Conductivity of Solutions: The Effect of Concentration

Name ______________________

Class ______________________

In this activity, you will explore the following:

- *the effects of solute concentration on the electrical conductivity of a solution*
- *the effects of solute identity on the electrical conductivity of a solution*

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:

$$NaCl(s) \rightarrow Na^{+}(aq) + Cl^{-}(aq)$$

In this experiment, you will study the effect of increasing the concentration of an ionic compound on conductivity. The conductivity of the solution will be measured as drops of NaCl are added into the solution. The addition of NaCl drops increases the concentration of the solution. The same procedure will be used to investigate the effect of adding two other solutions: aluminum chloride ($AlCl_3$) and calcium chloride ($CaCl_2$). These solutions have the same concentration (1.0 M) as NaCl, but they have different numbers of ions in their formulas. You will use a conductivity probe to measure the conductivity of the solution. Conductivity is measured in microsiemens (μS).

Problem 1 – Preliminary Questions

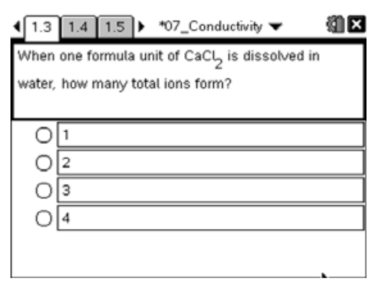
Step 1: Open the file **07_Conductivity.tns** and read the first page. Then, answer questions 1–4.

Q1. When solid NaCl is dissolved in water, ______ are formed.

- o Na molecules
- o Cl molecules
- o NaCl molecules
- o Na^{+} and Cl^{-} ions

Q2. When one formula unit of $CaCl_2$ dissolves in water, how many total ions form?

- o 1
- o 2
- o 3
- o 4



Q3. When solid NaCl, $CaCl_2$, or $AlCl_3$ is dissolved in water, the resulting solution conducts electricity because of the presence of_____.

- o atoms
- o molecules
- o electrons
- o ions

Q4. As the concentration of an ionic compound in solution increases, the conductivity of the solution will_______.

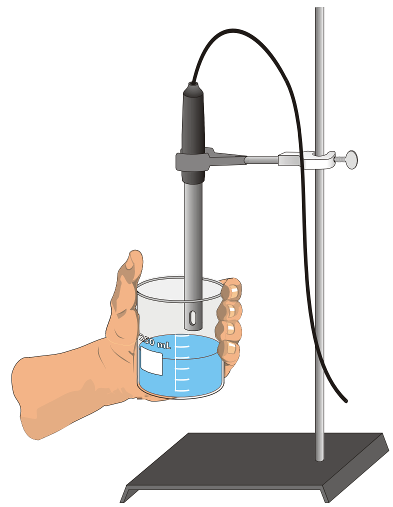
- o increase
- o decrease
- o remain the same
- o vary depending on the compound

Problem 2 – Data Collection and Analysis

Step 1: Put on safety goggles.

Step 2: Use soapy water to clean a 100-mL beaker. Thoroughly rinse and dry the beaker. Add 70 mL of distilled water to the clean 100-mL beaker. Obtain a dropper bottle that contains 1.0 M NaCl solution.

Step 3: Plug the EasyLink cable into the TI-Nspire handheld and plug the Vernier conductivity probe into the Easy Link. Set the selector switch on the side of the conductivity probe to the 0−2,000 range. Place the conductivity probe in an electrode support attached to a ring stand as shown to the right.



Step 4: A data collection console should appear on the handheld device. Move to page 2.1. Set up the collection for **Events with Entry** (**Menu > Experiment > Set Up Collection > Events with Entry**).

Step 5: Start the data collection. 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.

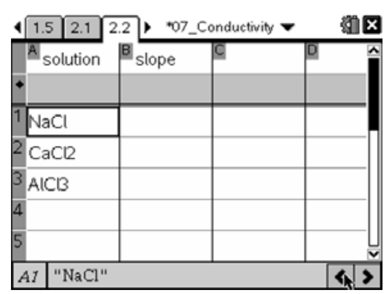
Step 6: To record the first data point (the conductivity of the pure water), press enter and enter **0** as the data value (the number of drops added to the solution). Select OK to save the data point. Once you have collected the data point, carefully lower the beaker away from the probe.

Step 7: Add one drop of NaCl solution to the beaker. Stir the solution to ensure it is completely mixed.

Step 8: 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. Briefly swirl the beaker contents. Monitor the conductivity of the solution for 5 seconds. When the conductivity readings stabilize, record another data point. Use **1** instead of **0** for the data value.

Step 9: Repeat steps 7 and 8 until you have added 8 total drops of NaCl solution to the beaker. Make sure that the data value you enter each time is equal to the number of drops of NaCl you have added.

Step 10: Stop the data collection.



Step 11: To analyze the relationship between conductivity and volume, determine the best-fit line through your data points using the **Linear Regression** tool (**Menu > Analyze > Regression > Show Linear (mx + b)**). (You can hide the data console by pressing ctrl D.) Because increasing the volume (number of drops) of NaCl increases the concentration of NaCl in the solution, the graph represents the relationship between conductivity and concentration. The linear-regression statistics for these two lists are displayed for the equation in the form $y = mx + b$, where y is conductivity, x is volume, m is the slope, and b is the y-intercept. Record the value of the slope of the best-fit line in the data table on page 2.2. Round the slope to the nearest 0.1 μS.

Step 12: Move back to the graph on page 2.1. If necessary, show the data console again by pressing ctrl D. Begin the data collection again. When you are asked whether to save the previous run, choose **Store**.

Step 13: Empty the solution from the beaker. Wash it with soapy water, rinse it thoroughly, and dry it. Add 70 mL of distilled water to the beaker.

Step 14: Repeat Steps 5–11, substituting $AlCl_3$ solution for NaCl solution.

Step 15: Repeat Steps 5–13, substituting $CaCl_2$ solution for NaCl solution.

Step 16: Once you have collected all three data sets, you can display them on the same graph. With the third data set displayed on the *Data & Statistics* application on page 2.1, add a new *y*-variable (**Menu > Plot Properties > Add Y Variable**). From the menu, select **dc01.cond1** to show the data for the NaCl trial. Select **dc02.cond1** to show the data for the $AlCl_3$ trial.

Step 17: Disconnect the conductivity probe from the handheld device. Then, answer questions 5–8.

Q5. Compare the shapes and slopes of the three different curves.

Q6. 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?

Q7. Write chemical equations for the dissociation of NaCl, $AlCl_3$, and $CaCl_2$ in water.

Q8. Which graph had the largest slope value? Which graph had the smallest slope value? Given that all solutions had the same original concentration (1.0 M), how can you explain the differences between the slopes of the three plots?