TEACHER INFORMATION

Properties of Solutions: Electrolytes and Non-Electrolytes

1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.

2. We suggest that you set up the Conductivity Probes before the experiment. Set the selection switch on the amplifier box of the probe to the 0–20000 μS/cm range.

3. Fewer sets of Groups A, B, and C can be prepared if students are advised that they need not start with Group A. Add solutions to 100 mL beakers or small vials to a depth that easily allows the hole near the Conductivity Probe tip to be completely submerged (the graphite electrodes of the probe are located on either side of this hole).

4. Preparation of solutions (prepare all solutions in distilled water):

   0.050 M $CaCl_2$ (5.55 g of solid calcium chloride, $CaCl_2$, per 1 L solution) Hazard Code: D—Relatively non-hazardous. Alternatively, 7.35 g $CaCl_2 \cdot 2H_2O$, per 1 L solution. **HAZARD ALERT:** Toxic by ingestion. Hazard Code: D—Relatively non-hazardous.

   0.050 M NaCl (2.93 g of solid sodium chloride, NaCl, per 1 L solution) **HAZARD ALERT:** Moderately toxic. Hazard Code: D—Relatively non-hazardous.

   0.050 M $AlCl_3$ (12.05 g of solid aluminum chloride, $AlCl_3 \cdot 6H_2O$, per 1 L solution)—preferred. Hazard Code: D—Relatively non-hazardous. Alternatively, 6.67 g anhydrous $AlCl_3$ per liter of solution. **HAZARD ALERT:** Reacts very violently with water; toxic by inhalation and ingestion; strong skin irritant. Hazard Code: A—Extremely hazardous.

   0.050 M HCl (4.2 mL of concentrated hydrochloric acid, HCl, per 1 L solution) **HAZARD ALERT:** Highly toxic by ingestion or inhalation; severely corrosive to skin and eyes. Hazard Code: A—Extremely hazardous.

   0.050 M $HC_2H_3O_2$ (2.9 mL of concentrated acetic acid, $HC_2H_3O_2$, per 1 L solution) **HAZARD ALERT:** Corrosive to skin and tissue; moderate fire risk (flash point: 39°C); moderately toxic by ingestion and inhalation. Hazard Code: A—Extremely hazardous.

   0.050 M H_3PO_4 (3.4 mL of concentrated phosphoric acid, H_3PO_4, per 1 L solution) **HAZARD ALERT:** Skin and eye irritant; moderately toxic by ingestion and inhalation; corrosive; burns tissue. Hazard Code: A—Extremely hazardous.

   0.050 M H_3BO_3 (3.09 g of solid boric acid, H_3BO_3, per 1 L solution) **HAZARD ALERT:** Moderately toxic by ingestion; irritant to skin in dry form. Hazard Code: C—Somewhat hazardous.

   0.050 M CH_3OH (1.60 g (2.1 mL) methanol per 1 L solution) **HAZARD ALERT:** Flammable; dangerous fire risk; toxic by ingestion (ingestion may cause blindness). Hazard Code: B—Hazardous.

   The hazard information reference is: Flinn Scientific, Inc., *Chemical & Biological Catalog Reference Manual*, (800) 452-1261, www.flinnsci.com. See *Appendix F* for more information.

5. Conductivity readings are normally reported in microsiemens per centimeter, or μS/cm. This SI derived unit has replaced the conductivity unit, micromho/cm.

6. Students are instructed to rinse the probe with distilled water between samples. They are told to blot the probe tip dry—however, the directions also remind them that they do *not* need to blot dry the inside of the hole containing the graphite electrodes. It is cumbersome to do so, and leaving a drop or two of distilled water does not significantly dilute the next sample.

7. Using the stored calibration, measured conductivity values for H_3BO_3, CH_3OH, or distilled water will be in the range of 0 to 30 μS/cm. If a two-point calibration is performed, students will get readings closer to 0 μS/cm. These four samples will usually have a small conductivity value due to dissolved carbon dioxide, which forms aqueous ions according to the equation:

$$CO_2(g) + H_2O(l) \longleftrightarrow H^+(aq) + HCO_3^-(aq)$$

   The resulting conductivity, usually about 1–3 μS/cm, can be accurately measured using the narrower 0–200 μS/cm setting and calibration for the Conductivity Probe. You could do this as a teacher demonstration, or instruct your students to do it as an extension to the experiment.

   At the 0–200 μS/cm setting, students will also notice that the conductivity of boric acid is higher than distilled water, 0.05 M methanol, or 0.05 M ethylene glycol. This way, they can see that boric acid is a weak acid that ionizes to a very small extent. For example, we get a reading of 3.2 μS/cm for 0.05 M boric acid, but only 1.0 μS/cm for distilled water, and 1.0 μS/cm for 0.05 M methanol, using the 0–200 μS/cm setting.

8. If you wish to calibrate the Conductivity Probe to improve conductivity readings at low concentrations (as discussed in item 7 above), follow these directions:

   First Calibration Point

   a. Choose Set Up Sensors ►Calibrate ► Two Point from the Experiment menu.
   b. For the first calibration point, the Conductivity Probe should simply be in the air (out of any liquid or solution).
   c. Enter **0** as the first reference value.
   d. When the voltage stabilizes, select OK.

   Second Calibration Point

   e. Place the Conductivity Probe into a standard solution that is equivalent to 10,000 μS/cm. **Note:** This standard can be prepared by dissolving 5.566 g of solid sodium chloride, NaCl, in enough distilled water for 1 liter of solution.
   f. Enter **10000** as the second reference value (in μS/cm).
   g. When the voltage stabilizes, select OK.
   h. Select OK to complete the calibration.

SAMPLE RESULTS

Solution	Conductivity (µS/cm)
A - $CaCl_2$	9362
A - NaCl	5214
A - $AlCl_3$	11707
B - $HC_2H_3O_2$	461
B - HCl	17330
B - H_3PO_4	6661
B - H_3BO_3	0
C - $H_2O_{distilled}$	0
C - H_2O_{tap}	(varies) 20 – 1000
C - CH_3OH	0

ANSWERS TO QUESTIONS

1. All three are ionic. They completely dissociate in water.

2. $AlCl_3 \longrightarrow Al^{3+} + 3\ Cl^-$ (4 moles of ions per mole)

   $CaCl_2 \longrightarrow Ca^{2+} + 2\ Cl^-$ (3 moles of ions per mole)

   $NaCl \longrightarrow Na^+ + Cl^-$ (2 moles of ions per mole)

   Even though all three solutions have the same initial concentration, 0.05 M, $AlCl_3$ dissociates to yield the largest number of moles of ions per mole, and as a result exhibits the highest conductivity in this series. $CaCl_2$ is next, and NaCl yields the fewest moles of ions per mole.

3. All three are molecular acids. HCl is a strong acid. H_3PO_4 is borderline between strong and weak, but is usually classified as a weak acid. Acetic acid, $HC_2H_3O_2$ is the next weakest acid and H_3BO_3 is the weakest.

4. $HCl \longrightarrow H^+ + Cl^-$ $H_3PO_4 \longleftrightarrow H^+ + H_2PO_4^-$

   $HC_2H_3O_2 \longleftrightarrow H^+ + C_2H_3O_2^-$ $H_3BO_3 \longleftrightarrow H^+ + H_2BO_3^-$

5. Since H_3PO_4 and H_3BO_3 are two of the weak acids in this series, one would conclude that the subscript "3" contributes little to their strengths. The equations for their dissociations indicate that only one H^+ dissociates to any appreciable extent from either of these weak acids. The dissociations of the second and third H^+ ions are insignificant by comparison.

6. All four compounds in Group C are molecular. None of them dissociates significantly.

7. Even though the water itself is molecular, it contains ionic impurities, such as Ca^{2+}, Mg^{2+}, HCO_3^-, and Cl^-. The ionic impurities contribute significantly to the conductivity of the solution. These ionic impurities have been removed from distilled water.