

## EXPERIMENT # 1 ELECTROLYTES AND NON-ELECTROLYTES

### Purpose:

Study the behavior of electrolytes and distinguish between weak, strong and non-electrolyte substances.

### Principles:

Many substances have the ability to conduct an electric current because they contain electrically charged particles. In an electric field, charged particles are attracted and move toward oppositely charged plates, called electrodes. In this manner, a closed electrical circuit is created. Metallic conductors conduct electricity by a movement of electrons. Other substances conduct electricity by the movement of ions. Substances, which conduct electricity by ionic movement, are called **electrolytes**. Substances, which are not able to conduct electricity by ionic movement, are called **non-electrolytes**.

For a particular substance to be an electrolyte, it must meet two conditions:

- The substance must contain ions.
- The ions must be mobile (free to move).

It follows that any substance, which contains mobile ions, is an electrolyte and will conduct electricity by ionic movement.

If an electric current passes through an electrolyte:

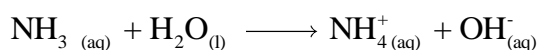
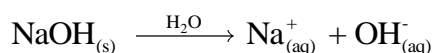
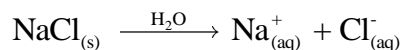
- The negative ions move toward the positively charged electrode called **ANODE (+)**. Hence, negative ions are called **ANIONS (-)**.
- The positive ions move toward the negatively charged electrode called **CATHODE (-)**. Hence, positive ions are called **CATIONS (+)**.

Solid substances (both molecular and ionic) are non-electrolytes, either because they do not contain ions at all, or because although the ions are present, they are not mobile.

### **For example:**

- Solid sucrose,  $C_{12}H_{22}O_{11(s)}$ , is a non-electrolyte because it does not contain ions. (Sucrose is a molecular substance made up of molecules).
- Solid sodium chloride (table salt),  $Na^+Cl^-(s)$  is also a non-electrolyte. Even though the crystal structure of table salt is made up of ions, these ions are not mobile in the solid phase.

In order for a substance to become an electrolyte, it must be capable of **dissociating** or **ionizing** into mobile ions. **Dissociation** occurs, when ions already present in the substance become separated from one another (by addition of water) and produce mobile ions. **Ionization** occurs when covalent molecules react with water to produce ions. Some examples of electrolytes are ionic compounds such as salts, basic hydroxides and covalent acids such as hydrochloric acid.



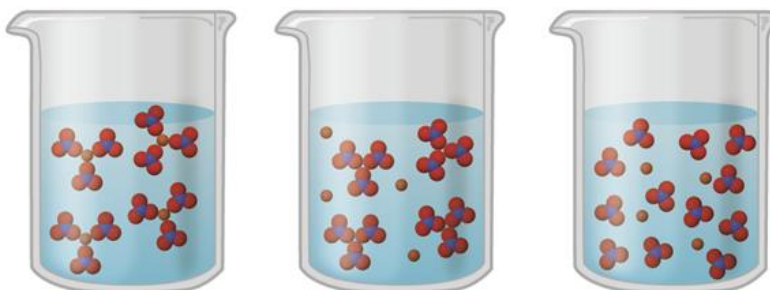
Several factors affect and determine the degree to which a given electrolyte solution conducts electrical current. The two most important factors are: (1) the amount (concentration) of ions present in solution, and (2) the type of the solvent. The concentration of the ions present in solution is affected by: (1) the solubility of the ionic compound or acid, and (2) the degree of dissociation or ionization.

### Summary:

- All solid substances (molecular and ionic) are **non-electrolytes**, since they either do not contain ions or their ions are not free to move (mobile).
- All soluble ionic compounds dissolved in water are **strong electrolytes**, because they are completely dissociated in aqueous solutions and as a result contain many ions.

Molecular substances dissolved in water may be:

- **non-electrolytes**, if they do not dissociate at all in aqueous solutions (e.g.  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ )
- **weak electrolytes**, if they undergo partial dissociation in aqueous solution (e.g.  $\text{HC}_2\text{H}_3\text{O}_2$ )
- **strong electrolytes**, if they undergo complete dissociation in aqueous solution (e.g.  $\text{HCl}$ )



The table on the next page lists various substances and their general classification as strong electrolyte, weak electrolyte or non-electrolyte.

**STRONG ELECTROLYTES**

| <b><u>Strong Acids</u></b>              | <b><u>Strong Bases</u></b>               | <b><u>Salts</u></b>                                 |
|---|--|---|
| <u>Soluble</u>                          | <u>Soluble</u>                           | <u>Soluble</u>                                      |
| H <sub>2</sub> SO <sub>4</sub> sulfuric | NaOH sodium hydroxide                    | KCl, NaCl   |
| HNO <sub>3</sub> nitric                 | KOH potassium hydroxide                  | Na <sub>2</sub> SO <sub>4</sub> , BaCl <sub>2</sub> |
| HCl hydrochloric                        | <u>Poorly Soluble</u>                    | CaCl <sub>2</sub>                                   |
| HBr hydrobromic                         | Ca(OH) <sub>2</sub> calcium<br>hydroxide | NaBr, KNO <sub>3</sub>                              |

**WEAK ELECTROLYTES**

| <b><u>Weak Acids</u></b>                           | <b><u>Weak Bases</u></b> | <b><u>Salts</u></b>             |
|--|--------------------------|---------------------------------|
| <u>Soluble</u>                                     | <u>Soluble</u>           | <u>Soluble</u>                  |
| HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>      | NH <sub>3</sub> (aq)     | SnCl <sub>2</sub>               |
| HNO <sub>2</sub>                                   |                          | HgCl <sub>2</sub>               |
| <u>Poorly Soluble</u>                              | <u>Poorly Soluble</u>    | <u>Poorly Soluble</u>           |
| H <sub>2</sub> CO <sub>3</sub> carbonic (unstable) | Pb(OH) <sub>2</sub>      | Hg <sub>2</sub> Cl <sub>2</sub> |
| H <sub>2</sub> S hydrogen sulfide                  | Zn(OH) <sub>2</sub>      | BaSO <sub>4</sub>               |
| H <sub>3</sub> BO <sub>3</sub> boric               |                          |                                 |

**NON-ELECTROLYTES**

|   |             |                                   |         |
|---|-------------|-----------------------------------|---------|
| C <sub>12</sub> H <sub>22</sub> O <sub>11</sub> | table sugar | C <sub>6</sub> H <sub>6</sub>     | benzene |
| C <sub>2</sub> H <sub>5</sub> OH                | ethanol     | C <sub>8</sub> H <sub>18</sub>    | octane  |
| CH <sub>3</sub> OH                              | methanol    | CH <sub>3</sub> COCH <sub>3</sub> | acetone |

**Procedure:**A) THE CONDUCTIVITY APPARATUS

The conductivity apparatus is a conductivity indicator (See Figure 1). It consists of a LIGHT EMITTING DIODE (LED) connected to two copper probes (electrodes).

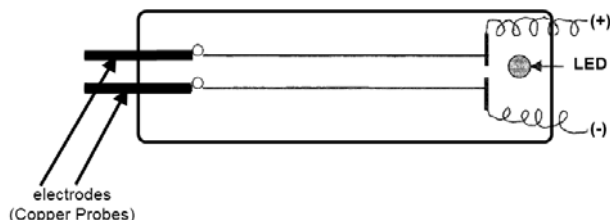


Figure 1: Conductivity Apparatus

**Setting up the conductivity apparatus**

The conductivity apparatus should be treated with care and concern. A 9-volt D.C. power supply is required for operation, which is available at the bench in the form of a raised electrical panel. The two posts of the conductivity apparatus are connected to the low power voltage power supply with two cords.

Touching the tips of the two copper electrodes to a coin or a piece of metal should test the circuit. If the LED glows red and blinks rapidly, the Conductivity Apparatus is working properly. If not, bring this to the attention of your laboratory instructor.

The response of the LED when both copper electrodes are directly in contact with a solid material or when immersed in a liquid will indicate the following types of conductivity:

**STRONG CONDUCTOR** ..... LED glows red and blinks rapidly ..... (+)

**WEAK CONDUCTOR** ..... LED glows a dull red glow (no blinking) ..... (+/-)

**NON CONDUCTOR** ..... LED does not light up ..... (-)

Using the conductivity apparatus

To test liquids, clean and dry spot plate (a plastic plate with 12 round depressions). Fill the depressions in the spot plate with several drops of the liquids to be tested. There should be enough liquid in the depression so that the conductivity apparatus electrodes are immersed in the liquid. Record in your notebook the name of the liquid you are testing.

In order to obtain consistent observations, each test should be performed in the same manner:

- The position of the conductivity indicator should be perfectly vertical (perpendicular to the spot plate).
- The green plastic plate that holds the conductivity indicator should be placed at the edge of the depression whose contents are being tested. This will ensure that the electrodes are always immersed in the liquid at the same depth.
- The same volume of liquid should be tested each time. In this experiment, each test will be performed with the same number of drops of liquid.

Before testing, you must ensure that the electrodes are clean. Immersing the electrodes in deionized water does this. It is convenient to use a 250 mL beaker with deionized water for this purpose.

**The electrodes are clean if the LED does not light up when the electrodes are immersed in D.I. water.**

If the LED does light up, discard the D.I. water, refill with fresh D.I. water and test again until the LED does not light up. Gently blot the excess water from the electrodes with tissue. Record in your notebook the name of the liquid you are testing. Perform the test and record your observation (+, +/-, or -).

Repeat the cleaning procedure every time you proceed to another test. It is convenient to keep the beaker with D.I. water handy since it is needed every time another liquid is tested. The D.I. water should be changed as needed.

Some tests (not all) require that the electrodes be dry. Drying is done by gently blotting the electrodes with tissue. Pay attention not to damage the electrodes. Since corrosion may cause a short in the circuit, the section between the contacts of the electrodes on the circuit board must be kept free of corrosion.

Rinsing and blotting the electrodes dry after each use may prevent corrosion.

B) GENERAL INSTRUCTIONS

There are several stations set-up in the lab corresponding to the different parts of the experiment. Most of the stations are in duplicate or triplicate. You may start working at any station and may go from station to station, in any order, depending on availability. As you move from station to station:

**DO:**

- take with you your spot plate (rinse and dry between tests)
- take with you a 250 mL beaker with D.I. water
- take with you a stirring rod
- check if the electrodes are clean before testing (D.I. water test)
- rinse and dry the electrodes after testing

**DO NOT:**

- remove reagents from stations
- leave reagent bottles open
- switch droppers from dropper bottles
- remove or disconnect the conductivity indicator

Observe and record the **CONDUCTANCE** of each substance using the following abbreviations:

**+** → **strong conductor** → corresponds to a strong electrolyte → **(SE)**

**+/-** → **weak conductor** → corresponds to a weak electrolyte → **(WE)**

**-** → **non-conductor** → corresponds to a non- electrolyte → **(NE)**

Recall that:

- If the solute is a **WEAK** or a **NON-ELECTROLYTE**, the predominant solute particles are **molecules** and the formula of the solute is written in **MOLECULAR FORM (AB)**
- If the solute is a **STRONG ELECTROLYTE**, the predominant solute particles are **ions** and the formula of the solute is written in **IONIC FORM (A<sup>+</sup> and B<sup>-</sup>)**

**PART I: Pure Substances**

For the tests that follow the electrodes and the spot plate must be dry! Test the following substances:

1. Pure (glacial) acetic acid, 100% pure,  $\text{HC}_2\text{H}_3\text{O}_2(l)$ .

**CAUTION: DO NOT INHALE THE GLACIAL ACETIC ACID**

2. Pure ethanol (absolute ethyl alcohol),  $\text{C}_2\text{H}_5\text{OH}(l)$ .
3. Deionized water

## **PART II: Aqueous Solutions**

For the tests that follow the electrodes and the spot plate must be well rinsed between tests with deionized water. They do not need to be dry.

1. Tap water
2. 95% Ethanol
3. Aqueous ammonia,  $\text{NH}_{3(\text{aq})}$  1M, or  $\text{NH}_4\text{OH}_{(\text{aq})}$  1M
4. Nitric acid,  $\text{HNO}_{3(\text{aq})}$ , 1M
5. Sucrose,  $\text{C}_{12}\text{H}_{22}\text{O}_{11(\text{aq})}$ , 1M
6. Sodium chloride,  $\text{NaCl}_{(\text{aq})}$ , 1M
7. Urea,  $\text{NH}_2\text{CONH}_{2(\text{aq})}$ , 1M
8. Sodium sulfate,  $\text{Na}_2\text{SO}_{4(\text{aq})}$ , 1M
9. Ammonium chloride,  $\text{NH}_4\text{Cl}_{(\text{aq})}$ , 1M
10. Acetic acid,  $\text{HC}_2\text{H}_3\text{O}_{2(\text{aq})}$ , 1M

## **PART III: The Effect of Concentration on Conductance**

Solution 1: Test 30 drops of hydrochloric acid,  $\text{HCl}_{(\text{aq})}$ , 1M. Leave Solution 1 in the spot plate.

Solution 2: Place 3 drops of  $\text{HCl}_{(\text{aq})}$ , 1M in a second depression. Add 27 drops of deionized water from the dropper bottle mix well but gently with your stirring rod. Test the solution and record the conductance. Leave Solution 2 in the spot plate.

Rinse the stirring rod with plenty of tap water and then with D.I. water. Make sure no acid is left on the stirring rod by testing it with blue litmus paper.

- If the litmus paper does not change color, the stirring rod is free of hydrochloric acid.
- If the litmus paper turns red, more washing is required.

Solution 3: Place 3 drops of Solution 2 in a third depression. Add 27 drops of deionized water from the dropper bottle and repeat the steps outlined above for Solution 2.

Solutions 4, 5 & 6: are prepared and tested in the same manner (See Report Form).

**CAUTION: FOR CORRECT OBSERVATIONS, BOTH THE STIRRING ROD AND THE DROPPER MUST BE VERY WELL RINSED BETWEEN TESTS (TEST WITH LITMUS TEST).**

**EXPERIMENT 1****REPORT FORM****Parts I and II:**

Complete the table below by listing the conductivity of each substance tested with the meter and indicating the chemical species that give rise to your observation (write formula for ions, molecule or both).

| <b>Substance</b>     | <b><u>Conductivity</u></b> | <b><u>Chemical Formula of Species Present</u></b> |              |
|----------------------|----------------------------|---|--------------|
|                      |                            | <b>major</b>                                      | <b>minor</b> |
| Glacial acetic acid  | _____                      | _____   | _____        |
| Ethanol              | _____                      | _____   | _____        |
| Distilled water      | _____                      | _____   | _____        |
| Tap water            | _____                      | _____   | _____        |
| 95% Ethanol          | _____                      | _____   | _____        |
| Ammonia, 1 M         | _____                      | _____   | _____        |
| Nitric acid, 1 M     | _____                      | _____   | _____        |
| Sucrose, 1 M         | _____                      | _____   | _____        |
| Sodium chloride, 1 M | _____                      | _____   | _____        |
| Acetic acid, 1 M     | _____                      | _____   | _____        |



**Parts III:**

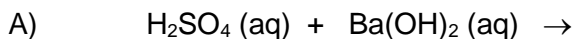
Complete the table below:

| <b>Volumes Used</b>                   | <b>Solution</b> | <b>Concentration<br/>(Show calculation)</b> | <b>Conductivity</b> |
|---------------------------------------|-----------------|---|---------------------|
| 30 drops HCl (1M)                     | 1               |   |                     |
| 3 drops soln 1 +<br>27 drops DI water | 2               |   |                     |
| 3 drops soln 2 +<br>27 drops DI water | 3               |   |                     |
| 3 drops soln 3 +<br>27 drops DI water | 4               |   |                     |
| 3 drops soln 4 +<br>27 drops DI water | 5               |   |                     |
| 3 drops soln 5 +<br>27 drops DI water | 6               |   |                     |



**Applications of Conductivity Measurements to Chemical Reactions:**

Predict products and write balanced chemical equations for the reactions below. Include state designations for each product formed in your equation. For each reaction, predict your expectations of the conductivity measurement, perform the conductivity measurement before and after the reactions, and explain your conductivity observations in terms of the nature of the various electrolytes present before and after the chemical reactions.



Predictions: \_\_\_\_\_

\_\_\_\_\_

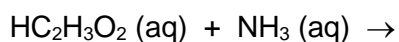
Results of conductivity measurement: \_\_\_\_\_

\_\_\_\_\_

Explanations: \_\_\_\_\_

\_\_\_\_\_

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Predictions: \_\_\_\_\_

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Results of conductivity measurement: \_\_\_\_\_

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Explanations: \_\_\_\_\_

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