

**Teacher’s Guide**

**Why a Pennsylvania Town has been Burning for 60 Years**

***October 2021***

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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 5](#_Graphic_Organizer_1)

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 6](#_Answers_to_Reading)

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

[Additional Resources 9](#_Additional_Resources_1)

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

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**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 Centralia fire began when trash was burned in a makeshift landfill. |
|  |  | 1. Coal is a type of metamorphic rock. |
|  |  | 1. There are three types of coal, each with different amounts of carbon content. |
|  |  | 1. Coal contains sulfur which is removed by using aqueous limestone when it is burned at power plants. |
|  |  | 1. All chemical reactions require activation energy to get started. |
|  |  | 1. Coal produces more kJ/g of energy than methane. |
|  |  | 1. For a fire to continue to burn, its temperature must remain above the ignition temperature of the fuel. |
|  |  | 1. Carbon monoxide is a colorless, odorless gas that can cause nausea, drowsiness, and death. |
|  |  | 1. Currently there are fewer than 10 underground fires in Pennsylvania. |
|  |  | 1. A mountain in Australia has burned for 6000 years. |

# Student Reading Comprehension Questions

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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

1. Which element is always in a combustion reaction? What are the two most common products in a combustion reaction?

2. State and give a brief description of the four parts of the tetrahedron of fire?

3. In terms of chemical bonds broken vs. chemical bonds formed, how is a chemical reaction exothermic?

4. How is coal naturally formed? What are the 2 main elements in coal?

5. Describe how scrubbers work. What are the final products made from this process?

6. How does the foam in a fire extinguisher put out a fire?

7. Compare the energy from wood and coal. Which would provide more heat when burned? Explain your answer in terms of heat of combustion. What other fuels would produce more heat?

8. Explain the heat transfer in the process of evaporation. How does this cool down hot objects (or fire)

9. In terms of evaporation, explain how sweating cools a person down during and after exercise.

10. State at least 1 way to remove each of the 4 components of the tetrahedron of fire in order to extinguish the fire.

11. How does ignition temperature in a combustion reaction relate to the activation energy in the reaction?

12. What does carbon monoxide (CO) do in the body that makes it dangerous to humans?

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

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

1. Carbon dioxide and sulfur oxides are commonly produced by the burning of coal. Research and explain how these gases react in the atmosphere and affect our climate.

2. The demand and use of coal has been greatly diminished over time. Think of one or two other forms of energy that we use now. Research the pros and cons of this/these energy sources.

# Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: As you read, complete the graphic organizer below to describe the factors contributing to the long-burning fire, and issues faced by Centralia residents once the fire began.

|  |  |
| --- | --- |
| **Issue** | **Description, including chemicals involved** |
| **Why the type of coal matters** |  |
| **Why the fire is still burning after 60 years** |  |
| **Hazards of burning coal** |  |
| **Attempts to extinguish the fire and why they did not work** |  |

**Summary:** On the back of this sheet, write a one-sentence summary (15 words or less) describing what you learned from the article.

# Answers to Reading Comprehension Questions, Graphic Organizer Rubric, & EdPuzzle

**1. Which element is always in a combustion reaction? What are the two most common products in a combustion reaction?**

*All combustion reactions include the element oxygen, because that is one of the components for fire. Carbon and hydrogen are present in combustions of organic compounds. The 2 most common products is typically carbon dioxide (CO2) and water (H2O).*

**2. State and give a brief description of the four parts of the tetrahedron of fire?**

*The four parts of the tetrahedron of fire:*

*- Oxygen –used to oxidize the fuel to produce the fire*

*- Heat- enough is needed to get the material to its ignition temperature to create fire*

*- Fuel- the chemical that is oxidized and produces the heat for fire*

*- Chain Reaction - self-sustaining to keep the fire going*

**3. In terms of chemical bonds broken vs. chemical bonds formed, how is a chemical reaction exothermic?**

*In an exothermic reaction, heat is released. This is because the energy released by the formation of product’s chemical bonds is greater than the energy absorbed to break the reactant chemical bonds.*

**4. How is coal naturally formed? What are the 2 main elements in coal?**

*Coal is formed from the remains of plants from millions of years ago. High pressures and temperatures convert the plant material into coal. The two main elements in coal are carbon (C) and hydrogen (H).*

**5. Describe how scrubbers work. What are the final products made from this process?**

*A scrubber is a chemical process that converts the poisonous gases (like SO2) to harmless products (gypsum). Typically, the harmful gases are passed through aqueous limestone to produce the gypsum.*

**6. How does the foam in a fire extinguisher put out a fire?**

*The foam in a fire extinguisher would smother the fire, meaning that the fuel would be cut off from the oxygen supply (like when they added the fly ash to the coal mines in Centralia).*

7. **Compare the energy from wood and coal. Which would provide more heat when burned? Explain your answer in terms of heat of combustion. What other fuels would produce more heat?**

*The heat of combustion is much greater for coal than it is for wood (-32.8 kJ/g vs. -17.3 kJ/g), so coal produces more heat when burned. Methane (natural gas) produces even more than both coal and wood (-55.5 kJ/g), so it would be a better fuel to use for energy.*

8. **Compare the energy from wood and coal. Which would provide more heat when burned? Explain your answer in terms of heat of combustion. What other fuels would produce more heat?**

*In evaporation, the evaporating substance absorbs the heat and turns into gas, and escapes. The remaining substance has less heat (kinetic energy), thus the temperature drops. (in terms of fire, the temperature would drop below the ignition temperature).*

**9. In terms of evaporation, explain how sweating cools a person down during and after exercise.**

*When a person sweats, the sweat (water) in the body absorbs the excess body heat. When the sweat evaporates (or is wiped off), the excess heat is also removed from the body. The result is an overall lower body temperature.*

**10.** **State at least 1 way to remove each of the 4 components of the tetrahedron of fire in order to extinguish the fire.**

*Ways to remove one of the four components of fire:*

*- Oxygen –smother the fire with a towel or other substance that will cut off the oxygen supply*

*- Heat- add water or other cool, non-flammable materials to lower the temperature below the ignition point*

*- Fuel- remove any unreacted fuel material before it reaches the ignition temperature*

*- Chain Reaction - surround or contain the source of the fire, and keep the flames away from anything else flammable.*

**11.** **How does ignition temperature in a combustion reaction relate to the activation energy in the reaction?**

*The activation energy in a reaction is the minimum amount of energy (usually heat) that is needed for the reactants to start the reaction. The ignition temperature is the temperature where enough heat is present to start a fire. Both are minimum amounts of energy to start the reactions.*

**12.** **What does carbon monoxide (CO) do in the body that makes it dangerous to humans?**

*Carbon monoxide will attach to the hemoglobin in blood, instead of oxygen. When less oxygen attaches to the hemoglobin, which will affect the health of a person.*

**Questions for Further Learning**

**1. Carbon dioxide and sulfur oxides are commonly produced by the burning of coal. Research and explain how these gases react in the atmosphere and affect our climate.**

*Carbon dioxide would react with the water in lakes (or air) to produce carbonic acid (HCO3). Sulfur oxides will react with water to make sulfuric acid (H2SO4). These would create high levels of acidity in lakes and rivers that could have detrimental effects to aquatic life. Also, this is how acid rain is created.*

*(Note: all nonmetal oxides react with water to make acids. All metal oxides react with water to make bases.)*

**2. The demand and use of coal has been greatly diminished over time. Think of one or two other forms of energy that we use now. Research the pros and cons of this/these energy sources.**

*Answers will vary.*

**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 |

**EdPuzzle Answers**

1. **What do you think are some reasons for the big drop in coal demand?**

*In the mid 1900’s, oil and natural gas became more poular for automobiles and heating. This was also the time the 1st nuclear power plant was built to produce electricity (see:* [*https://www.energy.gov/ne/articles/9-notable-facts-about-world-s-first-nuclear-power-plant-ebr-i*](https://www.energy.gov/ne/articles/9-notable-facts-about-world-s-first-nuclear-power-plant-ebr-i)*).*

**2.** **What is the leading theory on how the coal fire in Centralia started?**

*Burning trash*

**3. What happens at a substance's ignition temperature?**

*The fuel/substance has enough energy to react with oxygen. The substance will then burn.*

**4. How do increases in sulfur gases and carbon monoxide affect people?**

*When people inhale these gases, they could cause damage to lungs or other organs. (See the article to explain how CO affects the body).*

**5. How do you think wet sand would extinguish a fire?**

*The wet sand would cool the coal below its ignition point, as well as smother the flames thus cutting of the oxygen.*

**6**. **Although natural coal fires are quite common, what could we do to prevent human-made coal fires?**

*Answers may vary.*

# Additional Resources

**Labs and demos**

Combustion of food lab from Flinn. This activity will introduce the concept of calorimetry and investigate the caloric content of snack foods.

<https://www.flinnsci.com/api/library/Download/f9560a5fc7ef4a6b8f4598fea30626eb>

Simple Evaporation Experiments. Fun and simple evaporation experiments students can do--even at home--to learn more about evaporation.

<https://sciencing.com/simple-evaporation-experiments-15764.html>

Exothermic/Endothermic Lab. In this lab, students determine whether mixing two chemicals is endothermic or exothermic. One is a physical change, one is a chemical change.

<https://teachchemistry.org/classroom-resources/exothermic-and-endothermic-lab>

**Lessons and lesson plans**

EPA coal/acid rain. Information about acid rain from the U.S. EPA, including games and an animation.

<https://www3.epa.gov/acidrain/education/site_students/whatcauses.html#:~:text=Power%20plants%20release%20the%20majority,These%20pollutants%20cause%20acid%20rain>.

Fire Triangle/Fire Tetrahedron. A deeper dive into how the fire triangle became the fire tetrahedron, and what it means.

<https://www.thinkreliability.com/InstructorBlogs/Blog%20-%20Fire.pdf>

AACT Activity: Biofuels of the Future. This lesson has students exploring the world of automobile alternative energy sources through the study of biofuels.

<https://teachchemistry.org/classroom-resources/biofuels-of-the-future>

AACT Activity: What Makes Something Feel Warm. In this lesson students actively engage in thinking about energy issues in chemistry and the nature of energy (thermal) transfer.

<https://teachchemistry.org/classroom-resources/what-makes-something-feel-warm>

# Chemistry Concepts, Standards, and Teaching Strategies

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Activation energy
* Exothermic and endothermic
* Heat of combustion
* Chemical change

**Correlations to Next Generation Science Standards**

This article can be used to achieve the following performance expectations of NGSS:

**HS-PS1-4.** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends on the changes in total bond energy.

**HS-ETS1-3.**

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

**Disciplinary Core Ideas:**

* PS1.A: Structure and Properties of Matter
* ETS1.C: Optimizing the Design Solution

**Crosscutting Concepts:**

* Structure and function
* Scale, proportion, and quantity
* Energy and matter

**Science and Engineering Practices:**

* Planning and carrying out investigations

**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).

**Teaching Strategies**

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

* **Alternative to Anticipation Guide:** Before reading, ask students what they know about coal mining and the hazards involved. 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 coal mining and why the fire in Centralia is still burning.
* The ACS Reactions Video “Why This Town Has Been on Fire for 50 Years,” produced in 2015, has more information about the Centralia fire. You can find it at <https://youtu.be/fsgqy5FYP2c>. Consider sharing this video with students after they have discussed the article. Ask them what information is in the video that was not in the article. We also turned this video into an EdPuzzle for your convenience! <https://edpuzzle.com/media/6116963bddcd16413857c880>