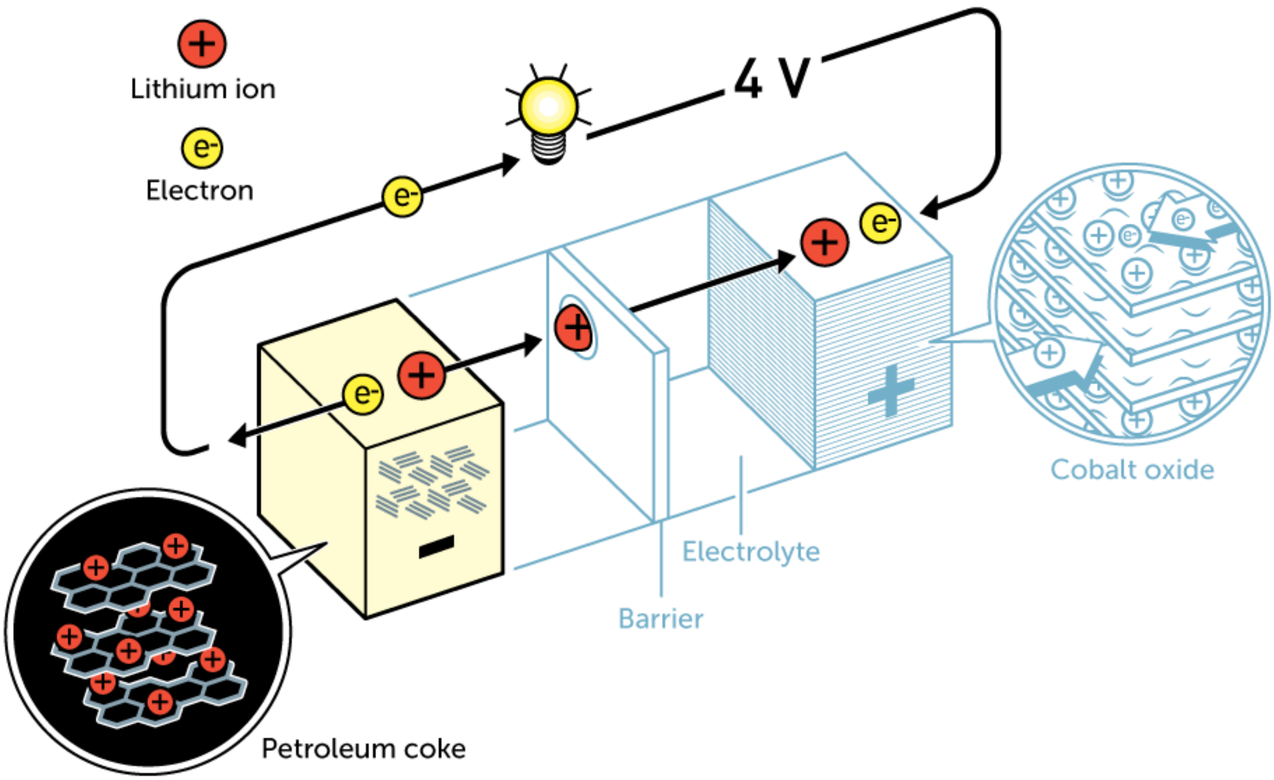
Science News

EDUCATOR GUIDE



November 9, 2019

Nobel Prize Winners Announced

SOCIETY FOR SCIENCE & THE PUBLIC

SN EDUCATOR GUIDE

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About this Guide

This guide, based on *Science News'* coverage of the 2019 Nobel Prizes, asks students to summarize the discoveries that won the prizes and create a timeline that puts one prize in context. Three activities from the Digital Library connect to the chemistry prize, awarded for the development of lithium-ion batteries.

This Guide includes:

Article-based Comprehension Q&A — These questions, based on the *Science News* article "Nobel Prize winners announced," Readability: 10.3, ask students to summarize the discoveries that won the Nobel Prizes this year. Related standards include NGSS-DCI: HS-PS2; HS-ESS1; HS-LS1; HS-ETS1.

> **Student Comprehension Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular Discussion Q&A — Students will track the scientific progress associated with a discovery or advance that was awarded a Nobel Prize by creating a timeline of key events and players. Related standards include NGSS-DCI: HS-PS2; HS-ESS1; HS-LS1; HS-ETS1.

> **Student Discussion Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

Activities: Reduction-oxidation Reaction Demonstration

> **Summary:** This teacher-led demonstration is a straightforward introduction to reduction-oxidation reactions. Related standards include NGSS-DCI: HS-PS1; HS-PS2; HS-PS3.
>
> **Approximate class time:** 15 to 20 minutes.

What Makes Different Types of Batteries Unique?

> **Summary:** Students will research specific battery types and report on what they find. Related standards include NGSS-DCI: HS-PS1; HS-PS2: HS-PS3.
>
> **Approximate class time:** 60 to 120 minutes.

Building the Best Battery

> **Summary:** Students will build, test and optimize their own batteries. Related standards include NGSS-DCI: HS-ETS1; HS-PS1; HS-PS2; HS-PS3.
>
> **Approximate class time:** 40 to 65 minutes.

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Article-based Comprehension, Q&A

Directions for teachers: After your students read "Nobel Prize winners announced," ask them to answer the following questions. Note that the Nobel Prize in economic sciences isn't always awarded for a scientific advance, in which case *Science News* may not report it.

1. What are the Nobel science prizes?

The Nobel science prizes are awards presented every year that recognize scientific discoveries and inventions that benefit humankind or advance our understanding of the world.

2. In what science categories is the Nobel Prize awarded?

The categories of the Nobel science prizes are physiology or medicine, physics, chemistry and economic sciences.

3. For each of these categories, what discovery or advance won the prize? Why is the research important?

The 2019 Nobel Prize in physiology or medicine recognized research into how cells sense and respond to oxygen. The research has implications for our understanding of cancer and how to treat it.

The 2019 physics prize recognized two discoveries: theoretical tools to study the universe and the discovery of the first exoplanet orbiting a sunlike star. The tools helped establish the makeup of the universe: about 5 percent ordinary matter, 27 percent dark matter and 68 percent dark energy. The discovery of the first exoplanet opened a new era in astronomy — there are now over 4,000 confirmed exoplanets.

The development of lithium-ion batteries won the 2019 Nobel Prize in chemistry. Lithium-ion batteries have impacted our everyday lives: The lightweight, rechargeable batteries power everything from portable electronics to electric cars.

A scientific approach to reducing the effects of poverty in education, health care and other areas won the 2019 Nobel Prize in economic sciences. The research established methods to tackle big questions such as "How can we fight global poverty?" by breaking them down into smaller, testable questions.

4. Identify one of the prizes that was given for collaborative work. Who were the winners, and how is their research related?

The 2019 Nobel Prize in chemistry was awarded to three scientists: John B. Goodenough of the University of Texas at Austin, M. Stanley Whittingham of Binghamton University in New York and Akira Yoshino of Asahi Kasei Corporation and Meijo University in Nagoya, Japan. Yoshino's work built on Goodenough's work, which built on Whittingham's work.

5. What did each winner contribute?

Whittingham tested lithium as an anode material. The element is lightweight and easily releases electrons and lithium ions. His rechargeable battery design also included a cathode made with the chemical compound titanium disulfide, which can store lithium ions released from the anode.

Goodenough improved on Whittingham's cathode by using the chemical compound cobalt oxide as a cathode. Cobalt oxide stores more lithium ions than titanium disulfide. Goodenough's design boosted the batteries' voltage potential from 2 volts to 4 volts.

Yoshino built an anode using petroleum coke, a by-product of oil production. Though it doesn't include lithium, petroleum coke can store lithium ions. Yoshino paired his petroleum coke anode with Goodenough's cobalt oxide cathode to make a more durable and lightweight rechargeable battery. Yoshino's design was used in the first commercial lithium-ion batteries.

6. Identify one prize-winning discovery or advance that spanned scientific fields. What fields were involved and how did they connect to each other?

The 2019 Nobel Prize in chemistry was awarded for a development spanning the fields of chemistry, materials science and engineering. Batteries store electrical energy in the form of chemical energy and run through oxidation and reduction reactions. Scientists needed an understanding of materials science to find the right chemical compounds for a battery's anode and cathode. And putting it all together into a consumer product that could be recharged hundreds of times was an engineering feat.

7. Were any of the prizes awarded to more than one specific discovery or advance? Identify the advances and explain how they are related.

The 2019 Nobel Prize in physics was awarded for two discoveries — theoretical tools for understanding the cosmos and the discovery of an exoplanet around a sunlike star. Both offer insights into components of the universe that are invisible to the human eye.

8. Did the article report the winner(s) of the Nobel Memorial Prize in Economic Sciences? If so, why do you think the economics prize is considered a science prize in this context? If not, why might the article have left this prize out?

The 2019 Nobel Prize in economic sciences went to three scientists for their work establishing a scientific approach to reducing the harmful effects of poverty. The economics prize is considered a science prize in this case because the research helped create a new, science-based subfield in economics and set standards for testing hypotheses in the subfield. If the economics prize isn’t awarded for a scientific advance, then a scientific publication might choose to not report on it.

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Student Comprehension Worksheet

Directions: After reading "Nobel Prize winners announced," answer the following questions.

1. What are the Nobel science prizes?

2. In what science categories is the Nobel Prize awarded?

3. For each of these categories, what discovery or advance won the prize? Why is the research important?

4. Identify one of the prizes that was given for collaborative work. Who were the winners, and how is their research related?

5. What did each winner contribute?

6. Identify one prize-winning discovery or advance that spanned scientific fields. What fields were involved and how did they connect to each other?

7. Were any of the prizes awarded to more than one specific discovery or advance? Identify the advances and explain how they are related.

8. Did the article report the winner(s) of the Nobel Memorial Prize in Economic Sciences? If so, why do you think the economics prize is considered a science prize in this context? If not, why might the article have left this prize out?

Nobel Prize Winners Announced

Cross-curricular Discussion, Q&A

Directions for teachers: Have students read "Nobel Prize winners announced" (Readability: 10.3), in the print version of the magazine, for an overview of the 2019 Nobel Prizes. (If time permits, they can complete the related comprehension questions.) Let students pair up and choose to explore one of the discoveries or advances recognized with a 2019 Nobel Prizes. If you want to give students additional options, they could also use the *Science News* archive to explore winning discoveries or advances from previous years.

Once students decide on a prize-winning discovery or advance, they should read the more in-depth, online *Science News* article covering the related prize. Students will then use the discussion prompts below and the *Science News* archive, along with other resources as necessary, to research and develop a timeline of key events associated with the discovery or advance. Students will distill each important event into a tweet of 280 characters or less. If time permits, students could find a creative way to display their timelines in the classroom.

2019 Nobel Prize article options include:

Nobel Prize in chemistry: "The development of the lithium-ion battery has won the chemistry Nobel Prize" (Readability: 13.2)

Nobel Prize in physics: "Physics Nobel awarded for discoveries about the universe's evolution and exoplanets" (Readability: 10.9)

Nobel Prize in physiology or medicine: "Discovery of how cells sense oxygen wins the 2019 medicine Nobel" (Readability: 11.7)

Nobel Memorial Prize in Economic Sciences: "Economics Nobel goes to poverty-fighting science" (Readability: 12.0)

Note to teachers: Example answers are given for lithium-ion batteries, which won the 2019 Nobel Prize in chemistry. But questions can be used for any current or previous Nobel Prize–winning advance or discovery.

Directions for students:

Read the article "Nobel Prize winners announced" and, if instructed, answer the questions provided by your teacher. With a partner, choose a Nobel Prize–winning advance or discovery to explore. Once you and your partner decide on an advance or discovery, read the more in-depth, online *Science News* article covering the related Nobel Prize.

Use the discussion prompts below and the *Science News* archive, along with other resources if needed, to develop a timeline of events that tracks the scientific progress associated with the discovery or advance you and your partner chose to explore. To access *Science News* articles that are only available to subscribers, enter your teacher's e-mail address.

Each event on your timeline should have a date, a tweet (in 280 characters or less) summarizing the event and including key players, an appropriate hashtag (as outlined below), and links to your reference resource(s). Aim to include eight to 12 events on your timeline.

1. First, create an event outlining the winning of the Nobel Prize for your timeline. The information below should be included.

Date: *2019*
Tweet (include key players): *John B. Goodenough, M. Stanley Whittingham and Akira Yoshino win the Nobel Prize in chemistry for their research on lithium-ion batteries.*
#NobelPrizein(subject area): *#NobelPrizeinchemistry*
Resource(s) referenced*:* *https://www.sciencenews.org/article/lithium-ion-battery-chemistry-nobel-prize*

2. Research the work completed by the scientist(s) who won the Nobel Prize. Create one or two events for each scientist that summarize his or her major contribution.

Scientist 1: *M. Stanley Whittingham*
Date: *1970s*
Tweet (include key players): *M. Stanley Whittingham creates the first lithium-ion battery by combining lithium as anode material with titanium disulfide as cathode material.*
#(last name of scientist)buildingblock: *#Whittinghambuildingblock*
Resource(s) referenced: *https://www.sciencenews.org/article/lithium-ion-battery-chemistry-nobel-prize*

Scientist 2 (if needed): *John B. Goodenough*
Date: *1970s–1980s*
Tweet (include key players): *John. B. Goodenough uses cobalt oxide instead of titanium disulfide as a cathode and doubles the voltage potential of the existing lithium-ion battery.*
#(last name of scientist)buildingblock: *#Goodenoughbuildingblock*
Resource(s) referenced: *https://www.sciencenews.org/article/lithium-ion-battery-chemistry-nobel-prize*

Scientist 3 (if needed): *Akira Yoshino*

Date: *1985*
Tweet (include key players): *Akira Yoshino uses petroleum coke as an anode and creates a safer and longer-lasting lithium-ion battery.*
#(lastnameofscientist)buildingblock: *#Yoshinobuildingblock*
Resource(s) referenced: *https://www.sciencenews.org/article/lithium-ion-battery-chemistry-nobel-prize*

3. Research findings from other scientists or additional developments that advanced the work or might advance it in the future. Create at least two timeline events for these additional #buildingblocks.

Date: *1991*
Tweet (include key players): *Lithium-ion batteries are commercially available for the first time.*
#buildingblock
Resource(s) referenced: *https://www.sciencenews.org/article/lithium-ion-battery-chemistry-nobel-prize*

Date: *2017*
Tweet (include key players): *Scientists at Stanford University test a way to add a flame retardant to lithium-ion batteries to make them safer while retaining their efficiency.*
#buildingblock
Resource(s) referenced: *https://www.sciencenews.org/article/new-smart-fibers-curb-fires-lithium-ion-batteries*

4. Identify the earliest mention of the topic or concept that you think should be noted on your timeline. Create at least one event for this historical foundation.

Date: *1800*
Tweet (include key players): *Alessandro Volta invents the first version of an electric battery. This prototype was known as a "voltaic pile" and was made of zinc and silver disks separated by pieces of cloth soaked in brine.*
#historicalfoundation
Resource(s) referenced: *https://www.aps.org/publications/apsnews/200603/history.cfm*

5. Make a list of the dates of your events and then think about the scale of your timeline. Does your timeline span decades, centuries or millennia? Are there any large chronological gaps? If so, research whether another development should be included as an additional event. Add it, if needed.

Our timeline covers decades of history.

Date: *1859*

Tweet (include key players): *A French physicist named Gaston Planté created the first rechargeable battery. Planté's design contained a lead anode, a lead dioxide cathode and sulfuric acid as an electrolyte.*
#buildingblock or #historicalfoundation: *#historicalfoundation*
Resource(s) referenced: *https://nationalmaglab.org/education/magnet-academy/history-of-electricity-magnetism/museum/plante-battery*

6. Identify one example of impact that the Nobel Prize–winning discovery or advance has had on the world. Create an event for this impact. Then predict one future event that will occur based on the work and include it in your timeline.

Date: *1990–2019*
Tweet (include key players): *In part because they are portable and rechargeable, lithium-ion batteries become widespread, used in everyday objects such as cars, cell phones and computers.*
#impact
Resource(s) referenced: *https://www.sciencenews.org/article/lithium-ion-battery-chemistry-nobel-prize*

Date: *2020–2035*
Tweet (include key players): *An increased reliance on electric vehicles will heighten the demand for lightweight and rechargeable lithium-ion batteries.*
#futureimpact
Resource(s) referenced: *https://www.sciencenews.org/article/search-new-geologic-sources-lithium-could-power-clean-future*

7. If instructed by your teacher, determine how you would display your timeline to present this information to your class. Try to make the presentation creative and engaging. Then, build your timeline and prepare to share it.

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Student Discussion Worksheet

Directions: Read the article "Nobel Prize winners announced" and, if instructed, answer the questions provided by your teacher. With a partner, choose a Nobel Prize–winning advance or discovery to explore. Once you and your partner decide on an advance or discovery, read the more in-depth, online *Science News* article covering the related Nobel Prize.

Use the discussion prompts below and the *Science News* archive, along with other resources if needed, to develop a timeline of events that tracks the scientific progress associated with the discovery or advance you and your partner chose to explore. To access *Science News* articles that are only available to subscribers, enter your teacher's e-mail address.

Each event on your timeline should have a date, a tweet (in 280 characters or less) summarizing the event and including key players, an appropriate hashtag (as outlined below), and links to your reference resource(s). Follow the event template provided, repeating it as many times as needed for each step in the directions. Aim to include eight to 12 events on your timeline.

1. First, create an event outlining the winning of the Nobel Prize for your timeline. The information in the event template below should be included.

Date:
Tweet (include key players):
#NobelPrizein(subject area):
Resource(s) referenced:

2. Research the work completed by the scientist(s) who won the Nobel Prize. Create one or two events for each scientist that summarize his or her major contribution.

Date:
Tweet (include key players):
#(last name of scientist)buildingblock:
Resource(s) referenced:

3. Research findings from other scientists or additional developments that advanced the work or might advance it in the future. Create at least two timeline events for these additional #buildingblocks.

Date:
Tweet (include key players):

#buildingblock
Resource(s) referenced:
4. Identify the earliest mention of the topic or concept that you think should be noted on your timeline. Create at least one event for this historical foundation.

Date:
Tweet (include key players):
#historicalfoundation
Resource(s) referenced:

5. Make a list of the dates of your events and then think about the scale of your timeline. Does your timeline span decades, centuries or millennia? Are there any large chronological gaps? If so, research whether another development should be included as an additional event. Add it, if needed.

Date:
Tweet (include key players):
#buildingblock or #historicalfoundation:
Resource(s) referenced:

6. Identify one example of impact that the Nobel Prize–winning discovery or advance has had on the world. Create an event for this impact. Then predict one future event that will occur based on the work and include it in your timeline.

Date:
Tweet (include key players):
#impact
Resource(s) referenced:

Date:
Tweet (include key players):
#futureimpact
Resource(s) referenced:

7. If instructed by your teacher, determine how you would display your timeline to present this information to your class. Try to make the presentation creative and engaging. Then, build your timeline and prepare to share it.

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Activity Guide for Teachers: Reduction-oxidation Reaction Demonstration

Class time: About 15 to 20 minutes.

Purpose: This is a simple demonstration for introducing reduction-oxidation (redox) reactions.

Notes to the teacher: Please handle and dispose of copper(II) sulfate solution in accordance with federal, state and local environmental control regulations.

Supplies:
Copper(II) sulfate (sold as a hydrate, or sold as root killer at hardware stores)
A large steel or iron nail/screw/bolt (or more than one if you want)
A beaker or clear plastic cup
A stirring rod

Directions:

1. Fill the beaker with hot water, pour in a few grams of copper(II) sulfate and stir until it dissolves. Show the students that the blue crystals of copper sulfate turn the water blue (due to Cu^{2+}). Show the students the steel (iron alloy) or iron nail, then put it in the beaker. After a few minutes, pull out the nail and show it to the students. The nail should be coated with a thin layer of reddish-bronze copper atoms, which can be easily scraped off with a paper towel. If you use more than one nail, or have a dilute enough copper(II) sulfate solution, your students may be able to notice that the blue solution gets lighter in color due to the decreasing concentration of Cu^{2+} ions.

2. Explain that the copper starts off in the solution as ions with two positive charges (having donated two electrons to sulfate), and the iron starts off as a solid composed of neutral iron atoms with the same number of protons as electrons in each atom. Since the copper has a greater affinity for electrons than the iron does, the iron loses two electrons and gets dissolved into solution. Each Cu^{2+} ion gains two electrons and becomes a solid where the iron had been. In chemistry notation, the reactions are:

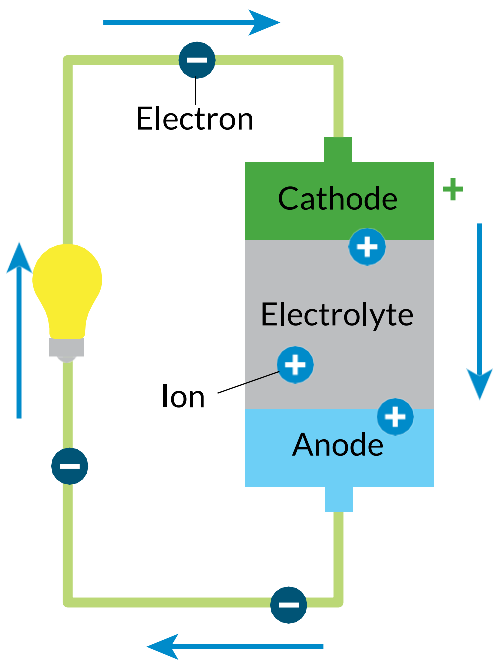
Oxidation:	$Fe_{(s)} \rightarrow Fe^{2+}{}_{(aq)} + 2\ e^-$
Reduction:	$Cu^{2+}{}_{(aq)} + 2\ e^- \rightarrow Cu_{(s)}$
Net reaction:	$Fe_{(s)} + Cu^{2+}{}_{(aq)} \rightarrow Fe^{2+}{}_{(aq)} + Cu_{(s)}$

The sulfate and the water were innocent bystanders in this reaction and did not directly participate. Explain that the ions, such as sulfate (SO_4^{2-}), are called spectator ions.

3. Explain that this is just one example of an oxidation and reduction reaction, but there are many others. Reduction and oxidation reactions are a mouthful to say and always occur together (electrons have to come from someplace and go to someplace), so they are called "redox reactions" for short. Also, it is important to note that the number of electrons lost in a reaction must be equal to the number of electrons gained, so the chemical equation may need to be balanced. To remember the difference between

oxidation and reduction reactions, use the mnemonic **OIL RIG**: **O**xidation **I**s **L**oss of electrons, **R**eduction **I**s **G**ain of electrons.

4. Copper wanted electrons more than iron did in this demonstration. Scientists can make a list of atoms or molecular groups in order from those that are least determined to hang on to their electrons (or in other words, those most likely to be oxidized) to those most determined to keep their electrons (or in other words, those most likely to be reduced). This difference in affinity for electrons may be expressed in terms of volts of electric potential energy, or the standard reduction potential of each material. Show an example of your favorite reduction potential table such as this one given by California State University at Dominguez Hills.



5. Using the diagram above, explain that a battery is a device that converts the chemical energy of a redox reaction to usable electrical energy. A battery has an anode made of one material, a cathode made of another material, an electrolyte allowing ion flow between the anode and cathode and an external electrical circuit allowing electron flow between the anode and cathode. Ignoring real-world inefficiencies and imperfections, the voltage of the battery is the difference in the standard reduction potentials of the anode and cathode materials. You may want to demonstrate calculating the difference in reduction potentials from the demonstration materials. A Khan Academy video gives a brief summary of how to calculate the overall redox reaction potentials under standard conditions from a standard reduction potential table.

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Activity Guide for Teachers: What Makes Different Types of Batteries Unique?

Class time: One or two class periods plus homework.

Purpose: Different student groups find and report information about different battery types.

Notes to the teacher: You can adapt this activity to your preferences by including more or fewer battery types, setting the number of students per battery type, providing specific references for the students or encouraging them to do more independent research, choosing how extensive the students' research and reporting should be, and selecting how the students report their findings (public service announcement, written paper, graphical poster, oral presentation in class, computer slide presentation, etc.).

Supplies:
List of battery types to research
Books or websites for students to research battery types
Materials for students to create posters, papers or presentations
What Makes Different Types of Batteries Unique? student activity guide

Directions:

1. Assign different battery types to different students or groups of students. Battery types could include:
    a. Carbon-zinc batteries (older non-rechargeable batteries)
    b. Alkaline batteries (newer non-rechargeable batteries)
    c. Lead-acid batteries
    d. Nickel-cadmium batteries
    e. Lithium-ion batteries
    f. Lithium-sulfur batteries
    g. Magnesium-ion batteries
    h. Flow batteries
    i. Lithium-air batteries
    j. Sodium-sulfur batteries
    k. Hydrogen-oxygen fuel cells (similar to batteries)

2. Provide the student activity guide, which lists the information students should find for their battery types.

3. Direct students to specific references for battery information, or let them do more open-ended self-directed research in the library or online. References may include:

    -Online sources: Battery University and JCESR.
    -Carl H. Snyder, *The Extraordinary Chemistry of Ordinary Things*. 4th ed. New York: Wiley. 2002. Chapter 11.
    -Theodore E. Brown *et al., Chemistry: The Central Science*. 14th ed. New York: Pearson. 2017. Chapter 20.

-*Encyclopedia Britannica*
-Wikipedia articles on specific battery types might provide a starting point to look for links to more reputable source material.

4. Let the students report their findings in the format(s) of your/their choice.

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Activity Guide for Students: What Makes Different Types of Batteries Unique?

Directions: Your group should take ownership of one battery type. Using the resources recommended by your teacher, find the following information for your battery (elaborate in areas where a lot of information is accessible) and summarize your findings according to your teacher's instructions.

Please be sure to include the following information:

1. Type of battery

2. Is it a primary or secondary cell (one time use or rechargeable)?

3. What is the overall redox reaction?

4. What gets oxidized (oxidation half reaction) and what gets reduced (reduction half reaction)?

5. What is the common electrolyte/ionic compound (to neutralize charge buildup)?

6. What is the voltage per cell?

7. What is the overall battery voltage, and how many cells are required to produce that voltage?

8. What is the maximum energy density in Joules per kilogram (and/or milliliter) for this electrochemical reaction? For reference, how does that compare to the energy density in Joules per kilogram (and/or milliliter) for gasoline?

9. What are the advantages of this battery type, and what aspects of the electrochemistry and battery design give it those advantages?

10. What are the disadvantages of this battery type, and what aspects of the electrochemistry and battery design give it those disadvantages?

11. What are the major applications of this battery type, and what aspects of the electrochemistry and battery design make it suitable for those applications?

12. What are the environmental concerns for the use and/or for the disposal of your battery type?

13. What is the best method of disposal for your battery type? Can it be recycled and, if so, how?

14. When and where was this battery type first developed?

15. What characteristics of this battery type could be improved, and what changes in the electrochemistry or the battery design might yield those improvements?

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Activity Guide for Teachers: Building the Best Battery

Class time: 40 to 65 minutes.

Purpose: Students create, test and optimize batteries using various electrodes and electrolyte compositions.

Notes to the teacher: If you have more time, you can allow the students more design options and let them figure out more things themselves. If you have less time, you can allow the students fewer design options by giving more guidance. You can order electrodes such as these from Home Science Tools or buy materials made from or coated with suitable metals from Home Depot or similar stores. Ideally students should be able to find the configurations that produce the most voltage, and then use those to light a lightbulb. If your time is limited, you could have the students focus on either the voltage measurements or lighting the bulb. This activity would work well for pairs of students working together.

Supplies:
Beakers or clear plastic cups (about 250 ml)
Copper electrodes (or copper tubing or stripped copper wire)
Zinc electrodes (or zinc or zinc-plated hardware)
Iron or steel electrodes (or iron or steel hardware)
Aluminum electrodes (or aluminum foil or strips cut from disposable aluminum pans)
Vinegar (5% acetic acid, sold by the gallon at many grocery stores)
Table salt (NaCl, not iodized)
Optional: other ionic solids to use as electrolytes such as KCl or $NaNO_3$
Scales or balances and weigh boats or weigh paper
Graduated cylinders
Water (distilled if you have it, otherwise tap water)
Stirring rods
Electric multimeter (inexpensive models are sold at Walmart or similar stores)
1.5 volt incandescent lightbulbs and sockets (see this example from Home Science Tools)
Wires with alligator clips (see for example these from American Science & Surplus)
Table of standard reduction potentials
Goggles
Gloves and other protective equipment such as aprons
Paper towels
Sandpaper or steel wool
Building the Best Battery student activity guide

Directions:

1. Have the students wear goggles and gloves (and other protective equipment such as aprons, if available).

2. Show the students how to use the table of standard reduction potentials to predict the voltage difference between two different electrode materials. A Khan Academy video gives a brief summary of

how to calculate the overall redox reaction potentials under standard conditions from a standard reduction potential table.

3. Show the students how to use the multimeter to measure voltage. Remind students that the multimeter leads must be in direct contact with the battery electrodes in order for the circuit to be complete. Also, when the voltage is positive, the metal electrode connected to the red lead is considered the positive terminal of the battery (the cathode) and the metal electrode connected to the black lead is the negative terminal (the anode). If the voltage is negative, the student should reverse the leads so that the voltage is positive.

4. Ideally students should determine battery configurations that produce the most voltage, and then use those to light a lightbulb. But if time is limited, determine which variables they should focus on. Students can start with determining the largest possible voltage from different combinations of electrodes (theoretically and experimentally). Once the maximum voltage is determined, students can use this electrode combination to test other variables such as the type and/or concentration of the electrolyte (how much vinegar, salt, water is in solution), the approximate distance between electrodes and the number of cells (depending on available supplies). Students can ultimately test their battery with a lightbulb. If students are more advanced, have them calculate the molarity of their electrolyte solutions.

Note the following:

Tap water may have enough impurities to make a fairly good electrolyte by itself; distilled water is less conductive and would show the students the importance of adding ions to the electrolyte. Salt (especially about 1 to 2 g per 200 ml of water) makes the water function as a much better electrolyte. Vinegar has enough ions to serve as a good electrolyte. Vinegar plus salt can be even better.

The specific electrode combination chosen will have a large effect on the voltage, generally in the ballpark of the standard reduction potentials but with some variation due to the electrolyte. (Standard conditions for the reduction potential table are defined as 25 degrees Celsius, 1 atm for any gas participating in the reaction, and 1 M concentration for each ion participating in the reaction.) The electrolyte chosen will have a smaller but still significant effect on cell potential. The spacing between the electrodes may have a small but measurable effect, depending on the electrodes, electrolyte and volume.

Show the students that they can use the alligator clip leads to connect multiple batteries in series if necessary to light a lightbulb.

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Nobel Prize Winners Announced

Activity Guide for Students: Building the Best Battery

You can make a simple battery using a beaker or clear plastic cup partially filled with a liquid electrolyte, and with two different types of metal electrodes partially immersed in the electrolyte but not touching. You can connect the battery to a multimeter to measure voltage, or even to light a lightbulb. You can choose the electrode types, electrolyte composition, electrode spacing and other design details to optimize your results. Listen to your teacher for more specific instructions for your class.

1. Fill the beaker at least halfway with water. What is the approximate volume of water as shown on the beaker (or measure the amount of water with a graduated cylinder)?

2. Weigh out a small amount of salt between 1 and 2 grams and record the value. Stir it into the water in the beaker until it is fully dissolved. How much salt did you add?

3. Use sandpaper or steel wool to clean the electrodes before your experiment. Note how each electrode material looks before and after cleaning.

4. Using the chart below, write down the theoretically predicted voltage for each pair of electrodes using a standard reduction potential table (provided by your teacher). Note that the table is for standard cell conditions which are defined as 25 degrees Celsius, 1 atm for any gas participating in the reaction, and 1 M concentration for each ion participating in the reaction. Then put the pair of electrodes in the beaker (not touching each other) and use the multimeter to record the actual voltage between the electrodes. How much does that differ (in %) from your theoretical prediction? Make sure the distance between the electrodes remains approximately the same among all trials.

Electrode 1	Electrode 2	Theoretical voltage	Measured voltage	% difference
Copper	Copper			
Copper	Zinc			
Copper	Iron			
Copper	Aluminum			
Zinc	Zinc			
Zinc	Iron			
Zinc	Aluminum			
Iron	Iron			
Iron	Aluminum			
Aluminum	Aluminum			

5. What factors could account for differences between your measured voltages and the theoretically predicted voltages?

6. Closely observe the surfaces of the electrodes after you remove them from the electrolyte. What do you see? What caused what you see? After your experiments, be sure to dry the electrodes and then clean them with sandpaper or steel wool.

7. Can you improve the performance by adjusting the spacing between electrodes? Record your results.

8. Can you improve the performance by using a different electrolyte? Try larger or smaller amounts of salt, different mixtures of water and vinegar ranging from pure water to pure vinegar, etc. Refer to your teacher for more specific instructions. Record your results.

9. Can you light a lightbulb with your battery? If one battery cannot produce enough voltage, you can connect two or more batteries in series (the positive terminal of one battery to the negative terminal of the next battery). Record what setup works best.

10. Summarize your results. What conditions were optimal for creating a battery that produced the highest voltage?

11. Reflect on your experimental quest for making the best battery. What did you enjoy about it? What made it difficult? After reading “Charging the future,” how do you think your experience compares to the challenges battery scientists face?