

Article-Based Observation

Directions: After reading the article "[Charging the future](#)," answer these questions:

1. According to materials scientist George Crabtree, how did the lithium-ion battery transform personal electronics?
2. What are current and potential future applications of batteries? Describe an environmental benefit to a future application.
3. How does a battery produce electricity? How does a battery recharge?
4. What is the best existing battery type, according to the article, and what is an advantage and disadvantage of it?

5. How do lithium-sulfur batteries work, and what are their potential applications, advantages and disadvantages? What are researchers doing to develop and improve them?
6. How do magnesium-ion batteries compare with lithium-ion batteries? What is a current drawback?
7. How do flow batteries work, and what are their potential applications, advantages and disadvantages? What are researchers doing to develop and improve them?
8. If you had 15 seconds to summarize this article to a classmate, what would you say?

Responses to Article-Based Observation

1. **According to materials scientist George Crabtree, how did the lithium-ion battery transform personal electronics?** Possible student response: Cell phones became commonplace, making landline telephones less common for many people. Cell phones also made the internet, photography and even video recording readily accessible.
2. **What are current and potential future applications of batteries? Describe an environmental benefit to a future application.** Possible student response: Smartphones, tablets, laptops, cameras, video recorders, clocks, smoke alarms, electric cars, electric airplanes and storing energy for the power grid are all current or potential applications of batteries. With better batteries that deliver more energy and last longer, the grid could run on greener fuels, such as sunlight, because energy could be stored and used on cloudy days.
3. **How does a battery produce electricity? How does a battery recharge?** Possible student response: A chemical reaction in a battery produces an external flow of electrons (electricity) that can be used to power a device. Batteries have three main components: a negative anode, a positive cathode and an electrolyte. Oxidation reactions occur at the anode and release electrons to the cathode where the reduction reactions takes place. The electrolyte passes the ions created by these reactions back and forth to complete the circuit. Batteries are recharged by supplying a current that forces the electrons to flow in the opposite direction. Essentially the chemical reaction occurs in reverse.
4. **What is the best existing battery type, according to the article, and what is an advantage and disadvantage of it?** Possible student response: Today's lithium-ion batteries have a graphite anode containing loose lithium atoms, an electrolyte and a cathode. Lithium-ion batteries can store at least twice as much energy as previous battery technologies and thus have become widely used in modern devices. However, they are not practical for storing and releasing enough energy to compete directly with gasoline in vehicles, and they drain too quickly to be useful for the electric power grid.
5. **How do lithium-sulfur batteries work, and what are their potential applications, advantages and disadvantages? What are researchers doing to develop and improve them?** Possible student response: Lithium-sulfur batteries have a lithium metal anode, a mainly sulfur cathode and a liquid electrolyte. They could be useful for electric cars and electronic devices. Sulfur can bond to twice as many lithium ions as existing cathodes and is much lighter, so a lithium-sulfur battery might store four or five times as much energy per mass as a lithium-ion battery. Unfortunately, the lithium and sulfur can form unwanted polysulfide compounds that gum up the inside of the battery after a few dozen cycles of discharging and recharging the battery. To minimize that problem, researchers are

improving the electrolyte composition and amount, as well as using membranes or nanotubes to protect the anode and/or cathode.

6. How do magnesium-ion batteries compare with lithium-ion batteries? What is a current drawback?

Possible student response: Magnesium-ion batteries are similar to lithium-ion batteries but use magnesium instead of lithium. Magnesium ions have twice the electric charge of lithium ions, so this substitution should allow the batteries to produce twice as much electrical current. They could be useful for electric cars and electronic devices. Presently, the charged magnesium ions travel too slowly through the electrolyte (thereby limiting the electric current flow), but researchers are trying to improve the electrolyte.

7. How do flow batteries work, and what are their potential applications, advantages and disadvantages? What are researchers doing to develop and improve them?

Possible student response: Flow batteries have two tanks of liquid (one positively charged and one negatively charged) that are separated by a membrane. A flow battery “seesaws,” allowing electrochemically active material to flow and create a current. Adjusting the angle can speed up or stop the flow. Because the tanks can be scaled up, flow batteries can store large amounts of energy, making them especially useful for electric cars and the power grid. Researchers are trying to simplify the mechanical design of flow batteries to eliminate pumps and other complex components. Yet-Ming Chiang of MIT and his team are working on an hourglass concept to this end. Another group is working on a way to replace expensive and toxic materials such as vanadium with better choices such as sulfur, and optimize the battery liquids and/or membranes to prevent unwanted leaks between the tanks.

8. If you had 15 seconds to summarize this article to a classmate, what would you say?

Possible student response: Researchers are trying to develop batteries that would store more energy, last longer, be cheaper, safer and/or easier to recharge than existing lithium-ion batteries.