Battery Construction and Degradation Demonstration

ACTIVITY SUMMARY:

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PROJECT DESCRIPTION: Students will have the opportunity to construct and observe a functioning battery which possesses the fundamental elements which a battery is comprised of. This will be achieved through the use of inserting two metal electrodes into a citrus fruit (or an alternative electrolyte) and measuring voltage with a multimeter. Students over a short period of using the multimeter will observe the gradual reduction in voltage of the battery which demonstrates the concept of "battery life."

GRADE LEVEL(S): 9, 10, 11, 12

SUBJECT AREA(S): Energy, electricity, battery, electronegativity, ionization

ACTIVITY LENGTH: 30-45 minutes

LEARNING GOALS:

- Students will understand the basic components of a battery, and the fundamental scientific concepts which explain how the battery functions.
- Students will be tasked with constructing a basic battery model.
- Students will be challenged to apply their knowledge of the concepts of electronegativity and ionization to devise combinations of electrodes which result in the production of higher voltages.

N.G.S.S. STANDARDS MET:

Standard	**Description**
HS-PS3-2	*"Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles and energy associated with the relative positions of particles."*
HS-PS3-3	*"Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy."*
HS-PS1-4	*"Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends on the changes in total bond energy."*

MATERIALS LIST (PER GROUP):

- At least one citrus fruit (alternatively, other liquid electrolytes such as salt water can be substituted for the citrus fruit) — Note: The group must continue to use the same type of electrolyte throughout each trial of this lesson. For example, a student can not switch from using an orange to using a lime midway through their series of trials
- One multimeter with two leads
- One timer, stopwatch, etc.
- Pieces of metal (ex. nails, wires, foil, rods, paper clip, etc.) that fit the following recommendations:
    - Long enough to be submerged at least halfway within the electrolyte
    - Are one of the following metals: Aluminum, Iron, Copper, Zinc, Nickel, Lead, Magnesium, Cadmium, Tin, Silver (Note: At least three different metals are recommended, but greater varieties of metal will enhance the challenge for the students)
- Electronegativity and Standard Reduction Potential Charts:
- Data Table Worksheet: **(see below)**

***OPTIONAL* MATERIALS LIST (PER GROUP):**

- Two wire alligator clamps for the multimeter leads — used to stabilize the connection between the leads and the electrodes, which will help the voltage readings have less fluctuation
- Paper towels are recommended in order to clean the metal pieces after being submerged in the electrolyte, and to clean up potential spills
- Students may be encouraged prior to the lesson date to bring their own pieces of metal from home to be used as electrodes. For example, a student might be able to bring in from home paperclips, metal nails, metal wire, etc.

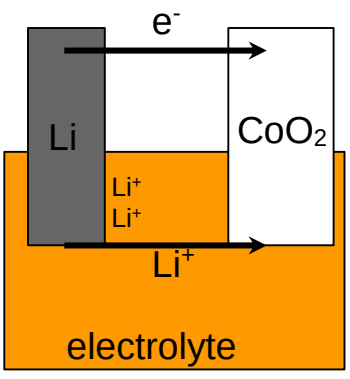
ACTIVITY VOCABULARY:

- Electricity
- Battery
- Electrolyte
- Electrode
- Electronegativity
- Reduction potential
- Redox
- Multimeter

STUDENT BACKGROUND:

Energy is a quantitative property of a system which depends on how the matter in that system interacts. Energy can change from and to different forms. In this experiment you will be turning chemical energy -energy stored in bonds- into electrical energy. An electrode is a solid conductor of electricity which is the focus of this experiment. **Electronegativity** is how much pull an atom has on an electron. For example, chlorine has a very strong pull on electrons because it needs only one more electron to fill its outer shell. Redox reactions are the basis of how a battery works. It is the transfer of electrons between the two electrodes because of their difference in electronegativity involved in the reaction. The term **redox reaction** comes from the longer term reduction-oxidation reaction. The substance that is being reduced gains electrons from the substance that is being oxidized. In biology, photosynthesis and cellular respiration are examples of redox reactions. This is how organisms store and use some forms biological energy. **Standard Reduction Potential** measures how likely a substance will be reduced at standard conditions. So a higher positive number will be very likely while a very negative number will more likely be oxidized. **Voltage** is the difference in electrical potential between the two electrodes in a redox reaction.

Multimeters are used to gather the data about electrical systems. Multimeter measures both voltage and current, but only voltage will be used in this experiment so current can be ignored. The flow of electrons from one electrode to the other goes through an external wire which is in this experiment the multimeter. However, the electrons that are flowing from the ionization that is happening at one of the electrodes. The most common of batteries that people are familiar with are Lithium batteries. So what happens with Lithium batteries is that the Li solid metal ionizes and becomes Li^+ and that ion goes to the surface of the metal. So when the battery is used the electrons start to flow but at the same time the ions of Lithium flow to the Cobalt Oxide through the electrolyte which produces voltage.



EDUCATOR BACKGROUND:

Important Note: This lesson will cover a variety of concepts and ideas that the students will need to understand to be able to complete the experiments. The students will need to have knowledge of the periodic table, reactions, valence electrons, ionization, and standard conditions because these will not be covered in the background for them. If they haven't been exposed to these concepts they will need to be taught before proceeding with this lesson.

An **electrode** is a solid conductor of electricity which is the focus of this experiment. **Electronegativity** is how much pull an atom has on a shared electron. For example, chlorine has a much greater pull on electrons because it needs only one more electron to fill its outer shell than sodium which actually wants to lose one. Redox reactions are the basis of how a battery works. It is the transfer of electrons between the two electrodes because of their difference in electronegativity involved in the reaction. The term **redox reaction** comes from the longer term reduction-oxidation reaction. The substance that is being reduced gains electrons from the substance that is being oxidized. In biology, photosynthesis and cellular respiration are examples of redox reactions. This is how organisms store and use some forms biological energy. **Standard Reduction Potential** measures how likely a substance will be reduced at standard conditions. So a higher positive number will be very likely while a very negative number will more likely be oxidized. **Voltage** is the difference in electrical potential between the two electrodes in a redox reaction. So if two electrodes are chosen which are on opposite sides of the standard reduction potential chard the voltage will be high but if the same electrode is chosen for both electrodes the difference would be 0 resulting in no volts.

The students will be using a multimeter to gather the voltage data. A multimeter measures both voltage and current, but only voltage will be used in this experiment so current can be ignored. The flow of electrons from one electrode to the other goes through an external wire which is in this experiment the multimeter. However, the electrons that are flowing from the ionization that is happening at one of the electrodes. The most common of batteries that people are familiar with are Lithium batteries. So what happens with Lithium batteries is that the Li solid metal ionizes and becomes Li^+ and that ion goes to the surface of the metal. So when the battery is used the electrons start to flow but at the same time the ions of Lithium flow to the Cobalt Oxide through the electrolyte which produces voltage.

The first standard that is met is **HS-PS3-2** which will be shown through the creation of the model (battery) and in the students background which defines energy and also explains that energy can have different forms. Energy in this lesson is how matter is stored in the battery and how the flow of electrons through the multimeter:
Hyperlink: https://cebrightfutures.org/sites/default/files/multimeter-cheatsheet.pdf

The second standard that this lesson can be applied to is **HS-PS3-3**, which involves designing, building, and refining a device for the purpose of converting one form of energy into another form. This lesson provides students with the opportunity to creatively construct and modify the design of their battery (by using different combinations of electrodes) in order to

yield the greatest voltage production. This voltage is created through the conversion of chemical energy stored in the chemical bonds of the electrodes into electricity.

The third standard that this lesson addresses is **HS-PS1-4**, which necessitates that a model is used to display how a shift in total bond energy can result in the release or absorption of energy from a chemical reaction system. This lesson meets this standard by allowing the students to construct a model battery, which facilitates chemical reactions that result in the release of energy from the two battery electrodes.

LESSON INSTRUCTIONS:

1. Have students power on their multimeter and switch the setting to direct current (Symbol: "⎓") voltage measurement setting to the range that at least include values from approximately 0.01 to 2 volts.
2. If alligator clips have been included with the multimeter, attach the clips to the multimeter leads.
3. Print out the provided data table worksheet and electronegativity/standard reduction potential charts and allow the students to have them on standby during the lesson.
4. Students may choose two electrodes (pieces of metal) to <u>partially</u> submerge into the chosen electrolyte (ex. citrus fruit, salt water, etc.). Note: Do not allow the students to position the electrodes in a manner that allows any physical contact between each other, and make certain that the students leave enough of the electrodes unsubmerged to allow the leads/alligator clips to securely make contact with the exposed electrode portions.
5. Have the students attach the multimeter leads/alligator clips to the exposed portions of the electrodes so that a stable connection is reached. Instruct the students to record (on their data table worksheets) their voltage reading on the multimeter when the connection is first made, one minute after the initial connection, and two minutes after the first connection. The students must keep the leads/alligator clips connected to the electrodes for the entire two minutes recording period.
6. Have students repeat steps 4-6 with different combinations of electrodes. Challenge the students to find the combinations of electrodes which result in the greatest voltage output. Students may use their electronegativity and standard reduction potential charts to guide them in this process. After repeated use of the same electrolyte, it may not yield high voltage, which means that the electrolyte may need to be switched for a new one.
7. When the lesson has been completed, dispose of all materials in a proper and safe manner.
8. Facilitate discussion among the students, and encourage them to use critical thinking to find explanations for their observations.

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Data Table Worksheet

Name:_____ Date:_____

Electrode Combination	***Initial Voltage***	***Voltage After One Minute***	***Voltage After Two Minutes***
Example: Aluminum and Copper	V_i	V_1	V_2