Lesson Plan: Battery Basics

FOR THE TEACHER

Summary
In this lesson students will explore the chemical reaction that occurs within a lead-acid car battery and the role of the battery within a car prior to creating their own batteries.

Grade Level
Middle School

NGSS Standards
- MS-PS1-2: analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
- MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure successful solution, taking into account relevant scientific principles.
- MS-ETS1-2: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Objectives
By the end of this lesson, students should be able to
- Describe the process of converting chemical energy into electrical energy
- Accurately define battery
- Identify the role of electrons in a battery
- Create a device to generate electric energy from chemical energy

Chemistry Topics
This lesson supports students’ understanding of
- Electrochemistry
- Subatomic particles, specifically electrons
- Chemical energy
- Electrical energy
- Chemical reactions

Time
Teacher Preparation: 30-40 minutes
Lesson:
- Engage: 15 minutes
- Explore: 20 minutes
- Explain: 20 minutes
- Elaborate: 20 minutes
- Evaluate: 15 minutes (outside of class)

Materials
- Car battery or a picture of a car battery (for observation only)
- Car battery tester (optional)
- Lemons (one per group of students)
- Items made of copper (pennies, wire, pipe)
- How Lead Batteries are Made video (2:48)
- Galvanized nails (or other metallic item containing zinc)
- Multimeter
- Various other objects: straws, coins, toothpicks, etc.

**Safety**
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.
- It is important to remind students that the lemon battery is safe to touch, but that they should not experiment with car or commercial batteries or electrical outlets as it could have deadly consequences.

**Teacher Notes**
- **Engage:** As the students enter the classroom, they will view a car battery (an actual battery will provide students with hands on access, but if one is not available, a picture of one will work). Depending on your group of students, some may recognize a car battery while others may not. Keeping their background knowledge in mind can help you determine whether to use a battery with a label on it or not. Examples:
  - Battery without label
  - Battery with label

  Asked students to generate a written response to the following questions:
  - Provide qualitative and quantitative observations about the black box.
  - What do you think the black box is used for? Why?

  Writing qualitative and quantitative observations will help the students closely examine aspects of the battery. Allowing the students to perform quantitative measurements (mass, length, volume) can provide them with measurement practice, but is not necessary for a successful lesson. Varying the number or type of observations required is one way to differentiate for students with varying needs, so each student is challenged and engaged in the initial activity. After the students have had a chance to write down their thoughts, they will share their responses within a small group (4-5 students), making additions to their writing, if necessary. Sharing their observations in a small group setting provides students with further opportunities for engagement and the opportunity to participate in meaningful dialog. Once the groups have had a chance to discuss, the teacher will ask the groups to share out their ideas, while recording them on a board and then develop a class consensus on what they believe is the purpose of the box.

- **Explore:** After the students have made their predictions, the teacher will reveal that the black box is a car battery and ask the students to explain why they think cars need batteries. Students may not be able to recognize or explain why a battery is necessary in a car. In this case, it may be helpful to begin by asking them what other types of items use batteries. They should be able to identify that batteries are used to provide electric energy. The teacher will then ask the students to attempt to explain how a car battery generates electricity by having them work in small groups (3-5 students) to draw and label what they think the inside of the battery looks like. The students will be asked to share their drawings with the class. This website provides a brief review of the role of a battery in a car. The students may also have difficulty describing what they think may be inside the car battery. It may be helpful to use guiding questions. For instance, students could be asked to name the subatomic particles found in atoms (protons,
neutrons, and electrons) and then to identify which particle is able to move from one atom to another. It may also be helpful to have students access a periodic table of elements and identify which elements may gain or lose electrons and what types of elements are good conductors. The electrical energy website or the electricity website may be helpful in developing student background on the topic.

- **Explain:** After the students share their diagrams with the class, it is time to review the chemical reactions taking place inside the battery. The students will view the three minute video, How Lead Batteries are made to see both how they are made and how they generate electricity. It may be helpful to have the students take notes during the video or to pause the video and write the battery elements on the board, to help facilitate discussion of how electrons move through the battery. The students will compare their initial ideas to the information presented in the video through small group discussion. Having the students identify items from their diagram that match information from the video will be helpful in connecting students’ prior knowledge to the newly gained information.

The teacher will walk students through two car battery animations which show how electrons and ions flow through a battery (Animation 1) and the components of a battery (Animation 2). These animations can help students visualize electron movement, and they can use the diagrams on the Hyperphysics website to explain the movement and the process of how batteries work. Careful attention should be paid to the battery components, lead and sulfuric acid, and the chemical equations used to describe the process. The reaction that takes place between the acid and the metal should also be emphasized and can be explained using information from the Acids and Metals website. Similarly, the Aus-e-tute website provides detailed information about the chemical equations involved in the production of electricity from a lead-acid battery. It is also important for students to understand that a battery consists of a cathode, an anode, and an electrolyte.

- **Elaborate:** Now that the students understand that a chemical reaction takes place in a battery, which enables electrons to move and cause an electric current, it is time for them to experiment. In this section of the lesson, students will be placed into groups (3-5) and are asked to generate electricity using a lemon. A variety of materials (wooden/plastic toothpicks, copper wire, aluminum wire, iron nails, zinc nails, silverware fork, plastic fork, quarters, nickels, pennies, pencil “lead”)—should be provided for student use, so they must experiment to determine which items will work to create a lemon battery. Be sure to label the experiment items, such as the galvanized nails as having zinc in them. It may be helpful to guide the students back to the idea of the lead-acid battery and to remind them of what types of materials are the best conductors of electricity. A brief tutorial on how to use a multimeter may be necessary. Once the students have created their lemon battery, they should draw a diagram and include the terms cathode, anode, and electrolyte. Possible answers for the definition section of the lab sheet include:
  - A cathode is an electrode through which a current leave an electrolytic solution.
  - An anode is an electrode through which a current enters the electrolytic solution.
  - An electrolytic solution is a solution that can conduct an electric current.

- **Evaluate:** It may be helpful to view and discuss the video How a Lemon Battery Works with the students. Having students use the CER (Claims-Evidence-Response) format when writing a response to the conclusion questions can be helpful and allows for a CER rubric to be used.

- **Extend:** The lemon battery lends itself to a variety of extensions including experimenting with other fruit or series. Examples of such extensions can be found in “Fruit Batteries” by Jerry Loomer.
### CER Rubric

<table>
<thead>
<tr>
<th>Component</th>
<th>Level</th>
<th>Feedback</th>
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<tbody>
<tr>
<td><strong>Claim</strong> - A statement that fully answers the original question.</td>
<td>2</td>
<td>Makes an accurate and complete claim.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Makes an accurate but incomplete claim.</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Does not make a claim, or makes an inaccurate claim.</td>
</tr>
<tr>
<td><strong>Evidence</strong> – Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.</td>
<td>2</td>
<td>Provides appropriate and sufficient evidence to support claim.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Provides appropriate but insufficient evidence to support claim. May include some inappropriate evidence.</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Does not provide evidence, or only provides inappropriate evidence (evidence that does not support the claim).</td>
</tr>
<tr>
<td><strong>Reasoning</strong> – A justification that links the claim and evidence. It shows why the data count as evidence by using appropriate and sufficient scientific principles.</td>
<td>2</td>
<td>Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Provides reasoning that links the claim and evidence. Repeats the evidence and/or includes some – but not sufficient – scientific principles.</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Does not provide reasoning, or only provides reasoning that does not link evidence to claim.</td>
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- **Resources:**
  - Acids and Metals website describes the general reaction that takes place between acids and metals.
  - Animation of Car Battery shows movement of electrons and ions.
  - Aus-e-tute website includes chemical formulas for the reactions that take place within a lead-acid battery.
  - Battery Stuff website explains how lead-acid batteries function.
  - Car Battery Animation provides visuals of car battery components and describes electron movement.
  - Motorist Assurance Program website provides a brief description and diagrams explaining the role of the car battery.
  - Electricity website includes a brief timeline as well as information about electricity and circuits.
  - Fruit Batteries provides a variety of extensions from the lemon battery.
  - How a Lemon Battery Works is a video explaining the chemistry behind the lemon battery.
  - How Batteries Work is a student friendly website about batteries.
  - How Does a Battery Work explains the chemistry behind the lemon battery.
  - How Lead Batteries are Made video showing how car batteries are made and the chemistry involved.
  - Hyperphysics website containing diagrams of the chemical reactions occurring in a lead acid battery.
  - Kinds of Energy website provides an atomic diagram of the movement of electrons.
  - Lead Acid Battery website provides an inside view of a lead acid battery.
  - Lead Acid Battery Principles of Operation website provides technical information about lead-acid batteries.
**FOR THE STUDENT**

Lesson

The Lemon Battery

**Background**
Remember that a battery uses stored chemical energy and turns it into electrical energy through a chemical reaction. The primary parts of a battery include the cathode, anode, and electrolyte solution.

**Prelab Questions**
1. What is a cathode?
2. What is an anode?
3. What is an electrolytic solution?

**Problem**
What materials can be used to generate electricity from a lemon?

**Materials**
- Lemon
- Multimeter
- Various objects – coins (penny, nickel, dime, quarter), metal wire, crayons, toothpicks, straws, plastic fork, metal fork etc.

**Safety**
- Always wear safety goggles and aprons when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- The lemon battery that you will make will generate a low amount of electricity, so we can experiment with it in the lab. It is important to remember that you should not experiment with car or other batteries or electric outlets because they produce a strong current that can be fatal.

**Procedure**
1. Obtain a lemon from the supply table.
2. Roll the lemon on the table, but do not break the skin.
3. Examine the items on the supply table.
4. Which item would you like to use as an anode? Why?
5. Which item would you like to use as a cathode? Why?
6. Select one item to use as an anode and push it through the skin of the lemon. Record your choice in the table below. Leave enough of the item sticking out to attach the multimeter to.
7. Select one item to use as the cathode and push it through the skin of the lemon, without having it touch the anode. Record your choice in the table below. Leave enough of the item sticking out to attach the multimeter to.
8. Attach the multimeter to the cathode and the anode. Record the registering voltage in the table below.
9. Select a different anode and cathode and repeat steps 6-8 two more times, or until you are able to generate voltage on the multimeter. Record your results.
Results

<table>
<thead>
<tr>
<th></th>
<th>Anode</th>
<th>Cathode</th>
<th>Voltage</th>
</tr>
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<tbody>
<tr>
<td>Test #1</td>
<td></td>
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<tr>
<td>Test #2</td>
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<td>Test #3</td>
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</tbody>
</table>

Analysis
1. How many attempts did it take for you to generate voltage?
2. Which anode and cathode combination produced the highest voltage?
3. Were there any available materials that you decided to not select to use as an anode or a cathode? Why/why not?
4. In this activity, what was the electrolytic solution?

Conclusion
1. Why does the lemon battery work? In your answer, explain what is happening to electrons?
2. Do we need the lemon? Why or why not?
3. Based on your experiment, would lemons be a good source of chemical energy for electronic devices? Why or why not?