**Lab 5 - Testing for Cations and Anions – Chm100 Lab**

**Objectives**

* Identify solutions as being electrolytes or nonelectrolytes.
* Determine the presence of a cation or anion in a solution by performing chemical tests.
* Identify the cation and anion present in an unknown solution.
* Write the correct formula of the salt contained in your unknown solution.

**Text References**: Review the following sections from the text before performing this experiment. (Timberlake: Chemistry – An Introduction to General, Organic and Biological Chemistry, 12th ed., Chapters 6.1 – 6.4 and 9.2 .

**Discussion**

Compounds can be classified as being either ionic or covalent.

Covalent compounds are formed when two nonmetals form a bond by sharing their valence electrons.

Ionic compounds are formed when a metal and a nonmetal bond together. In an ionic compound, electrons are transferred from the metal to the nonmetal. Thus, the metal loses electrons and the nonmetal gains electrons. Elements lose and gain electrons such that each ion formed has an octet in its outermost principal quantum.

When the metal loses electrons, it now has more protons than electrons, and thus the ion that is formed is positively charged. This positively charged ion is called a cation.

When a nonmetals gains electrons, it has more electrons than protons, and thus the ion produced has a negative charge. Negatively charged ions are called anions.

Elements lose and gain electrons such that each ion formed has an octet in its outermost principal quantum.

Since opposite charges attract, cations and anions attract each other, and form a bond called an ionic bond. Compounds that contain ionic bonds are called ionic compounds. In an ionic compound, the number of positive charges must equal the number of negative charges. The compound is thus electronically neutral.

Metals: Lose electrons Form cations Positive charge

Nonmetals: Gain electrons Form anions Negative charge

Cation + Anion = Ionic Compound

When ionic compounds are dissolved in water, they dissociate into cations and anions, and the solution thus contains charged particles. Since the solution contains charged particles, it is able to conduct electricity. Cations and anions in solution, able to conduct electricity, are called electrolytes. Thus, the solutions of ionic compounds contain electrolytes. The solutions of acids are also electrolytes.

1. **Electrolytes and Nonelectrolytes**.

This part of the experiment will be an Instructor Demonstration. A conductivity apparatus that detects electrolytes will be set up. This apparatus consists of electrodes connected to a light bulb. Solutions of electrolytes conduct electricity so are able to cause the light bulb to light. Solutions of strong electrolytes will allow the 60 watt bulb to light, solutions of weak electrolytes will allow *only* the 10 watt bulb to light, and solutions of non-electrolytes will not allow either bulb to light.

The following solutions will be tested:

* HCl, hydrochloric acid.
* NaOH, sodium hydroxide
* NaCl, sodium chloride
* NaHCO3, sodium bicarbonate
* C12H22O11, table sugar, sucrose
* 5% CH3COOH, vinegar, (acid)
* CH3COOH,Glacial acetic acid, (acid)
* H2O, deionized pure water
* C2H5OH, ethanol
* sat. Mg(OH)2, milk of magnesia.

Your instructor may also include some other solutions like

* tap water
* sat. Ca(OH)2, calcium hydroxide

You will classify each solution as being a strong electrolyte, a weak electrolyte or a non-electrolyte. You will also predict whether the bonds in the compound are ionic, covalent, or polar covalent (in acids).

1. **Tests for Cations.**

You will test cations in two ways: 1) by performing flame tests; 2) by performing chemical reactions. You will know that a chemical reaction has taken place when you observe one or more of the following:

1. Change in color.
2. Evolution of a gas.
3. Formation of a precipitate (solid).
4. Change in heat.

You will test known cation and anion solutions. Also, you’ll test a solution of an unknown anion and cation. Your unknown solution will contain one of the cations you have tested.

In this experiment you will test for the following cations contained in the indicated solutions.

**Cation** **Known** **Solution**

Sodium (Na1+) 1.0 M NaCl

Lithium (Li1+) 1.0 M LiCl

Calcium (Ca2+) 1.0 M CaCl2

Iron (Fe3+) 0.1M FeCl3

Ammonium (NH41+) 0.1M NH4Cl

Flame tests will be performed only on the solutions containing Na1+, Li1+, and Ca2+.

Chemical reactions will be performed on solutions containing Ca2+, Fe3+, and NH41+.

1. **Tests for Anions.**

You will test for anions by performing chemical reactions. You will know that a chemical reaction has taken place when you observe one of the changes described in part **B** above.

You will be testing for the following anions. Your unknown solution will contain one of these anions.

**Anion Known Solution**

Chloride (Cl1-) 0.1M NaCl

Phosphate (PO43-) 0.1M Na3PO4

Sulfate (SO42-) 0.1M Na2SO4

Carbonate (CO32-) 0.1M Na2CO3

* The chloride ion (Cl1-) reacts with silver nitrate (AgNO3) to form a white precipitate (silver chloride, AgCl) that is insoluble in nitric acid (HNO3).
* The phosphate ion (PO43-) reacts with ammonium molybdate ((NH4)6Mo7O24·4H2O) to form ammonium phosphomolybdate ((NH4)3PO4⋅12 MoO3), a yellow precipitate.
* The sulfate ion (SO42-) reacts with barium chloride (BaCl2) to form a white precipitate (barium sulfate, BaSO4) that is insoluble in nitric acid (HNO3).
* The carbonate ion reacts with hydrochloric acid (HCl), to form carbon dioxide (CO2) gas, which is evolved.

1. **Testing your unknown, and writing the formula of your unknown salt.**

You will choose an unknown solution from the hood. **You will use the same unknown to test for the cation and anion.** You will perform the same tests on your unknown sample as you did on the known samples. (Make sure you do not add the Known Solution to your test for the unknown, just add the reagents.) You will see a result that matches one of the results you obtained with the tests for the cations. You will see a test that matches the results you saw with one of the anions. You will then be able to identify the cation and anion present in your unknown compound.

You will then balance the charges on the cation and anion and write the formula of your unknown compound.

**Lab Information.**

Time: One lab period.

Directions:

* Please bring all the reagents from the hood to your work area in carefully labeled test tubes.
* Please dispose of your solutions in the containers in the hood at the back of the lab.
* If you spill anything, please clean it immediately with plenty of water, using a sponge.
* Keep the report sheets with the matching procedures.
* Make sure your test tubes are clean and rinsed with DI water before you use them.

**Experimental Procedures**

1. Instructor Demonstration.

Your Instructor will use the conductivity apparatus to test several solutions. You will note whether the solution is a strong electrolyte, weak electrolyte, or non-electrolyte.

If the solution is able to cause the 60 watt bulb to light, it is a strong electrolyte.

If the solution is able to cause *only* the 10 watt bulb to light, it is a weak electrolyte.

If the solution cannot cause any light bulb to light, it is a non-electrolyte.

Enter your results in the appropriate places on the report sheet.

1. Testing for Cations.

You will be using only 1 – 2 mL of each solution, so please bring only small amounts of each solution to your work space.

1. Flame Tests:

Four small test tubes, wooden splints (from the hood), known solutions of: NaCl, LiCl, and CaCl2; also bring your unknown salt solution (from the hood), Bunsen burner, beaker containing water.

1. Chemical Reactions:

Spot plate and test solutions calcium chloride (CaCl2), ammonium oxalate

((NH4)2C2O4), iron chloride (FeCl3), potassium thiocyanate (KSCN), ammonium chloride (NH4Cl), and 6M NaOH can be obtained from the hood. Use the unknown solution that you obtained before in this part of the experiment as well. Bring all the solutions from the hood to your work space in carefully labeled test tubes.

**PLEASE DISPOSE OFF ANY UNUSED SOLUTIONS IN THE WASTE CONTAINERS AT THE BACK OF THE LAB. DO NOT PUT THEM BACK INTO THE REAGENT BOTTLES.**

**B1. FLAME TESTS FOR Na1+, Li1+, Ca2+**

Unknown (Sample number \_\_\_\_\_\_\_)

Materials: 1.0 M NaCl, 1.0 M LiCl, 1.0 M CaCl2, Unknown solution, Bunsen burner, wood splints

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| **Section** | **Step** | **Procedure** |
| B | 1 | Make sure your test tubes are clean and rinsed with DI water before using them. Obtain four **small** test tubes and label them as Na1+, Li1+, Ca2+ and unknown respectively. |
| B | 2 | Add ~ 1 – 2 mL of NaCl solution into the test tube labeled Na1+. |
| B | 3 | Add ~ 1 – 2 mL of LiCl solution into the test tube labeled Li1+. |
| B | 4 | Add ~ 1 – 2 mL of CaCl2 solution into the test tube labeled Ca2+. |
| B | 5 | Add ~ 1 – 2 mL of unknown solution into the test tube labeled unknown. Record the sample number of your unknown sample. |
| B | 6 | Dip a wooden splint into each of the solutions above, and let each splint soak in each solution for 1 – 2 minutes. |
| B | 7 | Light your Bunsen burner, and adjust the flame so that you have a “roaring” blue flame. |
| B | 8 | Momentarily place the end of the splint with the liquid on it in the hot part of a Bunsen burner flame above the light-blue inner cone . If you hold the splint in the flame for more than one or two seconds, the splint may catch fire. If the splint catches fire, immediately extinguish the flame by plunging the splint into your beaker of water. |
| B | 9 | Record the color of the flame produced by each solution. |
| B | 10 | Compare the results obtained from testing the known solutions with the results obtained by testing the unknown solution. Elements that are the same, will give you flames of the same color. |

**B2. CHEMICAL REACTIONS: Tests for Ca2+, NH41+, Fe3+**

Materials: Spot plate, CaCl2 solution, Unknown solution, ammonium oxalate solution.

***Test for Ca2+***

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| **Section** | **Step** | **Procedure** |
| B | 11 | Obtain a spot plate from the storage bin, and place 20 drops of CaCl2 solution into one of the wells of the spot plate. |
| B | 12 | Place 20 drops of your unknown solution into an adjacent well of the spot plate. **Use the same unknown solution that you used in Part B1 of this experiment.** |
| B | 13 | Add 8 drops of ammonium oxalate, (NH4)2C2O4, solution to each. |
| B | 14 | Look for a cloudy white precipitate. A white precipitate, or white turbidity, indicates the presence of Ca2+ |
| B | 15 | Record the results seen for your known and unknown. |

***Test for NH41+***

Materials: Ammonium chloride (NH4Cl) solution, Unknown solution, sodium hydroxide (NaOH) solution, red litmus paper.

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| **Section** | **Step** | **Procedure** |
| B | 16 | Place 20 drops of NH4Cl solution into an empty well of the spot plate. |
| B | 17 | Place 20 drops of your unknown solution into another well of your spot plate. |
| B | 18 | Add 8 drops of 6M NaOH to each solution. Wipe up any liquid outside of the well with a piece of paper towel. **Caution: 6M NaOH is caustic.** |
| B | 19 | Moisten a strip of red litmus paper with D.I. water and place it across the top each well containing your solutions. *Do not* dip the paper into the well. |
| B | 20 | Red litmus paper will turn blue if the ammonium ion is present. |
| B | 21 | Record the results. |

***Test for Fe3+***

Materials: Iron (III) chloride (FeCl3) solution, Unknown solution, nitric acid (HNO3), potassium thiocyanate (KSCN).

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| **Section** | **Step** | **Procedure** |
| B | 22 | Place 20 drops of FeCl3 solution into an empty well of the spot plate. |
| B | 23 | Place 20 drops of unknown solution into another well of your spot plate. |
| B | 24 | Add 3 drops of 6M HNO3 to each solution. |
| B | 25 | Add 3 drops of potassium thiocyanate (KSCN) to each solution. |
| B | 26 | A deep red color shows that Fe3+ is present. |
| B | 27 | Record your results. |

**C. Tests for Anions.**

Materials: Spot plate, test tubes, stirring rod, hot water bath and the following solutions which are available in the hood: 0.1M NaCl, 0.1M AgNO3, 3M HCl, 6M HNO3, 0.1M Na2SO4, 0.1M BaCl2, 0.1M Na3PO4, (NH4)6Mo7O24 ·4H2O (ammonium molybdate), 0.1M Na2CO3.

***Test for chloride: Cl 1-***

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| **Section** | **Step** | **Procedure** |
| C | 1 | Place 20 drops of NaCl solution into an empty well of your spot plate. |
| C | 2 | Place 20 drops of your unknown into another empty well of your spot plate. |
| C | 3 | Add 10 drops of AgNO3 solution to each well. **CAUTION! AgNO3 stains the skin. If you get some solution on your skin, please rinse immediately with plenty of cold water.** |
| C | 4 | Add 5 drops of 6M HNO3 to each well. |
| C | 5 | Stir well with a stirring rod or wooden splint. |
| C | 6 | A white precipitate indicates the presence of chloride. |
| C | 7 | Record your results. |

***Test for sulfate: SO4 2-***

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| **Section** | **Step** | **Procedure** |
| C | 8 | Place 20 drops of Na2SO4 solution into an empty well of your spot plate. |
| C | 9 | Place 20 drops of your unknown solution into another empty well of your spot plate. |
| C | 10 | Add 10 drops of BaCl2 solution to each. |
| C | 11 | Add 2 drops of 6M HNO3 to each. |
| C | 12 | A white precipitate indicates the presence of sulfate |
| C | 13 | Record your results. |

***Test for Phosphate: PO43-***

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| **Section** | **Step** | **Procedure** |
| C | 14 | Place 20 drops of Na3PO4 solution in a **clean medium** test tube. |
| C | 15 | Place 20 drops of your unknown into another test tube. |
| C | 16 | Add 5 drops of 6M HNO3 to each test tube. |
| C | 17 | Add 7 drops of ammonium molybdate solution to each. |
| C | 18 | Warm the test tubes in a hot water bath for up to 5 minutes. |
| C | 19 | The presence of a yellow precipitate indicates the presence of phosphate. |
| C | 20 | Record your results. |

***Test for Carbonate: CO32-***

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| Section | Step | Procedure |
| C | 21 | Place 20 drops of Na2CO3 solution into an empty well of your spot plate. |
| C | 22 | Place 20 drops of your unknown solution into another empty well of your spot plate. |
| C | 23 | While carefully observing the solution, add 10 drops of 3M HCl to each solution. Watch for the evolution of CO2 gas as you add the HCl. The gas bubbles are formed quickly, and may be overlooked. |
| C | 24 | The presence of bubbles indicates the presence of carbonate. |
| C | 25 | Record your results. |

**D. Writing the formula of your unknown salt.**

Your unknown solution was composed of a cation and an anion. From your test results, you should have identified the cation present and the anion present. For example, if the cation tests for Ca2+ and your unknown matched, you can conclude that your unknown contains Ca2+. Similarly, you can identify the anion present in your unknown solution.

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| **Section** | **Step** | **Procedure** |
| D | 1 | Write the symbols and names of the cation and anion that were present in your unknown |
| D | 2 | Write the name of your unknown. |
| D | 3 | Use the ionic charges of the cation and anion to write the correct formula of your unknown. |

**Pre-Lab Questions Lab 5: Testing for Cations and Anions**

Date\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Section \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Partner \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Instructor \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. What are four things that indicate that a chemical reaction has taken place?
2. Will you use the same unknown throughout the experiment, or will you get a fresh unknown for each part of the experiment?
3. What tests would you use to confirm the presence of Na3PO4?
4. An unknown solution fails to light a light bulb in a conductivity apparatus. What possible conclusions can you draw from this data?

**Report Sheet – Lab 5: Cations and Anions**

Date\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Section \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Partner \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Instructor \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. **Electrolytes and Nonelectrolytes**

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| --- | --- | --- | --- | --- |
| Solution | Strong Electrolyte | Weak Electrolyte | Non Electrolyte | Type of substance (Ionic, covalent, acid). |
| Hydrochloric acid  0.1 M HCl |  |  |  |  |
| Sodium hydroxide  0.1 M NaOH |  |  |  |  |
| Sodium chloride  0.1 M NaCl |  |  |  |  |
| Sodium bicarbonate  0.1 M NaHCO3 |  |  |  |  |
| Table Sugar  C12H22O11 |  |  |  |  |
| Vinegar  5% Acetic Acid |  |  |  |  |
| Glacial Acetic acid  CH3COOH |  |  |  |  |
| Pure D.I. water |  |  |  |  |
| Ethanol  C2H5OH |  |  |  |  |
| Milk of Magnesia  Sat. Mg(OH)2 |  |  |  |  |
| Tap water |  |  |  |  |
| Water and glacial acetic acid |  |  |  |  |
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|  |  |  |  |  |

1. **Tests for Cations.**

**Unknown Solution Number\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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| --- | --- | --- | --- | --- | --- | --- | --- |
| ***Procedure*** | | **Cation Tested** | | **Observations for known** | | **Observations for unknown** | |
| ***Flame Tests*** | | Na1+ | |  | |  | |
| Li1+ | |  | |  | |
| Ca2+ | |  | |  | |
| ***Chemical Tests*** | **Cation Tested** | | **Test Reagent(s)** | | **Observations for known** | | **Observations for unknown** |
| **Oxalate Test** | Ca2+ | |  | |  | |  |
| **Ammonium Test** | NH41+ | |  | |  | |  |
| **Iron Test** | Fe3+ | |  | |  | |  |

Identification of the cation in the unknown solution

From your test results, what cation is present in your unknown solution? \_\_\_\_\_\_\_\_\_\_\_\_\_

1. **Tests for Anions.**

**Unknown Solution Number \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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| --- | --- | --- | --- | --- |
| **Procedure** | **Anion tested** | **Test Reagent(s)** | **Observations for known** | **Observations for unknown** |
| **Chloride test** | Cl1- |  |  |  |
| **Sulfate test** | SO42- |  |  |  |
| **Phosphate test** | PO43- |  |  |  |
| **Carbonate test** | CO32- |  |  |  |

Identification of the anion in the unknown solution

From your test results, what anion is present in your unknown? \_\_\_\_\_\_\_\_\_\_\_\_\_

1. **Writing the formula of your unknown.**

Unknown solution sample number \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Formula of cation \_\_\_\_\_\_\_\_ Name\_\_\_\_\_\_\_\_\_\_\_\_

Formula of anion \_\_\_\_\_\_\_\_\_ Name\_\_\_\_\_\_\_\_\_\_\_\_

Formula of unknown dissolved salt \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Name of unknown salt \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Post Lab Questions.**

1. Which type of ions can you identify by using flame tests – cations or anions?
2. An unknown solution gives a deep orange flame and a precipitate with both oxalic acid, and another with barium chloride that is insoluble in nitric acid. Write the correct formula of the substance in the solution.
3. What cation cannot be identified by using a flame test?
4. An unknown substance produced gas (bubbles) when treated with acid. Name one of the ions present in the substance.