# The Behavior of Two Families in the Periodic Table

The Periodic Table arranges the elements in order of increasing atomic number in horizontal rows of such length that elements with similar properties recur periodically, i.e., they fall directly beneath each other in the table. The elements in a given vertical column are referred to as a family. By noting the gradual trends in properties of the members of a family, it is possible to arrange them in the order in which they fall in the Periodic Table. This is what you will be asked to do in this experiment for two particular families.

The families to be studied are the alkaline earths, Group IIA, and the halogens, Group VIIA. The alkaline earths are all active metals and include barium, beryllium, calcium, magnesium, radium and strontium. Beryllium compounds, rarely encountered, are often very poisonous and radium is highly radioactive, so we shall not include these two elements in the experiment. The elements in the halogen family are astatine, bromine, chlorine, fluorine and iodine. Of these we will omit astatine, which is radioactive. and fluorine, which is the most chemically reactive of all the elements and very dangerous to work with.

The experiments with the alkaline earths involve determining the relative solubilities of the salts formed by the alkaline earth cations with sulfate, carbonate, oxalate and chromate ions. When solutions containing these $M^{+2}$ cations are mixed with the above $X^{-2}$ anions, the following reaction will occur if the salt MX is **not very soluble**:

$$M^{+2}_{(aq)} + X^{-2}_{(aq)} \rightarrow MX_{(s)}$$

$M^{+2} = Ba^{+2}$, $Ca^{+2}$, $Mg^{+2}$, or $Sr^{+2}$ ; $X^{-2} = SO_4^{-2}$, $CO_3^{-2}$, $C_2O_4^{-2}$, or $CrO_4^{-2}$

The trends in solubilities of these salts are consistent with the order of the IIA elements in the Periodic Table and can be used to establish that order.

The halides may be identified by two methods. The first of these involves their reaction with lead(II)nitrate forming an insoluble salt according to the reaction:

$$2\ NaX_{(aq)} + Pb(NO_3)_{2\ (aq)} \rightarrow PbX_{2\ (s)} + 2\ NaNO_{3\ (aq)}$$

$X = Cl^-$, $Br^-$, or $I^-$

We will investigate the relative solubilities of the salts formed between the silver ion and the various halide ions. If a solution of silver nitrate, $AgNO_3$, is added to a solution of a halide salt, MX (for example, sodium chloride), the following reaction will occur:

$$Ag^+_{(aq)} + X^-_{(aq)} \rightarrow AgX_{(s)}$$

An insoluble precipitate of AgX forms immediately. This precipitate, although it is very insoluble in water, may dissolve in $NH_3$ solutions, since there the following reaction tends to occur:

$$AgX_{(s)} + 2\ NH_{3\ (aq)} \rightarrow Ag(NH_3)_2^+{}_{(aq)} + X^-_{(aq)}$$

The tendency for this reaction to proceed increases with increasing $NH_3$ concentration and with the increasing solubility of the silver halide.

The solubilities of the silver salts of the halides in $NH_3$ solutions will allow you to arrange the halogens in the order in which they should appear in the Periodic Table.

Given the properties of the alkaline earths and the halogens as observed in this experiment, it is possible to develop a systematic procedure for determining the presence of any IIA cation and any given halide ion in a solution. In the last part of the experiment you will be asked to set up such a procedure and use it to establish the identity of an unknown solution containing a single alkaline earth halide.

**EXPERIMENTAL PROCEDURE**:

1. Relative Solubilities of Some Salts of the Alkaline Earths. Add about 1 mL (approximately 12 drops) of 0.1 M solutions of the nitrate salts of barium, calcium, magnesium and strontium to separate small test tubes. To each tube add 1 mL of 1 M $H_2SO_4$ and stir with your glass stirring rod. (Rinse your stirring rod with your wash bottle between tests.) Record your results in the table, noting whether a precipitate forms, as well as any characteristics that might distinguish it.

Repeat the experiment by mixing 1 mL of 1 M $Na_2CO_3$ (the precipitating reagent) with fresh portions of the alkaline earth nitrate salts. Record your observations. Then test for the solubilities of the oxalate salts using 1 mL of 0.25 M $(NH_4)_2C_2O_4$. Finally, determine the relative solubilities of the chromate salts. Mix 5 mL of $K_2CrO_4$ and 5 mL of acetic acid, then add 2 mL of this mixture to 1mL of each alkaline earth cation solution.

2. Solubilities of Silver Halide Salts. Add 1 mL of 0.1 M solutions of the three sodium halides to separate test tubes. Add 1 mL of 0.1 M $AgNO_3$ to each test tube and stir. Note the color of each precipitate. Centrifuge and discard the liquid. To the precipitate add 2 mL of 6 M $NH_3$ and stir well. If the solid does not dissolve, centrifuge and decant the liquid and add 2 mL of 15 M $NH_3$. Stir well. Record your results.

3. Identification of Unknown Salts. On the basis of your observations, devise a scheme by which you can establish which alkaline earth cation and which halide ion is present in a solution containing a single alkaline earth halide. Use your procedure to identify the salt in your unknown solution.

4. **Remember to discard all heavy metal wastes and organic wastes in the appropriate container. Your instructor will provide specific instructions for today's lab.**

# DATA SHEET: PERIODIC BEHAVIOR

NAME_____SECTION_____

## 1. Solubilities of Salts of the Alkaline Earths

| | $Ba(NO_3)_2$ | $Ca(NO_3)_2$ | $Mg(NO_3)_2$ | $Sr(NO_3)_2$ |
|---|---|---|---|---|
| 1 M $H_2SO_4$ | | | | |
| 1 M $Na_2CO_3$ | | | | |
| 0.25 M $(NH_4)_2C_2O_4$ | | | | |
| 1 M $K_2CrO_4$ and 1 M Acetic Acid | | | | |

P = precipitate forms; S = no precipitate

Note the color, amount or any other characteristic of the precipitates.

Consider the relative solubilities of the Group IIA cations in the various precipitating reagents. On the basis of the trends you observed, list the four alkaline earths in the order in which they should appear in the Periodic Table. **Start with the one which forms the most soluble oxalate.**

_____ _____ _____ _____

(most soluble **cation**) (Least soluble **cation**)

Why did you arrange the elements as you did? Is the order consistent with the properties of the cations in all of the precipitating reagents?

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_____

2. **Solubilities of the Salts of the Halides**

| | NaCl | NaI | NaBr | Unknown |
|---|---|---|---|---|
| $AgNO_3$ | | | | |
| Precipitate from first part of 2. and 6 M $NH_3$ or $NH_4OH$ | | | | |
| Any remaining precipitate from second step and 15 M $NH_3$ or $NH_4OH$ | | | | |

Again note solubility and any other distinguishing characteristics.

On the basis of the above tests, arrange the halogen ions in the order in which they should be listed in the Periodic Table. Start with the one which forms the most soluble silver salt.

_____ _____ _____

(most soluble **anion**) (Least soluble **anion**)

3. Your unknown solution contains one Group IIA cation and one Group VIIA anion. Based on the properties of the ions as you observed them in this experiment, perform tests which could allow you to determine which cation and which anion are present. In most cases one or two tests for the cation and one or two tests for the anion should be sufficient. Use your scheme to analyze your unknown solution.

**Data:**

Cation present _____ Anion present _____

Unknown # _____ Formula of the Compound_____

Lab #4

**Prestudy**

**A**

NAME_____ SECTION_____

## Periodic Behavior

1.(1 point) Calcium hydroxide is slightly soluble (1.85 g / L) in water, whereas barium hydroxide is more soluble (56 g / L). Would you expect magnesium hydroxide to be more soluble or less soluble than strontium hydroxide? Why?

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2.(6 points) Balance the following equations: (Assume all reactants are in aqueous solutions)

a) $H_2SO_4 + Sr(NO_3)_2 \rightarrow$

b) $Na_2CO_3 + Mg(NO_3)_2 \rightarrow$

c) $(NH_4)_2C_2O_4 + Ca(NO_3)_2 \rightarrow$

d) $K_2CrO_4 + Ba(NO_3)_2 \rightarrow$

e) $NaCl + AgNO_3 \rightarrow$

f) $NaI + Pb(NO_3)_2 \rightarrow$

3.(3 points) In each of the above reactions, identify which of the products are precipitates. (Solubility rules are found in Appendix II or in your text). In each reaction, one of the products will be a precipitate.

a) d)

b) e)

c) f)

Lab #4

**Prestudy**

**B**

NAME_____ SECTION_____

## Periodic Behavior

1.(1 point) Magnesium carbonate is soluble in water (100 mg / L) whereas strontium carbonate is only slightly soluble in water (11 mg / L). Would you expect barium carbonate to be more or less soluble than calcium carbonate? Why?

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2.(6 points) Balance the following equations: (Assume all reactants are in aqueous solutions)

a) $Sr(NO_3)_2 + H_2SO_4 \rightarrow$

b) $AgNO_3 + NaI \rightarrow$

c) $Pb(NO_3)_2 + NaBr \rightarrow$

d) $Mg(NO_3)_2 + (NH_4)_2C_2O_4 \rightarrow$

e) $Ba(NO_3)_2 + K_2CrO_4 \rightarrow$

f) $Ca(NO_3)_2 + Na_2CO_3 \rightarrow$

3.(3 points) In each of the above reactions, identify which of the products are precipitates. (Solubility rules are found in Appendix II or in your text). In each reaction, one of the pr5oducts will be a precipitate.

a) d)

b) e)

c) f)