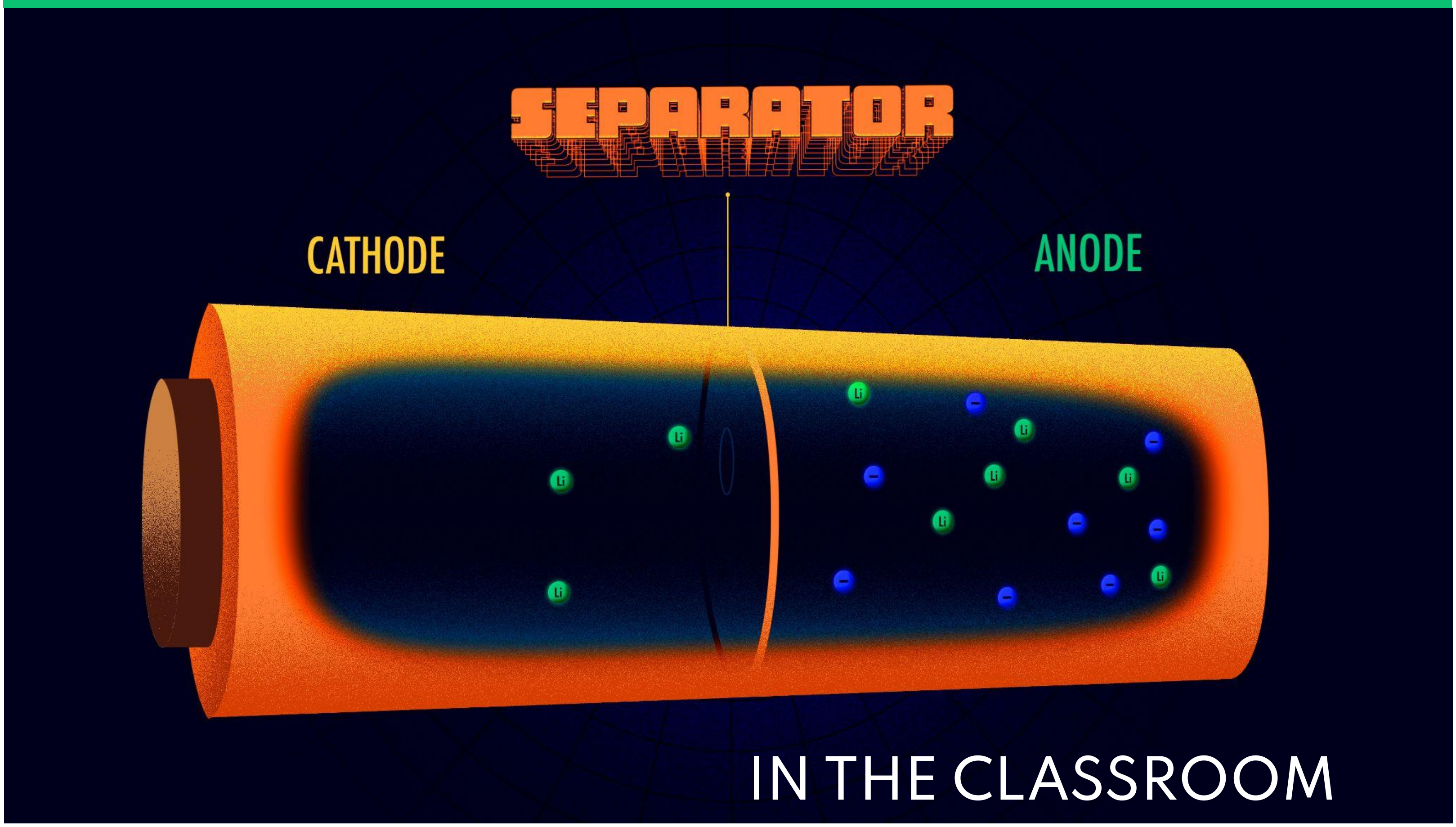
SHORT FILMS ABOUT CHEMISTRY

Energy to Spare



CLASSROOM LESSON PLAN
GRADES 9–12

CHEMISTRY SHORTS®

Overview

This lesson plan contains student activities, teacher notes, and additional resource suggestions that are intended for use with the *Chemistry Shorts®* film "Energy to Spare." The film is freely available for viewing online at http://chemistryshorts.org. The activities stand alone, with no additional background material needed. The activities are aimed at grades 9–12. Teachers may adjust or extend discussion of the chemistry involved depending on the students' level. The plan is designed for use as a complete package, although teachers may choose individual activities.

The lesson and materials are suitable for both in-person and virtual classrooms.

Classroom Materials

- Method for viewing *Chemistry Shorts®* film "Energy to Spare" (7 min., 2 sec.)
- Student Activity handouts (paper or digital copies)

Student Activities with Estimated Times

Pre-Class Activity Batteries in Your World	(15–20 min.)
In-Class Activity Battery Chemistry	(10–15 min.)
In-Class Activity Batteries as Bowling—A Model	(15–20 min.)
In-Class Activity Comparing Batteries	(5–10 min.)
After-Class Activity A Perfect Battery	(10–15 min.)

Related Standards

NGSS HS-PS1-1
Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

NGSS HS-PS2-6
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

NGSS 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 motions of particles (objects) and energy associated with the relative positions of particles (objects).

NGSS HS-ESS3-2
Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

NGSS HS-ESS3-4
Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

NGSS HS-ETS1-3
Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

CCSS.ELA-Literacy.RST.9-10.5
Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., *force, friction, reaction force, energy*).

CCSS.ELA-Literacy.RST.9-10.7
Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

CCSS.ELA-Literacy.RST.9-10.4 & 11-12.4
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics/grades 11-12 texts and topics.

CCSS.ELA-Literacy.W.11-12.2
Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

CCSS.ELA-Literacy.WHST.9-12.2
Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

Pre-Class Activity Teacher Notes
Batteries in Your World

Suggested Extensions

- “The Nobel Prize in Chemistry 2019.”The Nobel Foundation: https://www.nobelprize.org/prizes/chemistry/2019/summary/

  Resources that describe the 2019 Nobel Prize winners and their work on the development of lithium-ion batteries.

- “The 2019 Nobel Prize in Chemistry: The Batteries That Power Our Phones and Laptops.” Compound Interest: https://www.compoundchem.com/2019/10/09/2019nobelchemistry/

  Infographic that outlines the work done on lithium-ion batteries by the Nobel Prize winners.

- “The World’s Biggest Batteries Aren’t What You Think.” ACS Reactions: https://youtu.be/TIWIXzCwC8g

  Video that discusses larger-scale batteries that can help store renewable energy and also how a lake can serve as a battery.

Question 1
Students may not be able to view the type of battery, depending on the item. For example, they may not be able to access built-in batteries that are not designed to be replaced by the user, such as in a smartphone. Product information online often does not give many details about the battery.

Instructors could have an assortment of battery types available for students to view. Alternatively, they could show images of different batteries.

Question 3

- “Forms of Energy.” United States Energy Information Administration: https://www.eia.gov/energyexplained/what-is-energy/forms-of-energy.php

  Page with brief descriptions of different types of energy listed in Question 3.

In-Class Activity Teacher Notes
Battery Chemistry

Suggested Extensions

- "How a Battery Works." Australian Academy of Science: https://www.science.org.au/curious/technology-future/batteries

  Demonstration where students can quickly see the result of a redox reaction. A paper clip is plated with copper.

- "Inside a Lithium Ion Electric Car Battery." EV West: https://youtu.be/MUg9W4CbZUQ

  A company that does electric car conversions cuts open an electric car battery to show its innards.

- "I Made a Battery Out of Lasagna." ACS Reactions: https://www.youtube.com/shorts/yW5M7Q7IgFk

  Lasagnas in steel pans with aluminum foil over each one provide a charge, with the lasagna itself serving as an electrolyte.

Question 2
Some instructors use a mnemonic to help students remember which is oxidation and which is reduction. "Leo the lion goes ger" reminds students that Leo: lose electron(s) oxidation and ger: gain electron(s) reduction. Another mnemonic is Oil Rig: "Oxidation is loss, reduction is gain."

Question 3
Instructors could construct the hand battery using the directions at "Hand Battery," Exploratorium: https://www.exploratorium.edu/snacks/hand-battery

In-Class Activity Teacher Notes
Batteries as Bowling—A Model

Suggested Extensions

- "Save It for Later: Batteries Keep Us Energized." *ChemMatters*: https://www.acs.org/education/chemmatters/articles/save-it-for-later-batteries-keep-us-energized.html

  Magazine article written for high school chemistry students related to batteries.

Question 5

In addition to pointing out where the simplification of the model excludes parts of a battery and its operation, students could also discuss how the bowling model could be adapted to include them. Or, are there additional models they have seen used to explain batteries?

In-Class Activity Teacher Notes
Comparing Batteries

Suggested Extensions

- “The Button Battery… A Small Item That Can Cause a Big Problem.” Utah Poison Control Center: https://poisoncontrol.utah.edu/news/2024/11/button-battery-small-item-can-cause-big-problem

  Highlights the dangers if a child swallows a button battery, along with what companies are doing to try to prevent harm.

- “Water Batteries.” *Science*: https://www.science.org/content/article/how-giant-water-batteries-could-make-green-power-reliable

  Article that describes pumped storage hydropower plants.

- “Lithium-Ion Battery Fires.” CBS News: https://www.cbsnews.com/news/lithium-battery-fires-us-flights-new-faa-data/

  Article that discusses a rise in lithium-ion battery fires, including how they can happen, the damage they can cause, and what fire departments can do to fight them.

Question 1
Instructors could link this question, and its answer related to the potential of fires in lithium batteries, with another activity in the lesson plan. “Battery Chemistry” talks about the battery’s separator and what can happen if it breaks down.

After-Class Activity Teacher Notes
A Perfect Battery

Suggested Extensions
In the U.S., guidelines for disposing of or recycling batteries can vary from state to state. Students could investigate what their community requires.

- General information from the U.S. Environmental Protection Agency is at https://www.epa.gov/recycle/used-household-batteries
- A handout with state-specific information from the New Hampshire Department of Environmental Services is at https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/hw-23.pdf

Another type of device that would have specific requirements is one that needs a flexible battery. Recent research published by the American Chemical Society is available at https://www.acs.org/pressroom/presspacs/2024/july/completely-stretchy-lithium-ion-battery-for-flexible-electronics.html

Questions 1–4
"What's the Best Battery?" Battery University/Cadex Electronics: https://batteryuniversity.com/article/whats-the-best-battery#google_vignette

Compares several types of batteries and highlights advantages and disadvantages of each.

Question 2
The prices used in the question are from Energizer batteries, from walmart.com. (accessed Jan. 2025)

Name ______________________________ Date ______________

Pre-Class Activity
Batteries in Your World

1. Look around you. What do you see or have with you that uses a battery to operate? In the table below, list items you have come into contact with during the last week that use batteries to operate. Then, name, describe, and/or draw the type of battery used in each.

Item	Battery It Uses

Name ______________________________ Date ______________

Pre-Class Activity
Batteries in Your World (continued)

2. Consider the battery types you listed for question 1, along with any other types you are aware of.
   a. How are the batteries similar to each other?

   ____

   ____

   ____

   b. How are the batteries different from each other?

   ____

   ____

   ____

3. Several common types of energy are listed below.

Chemical	Sound	Radiant	Gravitational
Nuclear	Electrical	Thermal	Mechanical

   a. Which type of energy is originally present in a battery? ______________

   b. Choose one of the items powered by a battery that you listed for question 1. Into what other energy type(s) does the energy originally present in the battery transform?

   ____

   ____

Energy to Spare

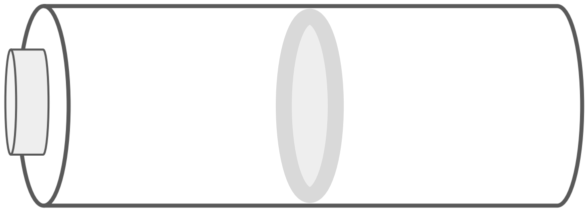
STUDENT ACTIVITY

Name ____ Date ___________________

In-Class Activity
Battery Chemistry

1. The film "Energy to Spare" describes the three main components of a battery:
   - electrodes
     - negatively charged anode
     - positively charged cathode
   - separator
   - electrolyte

   a. *Label these parts on the battery below.*



   b. A battery uses **redox reactions** at the anode and cathode. The term redox comes from putting together shortened forms of the words for two types of chemical reactions: <u>red</u>uction and <u>ox</u>idation. These reactions involve the movement of electrons. Electrons flow along an external circuit, or pathway, from the anode to the cathode. We are discharging, or using, the battery.

   Draw such a pathway from the anode to the cathode.

   c. At the anode, oxidation occurs. Electrons are "lost," or released. At the cathode, reduction occurs. Electrons are "gained," or accepted.

   On the pathway you drew in part b, draw 2–3 small circles to represent electrons. Add arrows to show the direction the electrons travel on the pathway.

   d. This flow of electrons can travel through a device to power it.

   On the pathway, draw and label something that represents a device your battery could power.

Name ______________________________ Date ______________

In-Class Activity
Battery Chemistry (continued)

2. The word *separator* suggests its main role in the battery—to separate.

a. What two other battery components does it separate?

_________________ _________________

b. Between these two components, along with the separator, is the *electrolyte*. It is typically chosen to have low electrical conductivity, so electrons don't flow through the electrolyte from one electrode to the other inside the battery. Instead, electrons flow from one electrode to the other on the pathway outside the battery, through the device you wish to power.

When negatively charged electrons move from one electrode to the other, it creates a charge imbalance. For the battery to continue operating, it needs to keep it balanced. To do this, what <u>do</u> the electrolyte and the separator allow to pass through them?

____

c. How does allowing these through maintain a charge balance? Explain.

____

____

____

3. A battery can even be made by placing one hand on a sheet of copper metal, the other hand on a sheet of aluminum (or zinc), and connecting a wire between the two sheets.

a. In this "hand battery," what are the electrodes?

____

b. What is the electrolyte?

____

____

Name ______________________________ Date ____________

In-Class Activity
Batteries as Bowling—A Model

1. The film "Energy to Spare" compares the chemistry of batteries to bowling. Fill in the remaining parts of the analogy based on the film.

Detail of Bowling	Associated Detail of a Battery
Bowler	*Battery anode, where electrons are released.*
Bowling balls	
Bowling pins/end of lane	
Length of bowling lane	
Ball return	

2. In the film, Team Lithium competes against Team Zinc.

a. Why would Team Zinc have the edge over Team Lithium in a game of bowling?

____

____

b. How does this part of the model show the benefit of zinc over lithium when storing charge?

____

____

____

Name ______________________ Date ______________

In-Class Activity
Batteries as Bowling—A Model (continued)

3. After all the bowlers on a team throw their bowling balls, what does this represent happening with a battery?

4. Since this model of a battery uses outside power to return the balls to the anode side where the bowlers are, is it representing a rechargeable battery or a non-rechargeable battery? Explain.

5. The film uses bowling as a model for the chemistry of batteries. Models can help us understand how a system works, but they also are a simplification of the system. What components of a battery and aspects of its operation does the bowling model not include?

Name ____ Date ___________________

In-Class Activity
Comparing Batteries

1. Rechargeable lithium-ion batteries are widely used. For example, they can power electric cars, smartphones, laptops, power tools, electric toothbrushes, and more. At the same time, this type of battery has several disadvantages. Which ones does the film "Energy to Spare" mention?

    -
    -
    -
    -

2. Researchers are investigating new materials, new electrodes, and new battery designs.
    a. Which material does the film highlight as one alternative to lithium?

    ____

    b. What reasons make this material an improvement over lithium?

    -
    -
    -
    -

3. Besides lithium and zinc, what other compounds are used in batteries?

____

____

____

Name ______________________________ Date ____________

After-Class Activity
A Perfect Battery

1. In the pre-class activity "Batteries in Your World," you listed different battery-powered devices and the types of batteries that they use.

   Which of the devices do you use most often? If you could design and manufacture a new, even better battery to power that device, list qualities that would make it ideal.

   ____

   ____

   ____

2. You need to purchase AA batteries for a remote control. At the store, the same brand offers 4-packs of AA batteries, but in two different types: alkaline and lithium. Neither type is rechargeable, with prices shown below. A home improvement store offers advice in a post "Lithium or Alkaline Batteries - Which Do I Need?"

   AA alkaline 4-pack $4.96　　　*AA lithium 4-pack $14.76*

   a. Circle the battery you would choose to purchase.

   b. What are advantages of your choice?

   ____

   ____

   c. What are disadvantages of your choice?

   ____

   ____

Name ______________________________ Date ______________

After-Class Activity
A Perfect Battery (continued)

3. Batteries are used to power different methods of transportation. How might the requirements for batteries in a jet ski, snowmobile, and electric car differ from one another?

____

____

____

4. Consider the range of different batteries that currently exist and the range of devices that they power. Could a single battery type be called "A Perfect Battery"? Why/why not?

____

____

____

Chemistry Shorts® is a film series that communicates the breadth and depth of chemistry's impact on humankind in an approachable manner, sponsored by the Camille and Henry Dreyfus Foundation. These films will celebrate the science and the people who share a passion for the vital role chemistry plays in the biggest issues, including human health, renewable energy, the nature of life, sustainability, new materials, and climate change. Each film incorporates a lesson plan that offers ideas for ways they may be incorporated into the classroom. We welcome your feedback at: chemistryshorts.org.

SHORT FILMS ABOUT CHEMISTRY

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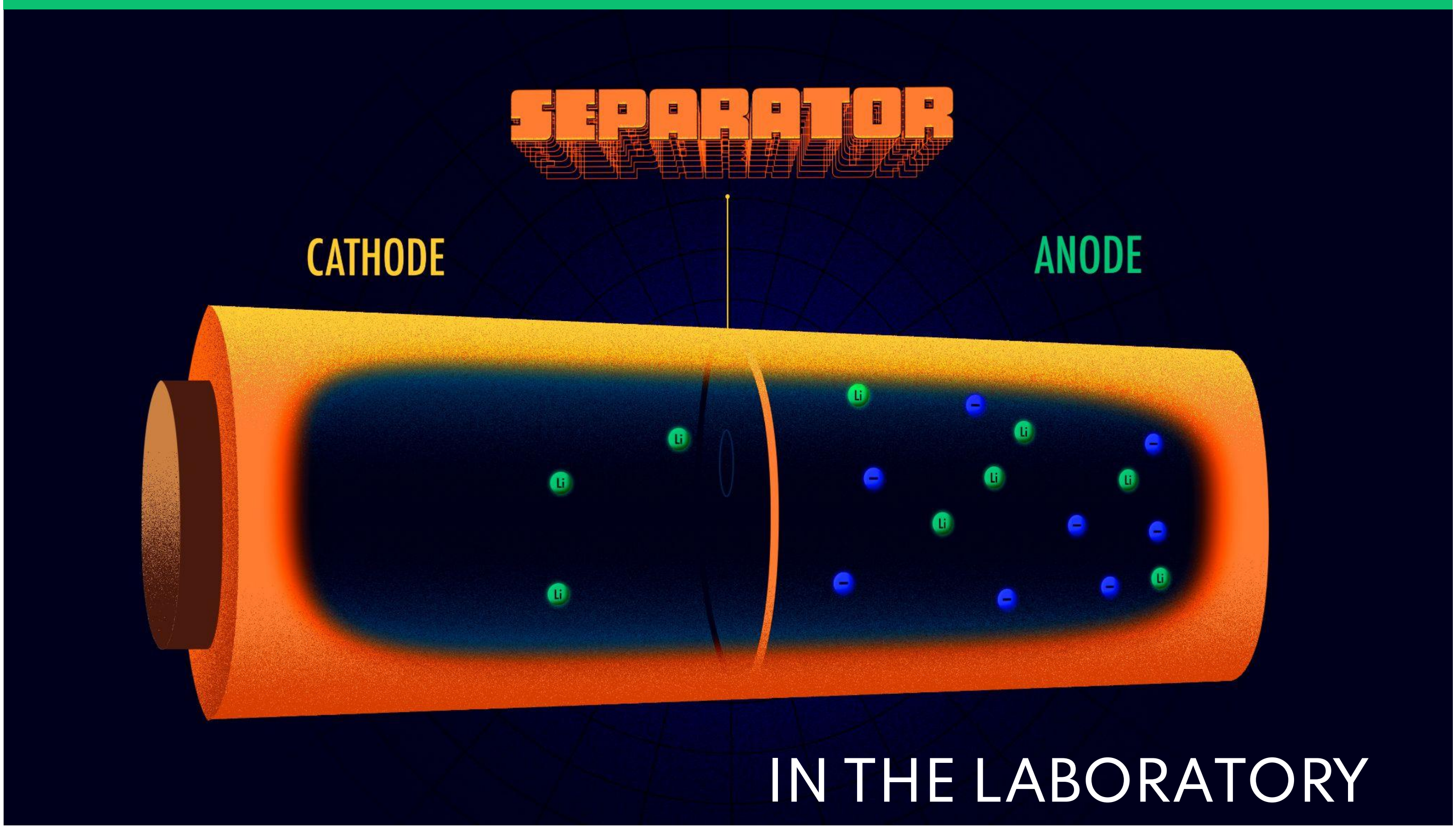
Energy to Spare



IN THE LABORATORY

LAB EXPERIMENT

GRADES 9–12

CHEMISTRY SHORTS®

Overview

This lab experiment complements the *Chemistry Shorts*® film "Energy to Spare." The film is freely available for viewing online at http://chemistryshorts.org. The experiment is aimed at grades 9–12. Teachers may adjust or extend discussion of the chemistry involved depending on the students' level.

Materials

- Student Handout "Building Batteries"
- Experiment materials per student pair/group
  - Water
  - Table salt (sodium chloride)
  - Small container
  - Measuring cup and spoon
  - Aluminum foil
  - 2 paper napkins or paper towels
  - 2 wire leads, dual-ended with alligator clips
  - 2 graphite drawing sticks (also called woodless graphite pencils or compressed graphite sticks)
  - Red LED (3 mm with clear, colorless lens, 2-2.2 V was used in testing)
  - Non-conductive surface
  - Optional: multimeter

Estimated Costs (24 students)

Reusable Materials	Cost
24 wire leads, dual-ended with alligator clips (purchase option at Amazon)	\$8.99 for 30
24 graphite drawing sticks (purchase option at Amazon)	\$15.98 for 24 (two 12-piece packages)
12 red LEDs, 3 mm with clear, colorless lens, 2 V (purchase option at Amazon)	\$4.79 for 100
	\$29.76

Estimated Times

Materials Preparation	10 min.
Battery Building & Testing	25 min.
Analysis	15 min.
Total	**50 min.**

Related Standards

NGSS HS-PS2-6
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

NGSS 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 motions of particles (objects) and energy associated with the relative positions of particles (objects).

Energy to Spare

STUDENT HANDOUT

Name ________________________________ Date ______________

Building Batteries

Buy a battery from the store and it's ready to pop out of the package and power up your device. But what's going on below its smooth, shiny surface to make it happen? In this experiment, you will construct battery cells that use the reaction between aluminum foil and air. Will they be enough to light an LED?

Materials

- ❏ Water
- ❏ Table salt (sodium chloride)
- ❏ Small container
- ❏ Measuring cup and spoon
- ❏ Aluminum foil
- ❏ 2 paper napkins or paper towels
- ❏ 2 wire leads, dual-ended with alligator clips
- ❏ 2 graphite drawing sticks (i.e., woodless graphite pencils or compressed graphite sticks)
- ❏ Red LED
- ❏ Non-conductive surface
- ❏ Optional: multimeter

Safety

Wear safety goggles and disposable gloves during the experiment. Wash hands with soap and water when finished. Aluminum foil and wet napkins can be disposed of in the trash. Alligator clips, graphite drawing sticks, and LED can be cleaned off, dried, and reused.

Procedure

1) In a small container, measure ~120 mL (1/2 cup) water and 2 tablespoons table salt. Stir thoroughly. You are preparing a saturated salt solution, so some of the salt will not dissolve.

2) Obtain an approximately 30-cm x 18-cm piece of aluminum foil. Fold in half along its length twice, smoothing it out, to make a long, four-layered strip. Then, fold it in half along its width. Use that fold as a guide to tear the long strip in half.

3) Fold a paper napkin in half. Spoon saturated salt solution onto it, taking care not to scoop up any remaining solid salt. Soak the front, then turn it over and repeat with any remaining dry areas on the back.

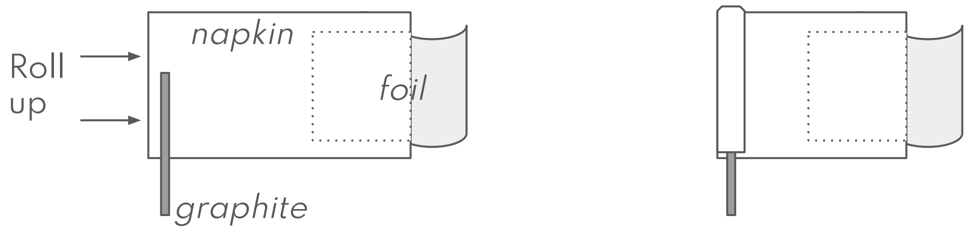
Name ______________________________ Date ______________

Building Batteries (continued)

4) Build a battery cell:

   a) Place one of the foil strips on a non-conductive surface. Bend ~1 ½ cm of the edge of one end upward.

   b) Set the wet paper napkin on the flat part of the foil. Lay a graphite drawing stick on the end of the napkin opposite the foil, with about half the pencil off the napkin. Roll the napkin around it as shown below.

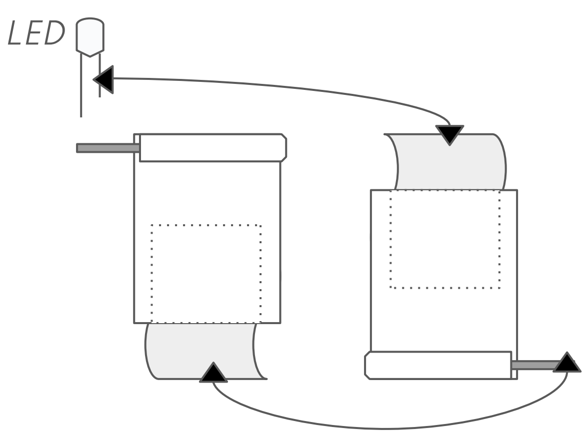


5) Attach an alligator clip wire lead to the foil that is bent upward. Attach the other end's clip to the short leg of the red LED.

6) Holding the alligator clip with the LED, touch the long leg of the LED to part of the graphite drawing stick that is sticking out of the rolled napkin. Does the LED light? You can also use a multimeter (optional) to measure the voltage of the battery cell. Should the voltage support lighting the LED?

7) Build a second battery cell in the same way using the other half of the foil strip you prepared in step 2. Fold and wet a second napkin and roll a second graphite drawing stick into it. Arrange the two battery cells and their components so they do not touch each other.

8) Connect the two battery cells together with alligator clip leads as shown below. Holding the alligator clip with the LED, touch the long leg of the LED to part of the graphite drawing stick that is sticking out of the rolled napkin. Does the LED light? You can also use a multimeter (optional) to measure the voltage of the battery cell. Should the voltage support lighting the LED?



Name ______________________________ Date ______________

Building Batteries (continued)

In a battery cell, half reactions can be used to represent the reaction at the anode and the reaction at the cathode separately. They are written to include electrons (e^-) as a reactant in one and a product in the other. In this experiment's battery, the half reactions are:

$$Al(s) + 3OH^-(aq) \rightarrow Al(OH)_3(s) + 3e^-$$

$$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$$

Questions

1) An oxidation reaction occurs at the anode. During oxidation, electrons are "lost," or released. Based on the half reactions above, what is being oxidized and serves as the anode in the battery?

____

2) A reduction reaction occurs at the cathode. During reduction, electrons are "gained," or accepted.
   a) Based on the half reactions above, what is being reduced? Where does it come from?

   ____

   b) Graphite, a form of carbon, is used in the experiment because it is a good conductor and inert in this environment. Even though it is not represented in the two half reactions, what is it serving as?

   ____

3) In a battery, an electrolyte separates the anode and cathode, but is also able to conduct ions. What is used as the electrolyte in the experiment?

____

4) Chemical energy is stored in the aluminum–air battery. What types of energy is it converted to when it powers an LED?

____

Teacher Notes

Background

The experiment questions use vocabulary and knowledge about battery components that is introduced in the video "Energy to Spare" and discussed in the classroom lesson plan that accompanies this experiment. It is recommended that students at least watch the video before answering questions about the battery they make in this experiment.

Students first construct a single aluminum–air battery cell using aluminum foil as the anode, a graphite drawing stick as the cathode, and a saltwater-soaked napkin as the electrolyte. The single cell produces ~0.9 volt, which is not enough to light the LED. They then construct a second cell and connect the two in series. In testing, a multimeter reading with two cells was 1.94 V and the red LED lit successfully.

Tips

- If two cells connected in series do not light the LED, first confirm that students have the correct connections to the LED since it only allows electricity to travel through it in one direction. The long leg (the LED's anode) should be touching the graphite cathode and the short leg (the LED's cathode) connected to the aluminum anode.
- If the LED is connected correctly, but does not light with two cells, have the student pair/group join with another pair/group to connect a third cell.
- Students could share a larger prepared amount of saturated salt solution instead of each pair or group preparing a smaller amount.
- Testing was done with the graphite sticks from the set in the first link below, because it could be purchased at a local store. However, amazon.com (see second link) and also arts & crafts stores such as JoAnn and Michael's may have less expensive alternatives. Search for "woodless graphite pencils" or "compressed graphite sticks."
    - https://www.walmart.com/ip/Royal-Langnickel-5pc-Mechanical-Pencil-Set/5290151228
    - https://www.amazon.com/General-Pencil-Compressed-Graphite-Sticks/dp/B004BPP4YC

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