EXPERIMENT A6: CONDUCTIVITY

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.

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- 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.

Reagents and Supplies

Reagent set for Part 1: solutions of sodium chloride, calcium chloride, aluminum chloride, hydrochloric acid, phosphoric acid, acetic acid, boric acid, methanol, and ethylene glycol. Also obtain deionized water and tap water.

Reagents for Part 2: 0.05 M concentrations of sodium chloride, calcium chloride, and aluminum chloride.

(See posted Material Safety Data Sheets)

Vernier kit with a conductivity probe (from stockroom), laptop computer (from the lab)

Procedure

PART 1: CLASSIFY THE GIVEN SOLUTION AS A STRONG/WEAK/NON ELECTROLYTE

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 in the Appendix). 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.

PART 2: DETERMINE THE EFFECT OF MOLAR CONCENTRATION AND NUMBER OF IONS IN A SOLUTION ON THE CONDUCTIVITY OF THE SOLUTION

1. Obtain around 10-ml each of 0.05 M NaCl, $CaCl_2$, and $AlCl_3$.

2. Obtain a burette stand, burette clamp and set up a microburette.

3. Rinse the burette with deionized water and then condition the burette with 0.05 M NaCl and fill the burette with 0.05 M NaCl.

4. Add exactly 35.0 ml of deionized water to a 125-ml Erlenmeyer flask.

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

6. Connect the vernier kit and the laptop computer according to "Instructions for Experiment A6" (found in the Appendix). Make sure that the toggle switch is set to 0 – 2000 μS/cm.

7. Rinse the conductivity probe with deionized water and wipe dry.

8. Measure the conductivity of the deionized water in the Erlenmeyer flask (from step 4) and record the value.

9. Add 0.1 ml of 0.05 M NaCl from the microburette into the Erlenmeyer flask. Swirl the flask to thoroughly mix the contents of the flask.

10. Measure the conductivity of the solution in step 9 and record the value.

11. Add another 0.1 ml of 0.05 M NaCl from the microburette into the same Erlenmeyer flask (from step 9). Swirl the flask to thoroughly mix the contents of the flask.

12. Measure the conductivity of the solution in step 11 and record the value.

13. Continue adding 0.1 ml of 0.05 M NaCl from the microburette into the Erlenmeyer flask, swirl to mix, measure the conductivity, and record the value for an additional **SIX** more times.

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

15. Discard the NaCl from the burette and the Erlenmeyer flask into a waste beaker.

16. Repeat all of the same steps with 0.05 M $CaCl_2$ and 0.05 M $AlCl_3$.

Data Table

PART 1: CLASSIFY THE GIVEN SOLUTION AS A STRONG/WEAK/NON ELECTROLYTE

Solution	**Conductivity (μS/cm)**
NaCl	
$CaCl_2$	
$AlCl_3$	
HCl	
H_3PO_4	
CH_3COOH	
H_3BO_3	
CH_3OH	
$C_2H_6O_2$	
H_2O (tap)	
H_2O (deionized)	

PART 2: DETERMINE THE EFFECT OF MOLAR CONCENTRATION AND NUMBER OF IONS IN A SOLUTION ON THE CONDUCTIVITY OF THE SOLUTION

		Conductivity (μS/cm)		
Trial	**Volume (ml)**	**NaCl**	**$CaCl_2$**	**$AlCl_3$**
1	0.0			
2	0.1			
3	0.2			
4	0.3			
5	0.4			
6	0.5			
7	0.6			
8	0.7			
9	0.8			

Data Analysis

PART 1: CLASSIFY THE GIVEN SOLUTION AS A STRONG/WEAK/NON ELECTROLYTE

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.

PART 2: DETERMINE THE EFFECT OF MOLAR CONCENTRATION AND NUMBER OF IONS IN A SOLUTION ON THE CONDUCTIVITY OF THE SOLUTION

1. Calculate the concentration of the electrolyte in each trial. (NOTE: Trial 1 has no electrolyte and has only deionized water, so the concentration of the electrolyte in this case is 0.00 M). Calculations for trial 2 are shown below as a sample.

   Trial 2:
   Initial molarity (M_1) = 0.050 M Initial volume (V_1) = 0.100 ml
   Final molarity (M_2) = ? Final volume (V_2) = 35.1 ml

   $M_1V_1 = M_2V_2$ $0.050\text{ M} \times 0.100\text{ ml} = M_2 \times 35.1\text{ ml}$ $\boxed{\mathbf{M_2 = 0.00014\ M}}$

   Trial 3:

   Trial 4:

   Trial 5:

   Trial 6:

   Trial 7:

   Trial 8:

   Trial 9:

2. Enter the conductivity values as a function of concentration of the electrolyte for each trial in the following table.

		Conductivity (μS/cm)		
Trial	**Concentration, M**	**NaCl**	**$CaCl_2$**	**$AlCl_3$**
1	0.00			
2				
3				
4				
5				
6				
7				
8				
9				

3. Plot a graph of the concentration of the electrolyte (x-axis) vs. the conductivity of the electrolyte (y-axis). Plot all three lines on the same graph and fit each line to the equation of a straight line and obtain the slope of each line. Attach the graph to your worksheets.

4. What are the slopes of the lines corresponding to each electrolyte solution in the above graph?

Electrolyte	**Slope**
NaCl	
$CaCl_2$	
$AlCl_3$	

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5. Write the dissociation equation for each of the electrolytes.

$NaCl_{(aq)} \rightarrow$

$CaCl_{2(aq)} \rightarrow$

$AlCl_{3(aq)} \rightarrow$

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6. Comment on the relationship between the slopes of the three lines and the number of ions in solution for each electrolyte.

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7. Comment on the effect of a) molar concentration and b) number of ions in solution on the electrical conductivity of a solution.
