

**Teacher’s Guide**

**Electric Vehicles! What’s the Chemistry That Makes Them Go?**

***February 2023***

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Activate students’ prior knowledge and engage them before they read the article.

[***Reading Comprehension Questions***](#_Student_Reading_Comprehension) ***3***

These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You’ll find the questions ordered in increasing difficulty.

[***Graphic Organizer***](#_Graphic_Organizer) ***5***

Thishelps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.

[***Answers***](#_Answers_to_Reading) ***6***

Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

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Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article

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# Anticipation Guide

**Directions: *Before reading the article*,** in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Emissions from gas and diesel engines account for less than 5% of total greenhouse gas emissions in the United States. |
|  |  | 2. Electric vehicles have no tailpipes, so no greenhouse gas emissions. |
|  |  | 3. Lithium-ion batteries can be recharged. |
|  |  | 4. A lithium-ion battery contains fewer than 100 lithium-ion cells. |
|  |  | 5. Lithium is used in batteries because of its low atomic mass. |
|  |  | 6. Fast charging an EV battery causes it to degrade more quickly. |
|  |  | 7. Lithium is more plentiful in nature than magnesium or sodium. |
|  |  | 8. Lithium-ion batteries can catch fire if damaged. |
|  |  | 9. Fuel cells require hydrogen for fuel. |
|  |  | 10. EVs cannot accelerate as fast as gas-powered cars. |

# Student ReadingComprehension Questions

**Directions**: Use the article to answer the questions below.

1. Which state will require all cars sold to be hydrogen-powered or electric by the year 2035?
2. What percentage of greenhouse gas emissions was caused by cars and light-duty vehicles in 2020?
3. Name two devices that contain secondary batteries.
4. What is lithium’s reduction potential?
5. What units are used to measure battery capacity?
6. List the three primary metallic elements used in a lithium battery.
7. Describe the difference between primary and secondary batteries.
8. Name three metals that have a reduction potential below zero.
9. Name two benefits of solid-state batteries over lithium-ion batteries.
10. What are the products of the reaction that takes place in a fuel cell?

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

***Write your answers on another piece of paper if needed.***

1. Describe at least two features of lithium that make it useful for batteries.
2. Explain why an EV battery contains thousands of individual lithium-ion cells.
3. List the four parts of a battery and the function of each.
4. Create an infographic, comic, or narrative to explain the path of a lithium ion as a lithium battery produces energy and then is recharged.

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# Graphic Organizer

**Directions**: As you read, complete the graphic organizer below to describe the chemistry of electric vehicles.

|  |  |
| --- | --- |
| **Vocabulary** | **Relate to lithium-ion battery** |
| **Secondary battery** |   |
| **Intercalation** |   |
| **Capacity** |   |
| **Energy density** |  |
| **Reduction potential** |  |
| **Hysteresis** |  |
| **Future batteries** | *Describe three ideas for future EV batteries.* |

**Summary:** On the back of this sheet, write three important facts about the chemistry of EVs that you would like to share with a friend.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Which state will require all cars sold to be hydrogen-powered or electric by the year 2035?
California will require all cars sold to be electric or hydrogen-powered by 2035.
2. What percentage of greenhouse gas emissions was caused by cars and light-duty vehicles in 2020?
In 2020, emissions from passenger cars and light-duty vehicles accounted for 14% of greenhouse gas emissions.
3. Name two devices that contain secondary batteries.
Cellphones and EVs contain secondary batteries.
4. What is lithium’s reduction potential?
Lithium’s reduction potential is -3.05.
5. What units are used to measure battery capacity?
The capacity of a battery is measured in ampere-hours.
6. List the three primary metallic elements used in a lithium battery.
The elements used in a lithium battery are lithium, cobalt, and nickel.
7. Describe the difference between primary and secondary batteries.
Primary batteries cannot be recharged but secondary batteries can.
8. Name three metals that have a reduction potential below zero.
Three metals that have a reduction potential below zero are nickel, zinc, and lithium.
9. Name two benefits of solid-state batteries over lithium-ion batteries.
Solid-state batteries have higher energy density and are less flammable.
10. What are the products of the reaction that takes place in a fuel cell?
The products of the reaction that takes place in a fuel cell are electricity, heat, and water.
11. Describe at least two features of lithium that make it useful for batteries.
Lithium is the lightest element that can reversibly exchange electrons. Lithium has a high capacity and high energy density and low reduction potential.
12. Explain why an EV battery contains thousands of individual lithium-ion cells.
A single lithium battery produces 3.6 volts of electricity, so thousands of lithium batteries are needed to provide the amount of electricity needed to power a vehicle.
13. List the four parts of a battery and the function of each.
A battery consists of two electrodes, electrolytes, and a separator. The electrodes release and gain electrons. The electrolyte allows electrons to flow between the electrodes while the separator prevents contact between the anode and cathode.
14. Create an infographic, comic, or narrative to explain the path of a lithium ion as a lithium battery produces energy and then is recharged.
Student responses will vary but should include information about how energy flows through a battery and how the battery is recharged.

**Graphic Organizer Rubric**

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

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# Additional Resources and Teaching Strategies

**Additional Resources**

* **Lessons and lesson plans**

* + [How Far Can We Go?](https://teachchemistry.org/classroom-resources/how-far-can-we-go) - This lesson plan will help students understand the relationship between electrochemical cell potentials and stored chemical energy.

* + [Biofuels of the Future](https://teachchemistry.org/classroom-resources/biofuels-of-the-future) - In this lesson, students demonstrate their understanding of alternative energy sources by creating an ebook.

* + [How Fuel Cells Work](https://teachchemistry.org/classroom-resources/how-fuel-cells-work) - This lesson incorporates an online animation to help students understand how fuel cells provide energy in vehicles.

* + [What Powers Your World?](https://teachchemistry.org/classroom-resources/what-powers-your-world) - In this lesson students examine various battery power sources and learn about oxidation-reduction reactions.

* **Simulations**

* + [Circuit Construction Kit](https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_en.html) - Students can explore this simulation to learn about electric circuits.

* **Projects and extension activities**

* + [Hybrid and Electric Cars Video](https://teachchemistry.org/classroom-resources/hybrid-and-electric-cars-video) - This video explains the chemistry that powers the batteries used in electric cars.

**Teaching Strategies**

Consider the following tips and strategies for incorporating this article into your classroom:

* **Alternative to Anticipation Guide:** Before reading, ask students if they have ridden in an electric car. Ask how EVs are different from a gas-powered car. Their initial ideas can be collected electronically via Jamboard, Padlet, or similar technology.
	+ As they read, students can find information to confirm or refute their original ideas.
	+ After they read, ask students how a knowledge of chemistry is helpful in improving batteries for EVs.
* For further information, share the ACS Reactions video “How Do Hydrogen Fuel Cells Work?” (8:11) at https://youtu.be/R6AdX-bdDaw. Students will learn more about the theory behind fuel cells and the efficiency of power sources. EVs and fuel cell cars are compared near the end of the video.

# Chemistry Concepts and Standards

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Atomic mass
* Electrochemistry
* Anode
* Cathode
* Electrolytic cells
* Oxidation
* Reduction
* Reduction potential
* Half reaction

**Correlations to Next Generation Science Standards**

This article relates to the following performance expectations and dimensions of the NGSS:

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

**HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

**Disciplinary Core Ideas:**

* PS.1.A: Structure and Properties of Matter
* PS.2.B: Types of Interactions
* PS.3.A: Definitions of Energy
* ETS1.A: Defining and Delimiting Engineering Problems
* ETS1.C: Optimizing the Design Solution

**Crosscutting Concepts:**

* Cause and effect
* Systems and system models
* Energy and matter

**Science and Engineering Practices:**

* Constructing explanations (for science) and designing solutions (for engineering)

**Nature of Science:**

* Scientific knowledge assumes an order and consistency in natural systems.

See how *ChemMatters* correlates to the[**Common Core State Standards** online](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html).