Chemistry 111 Laboratory
Experiment 2: Investigating Periodic Trends- Halogens and Alkaline Earths

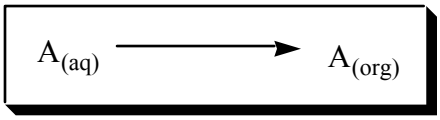
Introduction

The beauty of the periodic table is its elegant way of listing elements to assist our prediction of chemical and physical properties. Our discussion of periodic trends in class focuses on properties such as atomic radii, ionization energy, electron affinity, and electronegativity. However, the periodic table can also be used to logically categorize many other atomic and ionic properties. This experiment will lead your discovery of periodic trends involving reactivity and solubility.

Extraction

Some molecules are soluble in a variety of solvents, but they may *prefer* one solvent over another. If two of these solvents are *immiscible* it is possible to transfer the majority of a solute from one solvent to the other by shaking a solution of the solute in its less preferred solvent with some of the preferred solvent. When given a choice the solute molecules will migrate into the preferred solvent. When shaking is stopped the immiscible liquids separate from one another and the solute will be located primarily in the solvent it prefers. A mixture of immiscible liquids exists in two phases. Often the two liquids are water and an organic solvent.

The process of extraction can be symbolized as follows, where A is the solute:



This process is written as if the molecule prefers the organic solvent.

This phenomenon can be used to separate different chemical species from one another. Two species that start out in the same solution might partition differently into a second immiscible solvent. One might prefer the original solvent while the other might prefer the second solvent. Shaking the mixture will result in at least a crude separation of the two molecules. Separations like this are not likely to be perfect since the molecules have different *preferences*, not different absolute requirements. In other words, 100% of one solute does not stay in the first solvent while 100% of the second solute moves to the new solvent. Nonetheless, extractions are often used to isolate a crude product from a reaction mixture or to identify a reaction product.

Procedure

Part I

- Explore a mixture of equal amounts of water and heptane (an eyedropper full of each will do) in one of the small test tubes in your drawer. Shake up the mixture using a cork (from the front of the room) between your finger and the test tube contents. Describe the situation as completely as possible. Which solvent is where?

Part II

A

- Explore the solubilities of the sodium halide salts NaCl, NaBr, and NaI, in water, and then in heptane. Use samples of each solid about the size of an apple seed. Use one dropperfull of the solvent. Shake the test tube with a cork between your finger and the contents (from here on the use of corks will be assumed!). Record your observations. Explain your results based on polarities.

B

- Explore the solubility of solid iodine in both water (two dropperfulls) and heptane (two dropperfulls). Shake the test tubes. Record your observations.

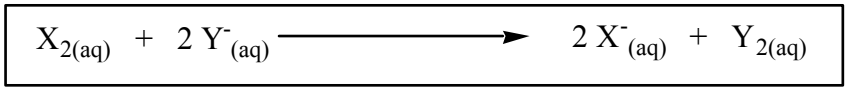
C

- Explore the relative solubilities of the halogens in water and heptane. Add a half dropperfull of each halogen-water solution (chlorine-water, bromine-water, and iodine-water) to two dropperfulls heptane. Shake vigorously (at least 10 seconds). Record your observations. It will be important to be able to refer back to these observations later! Which is the preferred solvent? Why?

[If you are unclear about what you have learned so far in this experiment, stop here and request a consultation with your instructor or prefect. Do not continue unless you feel confident!]

Part III

- Explore the relative reactivities of the halogens and halides. The reactions are of the general form:



Mix one dropperfull of each sodium halide solution (these solutions are provided in the lab) with half a dropperfull of a different halogen-water solution in test tubes. Note that there is no point in mixing NaCl with Cl_2, for example, as any reaction which occurs will not be noticeable since for every two Cl^- that become a Cl_2, one Cl_2 must become two Cl^-.

Any reaction (if one occurs) will occur quickly. Do you see evidence of a reaction? After recording your initial observations, add a dropperfull of heptane to each reaction mixture and shake each mixture. What conclusions can you draw? For each combination you tried, indicate if a chemical change took place and support your conclusion with evidence. Write the balanced chemical reactions for those test tubes in which a reaction occurred.

- Compare your results from this section with at least one other laboratory group. Repeat any part that does not agree and then compare your results again.

- Arrange the three tested halogens in order of their reactivity (lowest to highest). Comment on the relationship between this ranking and the positions of the halogens on the periodic table.

- Arrange the three tested halides in order of their reactivity (lowest to highest). Comment on the relationship between this ranking and the positions of the halogens on the periodic table.

- Predict what would occur if fluor*ine* and iod*ide* were given the opportunity to react with each other.

- Predict what would occur if astat*ine* and brom*ide* were given the opportunity to react with each other.

- Briefly support your conclusions.

Part IV

It is most efficient to use a well plate for this part of the experiment. Determine the relative solubilities of the sulfate, carbonate, oxalate, and chromate salts of the alkaline earth metal ions. Since all nitrate salts are soluble, start with approximately 1 mL volumes (one dropperfull) of 0.1 *M* solutions of barium nitrate, calcium nitrate, magnesium nitrate, and strontium nitrate. Add only one drop of the appropriate anion solution to each alkaline earth metal ion solution. You will be adding the anions of interest in the following forms:

sulfate	1 drop of 1 *M* H_2SO_4
carbonate:	1 drop of 1 *M* Na_2CO_3
oxalate:	1 drop of 1 *M* $K_2C_2O_4$
chromate:	1 drop of 1 *M* K_2CrO_4 (dissolved in 1 *M* acetic acid)

- Record your observations. Which alkaline earth salts are (essentially) insoluble? How do you know?

- Rank the *alkaline earth metal ions* in order of their tendency to form insoluble salts (most soluble to least soluble). Comment on the relationship between this ranking and the periodic table.

Part V

On the basis of your work so far, devise a scheme to analyze an unknown alkaline earth metal halide (available to you as a 0.1 *M* aqueous solution). [For example, we might give you an aqueous solution of CaI_2, or of $MgCl_2$, or any other combination of the four metals and the three halides you have tested in this experiment.] You need to determine which metal ion and which halide ion are present. Use any of the reagents you have used today. Try not to do unnecessary testing. Not every possible test will actually give you helpful data. Can you do this determination in a minimum number of tests? Present your plan to your instructor or prefect. The use of a flowchart is a convenient way of sharing your ideas with your instructor or prefect. After a discussion about your scheme, you will be given an unknown salt solution for analysis.

- Report the identity of your unknown salt (and the number it had on it when given to you). Describe completely how you arrived at this conclusion. If you don't have a flowchart describing all possible outcomes, answer these questions: (1) If the metal ion had been one of the other three, what would have happened differently? (2) If the halide ion would have been one of the other two, what would have happened differently?

Report

Your report for this experiment consists of your notebook pages. Your data and observations should be in an easy to understand format (tables). Answers to the questions posed throughout the procedure are required. These answers should be organized and straightforward for the person reviewing your notebook to follow.

Name_____

Chemistry 111 Laboratory
Experiment 2: Investigating Periodic Trends - Halogens and Alkaline Earths
Advance Study Assignment

Complete this Advance Study Assignment before you come to lab this week. Bring this completed sheet with you to lab. You will not have time to work on it at the start of lab: it needs to be done before you arrive! It will help you complete the lab successfully.

Provide a 1-2 sentence synopsis of the objectives and procedures of the experiment:

Please answer the following questions to the best of your ability:

1. Remembering the general rule that "like dissolves like," do you expect halogens or halides to be more soluble in water? Explain briefly.

2. Read about miscible and immiscible liquids in your textbook. From your everyday life give an example of two miscible liquids and two immiscible liquids. Explain your choices briefly. Discuss the relative polarities of the two miscible liquids vs. the relative polarities of the two immiscible liquids.

3. Read Part III of the procedure. Where are you performing an extraction? What molecules are being extracted? Describe briefly.

4. Plan tables to record your data. You will need data tables for procedure parts IIA, IIB, IIC, III and IV. Plan how you will organize these tables. What headings will be necessary for rows? For columns?

5. Study part IV of the procedure. If you see a precipitate form when you add a solution of a metal nitrate, $M(NO_3)_2$, to a solution of $K_2C_2O_4$, how do you know the identity of the precipitate? (Is it KNO_3? Is it MNO_3? What is it? Don't try to identify M, we haven't given you enough information for that.) [HINT: It is useful to examine the "solubility rules" for salts in your textbook before completing this ASA and conducting this experiment.]