Electrolytes and Nonelectrolytes

Science Objectives

- Use Vernier GDX Conductivity Probe to determine the conductivity values of common substances.
- Determine which substances are nonconductors, weak electrolytes, or strong electrolytes.

Math Objectives

- Understand the principle that total charge on the anion and the total charge on the cation in a chemical compound must equal zero.

Materials Needed

- TI-Nspire™ CX II
- Vernier® GDX Conductivity Probe
- Calculator Connection Cable (Mini-A to Micro-B USB)

Vocabulary

- Conductor
- Nonconductor
- Weak Electrolyte
- Strong Electrolyte
- Cation
- Anion
- Molecular Acid

About the Lesson

- This activity makes use of the Vernier GDX Conductivity Probe to measure the conductivity of common chemical compounds.
- Students will then determine which substances are nonelectrolytes, weak electrolytes, or nonelectrolytes.
- Time Required: 45-60 minute class period.

TI-Nspire™ Navigator™ System (if available)

- Class Capture to monitor student progress.

Tech Tip:
Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

Lesson Files:
Student Activity
- Electrolytes _Student.pdf
- Electrolytes _Student.doc

Activity Overview

1. Please print the student worksheet and make available to students before beginning the lab. Lab background information as well as lab procedures are included only in the student worksheet. Always remember to review any safety precautions thoroughly with your students prior to starting the lab.

2. Vernier Go Direct® (GDX) probes and sensors can be either directly connected to the TI-Nspire CX II with a Calculator Connection Cable (Mini-A to Micro-B USB) or through TI's Bluetooth Adapter. For this activity, we used the USB direct connection method. *Note: A TI-Nspire CX II is required to use the Go Direct probes, but this activity can also be done with the Vernier LabQuest Conductivity sensor, which can also be used with the TI-Nspire CX or TI-Nspire CX II.*
3. *Optional procedure* for the Bluetooth Adapter (instead of the USB cable), follow these pairing directions:
    - Turn the TI-Nspire™ CX II on.
    - Turn on the GDX Probe or Sensor of choice.
    - Plug the Mini-A end of the cable into the Npsire CX II and the Micro-B into the Bluetooth Adapter.
    - Press [**Menu]** on the TI-Nspire unit and choose **Add Vernier DataQuest**.
    - Select **Add Bluetooth Sensor** on the Handheld screen.
    - On the next screen, > **Connect for the Probe or Sensor** that you wish to add.
    - Choose OK on that screen and OK on the following screen.
    - The Probe or Sensor is now ready for use wirelessly.
    - *For more information on Go Direct Sensors, and TI Technology visit https://education.ti.com/en/product-resources/go-direct*

    Note: TI-Nspire CX II's Vernier DataQuest app can also support many of the newer Vernier GoDirect sensors, while also continues to support some of Vernier's older sensors and probes.

4. 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).

5. Teacher Preparation of solutions should be done in advance: (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.

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

7. 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.

8. 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. These four samples will usually have a small conductivity value due to dissolved carbon dioxide, which forms aqueous ions according to the equation:

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

QUESTIONS

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?

   Answer: Group A compounds are ionic and they would completely dissociate in water.

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

   Answer: Even though all compounds have the same concentration, the difference in conductivity is due to the number of ions produced by each in solution: three ions for $CaCl_2$, four ions for $AlCl_3$, and two ions for NaCl.

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.

Answer: Group B consists of molecular acids. HCl is a strong acid while the remaining three are weak. The order of strength is HCl, H_3PO_4, $HC_2H_3O_2$, and H_3BO_3.

4. Write an equation for the dissociation of each of the compounds in Group B. Use $\longrightarrow$ for strong; $\longleftrightarrow$ for weak.

   Answer: $HCl \rightarrow H^+ + Cl^-$

   $H_3PO_4 \longleftrightarrow H^+ + H_2PO_4^-$

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

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

5. For H_3PO_4 and H_3BO_3, does the subscript "3" of hydrogen in these two formulas seem to result in additional ions in solution as it did in Group A? Explain.

   Answer: The subscript "3" does not result in more ions. The number of ions and strength of the acid depends on the degree of ionization.

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?

   Answer: All four Group C compounds are molecular and, therefore, do not ionize.

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

   Answer: Tap water has various substances dissolved in it which provides some conductivity depending on the source of the tap water.

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

This activity was adapted from Experiment #22: Properties of Solutions: Electrolytes and non-Electrolytes from the *Science with TI-Nspire Technology™*, ©2019 Vernier®.