Lab 4 - Halogens

Purpose:
1. Explore some properties of halogens.
2. Predict the results of reactions between halogens and halide salts.

Background:
The concepts that will be investigated in this lab are polarity, electronegativity, solubility, and reactivity of halogens and their compounds. These concepts are interrelated.

Molecules can be described as ionic or covalent (nonpolar or polar). The factors that influence the polarity of a molecule include the presence, and magnitude, of an electronegative atom and the 3-dimensional molecular structure. The focus of this lab is electronegativity, which is the ability of an atom to attract electrons.

Solutions consist of solvents and solutes. The solvents (species doing the dissolving) that will be used in this lab are water and hexane. Water is a polar covalent solvent, and it will solvate (i.e. dissolve) polar and ionic substances (i.e. "like dissolves like"). A molecule is considered polar if the electronegativity (EN) difference of its atoms is greater than 0.5. Below 0.5, the molecule is nonpolar. Above 2.0, the species is considered ionic.[1] Using water as an example, the EN of an atom of oxygen is 3.5 and the EN of hydrogen is 1.0 (Figure 1). The difference is 2.5. As a result, the bond between oxygen and hydrogen is polar because the electrons that are being shared to form the bond between hydrogen and oxygen are attracted more towards the oxygen atom. As a result, the oxygen atom has a partial negative charge (δ-), and the hydrogen atoms have a partial positive charge (δ+). Why the overall molecule is polar will be more completely explained by the VSEPR theory, or the Valence Shell Electron Pair Repulsion Theory, which will be addressed in Chapter 8.

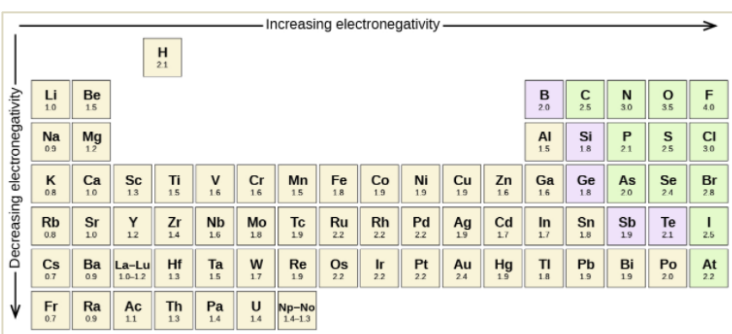

Figure 1. Electronegativity values.[2]

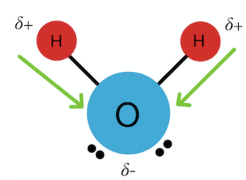

Figure 2. Polar covalent bonds of water.[3]

On the other hand, hexane (C_6H_{14}) is an organic nonpolar solvent. It will solvate nonpolar species.

[1] http://www.chemteam.info/Bonding/Electroneg-Bond-Polarity.html
[2] https://chem.libretexts.org/Courses/Oregon_Institute_of_Technology/OIT%3A_CHE_202_-_General_Chemistry_II/Unit_6%3A_Molecular_Polarity/6.1%3A_Electronegativity_and_Polarity
[3] https://www.expii.com/t/polar-and-nonpolar-covalent-bonds-overview-examples-8374

Since water is polar and hexane is nonpolar, they will not mix. When combined, two distinct, colourless layers are formed with water on the bottom because it is the denser liquid. If coloured substances are added to test tubes containing water and hexane, the polarity of the added substance can be determined based on solubility. If the coloured substance is nonpolar, it will dissolve in the hexane layer, thus changing the colour of this layer. If the substance is polar, it will dissolve in water changing its colour.

The relative electronegativity of elemental diatomic halogens ($Cl_{2(aq)}$, $Br_{2(aq)}$, and $I_{2(aq)}$) will be examined by combining each with a metal halide in solution: $NaCl_{(aq)}$ ($Cl^-_{(aq)}$), $NaBr_{(aq)}$ ($Br^-_{(aq)}$), or $NaI_{(aq)}$ ($I^-_{(aq)}$). See the reaction below. The more reactive halogen will displace the less reactive species from their compounds. The results of these displacement (oxidation-reduction) reactions will be used to determine the relative electronegativity of each halogen.

$$Cl_{2(aq)} + NaI_{(aq)} \rightarrow \textit{single displacement reaction?}$$

This lab is qualitative. There are no measurements to be made and no calculations. The data is "colorimetric," which means you will be observing and recording colours of solutions.

Pre-lab Work:

1. Read through this document thoroughly.
2. Prepare your lab notebook as usual.
3. Answer the prelab questions on Moodle.

Materials

- 9 x Test Tubes with rubber stoppers
- Test Tube rack
- Stainless steel micro lab spoon
- Plastic transfer pipettes

Chemicals

- Chlorine water (0.1%)
- Bromine water (0.1%)
- Iodine water (0.01 M)
- Sodium chloride
- Sodium bromide
- Sodium iodide
- Hexane
- Distilled Water

Protocol:

Part 1: Solubility of halide salts in water

1. Do Part 1 at your lab station.
2. Identify 3 tests tubes: Cl^-, Br^-, I^-.
3. Add a small scoop of $NaCl_{(s)}$ to the appropriately labelled test tube (ex. Cl^-).

4. Add approximately 5 mL of distilled water, cap, and agitate the test tube.
5. Write down observations **before and after** each possible reaction.
6. Repeat steps 4 and 5 for each of the other halide salts: NaBr*(s)* and NaI*(s)*.
7. These halide solutions will be used in Part 3.

Part 2: Solubility of elemental diatomic halogens in water and hexane

1. Write down observations from the lab technician's demonstration of the test tubes containing the following combinations.
    a. Hexane and water.
    b. Chlorine, or Bromine, or Iodine with water and hexane. See Figure 1.
2. Use these observations as a reference for Part 3.

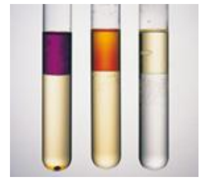

Figure 1: Test tubes left to right - I_2, Br_2, and Cl_2 in hexane (top layer) and water (bottom layer).

Part 3: Reactivity of halide solutions with halogen solutions

- **Note:** Part 3 tests the reactivity of halide solutions with halogen solutions (oxidation-reduction displacement reactions). Hexane is added to show if a displacement reaction occurs - or not - by observing the colour of the hexane layer as shown in Figure 1.

1. Label 6 test tubes as follows:
    - Cl_2 - I^-
    - Cl_2 - Br^-
    - Br_2 - I^-
    - Br_2 - Cl^-
    - I_2 - Cl^-
    - I_2 - Br^-

2. Using the test tubes labelled Cl_2-I^- and Cl_2-Br^-:
    a. Add 20 drops of chlorine water and 20 drops of hexane to each test tube. Cap and mix.
    b. To the test tube labelled Cl_2-I^-, add 15 drops of NaI solution (i.e. I^-) and mix well.
    c. To the test tube labelled Cl_2-Br^-, add 15 drops of NaBr solution and mix well.
    d. Compare to the reference tubes as shown in Part 2 and record observations.

3. Using the set of test tubes labelled Br_2-I^- and Br_2-Cl^-:
    a. Add 20 drops of bromine water and 20 drops of hexane to each test tube. Cap and mix.
    b. To the test tube labelled Br_2-I^-, add 15 drops of NaI solution and mix well.
    c. To the test tube labelled Br_2-Cl^-, add 15 drops of NaCl solution and mix well.
    d. Compare to the reference tubes as shown in Part 2 and record observations.

4. In the last set of tests tube labelled I_2-Cl^- and I_2-Br^-:
    a. Add 20 drops of iodine water and 20 drops of hexane to each test tube. Cap and mix.
    b. To the test tube labelled I_2-Cl^-, add 15 drops of NaCl solution and mixed well.
    c. To the test tube labelled I_2-Br^-, add 15 drops of NaBr solution and mix well.
    d. Compare to the reference tubes as shown in Part 2 and record observations.

Follow-Up Work (all individually):

- Complete the associated questions on Moodle.
- Your submission will be considered complete when you also have uploaded a PDF of your notebook pages.

Due date:

- On Moodle by the due date and time indicated by your instructor.