# **E10 - PERIODIC PROPERTIES**

When the elements in the periodic table are arranged in order of increasing atomic number, it is found that elements can be grouped together according to their similar chemical and physical properties. These groups are represented by the vertical columns in the periodic table. Two groups will be investigated in this experiment, Group 2 (IIA), the alkaline earth metals, and Group 17 (VIIA), the halogens.

The Group 2 metals are quite reactive and form ions of a 2+ charge. If the combination of the Group 2 cation and an anion, Z2–, leads to a product which is insoluble in water, mixing aqueous solutions of the ions will lead to a precipitate:

M2+(aq) + Z2–(aq) 🡪 MZ(s)

If solubility in water of the compounds of the type MZ is a periodic property, then the relative solubility’s should be predictable from the periodic table. For example, we might find a variation in solubility as follows:

MgZ > CaZ > SrZ > BaZ

In this experiment, the solubility’s of the compounds of Mg2+, Ca2+, Sr2+, and Ba2+ will be investigated. Compounds of Be2+ are toxic and Ra is a rare, radioactive element, so their properties will not be investigated, but predictions will be made. The anions that will be used are SO42–, CO32–, C2O42–, and CrO42–.

The Group 17 (7A) elements, the halogens, are also quite reactive. They all occur as diatomic molecules, X2, in the elemental state and tend to react by gaining electrons to form anions, X–. When a halogen reacts with a metal, the halogen acquires electrons from the metal forming a metal cation and a halide anion, F–, Cl–, Br–, I–, or At–. Always remember that the term **halogen** refers to the elemental state and **halide** refers to the anion formed after the halogen has reacted. The halide ions in water are all colorless and odorless while the halogens in water tend to be colored, with pungent odors, and are very reactive.

In this experiment, the relative tendency of the halogens to form halide anions will be investigated. As in Group 2, the first and last elements of the group will not be used since fluorine is extremely reactive and astatine is rare and radioactive. When a halogen reacts to gain electrons and form a 1- anion, it has been **reduced**; its oxidation number has been lowered from 0 to -1. Elements that are reduced have gained their electrons from another substance and that substance has been **oxidized**. Since the reactant being reduced has caused the oxidation of another substance, it is called an **oxidizing agent** while the other reactant is a **reducing agent**.

The strength of a halogen as an oxidizing agent is also a periodic property. The strongest oxidizing agent will be either the first or last element in the group while the weakest will be the other. The strength should then vary smoothly across the group.

If we compare two halogens, X2 and Y2, one will be stronger than the other as an oxidizing agent. If X2 is stronger than Y2, then the following reaction will occur:

X2(aq) + 2Y–(aq) 🡪 2X–(aq) + Y2(aq)

For example, if Cl2 is stronger than Br2, we have:

Cl2(aq) + 2Br–(aq) 🡪 2Cl–(aq) + Br2(aq)

When this reaction occurs, we will see the color of chlorine disappear and the color of bromine appear. However, since the colors of the halogens in water are not very distinctive, we take advantage of the fact that they are soluble in such organic solvents as hexane where they have a more distinctive color. This will aid in deciding whether a reaction has occurred.

If an aqueous solution of a halogen is shaken with hexane, the halogen will be extracted into the hexane layer and give to the hexane its distinctive color. Since hexane is not miscible with water, it will remain as a layer above the water. For example, the color of iodine in water is orange to brown, depending on concentration, but pink to purple in hexane.

To determine whether a reaction occurs with a halogen and iodide (I–), all that is necessary is to take a solution of halogen (e.g., aqueous Cl2), add hexane and shake. Then add a solution of iodide (from aqueous NaI) and shake. If a reaction has occurred, the color of the hexane layer will be purple, the color of iodine, otherwise it will have the color of the original halogen.

An unknown alkaline earth halide can then be identified by using the results of this experiment. Each metal cation will have distinctive solubility properties and each halide anion will react in the aforementioned redox reaction in a different manner with the other halogens. Luckily, the presence and identity of the ion of opposite charge does not affect the results of any of the tests. A systematic series of experiments can be planned to characterize the “known” ions present in the test solutions. This will allow the development of an efficient procedure to accurately identify the cation and anion in an assigned “unknown” solution

## **PROCEDURE**

Wear your **safety glasses** while doing this experiment.

### **Part I: Relative Solubilities of Some Salts of the Alkaline Earths**

**PLEASE NOTE THAT THESE REACTIONS ARE SENSITIVE TO CONCENTRATION. MIX THE CORRECT QUANTITIES ONLY, OTHERWISE A REACTION MAY NOT OCCUR WHEN IT SHOULD.**

Place 1 mL of water in a small test tube to use as a guide for the correct volume.

Add about 1 mL (approximately 12 drops) of the 0.1 M solutions of the nitrate salts of barium, calcium, magnesium, and strontium to separate test tubes. To each tube add 1 mL of 1 M H2SO4 and stir the mixture with a stirring rod, rinsing the stirring rod with deionized water before mixing each solution.

Record your observations in the table that you have written into your lab notebook, writing any additional observations that you wish to make such as color, tendency of precipitate to settle, size of particles, etc.

**Dispose of the solutions in the appropriate waste containers.** Rinse the test tubes with deionized water and add 1 mL of each of the nitrate salts once again, then add 1 mL of 1 M Na2CO3 to each, stirring as before and recording observations. Repeat the procedure two more times, once with 1 mL of 0.25 M (NH4)2C2O4 (ammonium oxalate) added to the four nitrate salt solutions, and finally with a mixture of 1 mL of 1 M K2CrO4 and 1 mL of 1 M CH3CO2H (acetic acid) added to the four.

### **Part II: Relative Oxidizing Powers of the Halogens**

**POUR ALL SOLUTIONS CONTAINING HEXANE, A FLAMMABLE ORGANIC SOLVENT, INTO THE DESIGNATED WASTE BOTTLE THAT IS IN THE HOOD. DO NOT POUR THEM DOWN THE DRAIN.**

**AVOID BREATHING THE HALOGEN VAPORS. DON'T USE YOUR FINGER TO STOPPER THE TUBE SINCE THE HALOGENS CAN CAUSE A BURN.**

Place 2 mL of bromine-saturated water into a small test tube and add 1 mL of hexane (or cyclohexane). **STOPPER THE TEST TUBE** or cover it with a small square of Parafilm and shake until most of the bromine is extracted into the hexane layer.

Repeat the experiment with 2 mL of chlorine water and 1 mL of hexane and then with 2 mL of iodine water and 1 mL of hexane. Record your observations, noting any color changes that occur between the color in water solution and the color in hexane.

Use the same precautions in carrying out the following procedures. You will do the procedure six times with six different mixtures of halogens and halides as listed in the table below.

**DO NOT CONFUSE THE SOLUTION OF THE HALOGEN, X2, WITH THE HALIDE, NaX.**

1. Mix 1 mL of a halogen, **X2**, with 1 mL of hexane. Shake the mixture. Observe and record the color of the hexane.
2. Add to the mixture 1 mL of a 0.1 M solution of halide, **NaX.** Shake the mixture. Observe and record the color of the hexane.

| Mixture number | 1 mL of halogen +  1 mL of hexane; shake and observe | then add 1mL of halide; shake and observe |
| --- | --- | --- |
| 1 | **Br2** | **NaCl** |
| 2 | **Br2** | **NaI** |
| 3 | **Cl2** | **NaBr** |
| 4 | **Cl2** | **NaI** |
| 5 | **I2** | **NaBr** |
| 6 | **I2** | **NaCl** |

### **Part III. Identification of an Alkaline Earth Halide**

The tests that you have just carried will allow you to identify Group 2 metal cations by their different solubilities with the four precipitating anions. In a similar way, a halide anion can be identified by its reaction with the halogen solutions of bromine, chlorine, and/or iodine.

Your unknown will contain only one Group 2 cation and one halide anion. Analysis of the data should suggest an efficient way, using minimal sample and the fewest possible number of tests, to determine the identity of each ion in the assigned unknown solution. Devise a procedure/flowchart to identify which ions are present in your unknown. Write the procedure/flowchart in your lab notebook, check your planned procedure with your instructor then carry it out, writing all observations.

State the identity of the unknown ions in your assigned unknown compound.

# **E10 - PERIODIC PROPERTIES**

# **REPORT SHEET**

Section\_\_\_\_\_\_\_\_\_\_\_\_\_ Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## **Solubilities of Salts of the Alkaline Earth Metals**

Fill in the following table with a summary of your observations. Use these abbreviations: **P**=precipitate forms; the compound is insoluble or **S**=no precipitate forms; the compound is soluble. If there is a precipitate, describe its color and its tendency to settle out.

|  | **1M H2SO4** | **1M Na2CO3** | **0.25M (NH4)2C2O4** | **1M K2CrO4 + 1M CH3CO2H** |
| --- | --- | --- | --- | --- |
| **Ba(NO3)2** |  |  |  |  |
| **Ca(NO3)2** |  |  |  |  |
| **Mg(NO3)2** |  |  |  |  |
| **Sr(NO3)2** |  |  |  |  |

By examining the results summarized in the chart above, list the four Group 2 elements in order of the number of precipitates formed, from the least to the most. (In case of a tie, the relative amount of precipitate can be used to determine the ranking.) Your order should correspond to that in the periodic table, indicating that relative solubility is a periodic property.

Order = \_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_

If Be2+ and Ra2+ were tested, where would they appear in the above order?

## **Relative Oxidizing Powers of the Halogens**

List below the colors found for the halogens in water and hexane:

**Br2 Cl2  I2**

**Water** \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_

**Hexane** \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_

Fill in the part of the following table concerning the reactions of the available halogens and halides. Summarize your observations of the reactions of the halogens with the halide ions. Indicate the initial and final colors of the hexane layer. State whether a reaction occurred with the abbreviations: **R**=reaction, **NR**=no reaction. In the rest of the table, predict whether a reaction will occur (R or NR) for the combinations of elements not tested in the experiment.

|  |  | **Halogens** | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| **Br2** | **Cl2** | **I2** | **At2** | **F2** |
| **H**  **a**  **l**  **i**  **d**  **e**  **i**  **o**  **n**  **s** | **Br-** | xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx |  |  |  |  |
| **Cl-** |  | xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx |  |  |  |
| **I-** |  |  | xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx |  |  |
| **At-** |  |  |  |  |  |
| **F-** |  |  |  |  |  |

List the halogens in order from weakest to strongest oxidizing agent:

Order = \_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_ \_\_\_\_\_\_

## **Identification of the Alkaline Earth Halide**

Unknown number\_\_\_\_\_\_\_

Summarize below the procedure/flowchart that you have devised for the identification of the cation and anion in the unknown.

Summarize below the observations that you made during your analysis.

Cation present\_\_\_\_\_\_\_\_

Anion present\_\_\_\_\_\_\_\_

# **PRE-LABORATORY ASSIGNMENT**

# **EXPERIMENT 10 PERIODIC PROPERTIES**

Section\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Carbon (as graphite) has a density of about 2.3 g/cm3. Germanium has a density of about 5.3 g/cm3. Using the periodic table, predict whether silicon will have a density greater than that of germanium. Make the same kind of prediction for tin. Explain your reasoning.

1. Consider three substances, A, B, C, which can all act as oxidizing agents. In their reactions they will be reduced to A–, B–, and C–. It is found that when a solution of A is mixed with a solution containing C–, an oxidation-reduction reaction occurs. It is then found that when a solution of A is mixed with one containing B–, no reaction occurs.
2. Write the equation for the reaction:
3. Which species is oxidized? \_\_\_\_\_\_\_\_ Which species is reduced? \_\_\_\_\_\_\_\_
4. Is A or B the better oxidizing agent? \_\_\_\_\_\_
5. Is A or C the better oxidizing agent? \_\_\_\_\_\_
6. Arrange A, B, and C in order of increasing strengths as oxidizing agents.
7. Chemists often make tables or flow charts to summarize the results of known tests and to use when identifying unknown samples.
8. Complete a table of the results of mixing A– with each of the oxidizing agents, A, B and C, based on the data in Problem 2. Add your predicted results for similar tests on B– and C– to your table.

1. When a student receives a solution containing one of the anions (call it X–), he can identify the unknown by one or, at most, two tests with the solutions of A, B and C. Write a flow chart to follow as a procedure for the identification.