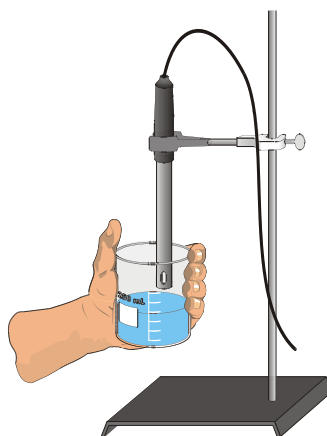# Conductivity Part 1:
Electrolytes and Non-Electrolytes

In this experiment, you will discover some properties of strong electrolytes, weak electrolytes, and non-electrolytes by observing the behavior of these substances in aqueous solutions. You will determine these properties using a Conductivity Probe. When the probe is placed in a solution that contains ions, and thus has the ability to conduct electricity, an electrical circuit is completed across the electrodes that are located on either side of the hole near the bottom of the probe body (see Figure 1). This results in a conductivity value that can be read by the computer. The unit of conductivity used in this experiment is the microsiemens per centimeter, or μS/cm.


Figure 1

The size of the conductivity value depends on the ability of the aqueous solution to conduct electricity. Strong electrolytes produce large numbers of ions, which results in high conductivity values. Weak electrolytes result in low conductivity, and non-electrolytes should result in no conductivity. In this experiment, you will observe several factors that determine whether or not a solution conducts, and if so, the relative magnitude of the conductivity. Thus, this simple experiment allows you to learn a great deal about different compounds and their resulting solutions.

In each part of the experiment, you will be observing a different property of electrolytes. Keep in mind that you will be encountering three types of compounds and aqueous solutions:
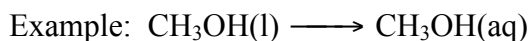
Ionic Compounds

These are usually strong electrolytes and can be expected to 100% dissociate in aqueous solution.

Example: $NaNO_3(s) \longrightarrow Na^+(aq) + NO_3^-(aq)$
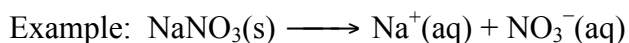
Molecular Compounds

These are usually non-electrolytes. They do not dissociate to form ions. Resulting solutions do not conduct electricity.

Example: $CH_3OH(l) \longrightarrow CH_3OH(aq)$

Molecular Acids

These are molecules that can partially or wholly dissociate, depending on their strength.

Example: Strong electrolyte $H_2SO_4 \longrightarrow H^+(aq) + HSO_4^-(aq)$ (100% dissociation)

Example: Weak electrolyte $HF \longleftrightarrow H^+(aq) + F^-(aq)$ (<100% dissociation)

PRELAB QUESTIONS:

1. What is an electrolyte?

2. What is the difference between a molecular and ionic compound?

3. What is a polyprotic acid? Give an example of a polyprotic acid?

OBJECTIVES

In this experiment, you will

- Write equations for the dissociation of compounds in water.
- Use a Conductivity Probe to measure the conductivity of solutions.
- Determine which molecules or ions are responsible for conductivity of solutions.
- Investigate the conductivity of solutions resulting from compounds that dissociate to produce different numbers of ions.

MATERIALS

From the Stockroom (or Your Instructor):
Vernier Lab*Pro* interface box-(LL)*
Power cord for Lab*Pro* interface-(ALL)
USB Cable for Lab*Pro* interface
Ethernet Cable
Laptop Computer-(CMP)
Vernier Conductivity Probe-(CON)

Found in the Lab or Your Locker:
30,50, and 250 mL beakers
wash bottle with deionized water
KimWipe tissues
2.00 mL Microburet

Found in the Lab or Your Locker:
Ring Stand
Buret Clamp and Probe Clamp
H_2O (deionized and tap)
0.05 M NaCl
0.05 M $CaCl_2$
0.05 M $AlCl_3$
0.05 M $HC_2H_3O_2$
0.05 M H_3PO_4
0.05 M H_3BO_3
0.05 M HCl
0.05 M CH_3OH (methanol)
0.05 M $C_2H_6O_2$ (ethylene glycol)

*Indicates stockroom abbreviation for device.

STOCKROOM EQUIPMENT

1. From the Chemistry stockroom check out the equipment listed in the table on the previous page.

PROCEDURE

1. Obtain and wear goggles! **CAUTION:** Handle the solutions in this experiment with care. Do not allow them to contact your skin. Notify your teacher in the event of an accident.

2. Setting up the equipment:

   a. Connect the conductivity probe to the Lab*Pro* interface box through channel 1(refer to Appendix 1).

   b. Connect the Lab*Pro* interface box to the power outlet with the power cord. The Lab*Pro* will beep to indicate it is ready.

   c. Connect the Lab*Pro* interface box to the laptop computer using the USB cable (refer to Appendix 1). The USB ports are found in the back of the laptop on the right hand side when the screen is facing you.

   d. Connect the computer to the Ethernet using the Ethernet cable and the port located on the lab bench. The Ethernet port for the computer is located in the back of the laptop on the right hand side when the screen is facing you.

3. **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 Figure 1.

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

5. From the fume hood obtain a set of the conductivity solutions in the small 30 mL bottles. The solutions are: 0.05 M NaCl, 0.05 M $CaCl_2$, 0.05 M $AlCl_3$, 0.05 M $HC_2H_3O_2$, 0.05 M H_3PO_4, 0.05 M H_3BO_3, 0.05 M HCl, 0.05 M CH_3OH, and 0.05 M $C_2H_6O_2$.

6. Measure the conductivity for each of the solutions.

   a. Before testing the first solution, clean the probe by surrounding it with the 250 mL beaker and rinsing it with deionzed water from a wash bottle. Blot the outside of the probe end dry using a KimWipe tissue. It is *not* necessary to dry the *inside* of the hole near the probe end.

   b. Measure the conductivity of the Group A solutions (0.05 M NaCl, 0.05 M $CaCl_2$, and 0.05 M $AlCl_3$,). Carefully raise the first bottle with the 0.05 M NaCl solution 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.

   c. 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.

   d. Once you have obtained a conductivity reading, recap the bottle and return the solution to the fume hood.

e. 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.

7. Measure the conductivity of the Group B solutions. These include 0.05 M H_3PO_4, 0.05 M $HC_2H_3O_2$, 0.05 M H_3BO_3, and 0.05 M HCl. Repeat the Step 6 procedure.

8. Measure the conductivity of the Group C solutions or liquids. These include 0.05 M CH_3OH, 0.05 M $C_2H_6O_2$, distilled H_2O, and tap H_2O. Repeat the Step 6 procedure.

DATA TABLE

Solution	Conductivity (µS/cm)
A - $CaCl_2$	
A - $AlCl_3$	
A - NaCl	
B - $HC_2H_3O_2$	
B - HCl	
B - H_3PO_4	
B - H_3BO_3	
C - $H_2O_{distilled}$	
C - H_2O_{tap}	
C - CH_3OH	
C - $C_2H_6O_2$	

PROCESSING THE DATA

1. Based on your conductivity values, do the Group A compounds appear to be molecular, ionic, or molecular acids? Would you expect them to partially dissociate, completely dissociate, or not dissociate at all?

2. Why do the Group A compounds, each with the same concentration (0.05 M), have such large differences in conductivity values? Explain. Write an equation for the dissociation of each compound in water.

3. In Group B, do all four compounds appear to be molecular, ionic, or molecular acids? Classify each as a strong or weak electrolyte, and arrange them from the strongest to the weakest, based on conductivity values.

4. Write an equation for the dissociation of each of the compounds in Group B. Use $\longrightarrow$ for strong; $\longleftrightarrow$ for weak. Remember that some of the acids are **polyprotic** and will have more than one ionization step!

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5. Examine the conductivity data for H_3PO_4 and H_3BO_3. These are polyprotic acids. Write out the dissociation steps for these acids (see your textbook). What are possible reasons for the differences observed in conductivity for these two compounds? Explain.

6. In Group C, do all four compounds appear to be molecular, ionic, or molecular acids? Based on this answer, would you expect them to dissociate?

7. How do you explain the relatively high conductivity of tap water compared to a low or zero conductivity for deionized water?

8. Did aqueous methanol, CH_3OH, have the same conductivity value as aqueous ethylene glycol, $C_2H_6O_2$? Should they have the same or different conductivity values? Explain.

Conductivity Part 2:
The Effect of Concentration

If an ionic compound is dissolved in water, it dissociates into ions and the resulting solution will conduct electricity. Dissolving solid sodium chloride in water releases ions according to the equation:

$$NaCl(s) \longrightarrow Na^+(aq) + Cl^-(aq)$$

In this experiment, you will study the effect of increasing the concentration of an ionic compound on conductivity. Conductivity will be measured as concentration of the solution is gradually increased by the addition of concentrated NaCl drops. The same procedure will be used to investigate the effect of adding solutions with the same concentration (1.0 M), but different numbers of ions in their formulas: aluminum chloride, $AlCl_3$, and calcium chloride, $CaCl_2$. A computer-interfaced Conductivity Probe will be used to measure conductivity of the solution. Conductivity is measured in microsiemens per centimeter (μS/cm).

OBJECTIVES

In this experiment, you will

- Use a Conductivity Probe to measure the conductivity of solutions.
- Investigate the relationship between the conductivity and concentration of a solution.
- Investigate the conductivity of solutions resulting from compounds that dissociate to produce different number of ions.

PROCEDURE

1. Obtain and wear goggles! **CAUTION:** Handle the solutions in this experiment with care. Do not allow them to contact your skin. Notify your teacher in the event of an accident.

2. Setting up the equipment:

   a. Connect the conductivity probe to the Lab*Pro* interface box through channel 1(refer to Appendix 1).

   b. Connect the Lab*Pro* interface box to the power outlet with the power cord. The Lab*Pro* will beep to indicate it is ready.

   c. Connect the Lab*Pro* interface box to the laptop computer using the USB cable (refer to Appendix 1). The USB ports are found in the back of the laptop on the right hand side when the screen is facing you.

   d. Connect the computer to the Ethernet using the Ethernet cable and the port located on the lab bench. The Ethernet port for the computer is located in the back of the laptop on the right hand side when the screen is facing you.

3. **IMPORTANT:** Make sure that the conductivity probe is set on the **0-2000** μS/cm position. (**This is a different setting than used in the first part of the experiment**). If you receive an error message stating that the settings are incorrect/different, it is because the toggle on the

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probe is in the wrong position. Clamp the probe on to the ring stand as illustrated in Figure 1. In addition, also use a buret clamp to hold the 2.00 mL Microburet.

4. **IMPORTANT:** Prepare the computer to monitor conductivity by opening the file **"Conductivity 2"** from the *Chemistry 1A* desktop folder. (**This is a different file than used in the first part of the experiment.**)

5. Using a graduated cylinder add 35.0 mL of deionized water to a clean 50 mL beaker. Using a 25 mL beaker obtain about 10-15 mL of 0.05 M NaCl solution from the large stock bottle.

6. Clean the probe by surrounding it with the 250 mL beaker and rinsing it with deionzed water from a wash bottle. Blot the outside of the probe end dry using a KimWipe tissue. It is *not* necessary to dry the *inside* of the hole near the probe end.

7. Before adding any drops of solution:
    a. Click ▶ Collect .
    b. Carefully raise the beaker and its containing the 35.0 mL of deionized water 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.
    c. Monitor the conductivity of the deionized water until the conductivity reading stabilizes.
    d. Click Keep , and then lower the beaker away from the probe. Type "0.00" (for 0.00 mL's added) in the edit box that appears on the screen. Press the ENTER key to store this data pair. This gives the conductivity of the water before any salt solution is added.

8. You are now ready to begin adding salt solution.
    a. Rinse and fill the 2.00 mL microburet with 0.05 M NaCl solution.
    b. Add 0.10 mL of 0.05 M NaCl solution to the 35.0 mL of distilled water.
    c. Raise the beaker until the hole near the probe end is completely submerged in the solution. Swirl the solution briefly.
    d. Monitor the conductivity of the solution until the reading stabilizes.
    e. Click Keep , and then lower the beaker away from the probe. Type "0.10" (the total volume in mL's added) in the edit box and press ENTER.

9. Repeat the Step 8 procedure by adding another 0.10 mL of 0.05M NaCl to the beaker, but this time entering "0.20" (the total volume in mL's added).

10. Continue this procedure, adding 0.10 mL portions of 0.05 M NaCl solution, measuring conductivity, and entering the total volume added—until a total of 0.80 mL has been added. At anytime you may click on the Ⓐ button located just below the menu bar to expand the graph.

11. Click ■ Stop when you have finished collecting data. Dispose of the beaker contents as directed by your teacher. Rinse the probe tip with deionized water from a wash bottle. Carefully blot the probe dry with a tissue.

12. **Important:** From the Experiment menu, choose Store Latest Run. This stores the data so it can be used later, but it will still be displayed while you do your second and third trials.

13. Repeat Steps 6-12, this time using 0.05 M AlCl$_3$ solution in place of 0.05 M NaCl solution.

14. Repeat Steps 6-12, this time using 0.05 M CaCl$_2$ solution.

15. Click on the Linear Fit button, 🔲. Be sure all three data runs are highlighted, then click ⬚ OK ⬚. A best-fit linear regression line will be shown for each of your three runs. In your data table, record the value of the slope, *m*, for each of the three solutions. (The linear regression statistics are displayed in a floating box for each of the data sets.)

16. To print a graph of concentration *vs.* volume showing all three data runs:

   a. Label all three curves by choosing Text Annotation from the Insert menu, and typing "sodium chloride" (or "aluminum chloride", or "calcium chloride") in the edit box. Then drag each box to a position near its respective curve.

   b. From the File menu select **Print Graph**. Print a copy of the graph, with all three regression lines displayed. Enter your name(s) and the number of copies of the graph you want. Make certain that each lab partner has his/her own copy.

   c. From the File menu select **Print Data**. Print a copy of the data table making sure that all three sets of data are present. Make certain that each lab partner has his/her own copy

DATA TABLE

Solution	Slope, *m*
0.05 M NaCl	
0.05 M AlCl$_3$	
0.05 M CaCl$_2$	

PROCESSING THE DATA

1. Calculate the concentration of chloride ion in each of the original 0.05 M solutions. Calculate the concentration of the cation in each of the original 0.05M solutions. What is the total ion concentration for each original 0.05 M solution?

2. Describe the change in conductivity as the concentration of the NaCl solution was increased by the addition of NaCl drops. What kind of mathematical relationship does there appear to be between conductivity and concentration?

3. Write a mathematical equation for each line. Remember to include units for the slope and y-intercept and write out what the x and y variables represent: "x" and "y" should not appear in the equation.

4. Which graph had the largest slope? The smallest? Since all solutions had the same original concentration (0.05 M) and were added to 35.0 mL of water, what accounts for the difference in the slope of the three plots? Explain.

5. Ideally what should the ratio between the three slopes be? What are your actual experimental ratios? Give possible reasons for any observed variations from these ratios.

6. Using the equation developed in question number 3, calculate the conductivity of the solution after 1.30 mL of 0.05 M CaCl$_2$ has been added to the 35.0 mL of water.