Experiment 17 - Periodic Properties of Elements: The Alkaline Earth Elements and the Halogens

The periodic table arranges the elements in order of increasing atomic number into horizontal rows whose lengths are such that elements with similar properties recur periodically - that is, groups of similar elements fall into a single vertical column on the table. The elements in any vertical column of the periodic table are similar in their chemical properties, and are therefore considered to make up a chemical family.

In this experiment, some of the properties of elements in two chemical families will be observed. These families are Group 2A, also known as the alkaline earth elements; and Group 7A, also known as the halogens. In each group, the four most important elements in the group will be studied. In Group 2A, these are magnesium (Mg), calcium (Ca), strontium (Sr), and barium (Ba). In Group 7A, they are fluorine (F), chlorine (Cl), bromine (Br), and iodine (I). These elements will be studied mostly in the form of ions, not as the neutral elements. All Group 2A elements react readily to lose two electrons and form ions with a +2 charge. All of the halogens readily gain one extra electron to form ions with a -1 charge. In Part 1 of the experiment, some properties of the Group 2A cations Mg^{2+}, Ca^{2+}, Sr^{2+}, and Ba^{2+} will be observed and compared. In Part 2, some properties of the halide ions F, Cl^-, Br^- and I^- will be studied. In part 3, an unknown ionic compound will be identified. The unknowns will be in the form of an aqueous solution and will contain a Group 2A cation and a Group 7A anion.

In Parts 1 and 2, you will observe that the properties of the elements in a particular group of the periodic table are generally similar to each other but they are not identical to each other. The information that is obtained in parts 1 and 2 about the differences in properties of elements in each group will be used in Part 3 to determine which of these elements is present in the unknown. When the properties of elements in the same group of the periodic table are different from each other, it is usually found that the properties change in progression in the same order in which the elements are arranged on the periodic table. The following chart illustrates this for some properties of the halogens. The elements are listed on the chart in the same order in which they appear on the periodic table.

Element	Melting Point	Boiling Point	Density (as liquid)	Ionization Energy
F	-218 °C	-188 °C	1.11 g/mL	403 kcal/mol
Cl	-101 °C	- 34 °C	1.56 g/mL	302 kcal/mol
Br	-7 °C	+ 59°C	3.12 g/mL	274 kcal/mol
I	+114 °C	+ 184 °C	4.93 g/mL (as solid)	243 kcal/mol

Safety Precautions:

- Wear your safety goggles.
- Silver nitrate ($AgNO_3$) solutions will stain skin and clothes. If you suspect you may have spilled $AgNO_3$ on yourself, rinse it off immediately. The stains are dark brown and they don't show up right away. You'll know the next day whether or not you spilled $AgNO_3$ on yourself.

Waste Disposal:

- All of the waste from this lab may be dumped in the **inorganic waste** bottles (which have a blue label) in the fume hood.

Procedure - Part 1 - Properties of Group 2A Cations

To study the Group 2A cations, four tests will be performed on solutions containing these ions. These solutions are labeled Mg^{2+}, Ca^{2+}, Sr^{2+}, and Ba^{2+}. The solutions actually contain the nitrates of the Group 2A elements: $Mg(NO_3)_2$, $Ca(NO_3)_2$, $Sr(NO_3)_2$, and $Ba(NO_3)_2$. Nitrate is a spectator ion and will not interfere with any of the tests.

Between tests, the test tubes should be washed, rinsed with tap water, and then rinsed twice with small amounts of deionized water. The tubes do not have to be dried.

Test 1: Add about 10 drops of each of the four solutions into separate test tubes. To each of the test tubes, add about 10 drops of 1 M H_2SO_4. Swirl the test tube vigorously to mix the contents. Observe whether or not an insoluble precipitate forms. If a precipitate does form, it the sulfate of the Group 2A ion. For example, adding H_2SO_4 to Ba^{2+} gives a precipitate of barium sulfate, $BaSO_4$. Record the results of these tests, including the colors of any precipitates formed.

Test 2: Again add about 10 drops of each of the four Group 2A cation solutions to each of four separate test tubes. To each sample, add about 10 drops of 1 M $Na_2CO_{3\,(aq)}$ and mix. The precipitates that form are the carbonates of the Group 2A ions, such as calcium carbonate ($CaCO_3$).

Test 3: Again add about 10 drops of each of the four Group 2A cation solutions to each of four separate test tubes. To each sample, add about 10 drops of 0.25 M $(NH_4)_2C_2O_{4\,(aq)}$. The precipitates that form are the oxalates of the Group 2A ions, such as barium oxalate (BaC_2O_4).

Test 4: Again add about 10 drops of each of the four Group 2A cation solutions to each of four separate test tubes. To each sample, add about 10 drops of 1 M $(NH_4)_2MoO_{4\,(aq)}$. The precipitates that form are the molybdates of the Group 2A ions, such as barium molybdate ($BaMoO_4$).

The data that you record for these four test should show that none of the Group 2A cations reacts in exactly the same way in all four of the tests as any other Group 2A cation. The differences in behavior of the cations will be used in Part 3 to determine which one is present in an unknown.

Procedure - Part 2 - Properties of Group 7A Anions

Obtain solutions containing each of the four Group 7A anions. These solutions are labeled F^-, Cl^-, Br^- and I^-. The solutions actually contain the sodium salts of these ions: NaF, NaCl, NaBr, and NaI. The sodium ion (Na^+) is a spectator ion and will not interfere with any of the tests.

Test 1: Add about 10 drops of each of the four halide ion solutions into separate test tubes. Add about 5 drops of 0.1 M $AgNO_3$ to each of the test tubes. **Caution: $AgNO_3$ can cause dark brown stains on skin or clothes! Rinse it off immediately if you come into contact with this solution.** Swirl the test tube vigorously to mix the contents. Observe whether or not an insoluble precipitate forms. The precipitates that

form are the silver salts of the halide ions, such as silver chloride (AgCl). Record the results of these tests, including the colors of any precipitates formed.

Test 2: Another test that distinguishes the halide ions from each other is to react them with a solution of chlorine (Cl_2) in water. Chlorine removes the excess electron from bromide ion (Br^-) and from iodide ion (I^-), and converts these ions to the uncharged elements bromine (Br_2) and iodine (I_2). In water solution, all of the halide ions are colorless, but the element bromine has a characteristic orange-red color and the element iodine has a much darker red-brown color. These colors will be observed when chlorine reacts with Br^- or I^-. Chlorine does not cause any reaction when mixed with the other halide ions, Cl^- and F^-.

To perform the test, add a small amount of each of the four halide ion solutions to separate test tubes. Add about 1 mL of chlorine water to each test tube. Record your results. Important: there will be no precipitates formed in this test. You are looking for the possible color of the solution.

Procedure - Part 3 - Identification of an Unknown

Obtain a numbered test tube that contains an unknown solution, and record the unknown number. The solution is a solution of a Group 2A halide in water - that is, it contains an ionic compound whose cation is from Group 2A and whose anion is from Group 7A. By performing the tests that were done in Parts 1 and 2 on small portions of the unknown solution, you should be able to identify both of the ions in the unknown solution. By identifying the ions that make up the compound that is dissolved in the unknown solution, you can then write the formula and name the compound that is in your unknown solution.

Note: When you are filling in the data table, if no reaction occurs, write "NR". If you see a precipitate, write "ppt" and the color of the precipitate.

Questions

1. Write a net ionic equation for each of the reactions that actually occurred in this experiment. (If you got no reaction for a particular combination, do not write an equation).