility/insolubility of various inorganic salts?

The goal of this investigation is to develop a set of statements about the aqueous solubility of inorganic salts by experimenting with a select few. This could be quite an undertaking if we didn't try to organize our observations. To help categorize our observations, we will examine the effect of individual anions on individual cations (or vice versa, as it really doesn't matter which test solution is added to which), then come up with some species specific rule of behavior. Our rules will be based on selected salts produced by mix in two test solutions. From these individual examples we might be able to expand the statements about solubility to cover families of salts, say chloride salts where the anion is always Cl-, or sulfate salts where the anion is always SO_4^{2-}, or alkaline metal salts where the cations are all in the first column of the Periodic Table (Li+, Na+, K+, etc).

Part I: Preparation for Experiment

Several inorganic salt **solutions** have been prepared for you – some are labeled with their cation, others with their anion, but each label also shows the formula and concentration of the salt used. Below is a list of these solutions:

Anion Sources		Cation Sources	
0.1 M NaCl	0.05 M Na_2CO_3	0.1 M NH_4NO_3	0.1 M KNO_3
0.1 M NaI	0.1 M Na_2S	0.1 M $AgNO_3$	0.1 M $Al(NO_3)_3$
0.1 M Na_2SO_4	0.1 M NaOH	0.1 M $Ba(NO_3)_3$	0.1 M $Ni(NO_3)_2$
		0.1 M $Ca(NO_3)_2$	0.1 M $Zn(NO_3)_2$
		0.1 M $Mg(NO_3)_2$	

Critical Thinking Questions:

1. What does it *mean* when we say these are solutions?

2. Give two general statements (or hypotheses) about the solubility (or insolubility) of certain types of inorganic salts based on the existence of the above solutions.

PART II: Experiment and Development of Hypotheses

The solutions are in small dropper bottles in locations designated by the instructor. As a group, make observations of all of these solutions, and use one or more of the following words to describe each solution: **clear, cloudy, opaque, colorless,** or **colored** (giving its particular color). Remember that clarity of language reduces confusion in communicating your observations, and note specifically that "clear" and "colorless" have two distinctly different meanings.

Your experiment consists of observing what occurs when each of the anion sources is mixed with each of the cation sources Instead of using large numbers of test tubes you will use a clear plastic 8 x 12 well plate. If the well plate appears dirty, wash and rinse it with distilled water (a squirt bottle would be handy here). Shake out the excess water. (Why is it NOT necessary to dry the wells before proceeding with this experiment?) The organization of your well plate should be logical but it need not be the same as any other group's. Just be sure that everyone in your group understands the layout of your well plate. You should enter something similar in our lab notebook to organize your recorded observations. Once you have determined where the solutions will go, place two drops of each of the appropriate solutions into the designated well, resulting in four drops total in each well. DO NOT START OVER if you add an extra drop, just make sure that equal numbers of drops are added to each well (for example, 3 drops cation + 3 drops anion).

Using the five observational words listed above, describe the contents of each cell. Also think about each of the following questions:

1. How do you **know** if the mixture of solutions produced a new compound that is insoluble in water?
2. Can you distinguish a partially soluble from an insoluble product?
3. What can you conclude if there is no apparent reaction?
4. Are there any trends within a family or across a period of elements?
5. What might be factors that affect whether or not two particular ions form an insoluble salt?

Hypotheses: Discuss your observation and your answers to the five questions above with the members of your group and develop several statements about the solubility of families of salts. Look for correlations with element families or possibly ionic charges. Some of these statements might be general and encompass *all* of the salts in a family, others might be somewhat general with limitations, and one or two might be very specific to just a few combinations of ions. The goal is to develop a few good general statements that can be easily remembered and applied, not dozens of statements specific to each test well. You should generate enough statements to account for all of the observations that you have made. Record them in your lab notebook.

PART III: Further Experimentation

The statements that have been developed thus far are hypotheses because they are based on only a few observations. As with all of the laboratory sciences, part of the scientific method in chemistry is to test and modify such hypotheses until they correctly generalize and predict the behavior of all the chemical reactions studied. There are five solutions in the back of the room labeled SOLUBILITY TEST, giving the ionic salt contents and concentrations. Two of these are to test anions, Br- and PO_4^{3}-, to be mixed with each of the previously used cations; the other three are the cations, $Sr^{2=}$, Cu^{2+}, and Fe^{3+}, that will be reacted with each of the previously used anions.

BEFORE mixing the test solutions, **use your hypotheses** (often referred to as **solubility rules) to predict the solubility of the products**. Use a second well plate to test the validity of our predictions, organizing the plate in some logical manner,. After observing the solubility of the products of these test ions, critique your solubility rules. If necessary, modify our solubility rules to account for any discrepancies between your predictions and your observations.

WASTE DISPOSAL: several of the anions used in today's experiment are poisonous and should not be disposed of in the city's water system. The ions of most concern are Cu^{2+} and Ba^{2+}, both being heavy metals. Carefully discard the contents of both well plates into the large beakers in the hood labeled "Solubility Waste." Using a squeeze bottle and a minimum of distilled water, rinse the planes over the waste container. Invert the clean plates over a paper towel and leave them on the back table for the next lab section.

Final Question:

1. You are the director of the city's wastewater treatment plant and you have just been informed that an F&M student has inadvertently dumped this week's collection of "Solubility Waste", containing the heavy metal cation poisons listed, down the drain. What single salt could you add to the water treatment process to insure that none of the poisons stayed in the water after treatment?