

**Teacher’s Guide**

**The Chemistry That Keeps Trains Moving**

***April 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. The first steam locomotive was built in the United States. |
|  |  | 2. Boyle’s Law helps explain how a steam engine works. |
|  |  | 3. Corrosion of steam engine boilers can be reduced by keeping the water in the boiler slightly acidic. |
|  |  | 4. Almost all commercial trains in the U.S. today have internal combustion engines. |
|  |  | 5. Rail ties in the U.S. are usually made of oak. |
|  |  | 6. Rails are joined together using an intensely exothermic thermite reaction. |
|  |  | 7. Expansion gaps are needed to prevent buckling of the train tracks. |
|  |  | 8. In very hot climates, rails may be painted white to reduce their temperature. |
|  |  | 9. Maglev trains can go very fast because they use more efficient fuels than other trains. |
|  |  | 10. Trains produce much less CO2 per passenger than cars or airplanes. |

# Student Reading Comprehension Questions

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

1. How many times greater is the volume of water in steam form than liquid form?
2. Why were laws passed to ban the use of steam engines?
3. What is the function of the wooden ties that rails are attached to?
4. Create a graph that compares the CO2 production of airplanes, automobiles, and trains.
5. List three factors that can impact the amount of load a locomotive can haul.
6. What is the function of the boiler of a steam engine and how does its structure impact the function?
7. What is boiler scale and what are three problems it can cause in a steam engine?
8. Explain why using alkaline water in a boiler can prevent corrosion.
9. Explain the function of an expansion joint between sections of rail.

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

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

1. List the reactants that make up thermite and explain why they are finely ground prior to being used in a reaction.
2. Explain what can happen to railroad rails under extreme temperatures.
3. The article notes that some countries are experimenting with railroad ties made from different types of materials. Select concrete, steel, or plastic and research its use as a railroad tie. Create an infographic that describes the chemical composition of the material you selected and include at least two benefits and two drawbacks of the material.
4. Create an infographic that describes at least three science aspects of trains. These aspects could include Boyle’s Law, neutralization reactions, solubility, the impact of surface area on chemical reactions, and magnetic forces.

# Graphic Organizer

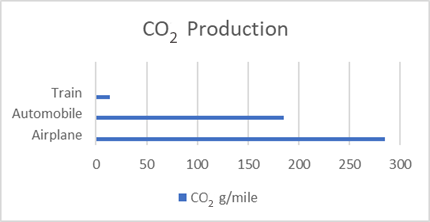
**Directions**: As you read, complete the graphic organizer below to describe the chemistry of train travel.

|  |  |  |
| --- | --- | --- |
| **Component** | **Chemistry** | **Safety problems and solutions** |
| **Steam Engine** |  |  |
| **Steam Engine Boilers** |  |  |
| **Diesel-electric engine** |  |  |
| **Rail ties** |  |  |
| **Metal rails** |  |  |
| **Future Trains** |  |  |

**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. How many times greater is the volume of water in steam form than liquid form?  
   The volume of water is 1,600 times greater in steam than in liquid.
2. Why were laws passed to ban the use of steam engines?  
   Laws to ban the use of steam engines were passed because the smoke produced by burning coal or wood for the boilers caused pollution in densely populated areas.
3. What is the function of the wooden ties that rails are attached to?  
   The wooden ties serve to stabilize the rails and transfer the load to a bed of gravel beneath the tie.
4. Create a graph that compares the CO2 production of airplanes, automobiles, and trains.



1. List three factors that can impact the amount of load a locomotive can haul.  
   The function of the boiler of a steam engine is to turn water into steam. A boiler is made of metal to contain the high pressure created by the steam.
2. What is the function of the boiler of a steam engine and how does its structure impact the function?  
   Boiler scale is the buildup of precipitates as water in a boiler evaporates. Boiler scale can decrease engine efficiency, clog pipes, lead to overheating and can cause explosions.
3. What is boiler scale and what are three problems it can cause in a steam engine?  
   Carbonic acid can cause corrosion in a boiler. Using alkaline water in a boiler can neutralize carbonic acid.
4. Explain why using alkaline water in a boiler can prevent corrosion.  
   Three factors that impact the amount of load a locomotive can haul include the horsepower of the locomotive, the steepness of the route, and the traction of the wheels on the rails.
5. Explain the function of an expansion joint between sections of rail.  
   Expansion joints are used to create a gap in the rail which prevents the rails from buckling when the temperature of the rails increases.
6. List the reactants that make up thermite and explain why they are finely ground prior to being used in a reaction.  
   The reactants that make up thermite are aluminum and iron oxide. They are finely ground to increase surface area to make it easier for them to react.
7. Explain what can happen to railroad rails under extreme temperatures.  
   Rails expand in extreme heat and can buckle. Extreme cold can cause the rails to contract, resulting in tensile stresses.
8. The article notes that some countries are experimenting with railroad ties made from different types of materials. Select concrete, steel, or plastic and research its use as a railroad tie. Create an infographic that describes the chemical composition of the material you selected and include at least two benefits and two drawbacks of the material.  
   Student responses will vary and should include an explanation of the material selected as well as two benefits and two drawbacks of the material.
9. Create an infographic that describes at least three science aspects of trains. These aspects could include Boyle’s Law, neutralization reactions, solubility, the impact of surface area on chemical reactions, and magnetic forces.Student responses will vary and should include at least three science connections.

**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**

* + [Simulation Activity: Gas Laws](https://teachchemistry.org/classroom-resources/simulation-activity-gas-laws-simulation) - This lesson plan aligns with the AACT Gas Laws Simulation and provides students with the opportunity to understand the indirect relationship between pressure and volume.

* **Simulations**
  + [Gas Laws Simulation](https://teachchemistry.org/classroom-resources/the-gas-laws-simulation) - Students can use this simulation to learn more about Boyle’s Law, Charles’ Law, Gay-Lussac’s Law.

* + [Gas Properties - Ideal Gas Law](https://phet.colorado.edu/en/simulations/gas-properties) - Using this simulation, students will explore relationships between pressure, temperature, and volume as they relate to ideal gas laws.

* **Labs**

* + [Boyle’s Law](https://teachchemistry.org/classroom-resources/boyle-s-law) - In this hands-on lab, students use lab materials to calculate the pressure of a gas.

**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 ever traveled on a train and if they know how the train was powered. In addition to passenger trains, some of them may have traveled on trains at theme parks which may operate differently. Ask them how chemistry can help solve safety issues related to train travel. 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 what they learned about the importance of chemistry in designing trains.
* After reading, ask students how they might use information from the article to make decisions about future travel.

# Chemistry Concepts and Standards

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Physical change
* Physical properties
* Gas laws
* Pressure
* Temperature

**Correlations to Next Generation Science Standards**

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

**HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

**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
* ETS1.C: Optimizing the Design Solution

**Crosscutting Concepts:**

* Scale, proportion, and quantity
* Systems and system models
* Structure and function

**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).