

# Conductivity of Solutions: 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:



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 other solutions with the same concentration (1.0 M), but different numbers of ions in their formulas: aluminum chloride,  $\text{AlCl}_3$ , and calcium chloride,  $\text{CaCl}_2$ . A Conductivity Probe will be used to measure conductivity of the solution. Conductivity is measured in microsiemens ( $\mu\text{S}$ ).

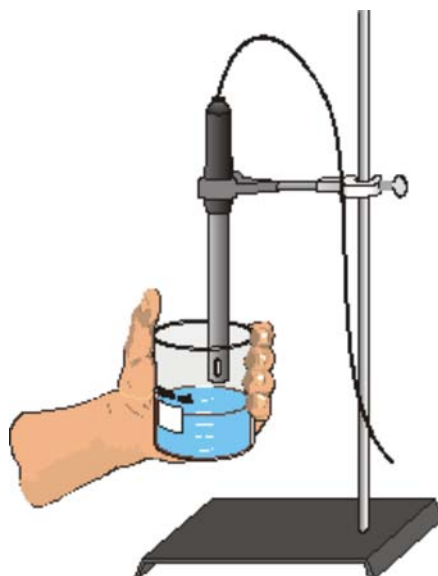


Figure 1

## MATERIALS

LabPro or CBL 2 interface  
TI Graphing Calculator  
DataMate program  
Conductivity Probe  
ring stand  
utility clamp  
stirring rod

100-mL beaker  
distilled water  
wash bottle  
1.0 M NaCl  
1.0 M  $\text{AlCl}_3$   
1.0 M  $\text{CaCl}_2$

## PROCEDURE

1. Obtain and wear goggles.
2. Add 70 mL of distilled water to a clean 100-mL beaker. Obtain a dropper bottle that contains 1.0 M NaCl solution.
3. Plug the Conductivity Probe into Channel 1 of the LabPro or CBL 2 interface. Set the selector switch on the side of the Conductivity Probe to the 0-2000 range. Use the link cable to connect the TI Graphing Calculator to the interface. Firmly press in the cable ends.
4. Turn on the calculator and start the DATAMATE program. Press **CLEAR** to reset the program.
5. Set up the calculator and interface for the Conductivity Probe.
  - a. Select SETUP from the main screen.
  - b. If the calculator displays the Conductivity Probe set to MICS in CH 1, proceed directly to Step 6. If it does not, continue with this step to set up your sensor manually.
  - c. Press **ENTER** to select CH 1.
  - d. Select CONDUCTIVITY from the SELECT SENSOR menu.
  - e. Select CONDUCT 2000 (MICS) from the CONDUCTIVITY menu.
6. Set up the data-collection mode.
  - a. To select MODE, press **▲** once and press **ENTER**.
  - b. Select EVENTS WITH ENTRY from the SELECT MODE menu.
  - c. Select OK to return to the main screen.
7. Before adding any drops of solution:
  - a. Select START to begin data collection.
  - b. Carefully raise the beaker and its contents 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. Before you have added any drops of NaCl solution, press **ENTER**. Type in “0”, the volume (in drops) on the calculator. Press **ENTER** to save the first data pair for this experiment.
  - d. Lower the beaker away from the probe.
8. You are now ready to begin adding salt solution.
  - a. Add 1 drop of NaCl solution to the distilled water. Stir to ensure thorough mixing.
  - b. Carefully raise the beaker and its contents up around the Conductivity Probe until the hole near the probe end is completely submerged in the solution being tested.
  - c. Briefly swirl the beaker contents. Monitor the conductivity of the solution for 4-5 seconds.
  - d. Press **ENTER** and enter “1” as the volume in drops. The conductivity and volume values have now been saved for the second trial.
  - e. Lower the beaker away from the probe.
9. Repeat the Step 8 procedure, entering “2” this time.
10. Continue this procedure, adding 1-drop portions of NaCl solution, measuring conductivity, and entering the total number of drops added—until a total of 8 drops has been added. **Important:** Because you are going to view three runs of data in Step 16, it is necessary to enter the same number of trials (0-8 drops) in each run.
11. Press **STO ►** when you have finished collecting data.

12. To analyze the relationship between conductivity and volume, use this method to calculate the linear-regression statistics for your data. Then plot the linear regression curve on your graph.
  - a. Press **ENTER**, then select ANALYZE from the main screen.
  - b. Select CURVE FIT from the ANALYZE OPTIONS menu.
  - c. Select LINEAR (CH 1 VS ENTRY) from the CURVE FIT menu. The linear-regression statistics for these two lists are displayed for the equation in the form
$$y = ax + b$$
where  $y$  is conductivity,  $x$  is volume,  $a$  is the slope, and  $b$  is the y-intercept. Record the value for the slope,  $a$ , in your data table.
  - d. To display the linear-regression curve on the graph of conductivity *vs.* volume, press **ENTER**. Note: Since increasing the volume (drops) of NaCl increases the concentration of NaCl in the solution, the graph actually represents the relationship between *conductivity* and *concentration*.
  - e. Press **ENTER** to return to the ANALYZE OPTIONS menu.
  - f. Select RETURN TO MAIN SCREEN.
13. Store the data from the first run so that it can be used later. To do this:
  - a. Select TOOLS from the main screen.
  - b. Select STORE LATEST RUN from the TOOLS MENU.
14. Repeat Steps 7-13, this time using 1.0 M AlCl<sub>3</sub> solution in place of 1.0 M NaCl solution.
15. Repeat Steps 7-12, this time using 1.0 M CaCl<sub>2</sub> solution. **Important:** Do not store this run as you did in the first two runs—proceed directly to Step 16 after you complete Step 12.
16. To view a graph of concentration *vs.* volume showing all three data runs:
  - a. Press **ENTER**.
  - b. Select GRAPH from the main screen, then press **ENTER**.
  - c. Select MORE, then select L2, L3, AND L4 VS L1 from the MORE GRAPHS menu.
  - d. All three conductivity runs should now be displayed on the same graph. Each point of NaCl is plotted with a cross, each point of AlCl<sub>3</sub> is plotted with a box, and each point of CaCl<sub>2</sub> is plotted with a dot.
17. (optional) Print a copy of the graph displayed in Step 16. Label each run as “1.0 M NaCl,” “1.0 M AlCl<sub>3</sub>,” or “1.0 M CaCl<sub>2</sub>.”

## PROCESSING THE DATA

1. Describe the appearance of each of the three curves on your graph in Step 16.
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 chemical equation for the dissociation of NaCl, AlCl<sub>3</sub>, and CaCl<sub>2</sub> in water.
4. Which graph had the largest slope value? The smallest? Since all solutions had the same original concentration (1.0 M), what accounts for the difference in the slope of the three plots? Explain.

## DATA TABLE

Solution	Slope, <i>m</i>
1.0 M NaCl	
1.0 M AlCl <sub>3</sub>	
1.0 M CaCl <sub>2</sub>	