**Chemical Detective**

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You have been hired by one of your professors to help clean out a lab that has not been used for a couple of years so that they can move their research program into the space. When you open one of drawers you find a set of eleven unlabeled bottles containing what appear to be colorless aqueous solutions. In the bottom of the drawer, there are eleven labels each showing a concentration and a chemical name.

Having listened many times to the safety portion of pre-lab lectures, you are well aware that it would be environmentally irresponsible to simply pour the solutions down the drain. While you remember from your safety training that there is a procedure for disposing of unknown materials, you also remember that disposing of unknown substances is way more expensive than disposing of known compounds. You wonder, is there a way that you can use information you learned in general chemistry to help you determine which solution is which?

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**Background1**

You do not have any chemicals available to you other than the eleven unknown solutions that you have labeled A-K. The suspected contents are given below:

0.1 M sodium oxalate

0.1 M silver nitrate

0.1 M sodium carbonate

0.1 M barium chloride

0.1 M ammonium chloride

0.1 M sodium thiosulfate

0.1 M manganese (II) chloride

0.1 M zinc chloride

0.1 M potassium chloride

0.1 M hydrochloric acid

3% hydrogen peroxide

Having done some research on the suspects and brushed-up on earlier gen. chem. topics, you have come up with some information that you might be able to use to help you distinguish between the different compounds. As a preliminary organizational step, you’ve divided the information into five groups listed below:

*Acid/Base chemistry:*

Looking at the list and using your knowledge of acid/base chemistry, you realize that one solution is highly acidic and one solution is more basic than the others. While other solutions may be weakly acidic or basic, the more acidic or basic solutions will stand out from the rest.

*Atomic spectroscopy:*

Barium and manganese ions give a yellowish-green flame test2. Potassium ions give a deeply purple/blue flame test. Sodium ions give an orange flame test, but they are difficult to distinguish from the flame color.

*Solubility:*

Combing through various literature sources you have crafted table 1 which shows whether or not you would expect the product of two ions to be soluble for every possible combination. In some cases, when the ions are mixed, something other than the direct salt is formed. “I” means that the salt is highly insoluble, “S” means that the salt is soluble, and “O” means that some other reaction occurs.

**Table 1.** Solubility of potential salts from reaction of two unknown solutions.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ion | Ag+ | Ba2+ | Mn2+ | Na+ & K+ | NH4+ | Zn2+ |
| Cl– | I | S | S | S | S | S |
| CO32- | I | I | I | S | O | I |
| C2O42- | I | I | I | S | S | Ia |
| NO3- | S | S | S | S | S | S |
| OH- | I | S | I | S | O | I |
| SO42- | I | I | S | S | S | S |
| S2O32- | O | S | S | S | S | S |

a) takes 5-10 minutes to form

*Redox chemistry:*

1. **In base**, hydrogen peroxide oxidizes Mn2+ and forms MnO2, (a dark solid); the peroxide is reduced to H2O.

2. **In acid**, thiosulfate decomposes into sulfate and elemental sulfur, turning the mixture cloudy.

3. Thiosulfate reduces silver ions to silver metal; sulfate ion is also formed.

*Other reactivity:*

1. In base, ammonium ions are neutralized to ammonia, which can be detected by its sharp odor. You may also wet a piece of pH paper, and the ammonia vapor should be detectable.

2. Excess thiosulfate can dissolve solid silver chloride by formation of the complex ion Ag(S2O3)23-.

**Procedure**

There is ***not*** a predefined procedure for this experiment. You will be responsible for designing your own procedure to correctly identify each of the solutions. These items will be available to you:

10 mL of each solution labeled A-K

pH paper

small test tubes with rack

plastic transfer pipets

24 well plate

saran wrap

bunsen burner and striker

spray bottles and/or nichrome wire loops

***Prior to lab:***

You will need to create a flowchart in your notebook showing what tests you will do and the order you will do them in to be able to identify each of the unknowns. For example, suppose we have five compounds that react differently with HCl, CH3CO2H, NaOH and Na2CO3, we might create a flowchart like the one in Figure 1.

React all five solutions with HCl

ppt?

yes, C1 & C2 no, C3, C4 & C5

form ppt with CH3CO2H? form ppt with NaOH?

yes, C1 no, C2 no, C3 & C4 yes, C5

bubbles with Na2CO3?

yes, C3 no, C4

**Figure 1.** Sample flowchart.

As you design your flowchart keep in mind the following:

1. An efficient flowchart will not use every test for every solution. It should clearly identify which solutions are expected to give which result and what the next test is based on the results.
2. Since you do not have any chemicals available to you other than your unknowns, your flowchart should identify some solutions early on that you can use to help identify the other solutions.
3. Some test results may not be 100% clear, so you will want to have at least three tests beyond those in your flowchart that you can use to nail down your suspects.

In addition to the flowchart write down a procedure for **each type** **of test** (for example, flame test) you will do. This is not meant to be a repeat of your flow chart in words. Remember that you will need to guard against cross contamination and wafting should be used to detect odors.

***In Lab:***

At the beginning of lab, discussions will be held to ensure you have a valid procedure. Once you have been given the green light, you will work on your own to identify the suspects. In your notebook you must:

1. Make any corrections to your flowchart and procedure to reflect what you actually do.
2. Create table(s) to record the results of each test. You may also want to include space for identification of each solution. *Good organization of tests done and results is the key to successful identification of your suspects.*

**References**

1. Adapted from Qualitative Analysis: Chemical Detective Work In*Introduction to Equilibrium and Reactivity, CH-231 Lab Manual*; College of the Holy Cross, Spring 2009.

2. Helmenstine, A. M. Flame Tests: How to Do a Flame Test & Interpret Results, About.com Guide, http://chemistry.about.com/od/analyticalchemistry/a/flametest.htm (accessed 4/26/2013).