

**Teacher’s Guide**

**Lithium: The 21st Century Gold Rush**

***April 2024***

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

[***Reading Comprehension Questions***](#_3znysh7) ***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***](#_9f8azrtnp6p5) ***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***](#_djipzn7z1r1b) ***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. Lithium is used in the cathode of lithium-ion batteries. |
|  |  | 2. Lithium is always found combined with other elements in nature because of its high reactivity. |
|  |  | 3. Lithium carbonate becomes more soluble in water as the temperature increases. |
|  |  | 4. Most of the world’s lithium deposits are found in the United States. |
|  |  | 5. In the Lithium Triangle countries, lithium is obtained by evaporating water from brine to concentrate the lithium. |
|  |  | 6. Direct lithium extraction works well for brines with low lithium ion concentrations. |
|  |  | 7. Future alternatives to lithium-ion batteries include sodium-ion batteries. |
|  |  | 8. Where speed and portability are not important, flow cell batteries are being considered as a safer alternative to lithium-ion batteries. |
|  |  | 9. Vanadium flow batteries being developed use different oxidation states of vanadium. |
|  |  | 10. Lithium metal is easily recycled. |

# Student Reading Comprehension Questions

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

1. Why does the electronics industry prefer to use lithium carbonate over other types of metals?
2. Which countries make up the Lithium Triangle?
3. Based on the graph in the article, which year had the lowest price of lithium at the start of the year?
4. List the names and formula of the three lithium compounds isolated and refined in the Lithium Triangle.
5. Which two states in the United States contain most of the lithium deposits in the country?
6. Name two possible sources of energy for flow batteries.
7. Explain how lithium is recovered in the Lithium Triangle.
8. Describe how the Direct Lithium Extraction process works.
9. Explain why researchers are looking for ways to use iron and manganese to replace cobalt in lithium cobalt oxide.

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

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

1. Name two common uses of lithium batteries and explain the characteristics of the batteries that make them useful for those devices.
2. What role does temperature play in separating lithium carbonate?
3. Explain why alkali metals react easily with other elements.
4. Describe both the advantages and disadvantages of sodium-ion batteries when compared with lithium-ion batteries.
5. The article briefly describes some problems associated with the mining of lithium and cobalt. Perform additional research and explain at least two of these problems in greater detail.
6. The article lists three alternatives to lithium-ion batteries: new cathode materials for lithium-ion batteries, sodium-ion batteries, and flow batteries. Select one of the alternatives, research the advancements on the alternative, and create a poster explaining the benefits of using the alternative.

# Graphic Organizer

**Directions**: As you read, complete the graphic organizer below to describe the chemistry involved in mining lithium and possible alternatives to lithium-ion batteries.

| **Chemistry of lithium** |  | |
| --- | --- | --- |
| **Common uses for lithium-ion batteries** |  | |
| **Current sources of lithium** |  | |
| **Lithium extraction processes** | 1. | 2. |
| **Advantages to lithium-ion batteries** |  | |
| **Disadvantages to lithium-ion batteries** |  | |
| **Alternatives to lithium-ion batteries** | 1.  2.  3. | |

**Summary:** On the back of this sheet, write a short summary (20 words or less) of the article.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Why does the electronics industry prefer to use lithium carbonate over other types of metals?  
   The electronics industry prefers lithium carbonate because it is easy to purify.
2. Which countries make up the Lithium Triangle?  
   Chile, Bolivia, and Argentina make up the Lithium Triangle.
3. Based on the graph in the article, which year had the lowest price of lithium at the start of the year?  
   2021 had the lowest price of lithium at the start of the year.
4. List the names and formula of the three lithium compounds isolated and refined in the Lithium Triangle.  
   The three forms of lithium produced in the Lithium Triangle are lithium hydroxide (LiOH), lithium chloride (LiCl), and lithium carbonate (Li2CO3).
5. Which two states in the United States contain most of the lithium deposits in the country?  
   Nevada and Utah are the two states that have most of the lithium deposits in the United States.
6. Name two possible sources of energy for flow batteries.  
   Flow batteries can be used to store wind or solar energy.
7. Explain how lithium is recovered in the Lithium Triangle.  
   In the Lithium Triangle brine from saltwater deposits is pumped into ponds where the water evaporates until the concentration of lithium is at 6%. The brine is then pumped to a facility where it is purified.
8. Describe how the Direct Lithium Extraction process works.  
   The Direct Lithium Extraction method uses a lithium-selective membrane to separate lithium ions from other types of ions.
9. Explain why researchers are looking for ways to use iron and manganese to replace cobalt in lithium cobalt oxide.  
   Researchers are looking for ways to use iron and manganese because they are more abundantly available than cobalt.
10. Name two common uses of lithium batteries and explain the characteristics of the batteries that make them useful for those devices.  
    Common uses of lithium batteries include cell phones, laptops, electric cars, pacemakers, digital cameras, and golf carts. Lithium batteries are used in these devices because they charge quickly, last for a long time, and have a high power density.
11. What role does temperature play in separating lithium carbonate?  
    Lithium carbonate becomes less soluble in water at warmer temperatures, so it separates from the rest of the solution making it easier to access.
12. Explain why alkali metals react easily with other elements.  
    Alkali metals react easily with other elements because the atoms are large and they have very low ionization energy, that is, it doesn’t take much energy to remove an electron.
13. Describe both the advantages and disadvantages of sodium-ion batteries when compared with lithium-ion batteries.  
    A disadvantage is that sodium-ion batteries generate less energy per unit of mass. Sodium is heavier than lithium but would produce the same number of electrons per atom, so we’d need more mass of sodium than we do for lithium which would make the batteries heavier for the same amount of energy. Advantages of sodium-ion batteries include lower production costs, there is a greater abundance of sodium in the earth’s crust and it can be more reliably sourced.
14. The article briefly describes some problems associated with the mining of lithium and cobalt. Perform additional research and explain at least two of these problems in greater detail.   
    Student responses will vary. The article explains that the mining of lithium is being contested in Nevada because the lithium is located on a site that is sacred to Native Americans. Cobalt is difficult to source and mining it has destroyed the landscape and exploited local laborers.

**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 AACT lesson plan leads students through the process of comparing the densities of lithium ion and lead acid batteries to develop an understanding of the relationship between electrochemical cell potential and stored chemical energy.
  + [What Powers Your World?](https://teachchemistry.org/classroom-resources/what-powers-your-world) - Students can use this lesson from AACT to explore the way batteries work to power everyday objects.
  + [Building Batteries - Chemistry](https://energy.utah.gov/wp-content/uploads/Batteries_Chemistry-Full-Lesson-Plan-1.pdf) - This lesson plan from the Utah Office of Energy Development provides instructions for experimenting with battery creation.
* **Simulations**
  + [Galvanic/Voltaic Cells](https://teachchemistry.org/classroom-resources/voltaic-cells) – Students can use this simulation to investigate battery function by testing a variety of different electrodes.
* **Projects and extension activities**
  + [Hybrid and Electric Cars Video](https://teachchemistry.org/classroom-resources/hybrid-and-electric-cars-video-questions) – This AACT activity includes a video and questions related to the ways that batteries power hybrid and electric cars. Lithium battery function is also included in the video.

**Teaching Strategies**

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

* **Alternative to Anticipation Guide:** Before reading, ask students where they might find lithium-ion batteries in their everyday lives, and why they are important. Ask them about the chemistry of lithium, and if they know where lithium is mined. Ask about hazards posed by lithium-ion batteries. 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 reading, ask students what they learned about lithium-ion batteries, including where they are used, how lithium is mined, problems with lithium-ion batteries, and alternatives for the future.
* Consider asking students to read the “Open for Discussion” article on page 4 of this issue to consider relating sustainability to the production of batteries.
* Students can also read the “Chemistry in Person” article to learn more about lithium-ion batteries from an interview with the 2019 Nobel laureate who helped develop them.

# Chemistry Concepts and Standards

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Anode
* Cathode
* Oxidation
* Oxidation number
* Reduction
* Solubility
* Precipitate
* Separating mixtures

**Correlations to Next Generation Science Standards**

This article relates to the following performance expectations and dimensions of the 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.

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

**Disciplinary Core Ideas:**

* PS.1.A: Structure and Properties of Matter
* PS.2.B: Types of Interactions
* ETS1.C: Optimizing the Design Solution

**Crosscutting Concepts:**

* Scale, proportion, and quantity
* Systems and system models
* Energy and matter: Flows, cycles, and conservation

**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).