CHEM 30A EXPERIMENT 7: CONDUCTIVITY (STRONG ELECTROLYTES, WEAK ELECTROLYTES AND NONELECTROLYTES)

Learning Outcomes

Upon completion of this lab, the student will be able to:

1) Analyze different solutions and classify them as being a strong electrolyte, weak electrolyte, or a non-electrolyte.
2) Measure the conductivity of ionic solutions and determine the effect of molar concentration as well as the number of ions in solution on the conductivity.

Introduction

Based on their ability to conduct electricity, solutions may be classified as being strong, weak, or non-electrolytes. Strong electrolytes dissociate completely into their component ions and are as a result strong conductors. Weak electrolytes only dissociate partially into their component ions and are as a result poor conductors. Non-electrolytes, on the other hand, do not dissociate into ions and as a result do not conduct electricity.

Soluble ionic compounds (such as NaCl), and aqueous solutions of strong acids (such as HNO_3) and strong bases (such as NaOH) are considered to be strong electrolytes. The dissociation equations for these strong electrolytes are shown below:

$$NaCl_{(aq)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

$$HNO_{3(aq)} \rightarrow H^{+}_{(aq)} + NO_3^{-}{}_{(aq)}$$

$$NaOH_{(aq)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$$

In each of the above cases, the arrow pointing in one direction implies that every molecule of the substance on the left dissociates into its respective ions. For instance, one mole of $NaCl_{(aq)}$ would dissociate into one mole of $Na^{+}_{(aq)}$ and one mole of $Cl^{-}_{(aq)}$.

Weak acids (such as HF) and weak bases (such as NH_3 or NH_4OH) are considered to be weak electrolytes. The dissociation equations for these weak electrolytes are shown below:

$$HF_{(aq)} \rightleftharpoons H^{+}_{(aq)} + F^{-}_{(aq)}$$

$$NH_4OH_{(aq)} \rightleftharpoons NH_4^{+}{}_{(aq)} + OH^{-}_{(aq)}$$

In each of the above cases, the arrow pointing in both directions implies two important points: 1) Not all the molecules of the weak electrolyte dissociate to release their respective ions. In fact, a majority of the weak electrolyte remains as intact molecules. For instance in the case of $HF_{(aq)}$, for every 10,000 molecules of hydrogen fluoride dissolved in water, only ONE dissociates into $H^{+}_{(aq)}$ and $F^{-}_{(aq)}$. 2) The process is reversible. This is because these substances are made of covalent bonds rather than ionic bonds.

Molecular compounds (such as CH_4, CO_2 etc.) are considered to be non-electrolytes.

Since conductivity in aqueous solutions is a property that arises due to the presence of charged species (cations and anions), it is likely that a greater concentration of ions in the solution should result in greater conductivity. This hypothesis can be tested using different concentrations of a particular solution. As the molar concentration of the solution increases, the conductivity should also increase. An extension of this hypothesis is that, when one examines the same molar concentration of different solutions, the solution that generates the greatest concentration of dissolved ions will have the greatest conductivity.

Please check out the video at this link for a demonstration of conductivity:
https://www.youtube.com/watch?v=1XWnovm6JLs

Experimental Design

Conductivity of various solutions will be measured using a conductivity probe. The value of the conductivity is given in units of μS/cm (micro Siemens). A larger value indicates greater conductivity. In the first part of the experiment, the conductivity of a set of solutions will be measured and the conductivity values will be used to classify the solution as being a strong electrolyte, weak electrolyte, or a non-electrolyte. In the second part of the experiment, the conductivity of different molar concentrations of $NaCl_{(aq)}$, $CaCl_{2(aq)}$, and $AlCl_{3(aq)}$ will be measured to determine the effect of concentration and number of ions in solution on conductivity.

[Note: **Siemens (S),** is a unit of electrical conductance. In the case of direct current (DC), the conductance in siemens is the reciprocal of the resistance in ohms (S = amperes per volts); in the case of alternating current (AC), it is the reciprocal of the impedance in ohms. A former term for the reciprocal of the ohm is the mho (ohm spelled backward). It is disputed whether the siemens was named after the German-born engineer-inventor Sir William Siemens (1823–83) or his brother, the electrical engineer Werner von Siemens (1816–92).]

Reagents and Supplies

From the Lab: Reagents: solutions of sodium chloride, calcium chloride, aluminum chloride, hydrochloric acid, phosphoric acid (H_3PO_4), acetic acid (CH_3COOH), boric acid (H_3BO_3), methanol (CH_3OH), and ethylene glycol ($C_2H_6O_2$). Also obtain deionized water and tap water.

(See posted Material Safety Data Sheets)

From the Stockroom: Vernier kit with a conductivity probe, two-50 mL beakers

From your instructor: laptop computer

Procedure

1. Obtain a set of reagents including: 0.05 M $NaCl$, 0.05 M $CaCl_2$, 0.05 M $AlCl_3$, 0.05 M HCl, 0.05 M H_3PO_4, 0.05 M CH_3COOH, 0.05 M H_3BO_3, CH_3OH, $C_2H_6O_2$, tap water, deionized water. Each lab bench will have a set of these reagents to share.

2. Obtain a vernier kit containing a conductivity probe from the stockroom. Obtain a laptop computer from the instructor.

3. Connect the vernier kit and the laptop computer according to **"Instructions for Experiment A6" (found at the end of this document).** Make sure that the toggle switch is set to 0 – 20,000 μS/cm.

4. Rinse the conductivity probe with deionized water and wipe dry with a paper towel.

5. Place the probe into the first solution. Record the conductivity of the solution (it may be necessary to wait a few seconds for the value to stabilize).

6. Once again, rinse the conductivity probe with deionized water and wipe dry with a paper towel.

7. Place the probe in the next solution. Repeat the process until the conductivity of all the reagents have been measured.

Data Table

<u>CLASSIFY THE GIVEN SOLUTION AS A STRONG/WEAK/NON ELECTROLYTE</u>

Solution	Conductivity (μS/cm)	Strong Electrolyte, Weak Electrolyte, or Nonelectrolyte
NaCl		
$CaCl_2$		
$AlCl_3$		
HCl		
H_3PO_4 (Phosphoric Acid)		
CH_3COOH (Acetic Acid)		
H_3BO_3 (Boric Acid)		
CH_3OH (Methanol)		
$C_2H_6O_2$ (Ethylene glycol)		
H_2O (tap)		
H_2O (deionized)		

Data Analysis

1. Based on the data list all the strong electrolytes in the given set of reagents.

2. For each strong electrolyte listed above, write the dissociation equation.

3. Based on the data, list all the weak electrolytes in the given set of reagents.

4. For each weak electrolyte listed above, write the dissociation equation.

5. Based on the data, list all the non-electrolytes in the given set of reagents.

Instructions for Experiment A6

Setting up the Vernier equipment and obtaining measurements for Part 1

1. Connect the conductivity probe to the LabPro interface box through channel 1.

2. Connect the LabPro interface box to the power outlet with the power cord. The LabPro will beep to indicate it is ready.

3. Connect the LabPro interface box to the laptop computer using the USB cable. The USB ports are found in the back of the laptop on the right hand side when the screen is facing you.

4. IMPROTANT: Make sure that the conductivity probe is set on the 0-20,000 μS/cm position. If you receive an error message stating that the settings are incorrect/different, it is because the toggle on the probe is in the wrong position. Clamp the probe on to the ring stand as illustrated in the figure above

5. IMPROTANT: Prepare the computer to monitor conductivity by opening the file "Conductivity 1" from the Chemistry 1A desktop folder.

6. To measure the conductivity of a solution: Carefully raise the container with the solution whose conductivity is to be measured up around the Conductivity Probe until the hole near the probe end is completely submerged in the solution being tested. Important: Since the two electrodes are positioned on either side of the hole, this part of the probe must be completely submerged.

7. Briefly swirl the bottle contents. Once the conductivity reading has stabilized, record the value in your data table. Note: It is normal for the conductivity reading to fluctuate to a small degree.

8. Before testing the next solution, clean the probe by again rinsing it with deionzed water from a wash bottle. Blot the outside of the probe end dry using a tissue. Remember, it is not necessary to dry the inside of the hole near the probe end.