

Cross-Curricular Discussion

After students have had a chance to review the article "[Charging the future](#)," lead a classroom discussion based on the questions that follow. From the question bank, you can copy and paste only the questions that apply to your classroom out into a different document for your students. Before starting the discussion, you may want to supplement their introduction to batteries with one or more of the following videos listed below. Also, the first activity is a simple reduction-oxidation reaction demonstration that might be useful for student understanding.

Possible video resources

- [A TED-Ed video](#) titled "How batteries work" by Adam Jacobson. This video is approximately four minutes and shows an animated history of batteries.
- A CNBC video posted at the [Joint Center for Energy Storage Research \(JCESR\)](#) about the life-changing potential of advanced energy storage.
- A [LiveScience video](#) that gives a quick introduction to flow batteries.

CHEMISTRY AND PHYSICAL SCIENCES

Discussion Questions:

1. What is an oxidation reaction? What is a reduction reaction? [*Oxidation: an atom or group of atoms loses one or more electrons. Reduction: an atom or group of atoms gains one or more electrons.*]
2. What determines which atoms or groups get oxidized, and which get reduced? [*Order in list of standard reduction potentials.*]
3. What is a battery? Using the diagram on the second page of "Charging the future," define the major parts of a battery and explain their importance. [*Show the students a diagram with labeled anode (where oxidation occurs), cathode (where reduction occurs), electrolyte (helps ions move within the battery so electrons will continue to flow from the anode to the cathode) and electrons flowing through an external circuit. Point out that electrodes are conductors through which the electrons enter or exit the battery. Show students a diagram of a typical [electrochemical cell](#) and explain that the anode and cathode must be separated and that the electrolyte is contained in the salt bridge.*]
4. What is voltage and how do you determine the voltage of a battery? [*Voltage: the potential difference in charge between the anode and cathode (as determined by how badly electrons want to go someplace). It's measured in volts, where one electron with one volt of potential energy has approximately 1.6×10^{-19} Joules of potential energy. Battery voltage: determined by the difference between reduction potentials (show students a [reduction potential table](#)) at the anode and cathode, the number of identical cells put in series to make a large battery and so on.*]

5. Using your knowledge of atomic reactivity based on an atom's location on the periodic table, which atom would you expect to have the largest reduction potential? Looking at a common reduction potential table, what combination of elements would you use in a battery? Why? *[Largest reduction potential: fluorine, because it is the most electronegative element (located in the upper right corner of the periodic table). Student element combinations will vary, but they may choose fluorine (easily reduced) and lithium (easily oxidized) to get a large overall cell potential.]*

Extension Prompts:

6. What is electric current? *[Essentially how many electrons (or other charges) per second are going someplace, measured in amps, where $1 \text{ amp} \approx 6.2 \times 10^{18} \text{ electrons/second}$.]*
7. What is electroplating? What are some applications of electroplating? *[Electroplating: using electrochemical reactions to coat one metal with a thin layer of another metal, generally by putting electrical energy into a system. It's very much like operating a battery in reverse. Applications: depositing thin layers of silver or gold on jewelry, coating electrical connectors with gold, zinc-plating iron or steel hardware.]*
8. What is electrolysis? What are some applications of electrolysis? *[Electrolysis: putting electric current into a liquid to decompose molecules in the liquid into their components at the electrodes, such as electrolysis to split water molecules into hydrogen and oxygen gases. Applications: production of hydrogen and oxygen by the electrolysis of water, production of pure chlorine, aluminum and other elements by electrolysis of liquid or molten solutions containing them.]*
9. What is corrosion? How can corrosion be minimized? *[Corrosion: oxidation of a metal, usually forming a metal oxide, such as iron oxide (rust). Corrosion can be limited by minimizing salt buildup on metal car parts to prevent electrochemical reactions when wet, minimizing contact between dissimilar metals in the dishwasher, putting a "sacrificial anode" of a less noble metal such as magnesium, zinc or aluminum on ship hulls or pipelines to prevent rusting of iron in the main structure, zinc-coated ("galvanized") iron or steel hardware to prevent rusting of the iron, coating electrical connectors with gold and so on.]*

Chemistry and Physical Sciences Question Bank:

What is an oxidation reaction? What is a reduction reaction?

What factors determine which atoms or groups get oxidized, and which get reduced?

What is a battery? Using the diagram on the second page of "Charging the future," define the major parts of a battery and explain their importance.

What is voltage and how do you determine the voltage of a battery?

Using your knowledge of atomic reactivity based on an atom's location on the periodic table, which atom would you expect to have the largest reduction potential?

What is electric current?

What is electroplating? What are some applications of electroplating?

What is electrolysis? What are some applications of electrolysis?

What is corrosion? How can corrosion be minimized?

BIOLOGICAL SCIENCES

Discussion Questions:

1. How do your cells extract energy from the food you eat? How are the reactions involved similar to those in a battery? *[Students may discuss the set of metabolic reactions and processes involved in cellular respiration. Similar to a battery, redox reactions occur throughout these processes. During cellular respiration, electrons are transported through carrier molecules until the energy of the reactions is used to drive ATP synthesis.]*
2. The article discussed how batteries work by converting chemical energy into electrical energy to power a device. How does your body store energy (in what forms) and how is it converted to energy during exercise? How can you relate the process of storing and using energy in the body to a battery? *[Energy is stored as carbohydrates (short-term storage) or fat (long-term storage). Students might discuss how through the processes of aerobic/anaerobic respiration, the body creates ATP which is used by the muscles to contract. Carbs/fats are converted into ATP to power our muscles, just as the chemical energy in batteries is converted to electrical energy to power devices.]*

Extension Prompts:

3. How do NADH, NADPH and FADH_2 accept or donate electrons in biological redox reactions? *[Show the students images of NADH, NADPH and FADH_2 losing or gaining electrons and protons from Campbell Biology or other references.]*
4. What specific roles do redox reactions play in respiration in cellular mitochondria? *[Show the students images from Campbell Biology or other references.]*
5. What roles do redox reactions play in photosynthesis in plant chloroplasts? *[Show the students images from Campbell Biology or other references.]*
6. How can redox reactions be used to quantitatively measure concentrations of compounds such as ascorbic acid (vitamin C)? *[Since there are many acids and bases in food, acid/base titration reactions cannot often be used to measure the amount of ascorbic acid in food. A redox reaction can be used where ascorbic acid is oxidized and 2,6-dichloroindophenol is reduced. [See the related lab activity from the University of California, Santa Cruz here.](#)]*

Biological Sciences Question Bank:

How do your cells extract energy from the food you eat? How are the reactions involved similar to a battery?

The article discussed how batteries work by converting chemical energy into electrical energy to power a device. How does your body store energy (in what forms) and how is it converted to energy during exercise? How can you relate the process of storing and using energy in the body to a battery?

How do NADH, NADPH and FADH_2 accept or donate electrons in biological redox reactions?

What specific roles do redox reactions play in respiration in cellular mitochondria?

What roles do redox reactions play in photosynthesis in plant chloroplasts?

How can redox reactions be used to quantitatively measure concentrations of compounds such as ascorbic acid (vitamin C)?

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion Questions:

1. How many different types of batteries and their applications can students think of? [*Non-rechargeable alkaline batteries in small electronic devices; rechargeable Ni-Cd batteries in household tools; lithium-ion batteries in personal electronic devices, computers and household tools; lead-acid batteries in cars and so on.*]
2. How does gravity play a role in the design of a flow battery? How might a flow battery work on another planet with a gravitational pull that is greater or less than that of Earth? [*Students also may pick a planet, research, then draw a model of a flow battery on that planet.*]

Extension Prompts:

3. What are desirable characteristics for a battery for portable electronic devices? [*Very small mass, very small volume, high energy density, low heat output, very large number of recharging cycles, very impact-resistant, does not explode during airline flights, etc.*]
4. What are desirable characteristics for a battery for electric cars? [*Very high energy density, very impact-resistant, rapid recharging, etc.*]
5. What are desirable characteristics for a battery for electric power grid storage? [*Very large capacity, storage times of many days or weeks, widely variable discharge rate depending on the needs, etc.*]
6. How would an engineer consider desired battery characteristics to determine the basis for new battery designs? Discuss engineering design and how essential characteristics drive a product's design. What other considerations affect design decisions?
7. Using [Blackline Master 3](#), examine the table of battery types from "Charging the future." If funding were not an issue, what type of battery would you choose to power a device that you use regularly? Name the device and explain your reasoning.

Engineering Question Bank:

How many different types of batteries and their applications can students think of?

How does gravity play a role in the design of a flow battery? How might a flow battery work on another planet with a gravitational pull that is greater or less than that of Earth?

What are desirable characteristics for a battery for portable electronic devices?

What are desirable characteristics for a battery for electric cars?

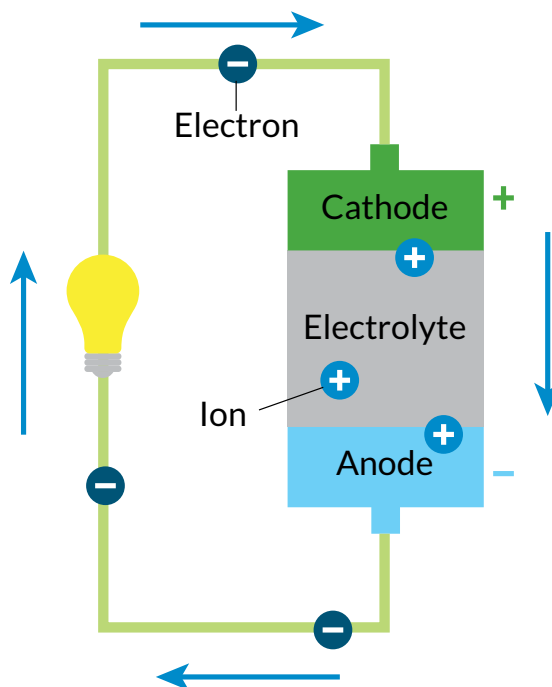
What are desirable characteristics for a battery for electric power grid storage?

How would an engineer consider desired battery characteristics to determine the basis for new battery designs? Discuss engineering design and how essential characteristics drive a product's design. What other considerations affect design decisions?

Using [Blackline Master 3](#), examine the table of battery types from "Charging the future." If funding were not an issue, what type of battery would you choose to power a device that you use regularly? Name the device and explain your reasoning.

Cross-Curricular Discussion

Directions: Use the diagram and chart below from “Charging the future” to answer the related discussion questions assigned by your teacher.



Battery	How it works	What it's used for	Advantages	Obstacles
Lithium-sulfur	Lithium ions from the anode react with sulfur held in the cathode to produce electric current	Cars, cell phones, laptops	Sulfur is cheap and very light, good for packing more capacity into a lighter package	Current versions have short lifetimes and the electrolyte needs work — it tends to dissolve the cathode and react with the anode
Magnesium-ion	Similar to lithium-ion batteries, but magnesium ions do the work	Cars, cell phones, laptops	Magnesium, more plentiful than lithium, provides two electrons (vs. lithium's one) so it could provide twice as much juice	Chemistry not well understood yet; batteries have short lives
Flow batteries	Two tanks of liquid, one positively charged and one negative, are separated by a membrane. Where they meet, the ions react, generating electrons	Cars, grid, backup power	Separating the two parts of the battery makes it easier to design batteries with maximum power or lighter weight; some new designs eliminate pumps and use gravity to adjust speed of energy flow	Current versions can't hold as much energy as lithium-ion; when pumps are used, maintenance remains a problem
Lithium-air	Oxygen molecules from the air react with lithium ions in the anode to release energy. Recharging forces out the oxygen atoms, and the lithium is ready to start again	Cars	Could make a very light battery	Finding electrolytes that don't react with other components is a challenge; batteries have very short life span and may need extra safety engineering
Sodium-sulfur	A molten sodium core exchanges ions with sulfur through a solid electrolyte barrier	Large-scale energy storage (holding power generated from wind or solar)	Materials are cheap and abundant; fairly long lifetime	Must operate at high temperatures, so not possible to use in a car