

# Lab Activity H10

## Conductivity of Solutions

### OUTCOMES

After completing this lab activity, the student should be able to

- Perform a simple test to determine whether a substance is a strong electrolyte, weak electrolyte, or nonelectrolyte
- Classify several substances as strong electrolytes, weak electrolytes, or nonelectrolytes based on their solubility and chemical name/formula



### DISCUSSION

Most of us have heard of electrolytes, advertised in sports drinks such as Gatorade®, but what are they? An electrolyte may simply be defined as a substance that conducts electricity when dissolved in water. This definition specifies two criteria that must be met. First, the substance must be dissolved in water (so it must also be soluble in water). Second, it must conduct electricity when dissolved in water.

Electrolytes, themselves, are further categorized into strong electrolytes and weak electrolytes. A strong electrolyte is an aqueous solution that is strongly conducting, while a weak electrolyte is an aqueous solution that is weakly conducting. However, it is also possible for a substance to be dissolved in water without conducting electricity, in which case it would be classified as a nonelectrolyte.

In acid-base chemistry, the distinction between a strong electrolyte and a weak electrolyte leads to further classification of acids and bases. If an acid is also a strong electrolyte, it is called a strong acid. And if an acid is also a weak electrolyte, it is called a weak acid. A base that is a strong electrolyte is a strong base and a base that is a weak electrolyte is a weak base.

One may wonder why the conductivity of solutions is so important or why we need to consume substances that conduct electricity when dissolved in water. In the case of the human body, electrolytes are important in the regulation of bodily fluids. Electrolytes also allow the transmission of electrical signals within the brain, nervous system, muscles, and heart. After all, an electrocardiogram (EKG) monitors the electrical activity of a heartbeat. When a person exercises and sweats, electrolytes are lost through perspiration. That's why Gatorade® has long been associated with sports and athletes.

Electrolytes also play an important role in electrochemistry. In batteries, electrons flow from one electrode to another in the external circuit, while the electrolytes close the circuit internally and maintain the balance of charge within the cell. A fuel cell makes use of a solid

electrolyte to conduct ions and to keep the reactants physically separated. In electroplating, the metal ions in the electrolyte are deposited onto the object to be plated, while it also keeps the current flowing in the circuit. These are but a few of the many other examples that may be cited.

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### MATERIALS (Provided By Student)

Clean plastic lid(s) – to be discarded upon completion of the lab

9-volt battery	Rubbing alcohol (isopropyl alcohol in water)
Distilled water	Salt (sodium chloride)
Household Ammonia* (ammonia in water)	Sugar (sucrose)
Hydrogen peroxide (3%, in water)	Vinegar (acetic acid in water)
Baking <b>soda</b> ** (sodium bicarbonate)	Tape (optional)

\*Window Cleaner containing ammonia is **not** a suitable substitute for household ammonia.

\*\*Baking powder is **not** a suitable substitute for baking soda.

### MATERIALS (From Kit)

Miniature bulb and wire assembly (referred to in the procedure as the bulb assembly)

Copper (II) sulfate (0.5M in Beral pipet)	9-volt battery clip
Hydrochloric acid (0.5 M in Beral pipet)	Graduated cylinder - 10 mL
Potassium nitrate (0.5 M in Beral pipet)	Portion cups - 2 oz (3 needed)
Sodium hydroxide (0.5 M in Beral pipet)	Electrogalvanized nails, 2" (2 needed)
Empty Beral pipet	Safety goggles/glasses

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**NOTE:** Any plastic lid will work, but colored lids make it easier to observe gas bubble formation. Also, any size lid should work, including caps from milk jugs, cottage cheese containers, frosting containers, or ice cream pails. Metal lids may NOT be used. The plastic lids should be rinsed and discarded upon completion of the lab.

**NOTE:** The copper (II) sulfate, potassium nitrate, and sodium hydroxide provided in the kits are all aqueous solutions in which the respective solid has been dissolved in water. Hydrochloric acid always comes as an aqueous solution in which hydrogen chloride gas is dissolved in water.

## PROCEDURE

PROTECTIVE EYEWEAR MUST BE WORN AT ALL TIMES DURING THIS EXPERIMENT!

### Part 1. Constructing the Conductivity Tester

1. Obtain the 9-volt battery clip and one of the bulb assemblies from the lab kit. If necessary, remove about half a centimeter of insulation from the ends of each of the four wires.
2. Attach the battery clip to a fresh 9-volt battery. Then attach one end of the bulb assembly to the end of the red wire from the battery clip by securely twisting the exposed portions of the wires together. If desired, wrap the connection with tape to hold the wires together and to prevent accidental shorting.
3. Test the apparatus by touching the unattached, exposed wire of the bulb assembly to the end of the black wire of the battery clip. The bulb should light. If it does not, recheck the connections, or try a fresh battery or bulb assembly.
4. Set the apparatus aside and make sure that the exposed wires do not touch. If they touch each other for a prolonged period of time, the battery will go dead and a fresh battery will be needed, or the bulb may burn out.

### Part 2. Testing the Solutions

5. The following liquids/solutions may be tested in any order. The data table is arranged with household chemicals listed first followed by kit-provided chemicals.
  - a) Distilled water and tap water will be tested WITHOUT the addition of any solute.
  - b) For each solid to be tested, dissolve a pea-sized amount into approximately 5 mL of distilled water in a portion cup: salt, sugar, baking soda (**not** baking powder).
  - c) The following chemicals already come as aqueous solutions: vinegar, ammonia, rubbing alcohol, hydrogen peroxide, copper (II) sulfate, hydrochloric acid, potassium nitrate, and sodium hydroxide. Therefore, they do not need to be dissolved in water.
6. Place a small pool (1-2 cm in diameter) of the liquid or solution to be tested onto an inverted plastic lid. If the lid is large enough and if careful, it may be possible to place several pools of solution on a single lid. Avoid allowing the different solutions to come into contact with each other. Label the pools to keep track of which solution is which. **REQUIRED PHOTO: Includes your face and/or clearly shows a Picture I.D. (with name), with the inverted plastic lid and pool(s) of liquid(s) to be tested.**

**NOTE:** Rubbing alcohol has a low surface tension and should not be placed onto the lid simultaneously with other solutions, as it has a tendency to spread out. There may be other solutions that will need to be tested independently.

7. To test a solution for conductivity, press and hold the exposed wire of the bulb assembly to the tip of one nail and the exposed portion of the black wire to the tip of a different nail. Without touching them together, lower the heads of the nail into the pool of solution to be tested.
8. Two observations should be made. First, note whether the bulb lights or not. Also, note whether bubbles are produced or if there is any discoloration on the surface of either of the submerged nail heads. Bubbles may be produced slowly in cases when the bulb does not light, so allow several seconds and observe carefully.

**NOTE:** Avoid dipping the wires directly into the liquid or solution, since insoluble oxides may form on the surface of the wire, preventing the bulb from lighting or gases from forming. The ends of the wires may be dried and sanded if they have come into contact with any of the liquids or solutions.

9. Test each of the solutions for conductivity. To avoid contamination of solution to be tested, rinse and dry the surface of the metal pieces before lowering them into the solution. If necessary, thoroughly clean, rinse, and dry the lid before placing new solutions on the lid.  
**REQUIRED PHOTO:** Includes the date clearly shown on a calendar, newspaper, cell phone, or written on a sheet of paper, along with bulb assembly dipped into a pool of liquid that conducts electricity. .
10. All of the solutions may be discarded down the drain with plenty of water.

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### EXTENSION (not required)

Test other substances for conductivity.

## TYPING PROPER CHEMICAL FORMULAS

It is expected that you write proper chemical formulas and charges in all of your lab reports when formulas are written (using subscripts and superscripts).

Examples:

- Write the chemical formula for water as  $\text{H}_2\text{O}$ , **not**  $\text{H2O}$ .
- Write the formula for the sulfate ion as  $\text{SO}_4^{2-}$ , **not**  $(\text{SO4})^{2-}$ .
- Write the number 0.00074 in scientific notation as  $7.4 \times 10^{-4}$ , **not**  $7.4 \times 10^{\wedge-4}$ .

In most **Windows**-based applications, including Microsoft *Word*, the keystroke combination **[Ctrl] + [=]** turns subscripts on and off, while **[Ctrl] + [Shift] + [=]** turns superscripts on and off. Subscripts and superscripts may also be accessed from the ribbon as follows: *Home > Font > select either  $\text{X}_2$  or  $\text{X}^2$* . OpenOffice *Write* uses a different keystroke combination than most Windows applications – for subscripts, use **[Ctrl] + [Shift] + [B]** and for superscripts, use **[Ctrl] + [Shift] + [P]**.

In most **Mac**-based applications, **[Cmd] + [=]** turns subscripts on and off, while **[Shift] + [Cmd] + [=]** turns superscripts on and off. If you are using a Windows keyboard with a Mac, you need to assign the function of the keys. For most keyboards, the default setting is that the **[Windows]** key acts as the **[Cmd]** key. Subscripts may also be accessed from the menu on a Mac as follows: *Format > Font > Subscript* and *Format > Font > Superscript*.

Within **D2L**, click on the pencil icon or on the answer box below to answer a question. To write proper chemical formulas, click on the "Advanced" tab. Clicking on the  $\text{X}_2$  icon turns on subscripts. Clicking on  $\text{X}_2$  a second time will turn the subscripts off. Clicking  $\text{X}^2$  toggles superscripts on and off.

**Chemical formulas and mathematical formulas should always use subscripts and superscripts where appropriate.**

Name\_\_\_\_\_

Lab Section\_\_\_\_\_

**PRELAB QUESTIONS**

1. What is an electrolyte? What is a nonelectrolyte?
2. Without looking them up, predict which of the following substances are electrolytes and which are nonelectrolytes. You will not be penalized for incorrect predictions.

Substance	Prediction: Electrolyte or Nonelectrolyte?
Distilled Water	
Salt	
Sugar	
Baking Soda	
Vinegar	
Ammonia	
Rubbing Alcohol	
Hydrogen Peroxide	
Copper (II) Sulfate	
Potassium Nitrate	
Sodium Hydroxide	
Hydrochloric Acid	

3. Which safety precautions, if any, must be observed during this lab activity?

**PHOTOS** - Please compress photos and save your file **before** uploading to the dropbox. Photos should come close to filling the boxes below and all required items should be **clearly visible**.

Required Photo 1:

Required Photo 2:

Name\_\_\_\_\_

Lab Section\_\_\_\_\_

**DATA**

Substance	Bulb Lights?	Bubbles or Discoloration?	Chemical Formula of the Solute?	Strong Electrolyte, Weak Electrolyte, or Nonelectrolyte?
Distilled Water				
Salt				
Sugar				
Baking Soda				
Vinegar				
Ammonia				
Rubbing Alcohol				
Hydrogen Peroxide				
Copper (II) Sulfate				
Potassium Nitrate				
Sodium Hydroxide				
Hydrochloric Acid				
Tap Water			X X X X X X X X	

**POSTLAB QUESTIONS**

1. The production of gas bubbles, discoloration of the nails, and the bulb lighting are each indicators of solution conductivity. The possible observations should fall into one of three categories:
  - The bulb lights **and** there are gas bubbles and/or discoloration of the nails.
  - The bulb does **not** light, but there are gas bubbles and/or discoloration of the nails.
  - The bulb does **not** light. There are **no** gas bubbles and **no** discoloration of the nails.

**Ignore the light intensity** with this particular apparatus, as it usually is **not** an accurate reflection of electrolyte strength. (Note: However, with many other types of light bulb apparatuses, the light intensity **is** an accurate reflection of electrolyte strength.)



- a) Given the preceding information and referring to the prelab discussion, determine whether each substance is a strong electrolyte, weak electrolyte, or nonelectrolyte. There should be at least one of each.
  - b) Write the chemical formula for each substance in the table. For aqueous solutions, include the solute only. **Salt** contains **sodium chloride**. **Baking soda** is **sodium bicarbonate**. **Sugar** is also known as **sucrose**. **Vinegar** is an aqueous solution of **acetic acid** and **rubbing alcohol** is an aqueous solution of **isopropyl alcohol (2-propanol)**.
2. Which criteria did **you** use in this lab activity to determine whether a substance was a:
- a) strong electrolyte?
  - b) weak electrolyte?
  - c) nonelectrolyte?
3. Based on the results of **this** lab activity, does sugar, salt, or both supply electrolytes lost through vigorous exercise and perspiration? Give a brief explanation.

4. You may have heard that you should stay off lakes during thunderstorms or avoid placing radios or blow-dryers near tubs while bathing. Is this good advice? Why? Is pure water a good conductor of electricity?
5. Another way to define a strong electrolyte is as a substance that dissociates or ionizes completely when dissolved in water. Strong electrolytes include soluble ionic compounds and strong acids. Since all strong bases are also soluble ionic compounds, they are also strong electrolytes.
- a) Select two of the substances in this experiment that were found to be strong electrolytes. Then tell which ions were produced when the substance was dissolved in water.

Strong Electrolyte	Ions Produced
Example: $\text{Sr}(\text{OH})_2$ (substance not actually used in this lab)	$\text{Sr}^{2+}, \text{OH}^-$

- b) Circle the substances in the following list that are strong electrolytes:

lithium phosphate	calcium carbonate	acetone ( $\text{CH}_3\text{COCH}_3$ )
ethanol ( $\text{CH}_3\text{CH}_2\text{OH}$ )	magnesium sulfate	sodium acetate

Note: In case you are curious, none of these substances are strong acids.

## Lab Report Submission Checklist

Complete the appropriate checklist and **submit this page** along with your lab activity.

### Lab Activity Submitted Via the D2L Dropbox

	Prelab assignment is complete.
	Remainder of lab activity is complete (data, questions, photos. etc.).
	Required photos of the procedure included.
	At least one photo shows face or photo I.D. At least one photo clearly shows the date.
	Document filename in format of <b>Lastname Firstname HX</b> .
	File size is no larger than 10 MB.
	Only one document submitted for this lab activity.
	Lab submitted on time.
	If late, this is your first extension.

### Lab Activity Submitted Via the US Postal Service or In Person

	Prelab assignment is complete.
	Remainder of lab activity is complete (data, questions, photos. etc.).
	Required photos (at least one showing face or photo I.D.; at least one shows the date of the procedure or a tangible artifact or product from the lab activity is included.
	If return is desired, a self-addressed stamped envelope <b>with sufficient postage</b> is included*.
	Lab submitted on time (postmarked by due date if sent via USPS).
	If late, this is your first extension.

\*You may find a postage calculator at <http://postcalc.usps.gov>. Use the balance in your kit to find the weight.